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WORKING PAPER

Improving metro access in India: Evidence from three cities

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues.

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HIGHLIGHTS

- Poor access (last-mile connectivity) to metro rail systems in India has contributed to lower-than-planned ridership, causing the underutilization of over US$25 billion in investments in the sector.
- There is little understanding of what metro commuters seek from their last-mile commute. Thus, policy pushes to improve last-mile connectivity since 2017 have not brought about meaningful improvement.
- This paper draws from a three-city survey of 7,200 metro commuters to understand current metro user demographics and last-mile choices and preferences.
- Our data show that Indian metro systems attract young (19–35), middle-income commuters. Affluent users are not attracted to the system, and low-income users are priced out of it.
- Indian metro commuters are highly sensitive to last-mile wait times and costs. Women are especially averse to waiting, and may opt for more expensive services to avoid waiting. Planners must prioritize high-frequency, low-cost shared services and improve pedestrian infrastructure around metro stations.
- There is, however, no universal approach to deploying last-mile services at metro stations. Robust, periodic data collection and analysis are required to plan viable commuter-centric last-mile services.

EXECUTIVE SUMMARY

Context

India's central government has invested heavily in metro rail systems to tackle urban traffic congestion, higher transport emissions, and road crash fatalities. Although these systems have improved the commute for millions of citizens, their severe underutilization—in some cases, just 10 percent of the projected ridership (UITP India 2021) has been achieved—is concerning. Poor access to stations (the last-mile problem) is a major contributor to low ridership (Chidambara 2012; Kumar 2015; Kanuri et al. 2019; Irani 2022). Pedestrian and cycling infrastructure is usually inadequate, and motorized modes (such as feeder buses and shared or on-demand paratransit) to metro stations can be infrequent, unsafe, uncomfortable, and unaffordable. This deters commuters from taking the metro.

Recognizing the problem, India's central government focused on improving last-mile connectivity to increase metro rail ridership. The Metro Rail Policy of 2017 mandated last-mile services planning for metro projects seeking central financial assistance, and appraisal guidelines for upcoming projects include feeder bus route plans (MoHUA 2017). Amendments to the Motor Vehicles Act ease issuance of permits for services enhancing last-mile connectivity to mass transit (MoRTH 2019). Yet, little has improved on the ground.

Last-mile planning continues to be driven by the "intuition" of local-level planners rather than by data. There is often a lack of understanding of commuter last-mile requirements, how these vary across commuter segments, and what data need to be collected and analyzed to design commuter-centric last-mile services.

About this working paper

This paper uses a three-city survey conducted by WRI India and the Toyota Mobility Foundation (Nagpur: March 2022, Delhi: October 2022, Bengaluru: March 2023). The first published multicity survey of Indian metro commuters using a standardized questionnaire, it is a revealed preference, intercept survey of 7,200 existing metro rail users across three cities having different-sized metro rail networks. The survey captured data on metro rail travel patterns (including last mile), trip purposes, and socioeconomic characteristics (primarily gender, income, and age). This paper provides insights into

- existing metro commuter segments;
- last-mile mode choice preferences, disaggregated mode choices (by gender and income), and their implications for last-mile service provision; and
- aspects to consider and data to collect for designing viable commuter-centric last-mile services.

Although a limitation of this survey is its focus on existing commuters, it provides an important data baseline for metro commuter behavior. Complementary research on metro non-users will add value to the Indian transit literature.

Key findings

Our research highlights the following demographic trends across the metro, along with last-mile commuter preferences.

The metro attracts a specific demographic: commuters aged between 19 and 35, who use the metro to commute for work or education. The metro also attracts a specific income demographic: those with monthly household incomes between INR 10,000 and INR 40,000 ($121.26–$485.06; the exchange rate on June 12, 2023, was used: $1 = 82.46 INR). More affluent users (with personal vehicles) are yet to shift to the metro, and low-income users are priced out of it.

Metro users primarily walk or use low-cost shared last-mile modes. This is likely due to the aforementioned demographic's high price sensitivity, which makes the more costly on-demand last-mile modes unviable. Shared paratransit (such as shared auto-rickshaws) is especially popular.

Users, especially women, are averse to waiting for last-mile modes. A last-mile mode whose frequency exceeds 10 minutes is unlikely to be preferred.

Women pay more to access the metro. Women travel shorter last-mile distances than men, yet pay more on average. Aversion to waiting makes some women choose more expensive, faster last-mile modes. It is also likely that the current last-mile mode fare structures do not suit certain gendered travel patterns such as trip-chaining.

Users are willing to travel up to 20 minutes to access metro stations, including the time spent waiting for last-mile modes. This figure is consistent across cities and income groups, indicating that the "catchment region" of a metro station is determined more by access time than by a fixed area.

Recommendations

Prioritize low-cost shared services and non-motorized access infrastructure. Given the strong price sensitivity across users, low-cost last-mile services (and cycling/pedestrian infrastructure) should be prioritized at metro stations. Lower-income users should be attracted to the metro through targeted fare products.

Operate last-mile shared services at high frequencies (<10 minutes). Demand on the last-mile corridor needs to be understood, and last-mile vehicle service capacities must be aligned with this demand to offer financially viable high-frequency services. High-capacity feeder buses are not always the right option.

Base last-mile planning on the spatial demography around stations. The last-mile preferences of commuter segments vary. Understanding who resides, studies, and works around a metro station can help calibrate effective combinations of last-mile services. Higher-income areas, for example, may benefit from new on-demand, app-based mobility services.

Drive last-mile service design using a commuter-oriented perspective. Our data show clear commuter last-mile preferences. Although the exact parameters vary across cities, commuter preferences—not operational convenience—should be prioritized in last-mile service design.

Mandate a clear, periodic last-mile data-gathering (and analysis) process. Data on commuter travel requirements and constraints, and data detailing the reasons for metro non-usage, should be collected periodically. This could be mandated by the Ministry of Housing and Urban Affairs (MoHUA). Data could be collected by metro rail last-mile planning departments, and last-mile interventions regulated and instituted through the state's transport department.

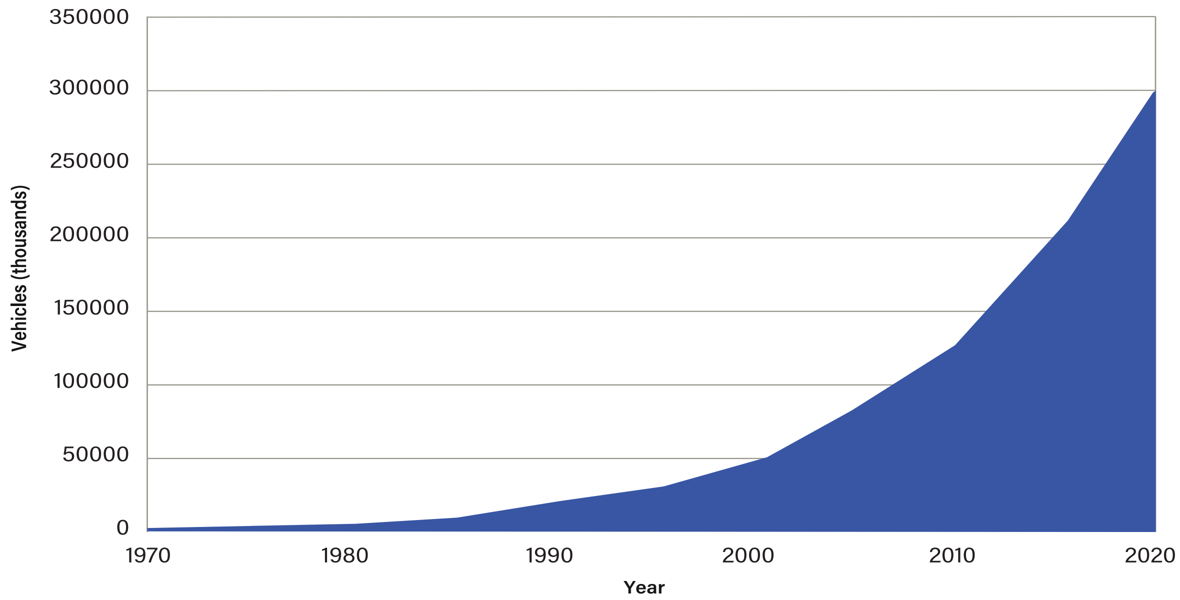
INTRODUCTION

Background

In line with global trends, India has been urbanizing. The share of India's urban population increased from 20 percent in 1970 to 35 percent in 2021 (World Bank 2023), and the 2001–11 decade marked the first time India's urban population growth exceeded its rural population growth (Bhagat 2018). The growing urban population has already begun to stress urban infrastructure, a visible symptom of which is increasing traffic congestion in cities and towns, which is estimated to cost the economy an estimated $22 billion annually in just Bengaluru, Delhi, Kolkata, and Mumbai (Chin et al. 2018).

An important reason for urban traffic congestion is the steep rise in vehicle ownership and usage. India's economic liberalization reforms in 1991 made it considerably easier for citizens to purchase vehicles. Urban public transport systems, however, remained chronically underfunded and thus unreliable (Pucher et al. 2005). Income increases—India's GDP per capita has increased sevenfold from $304 in 1991 (World Bank 2022)—have made it possible for more consumers to purchase a vehicle for the first time, and they have little incentive to stick to public transportation (see Figure 1).

Figure 1 | **Vehicular growth in India between 1970 and 2019**



Source: Registered vehicles in India from MoRTH (2021).

Although increased motorization improved citizens' access to economic opportunities, its externalities, apart from traffic congestion, are numerous: vehicle emissions have almost quadrupled since 2001 (Cazzola et al. 2021), and India reports among the highest road crash fatalities worldwide: approximately 150,000 annually (World Bank 2021). Left unchecked, this trend will further choke urban India.

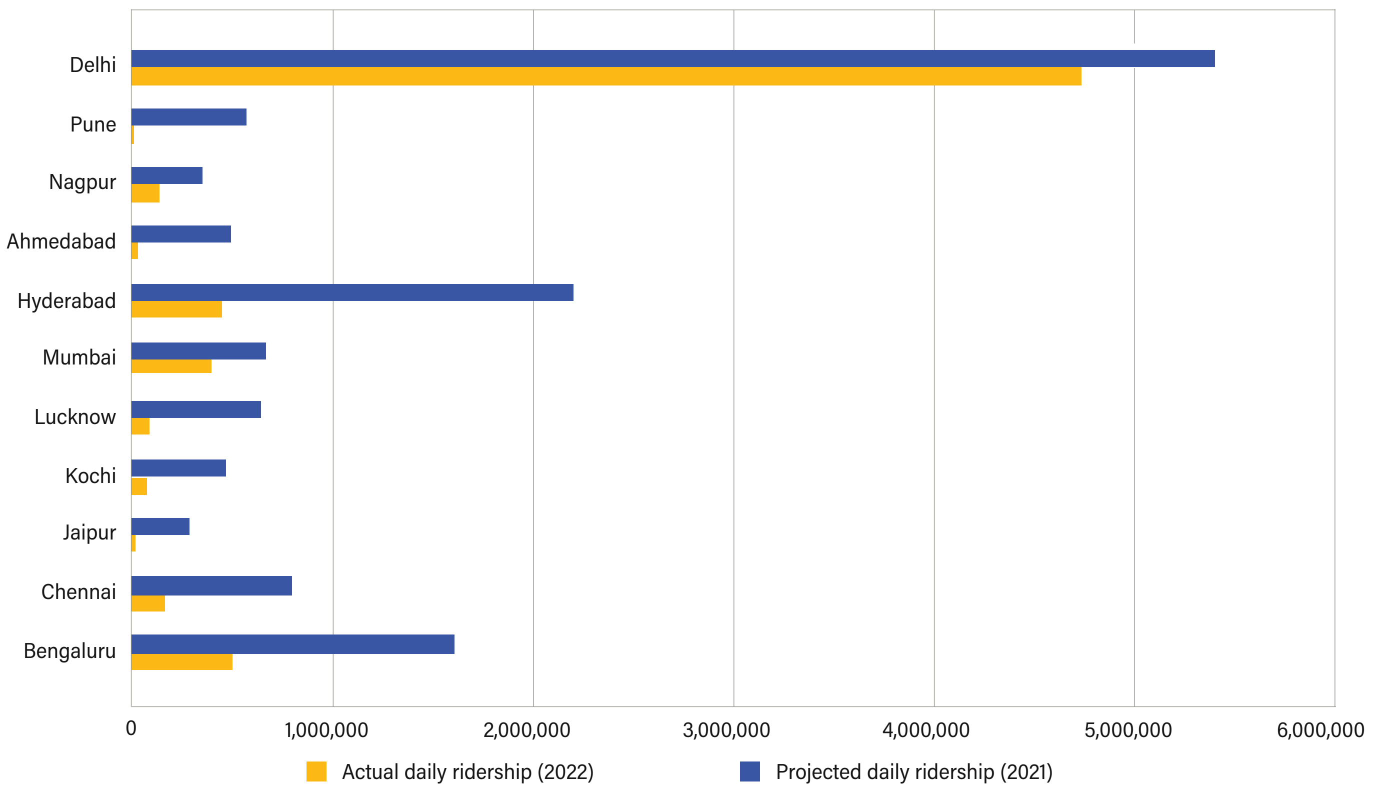
To tackle congestion, India's central and state governments have rapidly built and expanded metro rail systems across cities as a competitive public transport alternative. Over $25 billion has been invested in metro rail projects since 2010 (Mukherjee and Desai 2021). Metro rail systems are well perceived by users because of their high levels of comfort, speed, and efficiency (UNEP 2014). The uptake of the metro, however, has remained low across most cities, in some cases less than 10 percent of the projected ridership (UITP India 2021; see Figure 2).

Although numerous factors explain this ridership discrepancy, poor access to and from metro stations—the first- and last-mile problem—is frequently cited (Chidambara 2012; Kumar 2015; Kanuri et al. 2019; Irani 2022). Recent policies have recognized the link between poor last-mile connectivity and low metro rail ridership, and recommended the development of feeder bus networks to the metro as a policy solution (MoHUA 2017). However, many feeder bus services have failed due to a lack of ridership (Bangalore Mirror Bureau 2017; Gandhiok 2022; G. Sharma 2022).

A fundamental problem is the lack of comparable data across cities on the last-mile requirements of Indian metro commuters. This information gap motivated a recent three-city (Bengaluru, Delhi, and Nagpur) metro commuter survey and on-ground research conducted as part of WRI India and the Toyota Mobility Foundation's Station Access and Mobility Program (STAMP). This research aimed to provide insights into four interlinked questions around the metro last-mile problem:

- Who uses the metro in India currently, how do they use it, and what are their last-mile choices?
- What are users' last-mile connectivity requirements? That is, what does a "good" last-mile mode or option look like? How do fares, travel, and wait time impact last-mile choices?
- How do preferences vary across different user segments (for example, gender and income)?

Figure 2 | **Projected and actual metro ridership in India**



Source: See Appendix A.

- Given these user preferences (and their variance across different user groups), what types of last-mile modes should be prioritized and what parameters should they be based on?

This paper is structured into four sections:

- The first section sets the context and need for this study, discussing the metro rail last-mile problem and focusing on the research gaps.
- The second section discusses the design and methodology of the research, along with its findings and insights.
- The third section extends these insights to last-mile mode planning, using commuter preferences to highlight when different modes are likely to succeed at a station.
- The final section ties this paper together, explaining why existing measures to improve last-mile connectivity have failed and how better data collection and analysis is required to improve metro access.

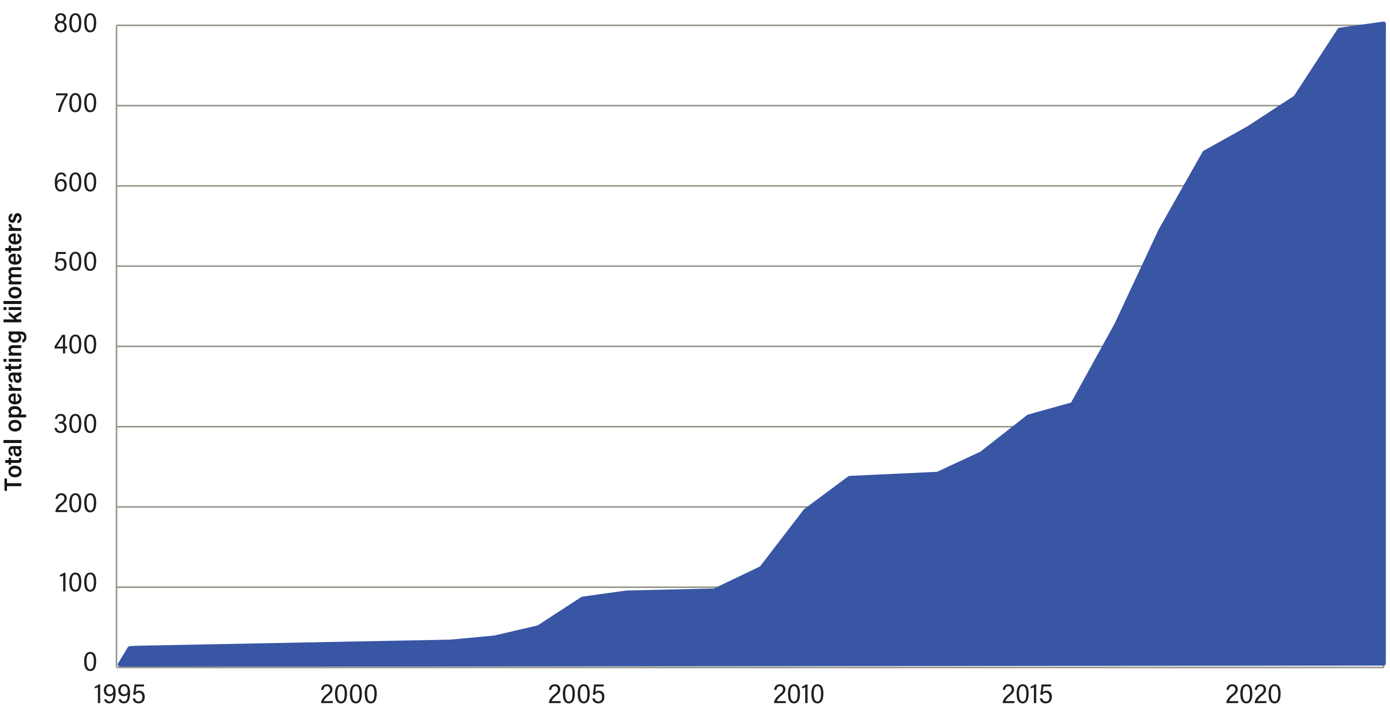
Setting the context: The metro rail "paradox"

India's conventional approach to urban transport funding has been to prioritize roadway expansion projects over public transport investments (Hidalgo et al. 2013). This approach often accelerates motorization by incentivizing the purchase of personal vehicles (Vox 2015). Even today, India unfortunately invests far more on urban road expansion projects than on public transport (Verma et al. 2021).

However, India's central government did note India's rapid motorization and the associated problems. India's National Urban Transport Policy (2006) emphasized public transport and prioritized the movement of people over vehicles on roads (MoHUA 2006). Earlier, India's Ninth and Tenth Five Year Plans (1997–2002 and 2002–2007) envisaged mass transit systems as a solution for urban transport problems, highlighting the need for structured funding of such projects (Dawda et al. 2021). In 2005, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was introduced, providing central financial assistance to harness urban reforms, including transport reforms (MoHUA 2005).

Although public buses were funded under JNNURM, the growth of metro rail systems has been more visible. In 2000, only 1 Indian city (Kolkata) had a functional metro rail network; by December 2022, this number had risen to 18 (MoHUA 2022). Eleven more metro rail networks are under construction, with another 31 at the planning and approval stage (KPMG 2022; see Figure 3).

Figure 3 | **Metro rail growth in India**



Source: See Appendix B.

Metro rail systems have benefited millions of citizens, especially in Delhi, where the metro network spans almost 400 km. Ethnographic research has identified how the Delhi metro has been especially empowering for women as a "safe" mass transit option that allows them to travel alone (Sadana 2010), linking them with employment they could not have accessed otherwise (Tayal and Mehta 2021). The safe reputation of the metro made families less likely to discourage women from traveling. Often, women looked for metro-accessible jobs and reported feeling independent because they could access more of the city. By allowing women to travel farther, the metro also "expanded … (their) conceptions of the geographic boundaries of the city" (Gopal and Jin Shin 2019). The metro has enabled many other commuter segments to access education, employment, and leisure. In addition, it has catalyzed cost and efficiency gains by encouraging residential, industrial, and commercial development near stations (Mukherjee and Desai 2021).

Still, metro rail systems in India fall well short of the ridership projections in their detailed project reports (DPRs). As of December 2022, no Indian city has met ridership projections, with many cities struggling to achieve a fraction of their projected ridership.

Rail ridership estimates are commonly overinflated to secure project approval; sometimes, faulty demand modeling produces unrealistically high estimates (Flyvbjerg et al. 2014). Yet, the disjunction in the Indian context is concerning (Sharma et al. 2013). Cities with the highest disparities between anticipated and actual ridership are smaller cities with a single metro rail corridor that lack city-level network coverage, and perhaps did not need a metro rail system in the first place. However, even metropolitan cities with larger metro networks have not achieved the expected ridership levels.

One barrier is affordability. Using an accepted global definition of "affordable" public transport—where expenditure on transport does not exceed 10–15 percent of a family's monthly budget (CSE 2019)—the metro prices out India's lower-income segments. However, even for segments that can afford the metro, a fundamental issue is the last-mile problem: problems in metro access disincentivize many commuters. The metro cannot provide door-to-door connectivity, necessitating some access mode. In India, last-mile mass transit access modes include the following:

- Non-motorized access: Walking is extremely popular, and cycling is less frequently used.
- Auto-rickshaws: These are partially enclosed, motorized 3–6 seater three-wheelers that can be hailed off the road or via apps. Drivers obtain permits from the government and either own or rent the vehicle. Auto-rickshaws are cheaper than taxis and can maneuver on narrower roads. However, complaints of overcharging are common.
- Buses: These are run by government transport corporations and private operators.
- Shared paratransit: This consists of auto-rickshaws, smaller and slower e-rickshaws, and larger vehicles such as jeepneys and maxicabs. These services run on fixed routes and charge per seat. They are usually frequent and affordable; however, they do sometimes run overloaded and without permits.
- Taxis: Some cities have "hail" taxis (known as kaali-peelis). App-based services have also become prominent.
- Own vehicles: These are often two-wheelers.
- Pick-ups and drop-offs by friends, colleagues, or family members.
- Company-provided shuttle services.
- New mobility solutions, such as app-based e-bike rentals.

Despite many (theoretical) options, last-mile connectivity to the metro remains a bottleneck. WRI India's research in Bengaluru indicated that about 70 percent of potential metro users surveyed avoid the metro due to inconvenient access (Kanuri et al. 2019), and other surveys reported similar percentages (Chidambara 2012; Kumar 2015). Other academic papers, briefs, and media articles have also highlighted the importance of last-mile connectivity in metro rail usage (CSE 2017; Singh 2020; Irani 2022).

This results in the metro rail paradox: although the metro rail journey itself is reliable, safe, and convenient, accessing the metro (including non-motorized modes such as walking and cycling) often entails unreliable, expensive, unsafe, uncomfortable, and inconvenient modes. Commuters choose a travel mode aligning closely with their overall travel requirements. If the first- or last-mile component of their journey fails to meet their requirements, the metro is unlikely to be a compelling choice.

Thus, the investments made in high-quality metro rail projects—$25 billion just since 2010, with a further $3.8 billion committed to upcoming projects up to 2026 (Mukherjee and Desai 2021)—must be properly utilized, which will attract more users to public transport and reduce motorization. The opportunity cost of inadequate access to the metro is considerable; the International Labour Organisation (ILO) estimates that better access to safe transportation can improve the participation rates of women in developing countries by 16.5 percentage points (ILO 2017). Indeed, research indicates that women are considerably less likely to use the metro if it does not cover the entire journey, because of the concomitant dependence on last-mile services (Tayal and Mehta 2021).

Policy responses

Central government policy documents acknowledge that poor last-mile connectivity hampers metro rail ridership. The Metro Rail Policy of 2017 clarifies that proposals for new metro rail systems seeking central financial assistance must include feeder systems and commit to developing them:

> *Every proposal for Metro Rail should necessarily include proposals for feeder systems that help to enlarge the catchment area of each metro station at least to 5 kms. Last mile connectivity through pedestrian pathways, Non-Motorized Transport (NMT) infrastructure, and induction of facilities for para transit modes will be essential requirements for availing any central assistance for the proposed metro rail projects. State governments will be required to commit provisioning of feeder systems for the metro rail proposed for availing central financing assistance (MoHUA 2017).*

The accompanying appraisal guidelines for new metro rail lines include a checklist to ensure that last-mile feeder network planning is incorporated into such proposals. The Motor Vehicles Act, one of the principal acts governing road transport in India, was amended in 2019. Among other changes, to improve last-mile connectivity to mass transit, it allowed state governments to relax several stringent provisions governing the issue of permits for passenger transport vehicles (MoRTH 2019).

In over half a decade since the Metro Rail Policy was instituted, complaints of poor last-mile connectivity to metro rail lines have persisted, leading a recent Parliamentary Standing Committee to note the following:

> *The Committee, however, express[es] concern that all metro networks do not have … First and Last Mile Connectivity facilities … The Committee are of the opinion that presence of First and Last Mile Connectivity is something that makes metro networks "Mass Transportation Systems" in [the] true sense and it should be made mandatory for all the metro stations. Further, the ridership is directly proportional to [the] presence of First and Last Mile connectivity. In the absence of First and Last Mile Connectivity, the projected ridership cannot be achieved (Standing Committee on Housing and Urban Affairs 2022).*

The need for this study

Despite acknowledging the problem and mandating better last-mile planning, the government has not made significant progress toward solving it. Moreover, interactions with several metro rail operators and last-mile provision stakeholders revealed that data-driven methods are not used for planning last-mile connectivity. Instead, feeder services are planned based on "intuition," or the number and type of buses that can be spared for the route. Although some services have worked, many have eventually been canceled owing to a lack of ridership (TNIE 2011; Bhasin 2014; ToI 2018). These abrupt cancelations compound the uncertainty around metro access.

Designing successful metro last-mile services requires understanding what metro commuters want. At present, the only data available on commuter origin-destination demand patterns are ridership forecasts from the DPRs. However, this analysis uses a conventional four-step transport modeling process that usually analyzes travel demand at the city ward level (Sreenivas 2011; N. Sharma et al. 2013; Yadav and Ghodmare 2021). As wards can span several square kilometers, they are too large a unit of analysis for accurate inferences on commuter last-mile preferences to be drawn from them. A commuter whose destination is 250 meters (m) from the metro station is unlikely to choose the same last-mile mode as a commuter whose destination is four km away from it.

At a more academic level, research has been conducted on the factors influencing metro last-mile mode choice. The literature identifies four broad sets of factors that influence last-mile mode choice (see Table 1).

A few studies have been conducted on metro last-mile mode choice in India. Kumar (2015) surveyed commuters in Delhi and examined the relationship between last-mile characteristics and metro ridership, finding correlations between income level, metro trip length, land-use patterns, and non-walk last-mile mode choice. Goel and Tiwari (2016) surveyed 1,112 existing metro users in Delhi. Using a multinomial logit regression model, they found that vehicle ownership, trip length, and population density around the metro station had statistically significant impacts on respondent last-mile mode choice. Swami and Parida (2015) used data envelopment analysis (DEA) of a commuter survey sample of 1,450 Delhi metro rail commuters to identify "efficient" stations and last-mile cases. However, this analysis did not explore how their study parameters influenced commuter mode choice at a network level.

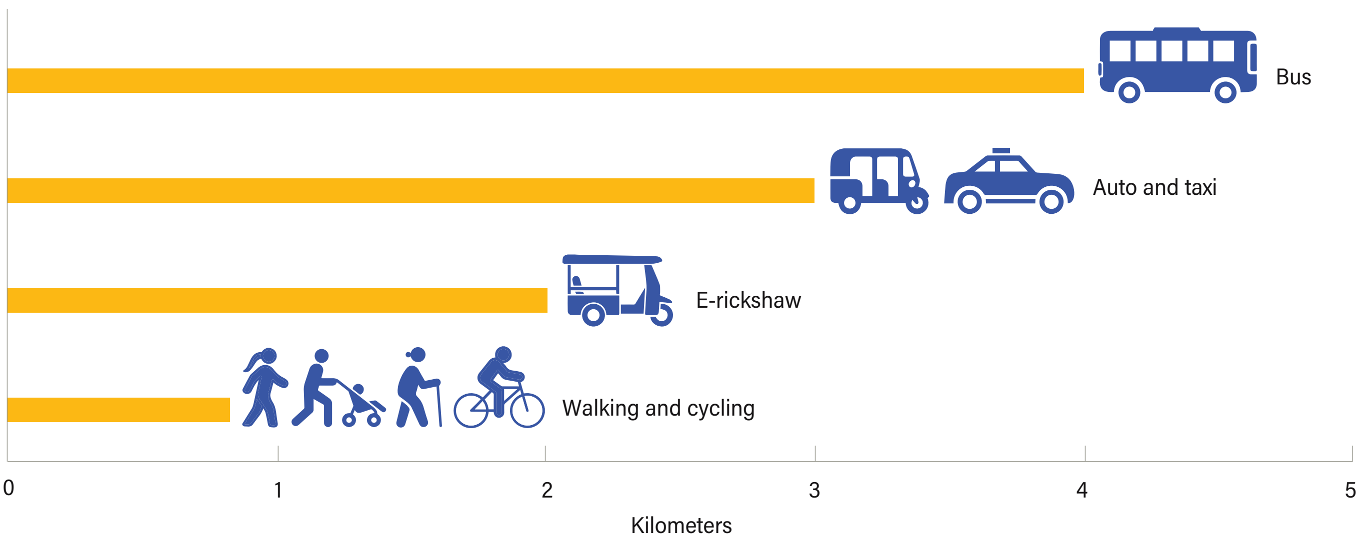
There is thus a lack of standardized data to compare last-mile travel patterns and preferences across cities and different user segments. For example, if women prefer certain last-mile modes, they can be prioritized in areas with more women travelers. Also, at present, several planning assumptions for last-mile access are guided by old metrics or international case studies. For example, globally, the influence zone for walking—the distance that a commuter is willing to walk to access a transit station—is approximately 800 m (Transit Cooperative Research Program 2003). There is a need for recent data to validate these assumptions in India. Similarly, if data indicate that metro commuters are often willing to travel more than the standard three km "catchment" radius to access

Table 1 | **Factors influencing last-mile mode choice**

CHARACTER GROUP	VARIABLES
Socioeconomic characteristics Aspects of individuals that influence their choice of mode from the available options	Income Gender Age Occupation Vehicles ownership Household members
Trip characteristics Characteristics of the trip being made	Access distance of trip to the station Purpose of trip Time of trip
Mode characteristics Characteristics of the modes available to perform the journey	Availability Travel cost Travel time Reliability Number of transfers
Station area characteristics Characteristics of the immediate surroundings and catchment area of the station	Population and employment density Land-use mix Road length density Road intersection density Quality of pedestrian infrastructure Access to bus stops in the catchment area Built environment

Source: Kumar 2015; Goel and Tiwari 2016; Meng et al. 2016; Mo et al. 2018.

Figure 4 | **Average travel distance ranges for different last-mile modes: A global case study**



Source: Los Angeles Country Metropolitan Transportation Authority – Metro 2014.

a metro station (Ann et al. 2019), route planning for last-mile modes will need to extend beyond this radius to tap the latent demand to the metro (see Figure 4).

To fill this research gap as part of STAMP, WRI India and the Toyota Mobility Foundation commissioned a three-city survey (Nagpur, Bengaluru, and Delhi) of metro rail commuters, aiming to answer the research questions articulated earlier:

- Who uses the metro in India currently, and how do they use the metro (including their last-mile choices)?
- What do users seek as part of their last-mile connectivity requirements? That is, what does a "good" last-mile mode or option look like? How do fares, travel, and wait time impact last-mile choices?
- How do preferences vary across different user segments (for example, gender and income)?

These broad data points, as a baseline, can help guide last-mile planning decisions and address the last research question: what types of last-mile modes should be prioritized, and which parameters should they be based on?

SURVEY PROCESS AND INSIGHTS

Survey methodology

To understand the existing metro rail user demographics and last-mile mode choices, we conducted a post-pandemic three-city revealed preference survey of metro rail users (Nagpur: March 2022, Delhi: October 2022, Bengaluru: March 2023). This is the first published research paper on this scale of Indian metro commuter travel patterns that uses a standardized questionnaire and a data analysis process. The survey questionnaire was designed to capture the trip patterns, mode choices, and socioeconomic parameters of the respondents, thus revealing the factors influencing their last-mile mode choices (for the full survey questionnaire, see Appendix C). This revealed preference approach aligns with similar methodologies from earlier studies that sought to understand usage of public transport and ways to improve ridership (Chauhan et al. 2016; Suman et al. 2017).

Surveying metro non-users to understand their reasons for non-usage and the last-mile modes and fare scenarios that would induce them to shift to the metro (i.e., a stated preference survey) could improve the ability of this research to suggest methods to attract current non-users. However, we decided against stated preference surveys due to methodological concerns about their accuracy in predicting actual respondent behavior (Calfee et al. 2001; de Corte et al. 2021; Lunke et al. 2021). Moreover, time and cost considerations made it impossible to conduct and triangulate both revealed and stated preference surveys. Data collected from respondents are shown in Table 2.

Our on-ground experience suggested that the age and length of the city's metro rail network are associated with different commuting patterns and mode choices. Indian cities with older metro rail networks often have more well-defined metro feeder networks, because last-mile services have had more time to evolve. Cities with larger metro rail networks are also likely to see longer first- and last-mile trips, and as metro commuters begin to travel longer distances, they are also more willing to travel farther to access stations (Krygsman et al. 2004). Because capturing data from only the busiest metro rail systems would bias the data, three cities with varying metro rail network characteristics were chosen for this analysis (see Table 3).

Table 2 | **Data collected from respondents as part of the survey**

PARAMETER	DATA COLLECTED	
Commuter socioeconomic profile	Gender Age Occupation Level of education	Monthly household income (INR) Number of household vehicles Access to vehicles for this trip
Trip patterns	Trip purpose Trip frequency Overall trip origin location Origin metro station Destination metro station	Overall trip destination location First- and last-mile mode chosen First- and last-mile distance traveled First- and last-mile cost and wait times In-vehicle travel time for first- and last-mile modes

Source: WRI India–TMF survey data.

Table 3 | **Cities chosen for the study**

CITY	DESCRIPTION	CITY POPULATION (2011 CENSUS)	METRO RAIL OPERATING LENGTH AND YEAR OF INTRODUCTION	DAILY RIDERSHIP	AVERAGE METRO TRIP LENGTHS (KM)
Nagpur	The third largest (but non-metropolitan) city in Maharashtra, with rapidly expanding infrastructure and industry.	4,653,570	Nascent metro: 26.1 km, 2 lines; inaugurated in 2019	140,000	4
Bengaluru	Capital of Karnataka, India's third-most populated city.	9,621,551	More evolved but not a completely mature network: 54.78 km, 2 lines; inaugurated in 2011.	500,000	9
Delhi	India's capital and its second-most populated city.	16,787,941	The country's most extensive metro rail network: 357.98 km, 9 lines; inaugurated in 2002.	4,732,016	13

Note: km = kilometer.

All figures (rail operating length, daily ridership, and average metro trip length) were the latest available figures when the surveys in each city were conducted (Nagpur: March 2022, Delhi: October 2022, Bengaluru: March 2023).

Source: WRI India–TMF survey data.

A total of 7,200 respondents were interviewed. Our target was at least 300 respondents at each surveyed station to ensure a representative sample with statistical power at the station level. For Nagpur—which was the first city surveyed—we collected 600 samples per station to ensure sufficient statistical power because pre-survey reconnoitering indicated that metro stations in Nagpur's (short) metro rail network tended to have a much wider spatial dispersion of first- and last-mile trips than the other two cities and to provide a greater margin if errors in the dataset made some samples unusable. After checking the dataset and finding minimal errors, we asked the same agency to collect 300 samples per station for Delhi and Bengaluru.

To ensure data capture from actual metro commuters, intercept surveys were conducted on users entering and exiting the selected metro stations. The sampled metro stations in each city were selected for representativeness across multiple categories:

- Geographic spread
- Distribution across different metro lines
- Number of last-mile modes available outside the station
- Station footfall
- Land use around the station

Because the route lengths of the metro networks in the three surveyed cities varied greatly and representativeness had to be maintained across the abovementioned parameters, the numbers of stations and respondents surveyed were not uniform across the three cities (see Table 4).

To ensure that the sample represented different trip purposes, data were collected across both the morning and evening peak periods and during the afternoon off-peak period. The only socioeconomic quota defined was gender; to ensure that the collected data possessed statistical power for gender-based metro commuting insights, we required that female respondents should constitute 40 percent of the samples.

This paper aims to provide key demographic and travel pattern descriptive insights from this analysis. These insights will enable a wide range of audiences to understand the primary inferences from this dataset, why such an exercise is important, and how building upon this dataset with data from more cities can vastly improve our ability to plan and design better last-mile services.

This survey does have its limitations. The revealed preference approach of interviewing existing metro users introduces an element of sample bias. Another problem with revealed preference surveys in mode-choice modeling is that the data make it difficult to ascertain why alternative modes were not chosen (Lunke et al. 2021); for example, a user may have

Table 4 | **Stations surveyed in the three cities**

CITY	NUMBER OF STATIONS SURVEYED	NUMBER OF RESPONDENTS	STATIONS
Nagpur	4	2400	Chhatrapati Square, Kasturchand Park, Shankar Nagar, Sitabuldi
Bengaluru	6	1800	Banashankari, Baiyyappanahalli, Cubbon Park, Indiranagar, Nayandahalli, Yeshwanthpur
Delhi	10	3000	Central Secretariat, Hauz Khas, ITO, Jamia Millia, Karol Bagh, Kashmere Gate, Najafgarh, Nangloi, Nehru Enclave, Rithala

Source: WRI India–TMF survey data.

chosen a particular last-mile mode simply because it was the only one available. To counteract this, we present data from last-mile route patterns where multiple options were available for metro commuters, ensuring that the respondent did have last-mile options.

Broad findings and inferences

Summary statistics from the survey are presented in Table 5.

This section is structured as follows. First, we discuss the profile of the average metro commuter in India and the primary last-mile mode trends observed. We then draw and juxtapose three insights from the survey: the effective catchment region of a metro station, income-based commuting patterns, and gender-based last-mile travel requirements. This juxtaposition highlights that important insights for metro last-mile planning require a spatial demographic analysis around metro stations. This analysis can identify the commuter segments likely to use the metro and the forms of last-mile modes that they are likely to favor.

Metro commuter profiles

Our survey data indicate a clear trend with metro commuters in India: young commuters who travel for education and work. Close to 90 percent of our sample fell between the ages of 19 and 35. In Nagpur, we witnessed a particular skew toward younger users, with 70 percent of our sample falling within the 19–25 age range. Unsurprisingly, travel to schools and colleges was the most frequently cited reason for using the metro in Nagpur—unlike the other two cities, where travel for work predominated. The reason for this difference could lie in the metro's sparse coverage at the time of the survey (26.1 km and

Table 5 | **Summary statistics**

		DELHI	BENGALURU	NAGPUR
N (sample size)		3000	1800	2400
Trip cost (INR)	**Mean**	6	13	7
	Median	0	0	0
Trip distance (km)	**Mean**	2	2	3
	Median	1	1	1
Age (%)	**Less than 18**	2	1	3
	19–25	43	50	68
	26–35	37	39	17
	36–50	15	9	9
	51–60	2	0	2
	60+	0	1	0

Table 5 | **Summary statistics (cont'd)**

		DELHI	BENGALURU	NAGPUR
Monthly household income- INR (%)	**<5,000**	0	3	2
	5,001-10,000	2	8	7
	10,001-20,000	32	22	35
	20,001-40,000	43	37	36
	40,001-60,000	19	20	13
	60,001-80,000	4	6	5
	80,001-100,000	0	2	1
	Above 100,000	0	2	1
Access to vehicle (%)	**Yes**	43	61	43
	No	57	39	57

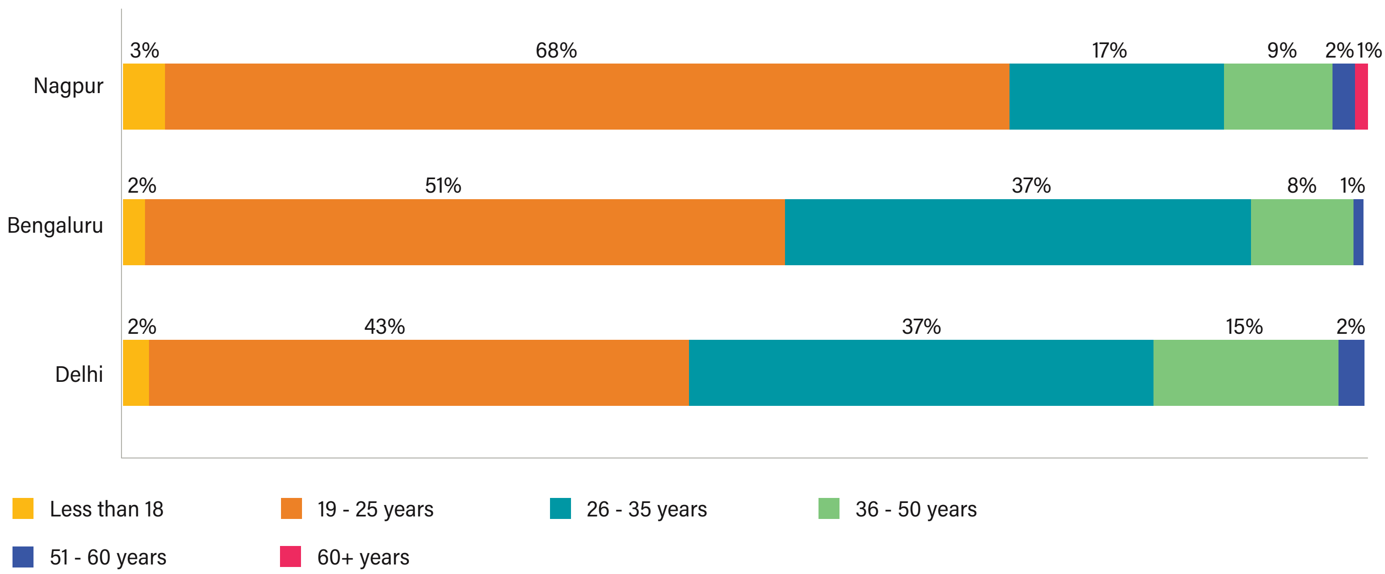
Note: INR = Indian rupees, km = kilometer.

Source: WRI India–TMF survey data.

2 lines), because of which many of the city's residential areas were not linked with its employment hubs. More importantly, Nagpur's metro fares at the time of the survey (March 2022) were lower than those of city buses, making it extremely affordable for students. Fares have, however, recently been hiked (The Live Nagpur 2023).

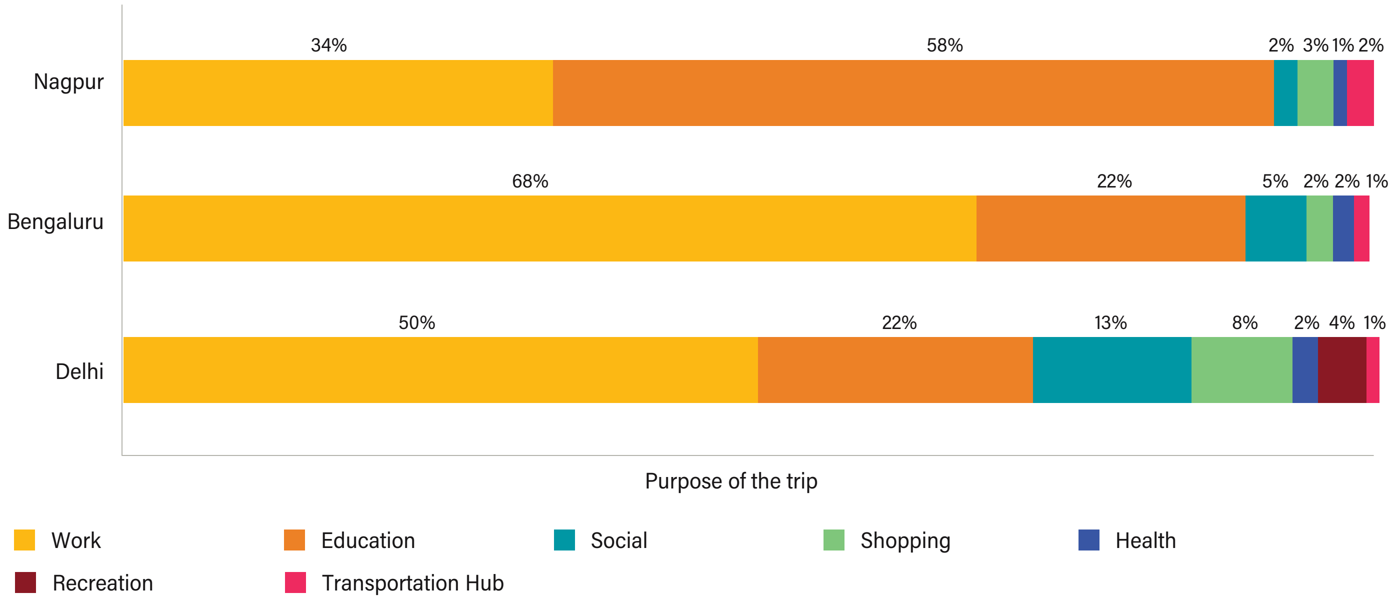
Delhi exhibited the most well-rounded user profile both in terms of age distributions and trip purposes, an indication that its extensive route network made the metro a viable option for leisure trips and for use by slightly older commuters as well. However, commuters aged above 50 formed a negligible proportion of users surveyed across all cities (see Figures 5 and 6).

Figure 5 | **Age distribution of surveyed metro commuters**



Source: WRI India–TMF survey data.

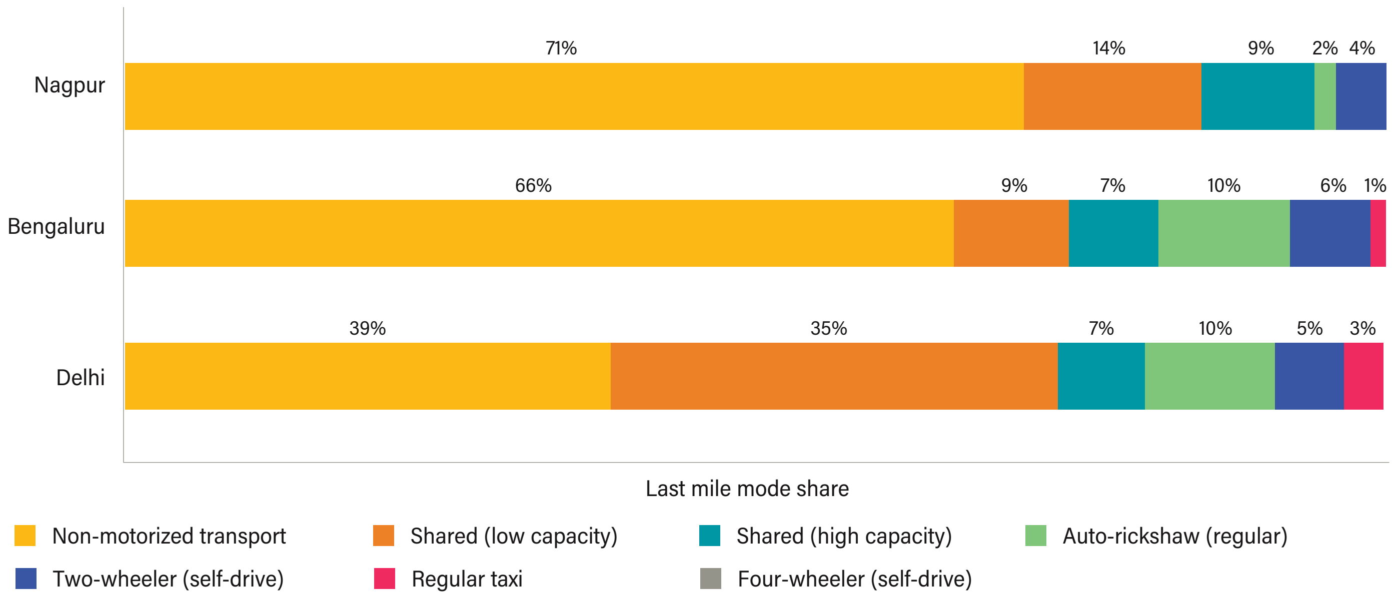
Figure 6 | **Trip purposes of surveyed metro commuters**



Source: WRI India–TMF survey data.

Our surveys reveal another trend: the predominance of walking and low-cost shared modes for last-mile access. In all the three cities, walking and shared modes contributed over 75 percent of last-mile trips (see Figure 7). The predominance of walking—despite the poor pedestrian infrastructure available in Indian cities—might stem from the metro's relatively young demographic. These commuters are likely to be physically fit and less likely to be deterred by low-quality or unsafe pedestrian infrastructure. However, this finding underscores the need for improved pedestrian infrastructure within the walking influence zone of the metro station, to attract commuters who are reluctant to walk or find it difficult to walk (e.g., elderly commuters or people with disabilities).

Figure 7 | **Last-mile mode shares**



Source: WRI India–TMF survey data.

Of the two primary shared modes (shared auto-rickshaws and buses), the former commanded a considerably higher share in both Nagpur and Delhi. The number of respondents claiming to have used a share auto-rickshaw for last-mile access in Bengaluru was unexpected because the city does not have a share auto-rickshaw network; however, further investigation revealed an informal system on specific last-mile sectors wherein different commuters traveling the same last-mile route boarded a regular auto-rickshaw and split the fare by mutual agreement. The relative lack of share auto-rickshaws in Bengaluru was made up for by an increased dependence on walking and regular auto-rickshaws, which are considerably more expensive.

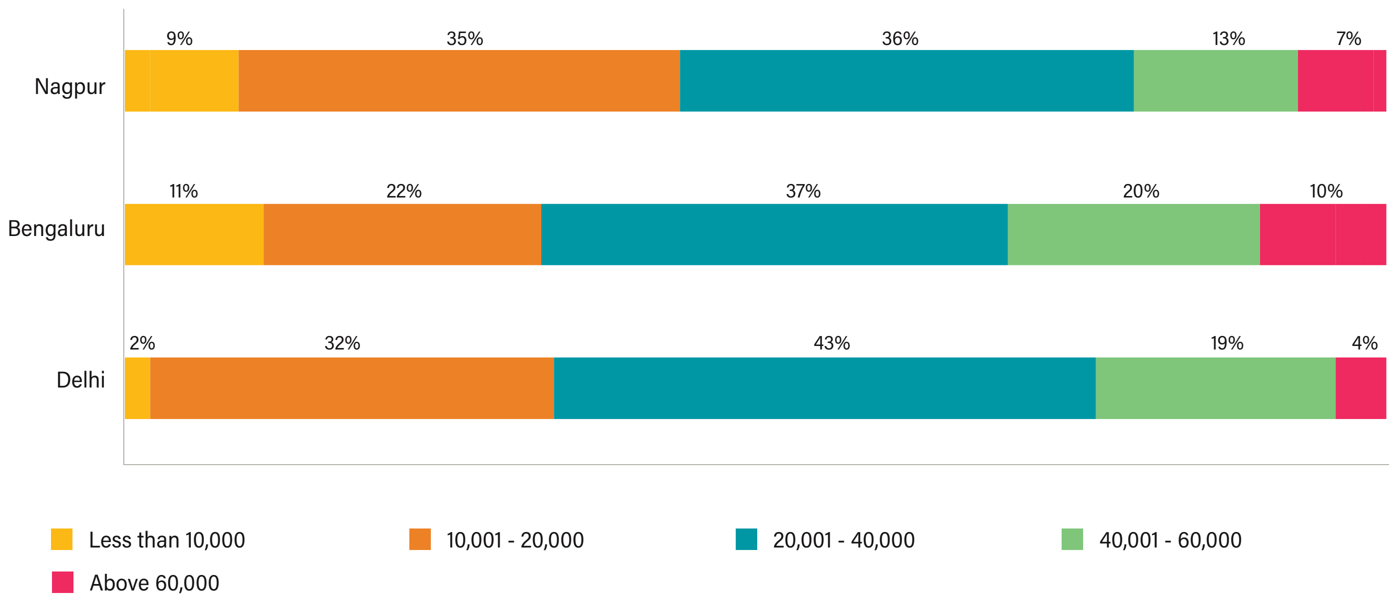
Income and last-mile mode selection

The dependence on walking and low-cost shared modes is explained by the income distribution of metro users. In all three cities, the primary monthly household income of metro users was between INR 10,000 and INR 40,000 ($121.26–$485.06), with at least 50 percent of the sample falling in this income bracket (see Figure 8). That income groups earning less than INR 10,000 ($121.26) are not well represented is unsurprising; the metro and associated last-mile commute costs are unaffordable at this income level. The low representation of users in income categories above INR 60,000 ($727.59) a month indicates that metro systems have not attracted many of India's more affluent commuters, who are likely to own and drive personal vehicles (Vijayalakshmi and Raj 2020).

Research indicates that habit formation among personal vehicle users, who become accustomed to the convenience of driving, plays an important role in their reluctance to switch to public transport (Idris et al. 2015). Further research is needed to understand how to induce more affluent users to switch to the metro. Without this, it is unlikely that Indian metro rail projects will be able to significantly reduce urban traffic congestion.

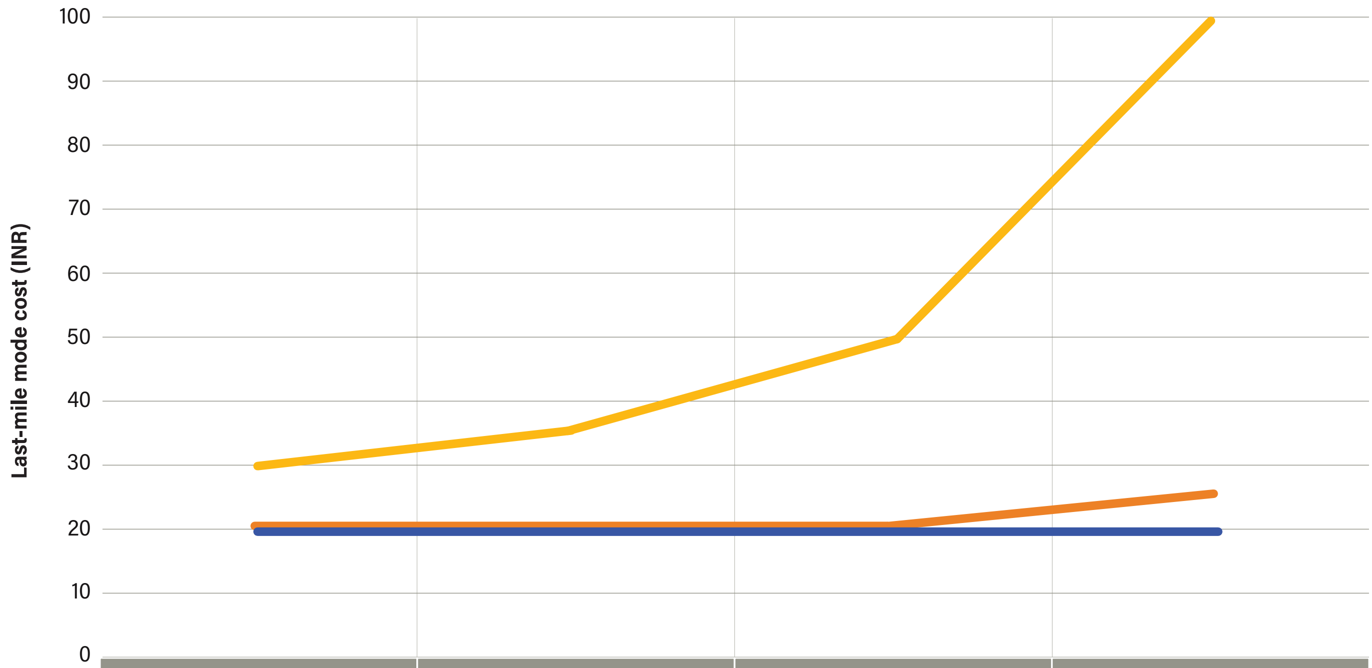
When stratifying metro station access costs by income, an interesting pattern emerges: the average first- and last-mile costs are relatively consistent across income groups in Nagpur and Delhi, but not in Bengaluru (see Figure 9). A reason is the presence of a robust share auto-rickshaw network in the former cities. Share auto-rickshaws operate frequently, can access narrower roads, and board or deboard users at any point along their route. This flexibility and low fare structure make them an attractive last-mile option even for commuters from slightly higher-income segments in Nagpur and Delhi (see Figure 10). Bengaluru lacks a share auto-rickshaw network, and buses do not provide frequent or reliable last-mile connectivity from several metro stations. As a result, some higher-income users accessing the metro choose on-demand modes such as regular auto-rickshaws, taxis, or new mobility modes such as rental scooters. This indicates that there is certainly some demand for higher-fare, on-demand services for metro last-mile connectivity. However, it is also likely that the lack of a proper share auto-rickshaw network prevents the metro in Bengaluru from achieving higher levels of ridership.

Figure 8 | **Monthly household income distribution of metro commuters (in INR)**



Note: INR = Indian rupees.
Source: WRI India–TMF survey data.

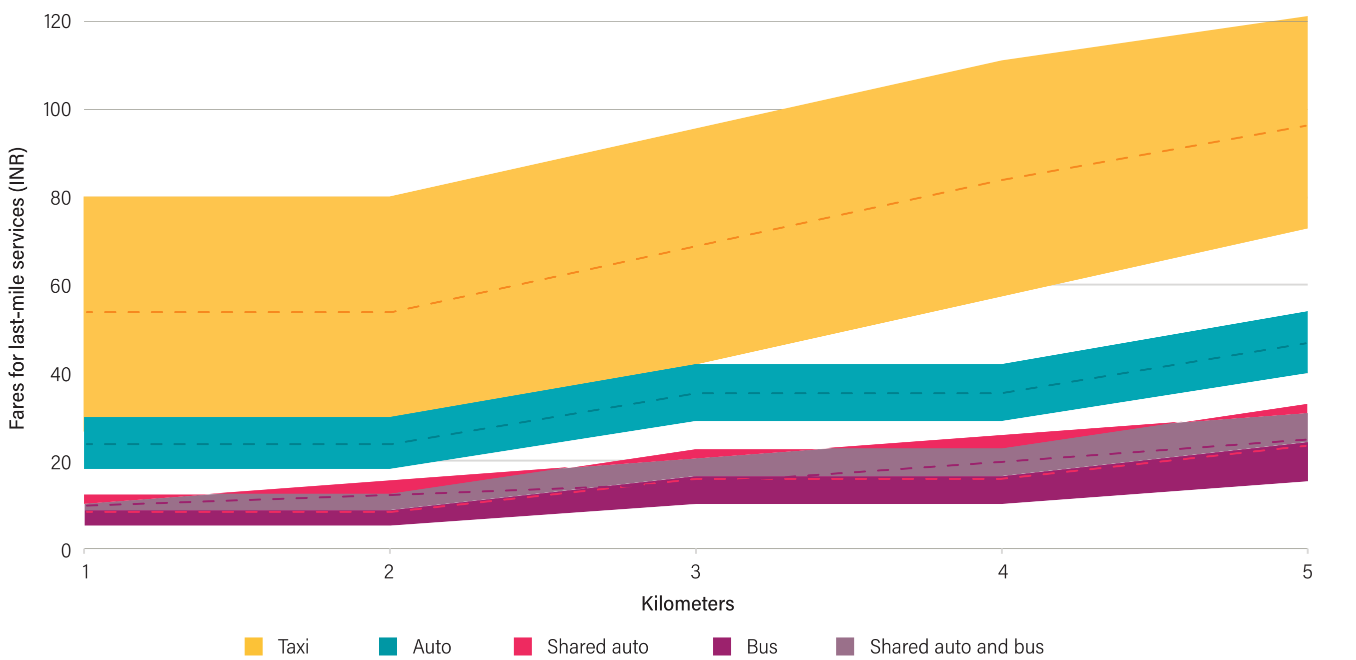
Figure 9 | **Comparison of trip costs for last-mile modes across different income brackets**



	10001-20000	20001-40000	40001-60000	60001-80000
Delhi	20	20	20	25
Bengaluru	30	35	50	100
Nagpur	20	20	20	20

Note: INR = Indian rupees. Source: WRI India–TMF survey data.

Figure 10 | **Average fares for last-mile services (cost per km)**



Note: INR = Indian rupees

Source: See Appendix D.

An insight from this section is the need to better understand income demographics around the metro station. Walking and low-cost shared services are the most successful modes across income groups; thus, improving pedestrian infrastructure and designing effective shared solutions for last-mile connectivity should form the baseline of last-mile planning at metro stations. Certain stations with higher-income demographics that lie beyond average walkshed ranges (approximately 800 m) can then be prioritized for more expensive but personalized, innovative, on-demand last-mile services that could induce those users to travel by metro.

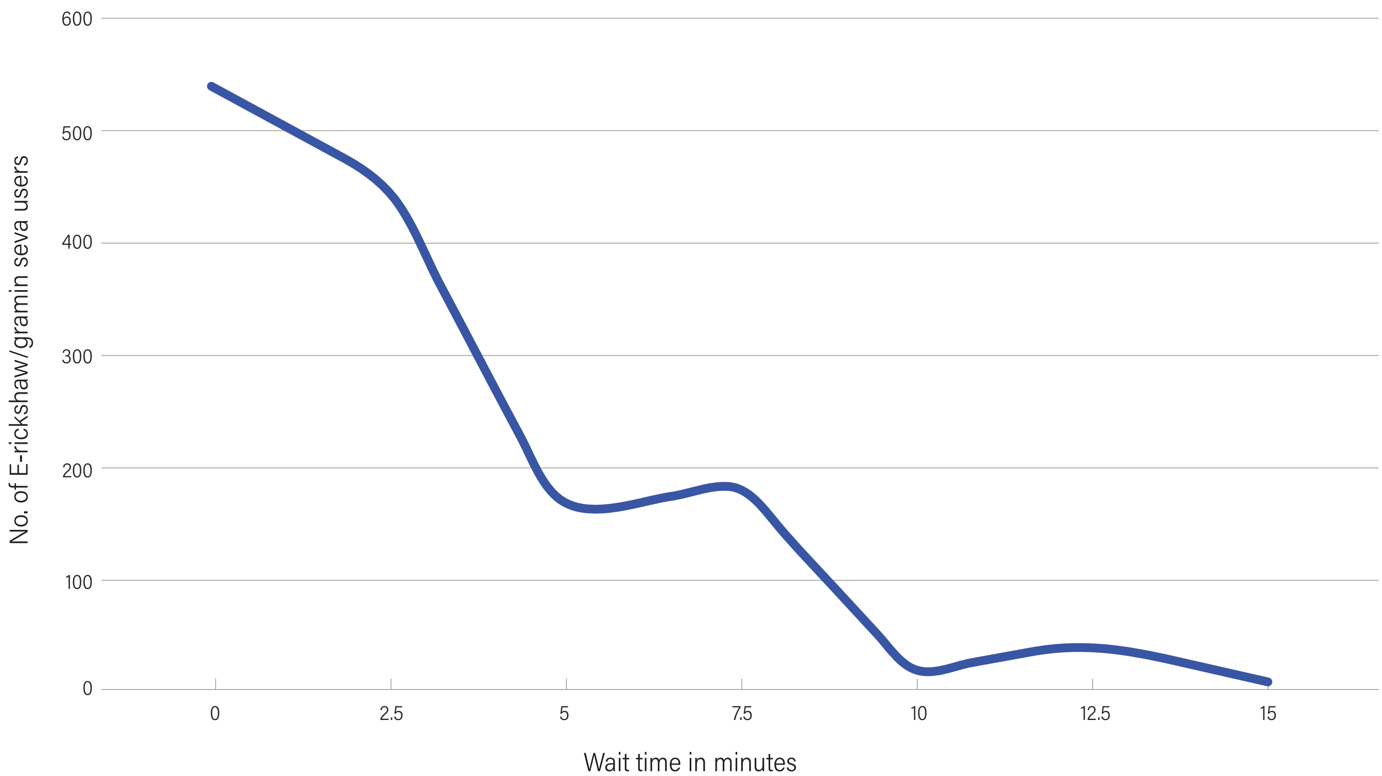
Gender

Data from our survey surprisingly did not exhibit statistically significant differences in last-mile mode shares by gender. More men used the metro for work than women, and more women used the metro for educational and shopping trips than men. However, three survey data points yield interesting inferences: although the wait times for last-mile modes are clearly associated with last-mile mode choice across respondents, women are more averse to waiting. Second, certain features of paratransit suit the needs of women commuters better than public transport. Third, given the last-mile trip patterns of women, the fare structures of many last-mile modes disadvantage them.

The marked aversion of women commuters to waiting for a last-mile service is well documented (Mishalani et al. 2006; Yoh et al. 2011; Fan et al. 2016; Chowdhury and Wee 2020; Shelat et al. 2022). A case study from our survey in Delhi is instructive: we analyzed the modal split between buses and share auto-rickshaws for metro last-mile trips where both modes operated. For these trips, 89 percent of our sample chose share auto-rickshaws over buses. This is especially interesting because women are allowed to travel without charge on government buses in Delhi (*The Economic Times* 2019). The distributions of users and wait times are displayed in Figures 11 and 12.

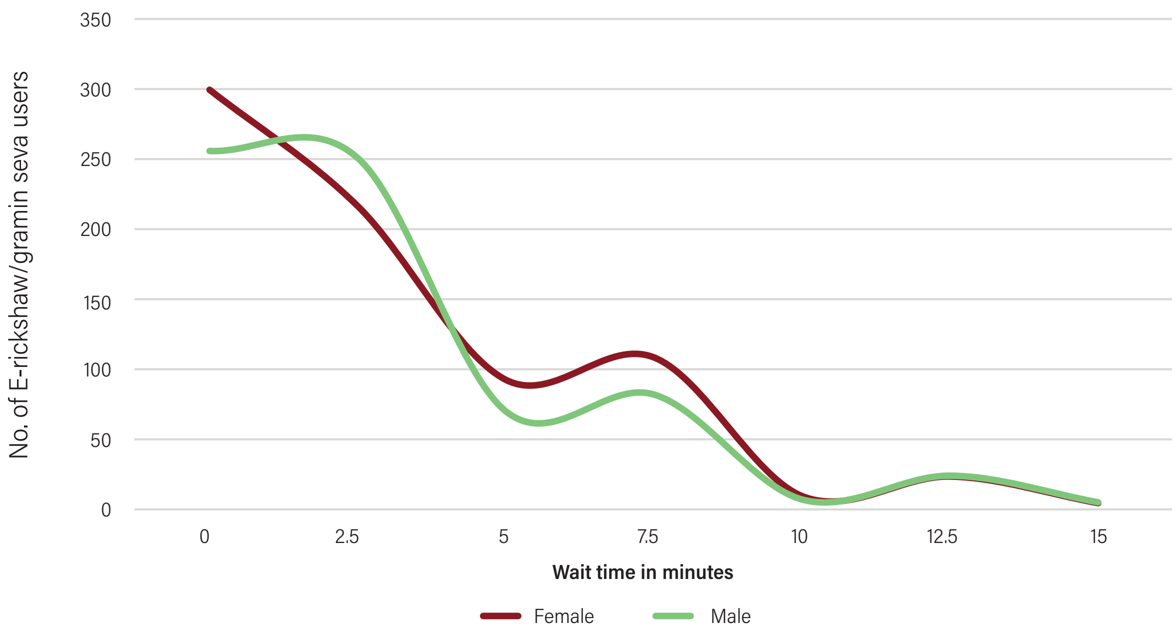
It is noteworthy that almost half of those who opted for share auto-rickshaws over a frequent bus were women, even though the latter mode was free for them. Also evident is the much steeper drop in the number of women waiting for longer periods of time than the overall sample, suggesting a higher aversion to waiting.

Figure 11 | **Wait time frequencies for users with access to high-frequency buses who opted for low-capacity shared services**



Source: WRI India–TMF survey data.

Figure 12 | **Gender-disaggregated wait time frequencies for users with access to high-frequency buses who opted for low-capacity shared services**



Source: WRI India–TMF survey data.

However, the choice of paratransit (share auto-rickshaws) by women may not be attributable only to frequency. Aspects of the commute that women perceive as threatening are the wait at isolated bus stops and traveling in crowded buses and trains, where sexual harassment, such as groping, is easier to perpetrate (Lea et al. 2017). As many as 71 percent of women in Kerala and 42 percent of women in Delhi reported having been harassed while waiting for public transport at bus stops (Cheranchery et al. 2019). Share auto-rickshaws offer the flexibility of being picked up or dropped off anywhere on their route, and they do not carry standing passengers. In this context, it is interesting to note that one state bus operator, the Telangana State Road Transport Corporation (TSRTC), has recognized the problem and now allows women to board and deboard buses at any point on the bus route after 7:30 PM (Livemint 2021).

Our data also indicate that women travel shorter last-mile distances on average, yet pay more than men. There are two possibilities: a slightly higher proportion of women opted for more expensive last-mile modes than men in the same income category, perhaps due to concerns about wait times and other safety concerns. Although this survey did not capture specific data on trip-chaining (combining multiple errands into a single trip), women tend to trip-chain more often (Nikore and Ollivier 2022). Because trip-chaining involves several shorter journeys, each with a relatively high base fare, the overall last-mile trip can be more expensive.

This survey provides some empirical backing to earlier theoretical studies on the problems faced by women during transit. It also underscores the need to schedule and design gender-sensitive last-mile modes and fare structures. Toward this end, an analysis of the TSRTC's decision to allow women to board and deboard buses anywhere along the route and its impact on gendered ridership may prove instructive.

These insights help us understand the preferences of different metro commuter segments for their last-mile commute. However, translating these insights into a better last-mile service design requires a clearer understanding of the demography within the catchment zone of a metro station. The following subsection focuses on our survey's insights into metro catchment zones.

Metro catchment zones

The catchment zone of a transit station is considered the spatial territory around the station from where users are drawn (Lin et al. 2016). Because the Metro Rail Policy focuses on "increasing" the catchment area of a metro station to at least five km, it is important to understand the existing catchment areas of metro stations across our survey cities. Figure 13 highlights the average metro station catchment areas (distances) along with the modes broadly used by respondents for different trip lengths within the catchment.

Table 6 | Gender-disaggregated average trip distances and costs

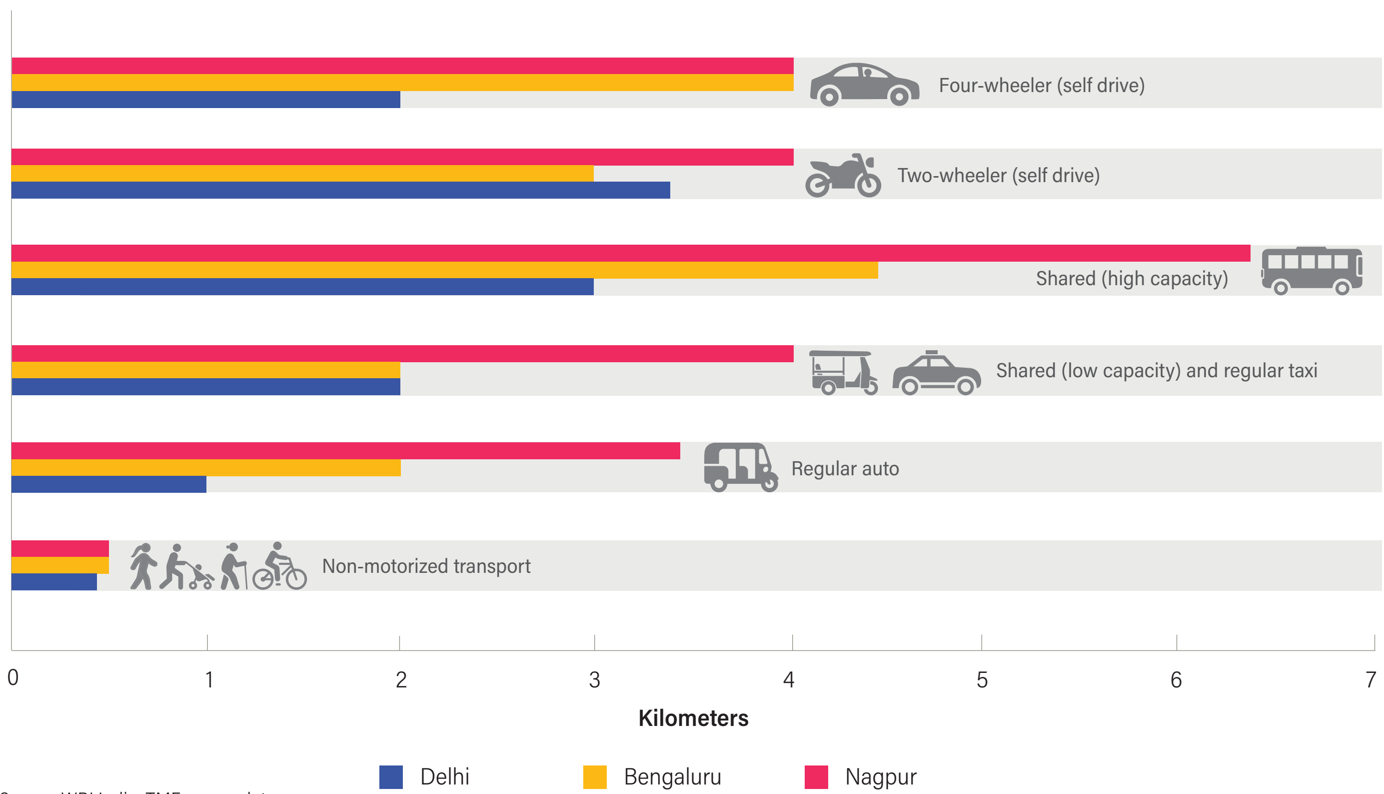
CITY	DELHI		BENGALURU		NAGPUR	
	Men	Women	Men	Women	Men	Women
Average trip distance (km)	1.86	1.73	2.28	2.18	2.88	2.87
Average cost (INR)	5.52	5.71	12.25	13.20	6.83	7.41
Average cost ($)	0.067	0.069	0.150	0.160	0.083	0.090

Note: km = kilometer; INR = Indian rupee.
Source: WRI India–TMF survey data.

The three cities exhibit different metro catchment zone regions. Delhi's distance range is lower because its extensive network and high density of metro stations necessitate shorter access travel distances, and a higher proportion of passengers in Nagpur access the metro station from far-flung suburbs. However, a consistent trend is the usage of specific last-mile modes for certain distance ranges: walking and cycling for distances up to a kilometer; paratransit modes for distances greater than the walkshed and up to three km; usage of self-drive two-wheelers for marginally longer distances; and a predominance of bus trips for the longest last-mile journeys. This broadly follows global patterns. It also suggests that specific last-mile modes serve different trip lengths well: walking for short-distance last-mile trips, the pick-up and drop-off flexibility of paratransit for marginally longer trips, the convenience of a self-drive two-wheeler for trips exceeding three km, and the advantages of higher bus speeds for longer-distance last-mile trips.

However, this survey uncovers an important aspect of Indian metro catchment zones: commuters are drawn to a particular metro station based on its access time (wait and travel time), not distance. The median last-mile access times for our three

Figure 13 | Catchment zones and distance ranges for different last-mile modes



Source: WRI India–TMF survey data.

Table 7 | **Metro station access time**

CITY	MEDIAN ACCESS TIME (MINUTES)	THIRD QUARTILE ACCESS TIME (MINUTES)
Bengaluru	10	19
Delhi	10	19
Nagpur	12	20

Note: Three quarters of the our sample access the metro station within this time.
Source: WRI India–TMF survey data.

cities are displayed below. Access times are remarkably consistent across income groups: in all the three cities, the range of median access times across income groups was 3.5 minutes or less, whereas the median distances varied considerably. This suggests that metro users consider metro use viable if they can access it within a specific time. In all the three cities, 75 percent of our sample accessed the station within a consistent time frame (see Table 7).

This suggests that if accessing the metro takes longer than 20 minutes, very few users consider taking it. This has important implications:

- Traffic congestion can reduce or expand the catchment area of a metro station.
- The catchment region of a metro station can be expanded—thereby serving a larger population and ideally increasing ridership—by providing last-mile services that reach the metro station faster. Increasing the effective speeds of these last-mile modes without dedicated bus/paratransit lanes is difficult; operating last-mile modes at a higher frequency (reducing wait times) is easier to implement.
- Even with the existing last-mile connectivity infrastructure, people are willing to travel for relatively long distances (or durations) to access the metro. Current planning for metro last-mile connectivity along the lines of the upcoming transit-oriented development (TOD) policies focuses on a much narrower catchment region: In Bengaluru, the draft TOD policy envisages servicing a metro catchment region of just two km by feeder bus (Asian Development Bank 2022). Although TOD is obviously desirable, limiting last-mile planning focus areas without empirical evidence on how far users are willing to travel to access the metro can artificially limit catchment zones, depriving many potential users of feeder services.

Implications

Insights from the previous three subsections feed into an overarching point: the need for a proper spatial demographic analysis for metro rail last-mile planning that is responsive to user needs. After identifying the effective catchment region of a metro station, understanding where different demographics reside is a necessary step to design services that they are likely to prefer. For example, if a significant number of women reside, work, or study along a particular last-mile corridor, running a shared service at a frequency of 15–20 minutes is unlikely to work. Similarly, a low-income group residing three km from the station is more likely to use the metro if they have access to an economical shared last-mile mode, as walking the same distance will take much longer than 20 minutes.

Thus, proper last-mile planning necessitates researching and answering the following questions:

- What is the effective catchment zone of the metro station, given the current traffic speeds and frequencies of shared last-mile services?
- What is the quality of pedestrian and cycling infrastructure within a 1 kilometer radius of the metro station?
- Within the current catchment zone, what is the spatial distribution of different commuter segments and what are their volumes?
- Based on the requirements of these different commuter segments and their spatial distribution, which modes or services are likely to be preferred?
- Are commuting segments on the periphery of the existing catchment region being priced out or timed out of metro station access?

This analysis can clearly identify last-mile service gaps that can be filled and the types of last-mile modes that are likely to be preferred by commuters. The types of data that should be collected and analyzed are indicated later.

LAST-MILE PLANNING

The previous section's findings provide some important insights into how users access the metro. They also highlight that a spatial analysis of demographics around the station is necessary to understand user preferences concerning the types of modes and services.

The income distributions of metro users and their price sensitivity make it evident that low-cost feeder modes (which are invariably shared services) are most likely to be preferred at most metro stations. This is also reflected in the Metro Rail Policy of 2017 and its appraisal guidelines, which mandate planning for and provisioning feeder bus systems at metro stations. However, many feeder bus services to metro rail systems across India have been withdrawn owing to a lack of ridership *(Hindustan Times 2010; Deccan Chronicle 2018; ToI 2018; Business Standard 2022; ToI 2022)*.

This section draws from the learnings in the previous section to provide a baseline planning schema for designing last-mile services that can gain enough ridership to be financially viable. These findings complement the findings of the previous section by matching commuter preferences with feasible last-mile services. This information is condensed into two schematic graphs summarizing the strengths of different feeder modes.

The frequency/capacity mismatch

It is important to closely examine the low-ridership-related failure of many feeder bus services, because current policy focuses on feeder bus systems as solutions to the metro rail last-mile problem. Failure to properly communicate information to potential users about the existence, routes, and frequency of new feeder bus services is one problem, and poor route design is another (WRI Ross Centre 2017). However, even on last-mile routes where information has been properly disseminated, many bus feeder services have been curtailed owing to a lack of ridership. This is likely due to a frequency/capacity mismatch.

Our survey shows that commuters are highly averse to waiting for a last-mile service; few users are willing to wait more than 10 minutes for a last-mile service. This agrees with the MoHUA' service level benchmarks for public transport, where an average wait time of over 10 minutes for a bus is classified under the poorest level of service (MoHUA 2009). During peak hours, commuters are likely to be more averse to waiting, which implies that shared services should run every five minutes or more frequently. This is closer to the highest level of service specified by the MoHUA benchmarks (MoHUA 2009).

Running a viable shared mobility last-mile service to the metro—that is, one that runs relatively full and can sustain operations in the long run—requires an understanding of three factors:

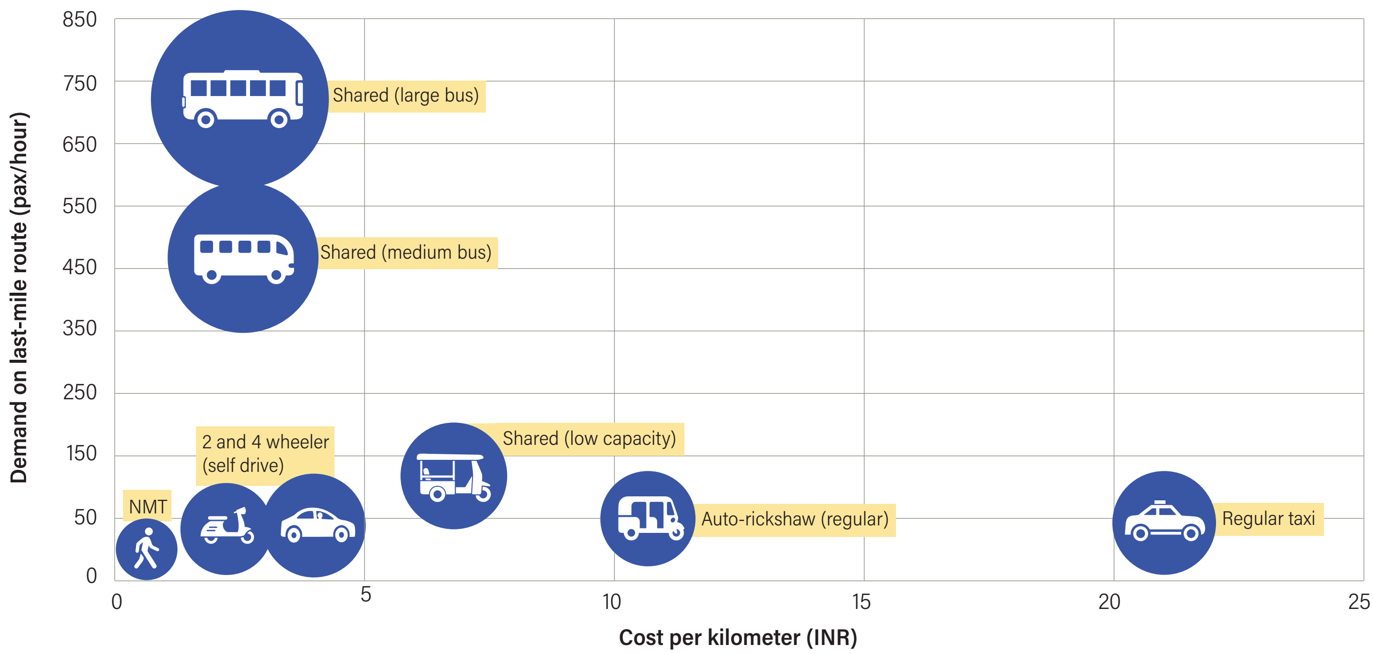
- The demand volume on the last-mile corridor
- The approximate number of people requiring shared mobility services from/to the station every 5 minutes (during peak hours) and 10 minutes (during off-peak hours)
- The capacity of the vehicles required to meet this demand at the desired frequencies

The starting point for shared-services last-mile planning should thus be the service frequency that commuters find acceptable. After understanding the demand volume on that specific last-mile corridor, shared modes whose vehicle capacities align with the demand at commuter-desired frequencies can be deployed. However, this process was not followed when operationalizing many feeder bus services. Because most city bus providers operate relatively high-capacity (30+ seater) buses on routes with lower demand, these vehicles either run with low occupancy or are forced to wait at the station for long periods to pick up passengers. This low occupancy necessitates frequency cuts, making the service even less useful for commuters. In Delhi, this problem has been recognized, with a recent route rationalization report recommending that lower-capacity buses be operated as last-mile services *(TNIE 2022)*.

We provide a broad schema, based on data classified by mode of transport from our survey, of the demand volume from a metro station at which different shared and other modes, operating at a five-minute frequency, can gain sufficient ridership. At lower demand, lower-capacity modes (up to eight passengers) can both satisfy commuter frequency requirements and run with sufficient occupancy to remain viable. At significantly higher levels of demand, this mode type becomes inefficient, causing congestion around metro stations: here, a bus can satisfy the frequency requirements and reduce congestion. Other on-demand modes, such as auto-rickshaws, taxis, and rental bikes, can be deployed across varying levels of demand at a station. However, because the fares of such services are higher, the commuter income demographics around a station must be understood to ensure that they are deployed at stations where users can afford these services. This schema is visualized in Figure 14.

This three-city graph provides an early-stage visualization of how last-mile planning can be improved by a better understanding of both which modes work well at different volumes

Figure 14 | **Demand-volume-based viability of different modes, evaluated on the basis of the per-kilometer fare**



Notes: NMT = non-motorized transport.
The size of the circle represents the capacity of the last-mile mode.
Source: See Appendix E.

of last-mile commuter demand at a station and the ability of users at a particular station to pay higher fares for more customized last-mile modes.

Effective ranges and adaptability to road networks

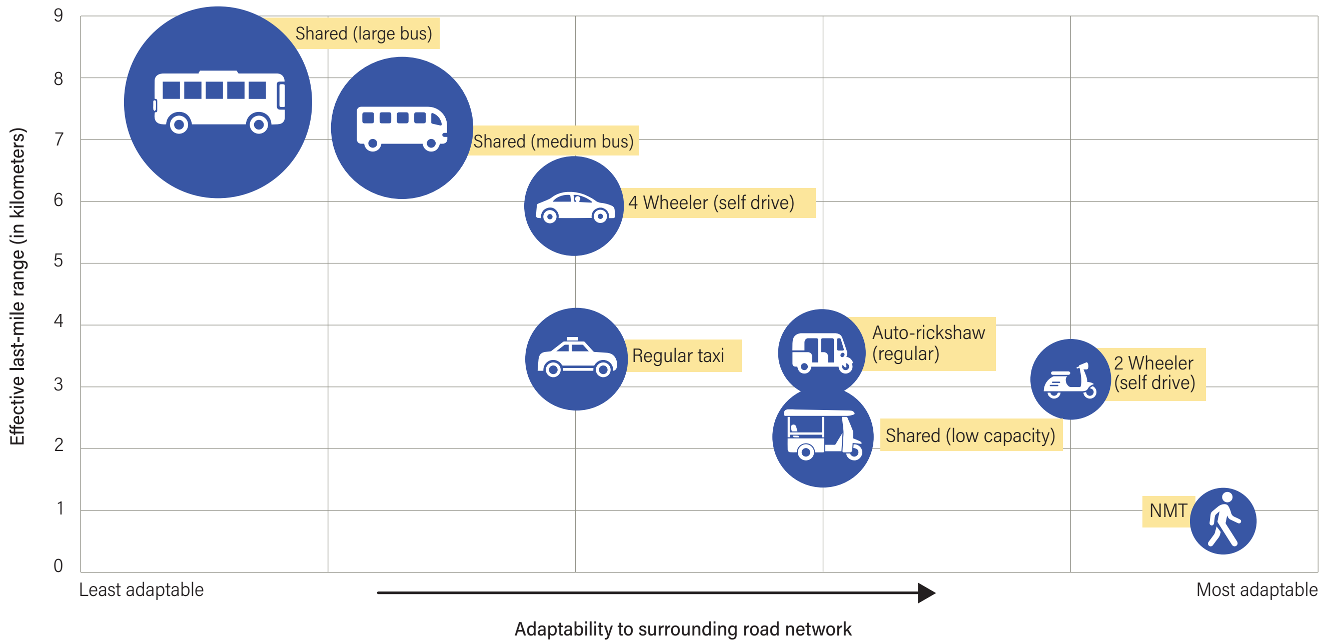
Although fares and demand are important principles in last-mile planning of viable services, other practical constraints exist. The first constraint is that different last-mile modes have different effective ranges, which is an outcome of commuter preferences and their operational characteristics. An understanding of broad last-mile trip patterns and distances from the metro station can help prioritize the right combination of last-mile modes based on trip patterns. For example, if a station experiences considerable last-mile demand to a destination six km away, a bus as a shared mode is likely to best fit this need. The second constraint is the adaptability of a mode to Indian road networks. Whereas non-motorized modes and two-wheelers (whether self-owned or rented) are most adaptable, buses require, at a minimum, a relatively wider road known as a collector street (15–30 m in width) to operate smoothly (IRC 2018). Figure 15 depicts these two considerations in a single graph.

This section has shown that successful last-mile planning requires two elements: understanding what commuters want and what can be feasibly provided. Figures 14 and 15 provide a baseline schema and visualization of the important parameters that must be considered. This research has provided insights into how existing commuters access the metro and how different last-mile modes may need to be provided. However, such a data gathering process must be periodically conducted at a larger scale, feeding into a well-defined analysis pipeline that guides decision-making on last-mile service provision. The following datasets are thus important:

- Existing metro commuter profiles and trip patterns (such as those captured in this survey)
- Non-user profiles and trip patterns for respondents residing/working within a three km radius of a metro station
- Characteristics of the existing access modes at metro stations, including frequency, fares, and coverage
- The spatial demography around the metro station, including population density and sociodemography
- Demand volumes along different last-mile corridors

These data could be gathered by the last-mile planning departments of metro rail agencies, though capacity building may be required before they can collect and analyze the data. The focus should be on overlaying these completed datasets to clearly identify last-mile service gaps, rather than on just generating reports summarizing the data that have been collected, a problem observed across many transit agencies in India.

Figure 15 | **Effective last-mile ranges of different modes, evaluated on the basis of their adaptability to surrounding road infrastructure**



Notes: NMT = non-motorized transport.
The size of the circle represents the capacity of the last-mile mode.
Source: *WRI authors.*

These gaps may need to be plugged through coordination between the metro operator, the state's transport department, bus transit agencies, city civic agencies, paratransit unions, and entrepreneurs.

Appendix F contains additional details about these datasets, including specific suggested parameters.

CONCLUSION AND RECOMMENDATIONS

The rapid growth of metro rail systems in India offers a promising opportunity to provide millions of citizens a reliable, comfortable, and convenient method of traveling within cities. Such systems can also reduce the country's growing transport emissions, road crash casualties, and the inequalities resulting from increased motorization. Despite the potential of these systems, ridership has remained lower than expected. Planning for metro rail systems and complementary transport often takes place in silos, without considering actual commuter preferences. If the entire metro journey is seamless—as determined by parameters such as accurate journey information; integrated, affordable fares and ticketing; easy access (first- and last-mile) to metro stations; quality station design; and comfortable trains—barriers to uptake will be low.

Unfortunately, the lack of high-quality last-mile infrastructure and service provision has created a paradox: a high-quality metro rail system hampered by poor access. This disincentivizes existing users from continuing with the metro and deters potential users from switching to the metro. Although better last-mile connectivity to the metro has been prioritized across multiple policies since 2017, the situation has not significantly improved.

Our three-city survey aimed to better understand the current demographic that uses the metro, delineate the broad trends driving mode choices, and provide actionable insights for last-mile planning. Each city (and metro network) has unique characteristics that drive usage patterns; the metro last-mile mode shares of a smaller city like Nagpur differ from those of Bengaluru and Delhi. The findings of this paper, however, indicate that the metro caters to a very specific age and income demographic and is seen as a viable commuting option if commuters can access metro stations within 20 minutes. Walking and low-cost shared modes predominate as last-mile modes, and we recommend that these modes (and the attendant infrastructure) be prioritized at stations to attract more commuters.

As the frequencies of the shared modes determine whether commuters select them, we also recommend last-mile planning processes that ensure high frequencies, ideally by clearly aligning last-mile mode capacities with demand.

From a gender standpoint, our research indicates that because women tend to make shorter trips and chain trips, they are disadvantaged by the fare structures of the shared modes. Further studies are needed to devise more gender-inclusive last-mile fare structures. The broader point (and recommendation) here is that the commuter—not operational exigencies—must be the central focus of any analysis, and collecting more data on actual commuter preferences can help provision services that reflect the needs of diverse user segments.

This study, based on the first published multi-city dataset of Indian metro rail travel patterns, offers several interesting insights. However, for a more robust last-mile planning process, data collection processes and datasets need to be built through a larger-scale, periodic process. The fact that last-mile planning has yet to improve six years after the MoHUA mandated better feeder route design is revealing. The failure to define a clear last-mile planning method and data collection process in the appraisal guidelines, including project DPRs, is a contributory factor.

The sections titled "Survey process and insights" and "Last-mile planning" have spotlighted several important datapoints and questions that need to be answered before effective last-mile services can be deployed at a metro station: commuter (and spatial) demographics and existing travel patterns; mode preferences of commuter segment; speeds, wait times, and fares of different last-mile modes; the demand volume on specific last-mile corridors; and the characteristics and travel patterns of current metro non-users. Further research identifying the reasons for metro non-usage by potential users, especially the affluent commuter segments, can identify the measures required to attract more users to the metro. There is also a need to ensure that metro services do not exclude lower-income segments.

We thus strongly recommend that the MoHUA mandate that these data be collected, perhaps once every three years, across all metro networks. Analysis of these data can reveal service gaps and the modes commuters are likely to prefer. An implementation mechanism will also need to be defined to ensure that the concerned agencies actually provide better last-mile access or infrastructure based on the analysis. As this database expands with information from more cities, its predictive power for upcoming metro rail systems is likely to improve as well.

Our survey has limitations; for example, its reliance on revealed preference data from existing metro users. The inclusion of a detailed land-use analysis in the future can improve this research. However, the insights yielded by our multi-city survey of metro users can help improve last-mile planning to the metro and deliver a more seamless commuting experience.

APPENDIX A: DATA SOURCES FOR FIGURE 2

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APPENDIX B: DATA SOURCES FOR FIGURE 3

The data for this figure have been compiled from a series of sources: – detailed project reports, annual reports, press releases, updates posted by the respective metro rail operator, and so on. The following URL contains a consolidated list of the various sources that have been referred to for this figure.

https://onewri-my.sharepoint.com/:x:/g/personal/archana_balachandran_wri_org/EVvzhRShkABMorFxqqoJO8kBW05v1mFm0puxUTNujkic-Q?e=XJW8gB

APPENDIX C: SURVEY QUESTIONNAIRE

Objective

The objective of the survey was to evaluate the level of service of last-mile connectivity in Indian metro networks as perceived by commuters. The questionnaire was accordingly framed to understand the first- and last-mile mode choices of commuters and their perceptions of these modes. Commuters were asked questions to elicit their day-to-day travel decisions: time spent traveling, expenditure on travel, wait time, and so on. To make the analysis more robust, a limited number of socioeconomic questions were also included in the survey.

Questionnaire

Start of the survey (filled-in by the surveyor):

1. Would like to participate in this survey?

a. Yes b. No (Survey terminates)

2. Date and time of survey ______________________________

3. Metro Station at which survey is being conducted?

____

4. Location within station where survey is being conducted?

a. Entry gate b. Exit gate

TRAVEL DIARY

6. How often do you travel by metro?

a. Traveling for the first time ______________________________
b. Travel occasionally every month (<5 times) ________________
c. 1-2 times a week ____________________________________
d. 3-5 times a week ____________________________________
e. >5 times a week ____________________________________

7. What is the purpose of this trip?

a. Work ____
b. Educational (visit School, College, etc.)
____
c. Recreational (visit movie theatre, shopping mall, etc.)
____
d. Shopping (visit supermarket, mandis, shopping mall, etc.)e. Social (visit friend, relative, etc.)
____
f. Health (visit Hospital, Clinic, etc.)
____
g. Transportation Hub (visit Airport, Railway St., Bus Terminus, etc.) (respondent to provide name of the transportation hub)
____
h. Any other (please specify) _____________________________

8. Is it an onward trip or a return trip?

1. Onward trip- From home
2. Return trip - Home-based trip

9. When do you make the onward trip (Non-home based)?

a. Early Morning (06:00 AM – 07:59 AM)
b. Morning Peak (08:00 AM – 10:59 AM)
c. Morning Off-Peak (11:00 AM – 04:59 PM)
d. Evening Peak (05:00 PM – 07:59 PM)
e. Evening Off- Peak (08:00 PM – 11:30 PM)
f. One way trip

10. When do you make the return trip (Home -based)?

a. Early Morning (06:00 AM – 07:59 AM)
b. Morning Peak (08:00 AM – 10:59 AM)
c. Morning Off-Peak (11:00 AM – 04:59 PM)
d. Evening Peak (05:00 PM – 07:59 PM)
e. Evening Off- Peak (08:00 PM – 11:30 PM)
f. One way trip

11. Please share the locality of your origin (Street Name, Area)

____

12. What is the nearest landmark/colony next to your origin?

____

13. Please share the locality of your destination (Street Name, Area)

____

14. What is the nearest landmark/colony next to your destination?

____

15. How do you make this trip from the origin to the destination? (Trip diary (Distance, fare, time to be calculated for each leg))

a. Walk
b. Cycle
c. Auto-rickshaw (regular)
d. Bus
e. Somebody picks or drops me (including carpool)
f. Two-wheeler (self-drive)
g. Four-wheeler (self-drive)
h. Regular taxi

FIRST MILE CONNECTION (LEG 1, LEG 2), IF APPLICABLE:

16. How much time do you spend on your first mile mode?

a. Less than 5 Minutes
b. 5 – 10 Minutes
c. 11 – 20 Minutes
d. 21 – 30 Minutes
e. 31 – 45 Minutes
f. 46 – 60 Minutes
g. More than 60 Minutes

17. How many minutes do you spend on waiting for your first mile mode?

a. Less than 5 Minutes
b. 5 – 10 Minutes
c. 11 – 15 Minutes
d. 16 – 20 Minutes
e. More than 20 Minutes

18. How much do you pay for the trip for your first mile mode?

a. 0
b. Up to INR 5
c. INR 6 – INR 10
d. INR 11 – INR 25
e. INR 26 – INR 50
f. INR 50 – INR 100
g. More than INR 100

19. How far do you travel in terms of distance by your last mile mode (km)?

____

20. Could you please tell us the primary reason for choosing these two modes for your first mile journey to the metro?

a. Most Affordable mode
b. Quickest mode
c. Most reliable mode (I know I will get one when I need to)
d. Most comfortable mode
e. Safest mode
f. Most convenient mode

21. Could you please tell us the secondary reason for choosing these two modes for your first mile journey to the metro?

a. Most Affordable mode
b. Quickest mode
c. Most reliable mode (I know I will get one when I need to)
d. Most comfortable mode
e. Safest mode
f. Most convenient mode

PRIMARY MODE (LEG 1, LEG2):

22. How much time do you spend on your primary mode?

____

23. How much time do you spend waiting for your primary mode?

____

24. How much do you pay for your journey by your primary mode?

____

25. How far do you travel in terms of distance (in km)?

____

LAST MILE CONNECTION (LEG 1, LEG 2), IF APPLICABLE:

26. How much time do you spend on your first mile mode?

a. Less than 5 Minutes
b. 5 – 10 Minutes
c. 11 – 20 Minutes
d. 21 – 30 Minutes
e. 31 – 45 Minutes
f. 46 – 60 Minutes
g. More than 60 Minutes

27. How many minutes do you spend on waiting for your first mile mode?

a. Less than 5 Minutes
b. 5 – 10 Minutes
c. 11 – 15 Minutes
d. 16 – 20 Minutes
e. More than 20 Minutes

28. How much do you pay for the trip for your first mile mode?

a. 0
b. Up to INR 5
c. INR 6 – INR 10
d. INR 11 – INR 25
e. INR 26 – INR 50
f. INR 50 – INR 100
g. More than INR 100

29. How far do you travel in terms of distance by your last mile mode (km)?

____

30. Could you please tell us the primary reason for choosing these two modes for your first mile journey to the metro?

a. Most Affordable mode
b. Quickest mode
c. Most reliable mode (I know I will get one when I need to)
d. Most comfortable mode
e. Safest mode
f. Most convenient mode

31. Could you please tell us the secondary reason for choosing these two modes for your first mile journey to the metro?
a. Most Affordable mode
b. Quickest mode
c. Most reliable mode (I know I will get one when I need to)
d. Most comfortable mode
e. Safest mode
f. Most convenient mode

32. What all are the modes that you use during your return/ onward trip to home? (Based on 8)
a. I use the same modes on my return trip
b. I use a different set of modes on my return journey
(In case of code b, capture travel diary for their return journey)

33. Why do you choose not to travel by public transport (bus or train)?
a. I don't like to walk to the nearest stop/station
b. Lack of safety at bus stops/on the bus
c. Services are unreliable (I don't know when the bus will arrive)
d. Takes too long
e. Too crowded/uncomfortable
f. Absence of Last mile connectivity to Bus/ train
g. Other (specify)

METRO RIDE

34. How do you usually pay for your Metro journey?
a. Single Ticket
b. Group Ticket
c. Smartcard (pay as you like)
d. Day pass (1 day/ 3 days)
e. Monthly pass
f. Mobile application (Please specify which one)

35. How do you recharge your smartcard/pay for the tickets?
a. Payment wallets (UPI/QR code)
b. Ticket counter
c. Ticketing machine
d. BMRCL services- WhatsApp services
e. Other (Specify)

36. (For options other than Smartcard) Would you be able to tell us, why don't you use the Smartcard?
a. I am not aware of the Smartcard.
b. I don't travel frequently enough to justify buying a Smartcard.
c. I don't want to pay the extra cost to buy and use a Smartcard.
d. Other (Specify)

37. Do you use journey planner?
a. Yes (please specify)
b. No

38. If given the choice, what kind of improvement would you like to see in your first or last mile travel? Multiple choice
a. Existing services are fine
b. Better footpaths
c. Providing cycle tracks
d. Better illumination (streetlights)
e. Journey Planner (integration of Metro, Bus, Cab, E-rickshaw etc.)
f. Signage
g. Providing bus stops closer to metro stations
h. Providing Bicycle or e-bike
i. Providing shared mobility
j. Providing Auto-Rickshaw
k. Providing Feeder bus service
l. Affordable and reliable Last mile options
m. Others (specify)

SOCIOECONOMIC DETAILS

39. Please code gender.
a. Male
b. Female
c. Others

40. What is your age?
a. Less than 18
b. 19 - 25
c. 26 - 35
d. 36 - 50
e. 51-60
f. 60+
g. Refused

41. What is your educational qualification?
a. No schooling completed
b. Up to 8th grade
c. Some high school, no diploma (10th pass)
d. High school graduate, diploma, or the equivalent (12th pass)
e. Some college credit, no degree
f. Trade/technical/vocational training
g. Bachelor's degree
h. Master's degree
i. Professional degree
j. Doctorate degree

42. What is your occupation?

a. Employed
b. Self-employed
c. Daily wage worker
d. Awaiting job
e. Unemployed
f. A homemaker
g. A student
h. Retired
i. Unable to work
j. Other (Specify)

43. What is your monthly household income (INR)?

a. <5k
b. 5,001 – 10,000
c. 10,001 – 20,000
d. 20,001 – 40,000
e. 40,001 – 60,000
f. 60,001 – 80,000
g. 80,001 – 1,00,000
h. Above 1,00,000
i. Refused

44. How many members are in the household?

____

45. Number of vehicles in the household

a. 2W: ___________
b. 4W: ___________
c. Cycle: __________

46. Is there a vehicle belonging to you/your family that you could have used to make this trip?

a. Yes
b. No

APPENDIX D: DATA SOURCES FOR FIGURE 10

Table D1 | **Average fares for last-mile services**

CITY	MODE	COST (MIN.) IN INR	REFERENCE
Nagpur	Bus	12	The Times of India. 2022. "Nagpur Municipal Corporation's 17% Hike in Aapli Bus Fare, Auto Fares Too up from Midnight." The Times of India, June 15. https://timesofindia.indiatimes.com/city/nagpur/17-hike-in-aapli-bus-fare-auto-fares-too-up-from-midnight/articleshow/92213818.cms.
	Share Auto	10	WRI India–TMF survey data
	Regular Auto	18	Taxi Auto Fare. 2023. "Nagpur Auto Fare Card." May 16. https://www.taxiautofare.com/taxi-fare-card/Nagpur-Auto-fare.
	Taxi	28	Maharashtra Motor Vehicle Department. 2022. "Black Yellow Taxi (CNG) Tariff Card." https://transport.maharashtra.gov.in/Site/Upload/GR/YB%20Taxi%20English%201.pdf.
Bengaluru	Bus	5	Bengaluru Metropolitan Transport Corporation. 2020. "Non AC/Ordinary Services Fares." May 26. https://mybmtc.karnataka.gov.in/page/Services/Non+AC+Services/en.
	Share Auto[a]	15	
	Regular Auto	30	The Times of India. 2022. "Minimum Charge for Aggregator Autos in Bengaluru Breaches Rs 100," October 6. https://timesofindia.indiatimes.com/city/bengaluru/minimum-charge-for-aggregator-autos-in-bengaluru-breaches-rs-100/articleshow/94668970.cms.
	Taxi	80	Taxi Calculator. 2013. "Taxi Rate Bangalore." October 2013. https://www.taxi-calculator.com/taxi-rate-bangalore/363.
Delhi	Bus	5	Delhi Capital. 2022. "DTC Bus Fares 2022." June 22, 2022. https://www.delhicapital.com/information/dtc-bus-fares/.
	Share Auto	10	WRI India–TMF survey data
	Regular Auto	30	Hindustan Times. 2023. "Delhi Auto, Taxi Fares Raised; ₹11 per Km for Autos and ₹20 for AC Taxis." Hindustan Times, January 11, 2023. https://www.hindustantimes.com/cities/delhi-news/delhi-auto-taxi-fares-raised-rs-11-per-km-for-autos-and-rs-20-for-ac-taxis-101673435414233.html.
	Taxi	40	Hindustan Times. 2023. "Delhi Auto, Taxi Fares Raised; ₹11 per Km for Autos and ₹20 for AC Taxis." Hindustan Times, January 11, 2023. https://www.hindustantimes.com/cities/delhi-news/delhi-auto-taxi-fares-raised-rs-11-per-km-for-autos-and-rs-20-for-ac-taxis-101673435414233.html.

Note: a. Regular auto being shared by 2 or 3 people, INR = Indian rupees
Source: WRI authors. Note:

APPENDIX E: ASSUMPTIONS FOR FIGURE 14

Figure 14, which illustrates the volume of demand-based viability of different modes, was drawn using the following assumptions about the capacity of different transport modes and their cost per kilometer.

Table E1 | **Cost per kilometer fares and maximum capacity for last-mile services**

MODE	COST PER KM (INR)	CAPACITY (MAX.)
Non-motorized transport	0	1
Two-wheeler (self-drive)	3	2
Auto-rickshaw (regular)	11	3
Shared (low capacity)	7	4
Regular taxi	21	4
Four-wheeler (self-drive)	4	4
Shared (medium bus)	3	28
Shared (large bus)	3	47

Note: INR = Indian rupees
Source: WRI authors.

APPENDIX F: DETAILED DATA PARAMETER LIST

Table F1 | **Data collection methodology**

BROAD DATA POINT	POTENTIAL COLLECTION METHOD	INFORMATION	UTILITY OF DATA
Existing commuter profiles	Intercept surveys at metro stations, such as the one conducted as part of this research.	Commuter gender, income ranges, age ranges, access to vehicles, digital literacy	Understanding the current commuting demographic, access choices made, cost/time sensitivity in metro access, and differences in access choices based on socioeconomic factors.
Existing commuter last-mile trip patterns (revealed preference)	Intercept surveys at metro stations, such as the one conducted as part of this research.	Origin and destination metro stations, broad trip origin and destination locations, first- and last-mile modes chosen, distances traveled, fares paid, access and egress times (including wait time), stated reasons for choosing these modes	Understanding the current commuting demographic, access choices made, cost/time sensitivity in metro access, and differences in access choices based on socioeconomic factors.
"Potential" user characteristics (stated preference)	Random intercept surveys within a 5 km radius of the station	Commuter profiles of metro non-users, broad primary trip patterns, stated reasons for non-usage of the metro	Although stated preference surveys do not necessarily predict potential behavior well, these surveys can help understand whether metro non-usage is a function of socioeconomic factors, access issues, or simply because the metro does not align with respondent trip patterns.
Existing mode characteristics	Drawn from the existing commuter trip pattern survey, supplemented by data from other transit agencies and on-ground observations	Availability of different modes along different last-mile routes, mode vehicle capacity, average wait and travel times, and journey fares across modes	Understanding whether existing modes serve commuter preferences well.
Spatial demography	GIS analysis and secondary data sources such as the economic census, rental rate data from housing websites, along with data extrapolated from the intercept surveys abovementioned	Population densities, broad spatial demographic characteristics	This will help understand whether the existing last-mile modes price out or time out certain areas from accessing the metro. **Due to the sensitivity of these data, adequate safeguards need to be put in place to ensure that they are used only for transit improvement purposes.**
Demand volumes along last-mile corridors	On-ground observation, extrapolation from the intercept surveys	Hourly volumes of commuters looking to travel along a last-mile corridor	Matching demand volumes with the capacity of last-mile modes is likely to satisfy this demand when operated at high frequencies.

Note: GIS = geographic information system.

Source: WRI authors.

ABBREVIATIONS

DEA	data envelopment analysis
DPR	detailed project report
GIS	geographic information system
FM/LM	first-mile/last-mile
ILO	International Labour Organization
INR	Indian rupee
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
MoHUA	Ministry of Housing and Urban Affairs
MoRTH	Ministry of Road Transport and Highways
NMT	non-motorized transport
NUTP	National Urban Transport Policy
STAMP	Station Access and Mobility Program

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ABOUT WRI INDIA

WRI India is a research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.