# Planning For Last-Mile Connectivity: Assessing Feeder Transport and Parking Strategies Around Metro Stations in Bhopal

**A THESIS**

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*by*

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# CANDIDATE'S DECLRATION

I hereby certify that the work which is being presented in the thesis entitled **"Planning For Last-Mile Connectivity: Assessing Feeder Transport and Parking Strategies Around Metro Stations in Bhopal"** in partial fulfillment of the requirements for the award of the Master of Planning (Urban Planning) and submitted in the Department of Architecture and Planning of the Maulana Azad National Institute of Technology, Bhopal is an authentic record of my own work carried out during the period from January 2026 to July 2026 under the supervision of **Dr. Jagdish Singh,** Professor, Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal.

The matter presented in this dissertation has not been submitted by me for the award of any other degree of this or any other Institution.

**Piyush Shrivastava**

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

**Dr. Jagdish Singh**

Date

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**ABSTRACT**

The thesis titled *"Planning for Last-Mile Connectivity: Assessing Feeder Transport and Parking Strategies Around Metro Stations in Bhopal"* examines the emerging challenges of metro accessibility and integrated urban mobility within the context of a rapidly growing Tier-II Indian city. The study is grounded in the recognition that the long-term success of metro systems depends not only on corridor-level transit infrastructure, but also on the efficiency, safety, and accessibility of last-mile connectivity systems surrounding metro stations.

Bhopal, currently experiencing rapid urban expansion, increasing motorization, dispersed urban growth, and fragmented public transport integration, presents a critical case for proactive metro accessibility planning. Since the Bhopal Metro system is under implementation, the research identifies an opportunity to incorporate integrated station-area planning strategies before operational deficiencies become institutionalized. The study therefore evaluates existing conditions related to feeder transport systems, parking infrastructure, pedestrian accessibility, non-motorized transport, and multimodal integration around selected metro station influence zones.

The research adopts a mixed-method and GIS-based analytical framework involving user perception surveys, parking inventory studies, feeder service assessment, walkability analysis, accessibility mapping, and comparative station-level evaluation. The findings reveal major challenges including fragmented pedestrian infrastructure, unregulated Intermediate Public Transport operations, weak feeder integration, parking spillovers, inadequate multimodal coordination, and increasing dependence on private vehicles. The study also identifies institutional fragmentation and absence of integrated station-area planning frameworks as key barriers affecting sustainable metro accessibility.

Based on these findings, the thesis proposes a comprehensive planning framework emphasizing pedestrian-priority development, complete street design, feeder route rationalization, structured parking management, park-and-ride systems, integrated IPT infrastructure, multimodal interchange planning, and Transit-Oriented Development (TOD)-based station area strategies. The proposals are supported through phased implementation strategies, governance mechanisms, and institutional coordination frameworks intended to improve accessibility, enhance metro ridership, and support sustainable urban mobility. The study ultimately demonstrates that last-mile connectivity must be approached as an integrated urban planning challenge linking transportation systems, land use, public realm design, and governance within the evolving urban structure of Bhopa

# सारांश

थीसिस *"भोपाल मेट्रो स्टेशनों के आसपास अंतिम मील संपर्क (Last Mile Connectivity) हेतु फीडर परिवहन एवं पार्किंग रणनीतियों का आकलन"* का मुख्य उद्देश्य भोपाल शहर में निर्माणाधीन मेट्रो प्रणाली के संदर्भ में स्टेशन क्षेत्रों की अभिगम्यता, बहु-माध्यमीय परिवहन एकीकरण तथा सतत शहरी गतिशीलता से संबंधित समस्याओं का अध्ययन कर एक समग्र नियोजन ढाँचा विकसित करना है। वर्तमान समय में भोपाल शहर तीव्र शहरी विस्तार, बढ़ते निजी वाहन उपयोग, अव्यवस्थित पार्किंग, कमजोर सार्वजनिक परिवहन एकीकरण तथा पैदल एवं गैर-मोटर चालित परिवहन अवसंरचना की कमी जैसी समस्याओं का सामना कर रहा है। इन परिस्थितियों में मेट्रो परियोजना शहर की भावी परिवहन संरचना को पुनर्गठित करने वाला एक महत्वपूर्ण शहरी हस्तक्षेप सिद्ध हो सकती है।

अध्ययन में मेट्रो स्टेशन प्रभाव क्षेत्रों के अंतर्गत वर्तमान अंतिम मील संपर्क व्यवस्था का विश्लेषण किया गया है, जिसमें पैदल यात्री सुविधाएँ, फीडर परिवहन प्रणाली, इंटरमीडिएट पब्लिक ट्रांसपोर्ट (IPT), पार्किंग प्रबंधन, सड़क संरचना तथा बहु-माध्यमीय अभिगम्यता को प्रमुख रूप से शामिल किया गया है। अध्ययन हेतु मिश्रित शोध पद्धति एवं GIS आधारित विश्लेषण का उपयोग किया गया, जिसमें उपयोगकर्ता सर्वेक्षण, पार्किंग इन्वेंट्री, फीडर सेवा मूल्यांकन, वॉकएबिलिटी विश्लेषण एवं स्टेशन-वार तुलनात्मक अध्ययन सम्मिलित हैं।

अध्ययन से यह स्पष्ट हुआ कि वर्तमान स्टेशन क्षेत्रों में पैदल मार्गों की असततता, अव्यवस्थित IPT संचालन, पार्किंग अतिक्रमण, सुरक्षित क्रॉसिंग की कमी, फीडर सेवाओं का कमजोर एकीकरण तथा निजी वाहनों पर अत्यधिक निर्भरता जैसी समस्याएँ विद्यमान हैं। इसके अतिरिक्त विभिन्न संस्थाओं के मध्य समन्वय की कमी एवं समेकित स्टेशन क्षेत्र नियोजन का अभाव भी प्रमुख चुनौतियों के रूप में सामने आया है। ये परिस्थितियाँ भविष्य में मेट्रो प्रणाली की प्रभावशीलता एवं यात्रियों की सुविधा को प्रभावित कर सकती हैं।

उक्त समस्याओं के समाधान हेतु शोध में एक समेकित अंतिम मील संपर्क नियोजन ढाँचा प्रस्तावित किया गया है। प्रस्तावों में पैदल यात्री प्राथमिकता आधारित सड़क विकास, कम्प्लीट स्ट्रीट अवधारणा, गैर-मोटर चालित परिवहन अवसंरचना, फीडर रूट पुनर्गठन, पार्क-एंड-राइड सुविधा, स्मार्ट पार्किंग प्रबंधन, बहु-माध्यमीय इंटरचेंज केंद्र, सार्वजनिक क्षेत्र उन्नयन तथा ट्रांजिट ओरिएंटेड डेवलपमेंट (TOD) आधारित स्टेशन क्षेत्र विकास को शामिल किया गया है। साथ ही चरणबद्ध कार्यान्वयन, संस्थागत समन्वय एवं नीति आधारित प्रबंधन ढाँचा भी प्रस्तावित किया गया है ताकि भोपाल में सुरक्षित, समावेशी एवं सतत शहरी परिवहन प्रणाली को विकसित किया जा सके।

यह अध्ययन दर्शाता है कि अंतिम मील संपर्क केवल परिवहन सुविधा का विषय नहीं है, बल्कि यह शहरी संरचना, भूमि उपयोग, सार्वजनिक स्थान, सामाजिक अभिगम्यता तथा संस्थागत समन्वय से जुड़ा एक व्यापक शहरी नियोजन विषय है। प्रस्तुत शोध भविष्य में भोपाल सहित अन्य उभरते भारतीय शहरों में मेट्रो आधारित एकीकृत शहरी गतिशीलता नियोजन के लिए उपयोगी मार्गदर्शक सिद्ध हो सकता है।

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# CHAPTER 1 INTRODUCTION

## 1.1 Introduction

Urbanization has emerged as one of the most significant transformative processes shaping contemporary cities across the world. In India, rapid urban growth during the past three decades has substantially altered urban structure, travel behavior, and transportation demand. Indian cities are increasingly experiencing severe mobility challenges including traffic congestion, rising motorization, environmental degradation, declining public transport efficiency, and unequal accessibility to urban opportunities (Tiwari, 2014; Mohan & Tiwari, 2015). These issues have become particularly critical within rapidly growing Tier-II cities where infrastructure development has often failed to keep pace with the scale of urban expansion.

Traditionally, Indian cities evolved around compact urban forms characterized by mixed land-use patterns, relatively shorter travel distances, and dependence on walking and non-motorized transport systems. However, economic liberalization, peripheral urban expansion, increasing automobile

ownership, and corridor-based urban growth have transformed mobility dynamics significantly (Cervero & Guerra, 2019). Residential colonies, institutional areas, commercial centers, and employment hubs are increasingly dispersed across wider urban regions, generating longer commuting distances and greater dependence on motorized transport systems.

The rapid increase in private vehicle ownership has emerged as one of the most defining characteristics of urban mobility transformation in India. Rising income levels, inadequate public transport systems, and increasing aspirations associated with private mobility have contributed to exponential growth in two-wheelers and automobiles across cities of all sizes (Tiwari, 2014). Consequently, urban road infrastructure frequently experiences congestion, operational inefficiencies, parking shortages, and declining travel reliability. Environmental impacts associated with vehicular emissions have also intensified concerns related to air pollution, energy consumption, and urban sustainability (UN-Habitat, 2022).

Simultaneously, public transport systems in many Indian cities continue to face challenges related to inadequate route coverage, poor service frequency, overcrowding, and weak multimodal integration. Pedestrian infrastructure remains fragmented and insufficient in several urban areas because of encroachments, discontinuous sidewalks, unsafe crossings, and lack of universal accessibility provisions. Informal Intermediate Public Transport (IPT) systems such as auto-rickshaws, e-rickshaws, and shared para-transit therefore continue to play a major role within everyday urban mobility (NIUA, 2021).

Within this context, metro rail systems have emerged as one of the most important urban transport interventions in India. Following the operational success of the Delhi Metro Rail Corporation (DMRC), metro systems have expanded rapidly across metropolitan and emerging Tier-II cities including Bengaluru, Hyderabad, Jaipur, Kochi, Lucknow, Ahmedabad, Nagpur, Pune, Indore, and Bhopal (MoHUA, 2017). Metro systems are increasingly viewed as sustainable mobility solutions capable of reducing congestion, improving travel efficiency, encouraging modal shift from private vehicles, and supporting long-term urban growth management (Mishra, 2014).

However, experiences from global and Indian metro systems indicate that infrastructure investment alone cannot ensure effective public transport integration or ridership sustainability. The operational success of metro systems depends significantly upon the quality of accessibility surrounding transit stations (Guerra & Cervero, 2017). Even highly efficient metro corridors may fail to attract commuters if access and egress systems remain inconvenient, fragmented, or unsafe. Consequently, the concept of "last-mile connectivity" has emerged as a central concern within contemporary urban transport planning.

Last-mile connectivity refers to the movement of commuters between transit stations and their final destinations through intermediate mobility systems including walking, cycling, feeder buses, auto-rickshaws, e-rickshaws, shared mobility services, and parking infrastructure (Litman, 2019). Although these journeys generally involve short physical distances, they significantly influence commuter perception regarding convenience, safety, comfort, and reliability. Inadequate last-mile systems frequently discourage commuters from using public transport and reinforce dependence on private vehicles (Fan, Guthrie, & Levinson, 2016).

In the Indian context, last-mile connectivity challenges are particularly complex because of fragmented pedestrian infrastructure, informal feeder systems, weak multimodal integration, and unregulated parking activities. Metro station areas frequently experience congestion arising from informal IPT operations, pedestrian conflicts, parking spillovers, and inefficient circulation management. Consequently, several metro stations function as isolated infrastructure nodes rather than integrated multimodal mobility hubs.

Bhopal, the capital city of Madhya Pradesh, represents an important case within this context. As an emerging Tier-II city experiencing rapid urban expansion, increasing motorization, and changing mobility patterns, Bhopal faces growing transportation challenges related to congestion, parking management, weak public transport integration, and fragmented accessibility systems. The proposed Bhopal Metro Rail Project represents a major intervention intended to restructure the city's urban transport system and improve long-term mobility efficiency.

Since the metro system is currently under implementation, Bhopal presents a unique opportunity for proactive accessibility planning. Unlike older metro systems where last-mile deficiencies emerged after operations commenced, Bhopal's current stage allows integrated planning interventions to be incorporated before operational inefficiencies become institutionalized. This creates substantial scope for improving station-area accessibility through coordinated feeder systems, parking management strategies, pedestrian infrastructure, and multimodal integration frameworks.

The present study therefore focuses on "Planning for Last Mile Connectivity: Assessment of Parking Strategies and Feeder Services around Metro Stations in Bhopal." The research seeks to examine how integrated station-area planning can improve accessibility, enhance commuter convenience, and support sustainable urban mobility within the context of an emerging metro city.

### 1.1.1 Urbanization and Mobility Challenges in Indian Citiess

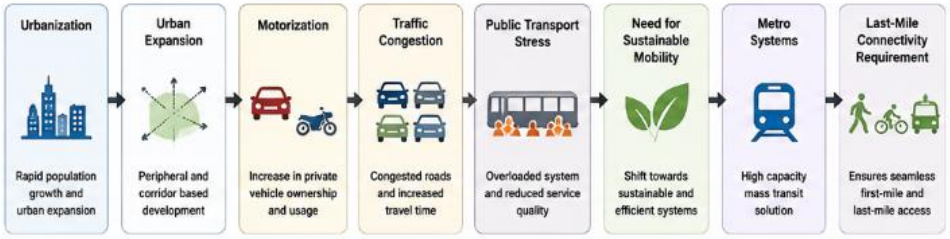



*Figure 1 Urbanization and Mobility Challenges Framework*

Urbanization in India has accelerated significantly since the economic reforms of the 1990s, fundamentally reshaping urban structure, land-use patterns, and transportation systems. According to the United Nations, India is expected to witness substantial urban population growth over the coming decades, intensifying pressure on urban infrastructure and mobility systems (UN-Habitat, 2022). Cities are increasingly functioning as centers of economic activity, institutional concentration, and regional development, thereby generating substantial travel demand and commuter movement.

One of the major consequences of rapid urbanization has been increasing motorization. Rising household incomes, changing consumption patterns, and inadequate public transport systems have contributed to rapid growth in private vehicle ownership across Indian cities (Mohan & Tiwari, 2015). Tier-II cities such as Bhopal, Indore, Jaipur, and Lucknow are increasingly experiencing mobility transitions previously associated primarily with metropolitan regions.

The expansion of urban areas toward peripheral corridors has also transformed mobility patterns significantly. Residential townships, institutional zones, commercial hubs, and industrial activities are increasingly dispersed across wider urban regions, resulting in longer commuting distances and increased dependence on motorized mobility systems (Cervero & Guerra, 2019). Consequently, urban transportation networks frequently experience congestion, travel delays, parking shortages, and operational inefficiencies.

Pedestrian and non-motorized transport infrastructure within many Indian cities remains inadequate despite the substantial role of walking and cycling in urban mobility. Encroachments, unsafe crossings, discontinuous sidewalks, and lack of dedicated cycling infrastructure reduce accessibility and discourage sustainable mobility practices (ITDP India, 2020). Public transport systems similarly face challenges related to overcrowding, unreliable services, weak multimodal integration, and limited commuter convenience.

These conditions collectively highlight the need for integrated and sustainable urban mobility planning approaches emphasizing public transport enhancement, accessibility improvement, multimodal integration, and station-area planning.

### 1.1.2 Emergence of Metro Rail Systems in Tier-II Cities

The emergence of metro rail systems in India reflects changing national priorities toward sustainable urban transportation and integrated mobility planning. The success of the Delhi Metro significantly transformed perceptions regarding urban rail transit and demonstrated the potential of metro systems to improve travel efficiency, reduce congestion, and modernize transportation infrastructure (Mishra, 2014).

During the last two decades, metro rail development has expanded rapidly across Indian cities. While earlier metro projects were concentrated within metropolitan regions, recent years have witnessed increasing expansion into Tier-II cities such as Jaipur, Kochi, Lucknow, Nagpur, Pune, Ahmedabad, Indore, and Bhopal (MoHUA, 2017). This transition indicates a major policy shift wherein medium-sized cities are increasingly adopting high-capacity public transport systems to address future mobility demand and urban growth pressures.

The emergence of metro systems within Tier-II cities is driven by increasing traffic congestion, environmental concerns, rapid motorization, and limitations of conventional public transport systems. Metro systems are increasingly perceived not merely as transportation infrastructure but also as instruments for promoting sustainable urban growth, reducing automobile dependence, and supporting transit-oriented development (Suzuki, Cervero, & Iuchi, 2013).

However, experiences across several Indian metro systems indicate that infrastructure development alone does not guarantee ridership success. In many cities, inadequate feeder integration, poor pedestrian accessibility, fragmented parking systems, and weak station-area planning have reduced commuter convenience and limited public transport usage (Guerra & Cervero, 2017). Consequently, improving last-mile connectivity has become essential for maximizing the effectiveness of metro systems.

### 1.1.3 Importance of Last Mile Connectivity in Urban Transit Systems

Last-mile connectivity has emerged as one of the most critical dimensions of sustainable urban transport planning because it directly influences commuter accessibility and transit ridership. The term refers to the movement of commuters between transit stations and their final destinations through various mobility systems including walking, cycling, feeder buses, shared mobility, and parking infrastructure (Litman, 2019).

Research across international transit systems demonstrates that commuters perceive travel as a continuous door-to-door experience rather than as isolated transport segments. Consequently, even highly efficient metro systems may fail to attract users if access and egress systems remain inconvenient, unsafe, or unreliable (Fan et al., 2016). Accessibility during the first and last stages of travel significantly affects commuter perception regarding comfort, safety, convenience, and transfer efficiency.

In Indian cities, last-mile connectivity challenges are intensified by fragmented pedestrian infrastructure, informal feeder operations, unregulated parking systems, and weak multimodal integration. Metro station areas frequently experience congestion arising from IPT activities, parking spillovers, pedestrian conflicts, and inefficient traffic circulation. Such conditions reduce commuter convenience and weaken the attractiveness of public transport systems.

The issue becomes particularly important within rapidly growing Tier-II cities where increasing private vehicle ownership continues to challenge sustainable mobility objectives. Without integrated accessibility planning, commuters may continue preferring personal vehicles despite improvements in metro infrastructure.

Effective last-mile connectivity therefore requires coordinated station-area planning integrating pedestrian systems, feeder services, parking management, public spaces, and multimodal accessibility frameworks. The present study recognizes that last-mile connectivity is not merely a transport operational issue but a broader urban planning and accessibility challenge requiring integrated intervention strategies.

### 1.2 Background of the Study

The growing concern regarding sustainable urban mobility has transformed transportation planning from a road-oriented approach toward integrated accessibility-based frameworks. Contemporary urban transport systems are increasingly evaluated not only on the basis of vehicular movement but also through their ability to provide equitable, efficient, and sustainable access to urban opportunities (Geurs & van Wee, 2004). Consequently, accessibility has emerged as a more significant planning objective than mobility alone.

Metro rail systems have become important components of this transformation because they provide high-capacity and relatively sustainable urban mobility. However, the operational effectiveness of metro systems depends significantly upon station accessibility and multimodal integration. Research across global and Indian transit systems demonstrates that feeder systems, pedestrian infrastructure, parking management, and transfer efficiency substantially influence commuter preference and ridership performance (Vuchic, 2005; Guerra & Cervero, 2017).

In many Indian cities, metro accessibility continues to remain fragmented because of weak feeder integration, informal transport operations, inadequate pedestrian systems, and unregulated parking activities. These conditions reduce commuter convenience and discourage public transport usage. Consequently, integrated station-area planning has become increasingly important within urban transport policy and planning frameworks.

The present study emerges within this context and seeks to examine how integrated planning approaches can improve last-mile connectivity around metro stations in Bhopal through coordinated feeder systems and parking management strategies.

### 1.2.1 Urban Mobility and Accessibility Concepts

Urban mobility refers to the movement of people and goods within urban areas through different transport systems and infrastructure networks. Traditionally, transport planning focused primarily on mobility enhancement through road expansion and traffic engineering interventions. However, contemporary planning approaches increasingly emphasize accessibility rather than mobility alone (Litman, 2019).

Accessibility refers to the ease with which individuals can reach employment centers, educational institutions, healthcare facilities, markets, and public services. Accessibility-based planning therefore recognizes that transportation systems should support equitable access to opportunities rather than merely improving vehicular movement (Geurs & van Wee, 2004).

Integrated land-use and transport planning has consequently become central to sustainable urban mobility frameworks. Compact urban development, mixed land-use patterns, walkability, and transit-oriented development are increasingly recognized as essential for reducing automobile dependence and improving public transport efficiency (Cervero, 1998). Cities characterized by dense and mixed-use development generally exhibit higher public transport usage and lower reliance on private vehicles.

Within the Indian context, however, dispersed urban growth and fragmented planning processes have weakened accessibility structures and intensified motorized transport dependence. Peripheral development and corridor-based expansion have increased commuting distances and generated pressure on transportation infrastructure (Tiwari, 2014). Improving station-area accessibility therefore becomes essential for enhancing public transport efficiency and supporting sustainable mobility objectives.

### 1.2.2 Metro Accessibility and Ridership Relationship

The relationship between metro accessibility and ridership constitutes one of the most important themes within urban transport research. Studies across international transit systems demonstrate that station accessibility significantly influences public transport usage patterns (Guerra & Cervero, 2017).

Metro stations characterized by efficient pedestrian systems, feeder integration, safe station environments, and multimodal transfer facilities generally exhibit higher ridership levels than poorly integrated stations. Accessibility affects commuter decisions through factors such as travel time, comfort, safety, transfer efficiency, and convenience (Fan et al., 2016).

Research from cities such as Hong Kong, Singapore, Seoul, and Tokyo demonstrates that seamless multimodal integration substantially improves transit competitiveness against private vehicles (Vuchic, 2005). Integrated ticketing systems, pedestrian-oriented station design, feeder services, and organized transfer infrastructure collectively improve commuter convenience and public transport efficiency.

In India, however, metro stations frequently experience fragmented accessibility environments because of inadequate pedestrian conditions, weak feeder systems, informal transport operations, and parking congestion. These conditions reduce the attractiveness of metro systems and encourage continued dependence on private vehicles (NIUA, 2021).

The relationship between accessibility and ridership becomes especially important within emerging Tier-II cities where public transport systems are still evolving and motorization levels are increasing rapidly. Consequently, improving station accessibility becomes essential not only for increasing ridership but also for achieving broader sustainable urban mobility objectives.

### 1.2.3 Role of Parking and Feeder Services in Metro Systems

Feeder systems and parking infrastructure constitute critical components of integrated metro accessibility. Feeder services extend the effective catchment area of metro stations and facilitate commuter movement between transit stations and surrounding urban areas. In Indian cities, feeder accessibility is generally provided through buses, shared autos, e-rickshaws, para-transit systems, walking, and cycling.

Globally, successful transit systems operate through highly coordinated multimodal integration frameworks wherein feeder services function as complementary components of metro infrastructure (Vuchic, 2005). Coordinated feeder systems improve transfer efficiency, reduce travel inconvenience, and increase public transport usage.

In India, however, feeder systems frequently operate through informal arrangements lacking route integration, designated infrastructure, and operational coordination. Intermediate Public Transport (IPT) systems such as shared autos and e-rickshaws play a significant accessibility role but often contribute to congestion and chaotic circulation around transit nodes (NIUA, 2021).

Parking management similarly influences metro accessibility and station-area efficiency. Increasing motorization has intensified parking demand around transit stations, commercial centers, and institutional areas. In the absence of structured parking policies, station areas frequently experience spillover parking, carriageway obstruction, and pedestrian conflicts (Shoup, 2005).

Integrated planning of feeder systems and parking infrastructure is therefore essential for improving multimodal accessibility and reducing operational conflicts within station areas.

### 1.3 Last Mile Connectivity in Indian Context

Last-mile connectivity in India reflects the broader structural characteristics of urban transportation systems including rapid motorization, fragmented infrastructure, institutional overlaps, and dependence on informal mobility networks. Although Indian cities differ significantly in terms of scale and urban structure, several common challenges continue to influence station accessibility and public transport integration.

Indian urban mobility systems operate through a combination of formal and informal transport modes. While buses, suburban rail systems, and metro networks constitute formal public transport infrastructure, a significant proportion of daily mobility is facilitated through Intermediate Public Transport systems such as auto-rickshaws, e-rickshaws, shared tempos, and para-transit vehicles (Mohan & Tiwari, 2015). These systems provide essential last-mile accessibility but often operate without coordinated planning frameworks.

Pedestrian accessibility remains another major challenge within Indian cities. Despite the significant role of walking in urban mobility, pedestrian infrastructure frequently remains fragmented because of encroachments, unsafe crossings, poor maintenance, and discontinuous sidewalks (ITDP India, 2020). Such conditions disproportionately affect economically weaker groups and vulnerable commuters who rely heavily upon walking and public transport systems.

Cycling infrastructure also remains underdeveloped despite its potential role within sustainable mobility systems. Increasing motorization and inadequate infrastructure have significantly reduced cycling usage in many cities, limiting opportunities for integrating non-motorized transport within metro accessibility frameworks.

Institutional fragmentation further complicates last-mile connectivity planning. Responsibilities related to transport planning, traffic management, parking regulation, metro operations, and urban infrastructure are often distributed across multiple agencies with limited coordination. Consequently, station areas frequently evolve without integrated planning approaches.

National policy frameworks such as the National Urban Transport Policy (2006), Metro Rail Policy (2017), Smart Cities Mission, and Transit-Oriented Development policies increasingly emphasize multimodal integration and accessibility enhancement. However, implementation gaps continue to persist because of institutional limitations and fragmented planning practices.

Within this broader context, emerging metro cities such as Bhopal provide significant opportunities to proactively incorporate integrated accessibility planning before operational challenges become embedded within urban transport systems.

### 1.3.1 First Mile and Last Mile Connectivity

First-mile connectivity refers to the movement of commuters from their origin points to transit stations, while last-mile connectivity refers to movement from transit stations to final destinations. Together, these segments determine the continuity and efficiency of the overall travel chain.

In transportation planning literature, these accessibility stages are increasingly recognized as decisive factors influencing public transport ridership and commuter satisfaction (Fan et al., 2016). Even efficient metro systems may fail to attract commuters if accessibility during the first and last stages of travel remains inconvenient or unsafe.

In Indian cities, first-mile and last-mile journeys are generally facilitated through walking, cycling, shared autos, e-rickshaws, feeder buses, and personal vehicles. Informal mobility systems often provide extensive accessibility coverage but lack operational coordination and infrastructure integration.

Walking constitutes one of the most important first-mile and last-mile mobility modes within Indian cities. However, inadequate pedestrian infrastructure significantly reduces accessibility efficiency and commuter safety. Encroachments, discontinuous sidewalks, poor streetscape conditions, and lack of universal accessibility provisions affect pedestrian movement around transit stations (ITDP India, 2020).

The growing dependence on two-wheelers within Indian cities has also increased parking demand around metro stations. In several emerging metro systems, commuters rely upon personal vehicles for first-mile accessibility because of inadequate feeder integration and weak non-motorized transport infrastructure.

Contemporary transport planning therefore increasingly emphasizes seamless multimodal integration wherein transit stations function as interconnected mobility hubs rather than isolated transport nodes.

### 1.3.2 Integrated Multimodal Transport Systems




*Figure 2 Components of last mile connectivity*

Integrated multimodal transport systems represent coordinated urban mobility frameworks wherein different transport modes function as interconnected components of a unified accessibility structure. The primary objective of multimodal integration is to reduce transfer inconvenience and improve travel continuity across urban transport networks (Vuchic, 2005).

Successful multimodal systems typically incorporate integrated ticketing systems, synchronized schedules, coordinated feeder networks, pedestrian-oriented station design, and structured transfer infrastructure. Such systems improve commuter convenience and increase the competitiveness of public transport against private vehicles.

International examples such as Singapore, Hong Kong, and Tokyo demonstrate how integrated planning can improve public transport efficiency and reduce automobile dependence (Cervero & Guerra, 2019). Transit stations within these cities function as multimodal hubs integrating metro systems, buses, pedestrians, cycling infrastructure, and shared mobility services.

In contrast, multimodal integration within Indian cities remains relatively fragmented because transport systems are frequently planned and operated by multiple agencies with limited coordination. Metro systems often function independently from feeder planning, pedestrian infrastructure, parking management, and land-use regulation (NIUA, 2021).

The emergence of metro systems within Tier-II cities has therefore increased the importance of integrated station-area planning capable of coordinating pedestrian systems, feeder services, parking infrastructure, and surrounding urban development.

### 1.3.3 Issues in Station Area Accessibility

Station areas represent critical interfaces between transit infrastructure and the surrounding urban environment. The effectiveness of metro systems depends substantially upon how efficiently commuters can access, navigate, and transfer within these spaces. However, station areas in many Indian cities continue to experience fragmented accessibility conditions and operational inefficiencies.

One of the major issues affecting station-area accessibility is inadequate pedestrian infrastructure. Metro stations frequently lack continuous sidewalks, safe pedestrian crossings, barrier-free infrastructure, and shaded walkways. Encroachments, parked vehicles, and informal activities further reduce pedestrian mobility and safety (ITDP India, 2020).

Safety concerns constitute another major challenge within station areas, particularly for women, elderly commuters, and persons with disabilities. Poor lighting conditions, traffic conflicts, inadequate surveillance, and congested circulation environments frequently discourage public transport usage.

The absence of organized feeder integration also contributes to operational inefficiencies. IPT systems such as auto-rickshaws and e-rickshaws generally operate without designated bays or circulation planning, generating congestion and reducing transfer efficiency around station entrances.

Parking spillovers similarly affect station accessibility and traffic circulation. Increasing motorization combined with inadequate parking management frequently results in carriageway obstruction and pedestrian conflicts within station influence zones (Shoup, 2005).

These issues collectively highlight the need for integrated station-area planning frameworks combining transport infrastructure, pedestrian accessibility, feeder systems, parking management, and public realm enhancement.

## 1.4 Study Context: Bhopal

Bhopal, the capital city of Madhya Pradesh, represents one of the most important emerging urban centers within central India. Historically known for its lakes, administrative significance, and planned urban character, the city has undergone substantial demographic, spatial, and infrastructural transformation during the past two decades. Rapid urban expansion, increasing motorization, changing land-use patterns, and growing economic activities have significantly altered mobility dynamics within

the city. Consequently, Bhopal today faces several transportation challenges associated with congestion, parking management, weak public transport integration, and fragmented accessibility systems.

As an administrative, educational, and institutional center, Bhopal generates substantial commuter movement across residential, commercial, healthcare, and institutional corridors. The city accommodates major government establishments, educational institutions, research organizations, healthcare facilities, and commercial activity centers that collectively contribute toward increasing travel demand. Simultaneously, peripheral urban expansion and corridor-based development have intensified dependence on motorized transport systems.

The proposed Bhopal Metro Rail Project therefore represents a major intervention aimed at restructuring urban mobility patterns and improving long-term transportation efficiency within the city. The metro system is expected to improve accessibility across major urban corridors while reducing congestion pressure on road infrastructure. However, the success of the project will depend substantially upon the quality of last-mile accessibility and station-area integration.

Since the metro system is currently under implementation, Bhopal presents a unique opportunity for proactive accessibility planning. Unlike several older metro systems where station-area deficiencies emerged after operations commenced, Bhopal's current stage provides scope for incorporating integrated planning strategies before accessibility problems become institutionalized. Consequently, the city offers an important case for examining how feeder systems, parking management, pedestrian accessibility, and multimodal integration can be systematically incorporated within metro planning frameworks.

### 1.4.1 Urban Growth and Spatial Structure

The urban growth of Bhopal has been shaped by administrative expansion, institutional development, industrialization, and planned residential growth. Historically, the city developed around the Upper Lake and surrounding historic settlements characterized by compact mixed-use urban morphology. Over time, post-independence urban planning and infrastructure development transformed Bhopal into an important administrative and institutional center within central India.

Planned residential areas such as Arera Colony, Shahpura, and Kolar Road emerged as significant urban growth zones, while commercial districts such as MP Nagar developed into major economic and business centers. Institutional development including educational campuses, healthcare facilities, and research organizations further contributed toward expanding commuter movement and transportation demand.

Contemporary urban growth within Bhopal increasingly exhibits a corridor-based and polycentric structure. Expansion along Hoshangabad Road, Airport Road, Raisen Road, and Kolar corridors has intensified peripheral development and increased commuting distances across the city (Bhopal Development Plan, 2031). Residential townships, commercial activities, and institutional establishments are increasingly dispersed across wider urban regions, thereby generating substantial inter-zonal travel demand.

The changing spatial structure of the city has significantly influenced mobility patterns. Increasing distances between residential areas and activity centers have intensified dependence on private vehicles and Intermediate Public Transport systems. Consequently, major corridors within the city frequently experience congestion, travel delays, and parking shortages during peak hours.

Land-use transformation within peripheral urban areas has also increased pressure on transportation infrastructure. Several newly developing areas continue to exhibit fragmented street networks, inadequate pedestrian infrastructure, and limited public transport accessibility. Such conditions reinforce the need for integrated transportation planning capable of improving accessibility across expanding urban regions.

The proposed metro corridors are expected to connect several important residential, commercial, and institutional areas within Bhopal. However, the effectiveness of these corridors will depend significantly upon the quality of accessibility within surrounding station influence zones.

### 1.4.2 Existing Urban Transport Scenario

The urban transport system of Bhopal is currently characterized by high dependence on private motorized transport, increasing traffic congestion, limited public transport modal share, and fragmented multimodal integration. Rapid urban growth and changing mobility patterns have substantially increased transportation demand across the city while existing infrastructure systems continue to face operational limitations.

Two-wheelers constitute the dominant mode of urban transport within Bhopal because of affordability, flexibility, and insufficient public transport integration. Rising vehicle ownership has significantly contributed to congestion along major urban corridors including MP Nagar, Hoshangabad Road, New Market, Bairagarh, and institutional zones surrounding AIIMS and educational campuses (CMP Bhopal, 2022).

Formal public transport within the city is primarily provided through city bus services operating under urban transport initiatives. However, these systems continue to face challenges related to service frequency, route coverage, operational reliability, and commuter preference. Consequently, a

substantial proportion of commuters depend upon informal Intermediate Public Transport systems such as shared auto-rickshaws and e-rickshaws for everyday mobility.

Intermediate Public Transport modes play a particularly important role within Bhopal because they provide flexible and relatively affordable mobility services connecting residential neighborhoods, commercial areas, and institutional corridors. Nevertheless, these systems generally operate without designated infrastructure, route integration, or circulation management frameworks. Consequently, IPT activities frequently contribute to congestion and operational conflicts around busy urban corridors and intersections.

Pedestrian infrastructure within many areas of Bhopal remains fragmented and inconsistent. Several commercial and institutional corridors lack continuous sidewalks, safe crossings, and universally accessible pedestrian facilities. Encroachments, informal parking activities, and weak streetscape management further reduce pedestrian safety and accessibility (ITDP India, 2020).

Parking management constitutes another major challenge within the city's transportation system. Increasing vehicle ownership combined with inadequate off-street parking infrastructure has intensified parking spillovers across commercial corridors and activity centers. Unregulated on-street parking frequently reduces effective carriageway width and disrupts traffic movement, particularly within areas such as MP Nagar, New Market, and mixed-use commercial districts.

These transportation conditions collectively reinforce the importance of integrated metro planning and last-mile connectivity enhancement within Bhopal. The implementation of the metro system presents a significant opportunity to reorganize urban mobility patterns and strengthen multimodal accessibility. However, achieving these objectives will require coordinated planning interventions focusing on feeder systems, pedestrian infrastructure, parking management, and station-area integration.

### 1.4.3 Overview of Proposed Metro Network

The Bhopal Metro Rail Project represents one of the most significant urban infrastructure initiatives undertaken within the city in recent decades. The project has been conceived as a strategic intervention for improving urban mobility, reducing congestion, and promoting sustainable transportation within Bhopal.

The proposed metro network primarily consists of two major corridors connecting important residential, commercial, institutional, and administrative areas of the city. These corridors are expected to improve east-west and north-south urban connectivity while reducing travel time across high-demand mobility corridors. Major urban nodes including Karond, AIIMS, Subhash Nagar, Bairagarh, MP Nagar, and

New Market are expected to be connected through the proposed metro system (Bhopal Metro DPR, 2019).

The metro network has been strategically aligned along corridors experiencing substantial travel demand and increasing congestion. Areas such as MP Nagar, Hoshangabad Road, and institutional corridors currently generate high commuter movement associated with educational institutions, healthcare facilities, commercial activities, and government establishments. The metro system is therefore expected to significantly improve accessibility across these urban zones.

The proposed metro infrastructure is also likely to influence future land-use dynamics and urban growth patterns within the city. International and Indian experiences indicate that metro systems frequently reshape urban development by increasing accessibility and encouraging higher development intensity around transit corridors (Suzuki et al., 2013). Consequently, metro stations often emerge as important urban activity nodes attracting commercial, residential, and mixed-use development.

However, the long-term success of the Bhopal Metro system will depend substantially upon the quality of station accessibility and multimodal integration. Metro stations are expected to generate concentrated commuter flows requiring efficient pedestrian systems, feeder integration, parking infrastructure, traffic circulation management, and public realm enhancement. If these supporting systems are not adequately planned, station areas may experience congestion, operational conflicts, and accessibility barriers similar to those observed within several Indian metro cities.

The Bhopal Metro project therefore presents an important opportunity for integrating station-area planning principles within the broader urban mobility framework of the city.

### 1.4.4 Need for Integrated Last Mile Planning in Bhopal




*Figure 3 Existing urban mobility issues*

The implementation of the Bhopal Metro Rail Project has intensified the need for integrated last-mile connectivity planning within the city. Although metro systems provide efficient corridor-level mobility, their effectiveness ultimately depends upon how successfully commuters can access stations from surrounding residential, commercial, and institutional areas.

Bhopal currently exhibits several mobility characteristics that reinforce the importance of integrated last-mile planning. The city's dispersed urban structure, increasing dependence on private vehicles, fragmented pedestrian infrastructure, and heavy reliance on Intermediate Public Transport systems collectively create complex accessibility conditions around major corridors.

One of the most significant concerns relates to pedestrian accessibility. Metro stations are expected to generate substantial walking activity within surrounding influence zones. However, many urban corridors within Bhopal currently lack continuous sidewalks, safe crossings, barrier-free infrastructure, and pedestrian-oriented streetscape design. Encroachments, informal parking, and weak traffic management further reduce pedestrian safety and mobility efficiency.

The role of feeder systems is equally important within the city's mobility framework. A substantial proportion of commuters are expected to depend upon shared autos, e-rickshaws, feeder buses, and para-transit systems for first-mile and last-mile accessibility. However, Bhopal currently lacks

organized feeder integration frameworks capable of coordinating these systems with future metro operations.

Parking management represents another critical concern within station-area planning. Increasing two-wheeler ownership indicates that many commuters may continue relying on personal vehicles for accessing metro stations unless efficient feeder systems are developed. Consequently, parking demand around metro stations is likely to increase substantially. In the absence of structured parking management strategies, station areas may experience spillover parking, congestion, and circulation conflicts.

Another important dimension involves the relationship between metro infrastructure and urban development. Metro stations frequently attract commercial activities and increased development intensity because of improved accessibility. Without coordinated station-area planning frameworks, such growth may occur in an unregulated manner leading to congestion, encroachments, and inefficient land utilization.

Integrated last-mile planning is therefore essential not only for improving commuter accessibility but also for supporting organized and sustainable urban growth around metro corridors. Effective station-area planning requires coordinated integration of mobility systems, pedestrian infrastructure, feeder networks, parking management, land-use planning, and public spaces.

The present study therefore approaches last-mile connectivity in Bhopal as a comprehensive urban planning challenge rather than merely a transportation operational issue.

### 1.5 Research Problem

The rapid expansion of metro rail systems across Indian cities reflects increasing recognition of the need for sustainable and high-capacity public transport systems. However, experiences from several Indian metro projects indicate that infrastructure development alone does not necessarily ensure successful public transport integration or ridership sustainability. In many cities, inadequate attention to station accessibility, feeder integration, pedestrian infrastructure, and parking management has reduced the operational effectiveness of metro systems and limited commuter preference for public transport (Guerra & Cervero, 2017).

The proposed Bhopal Metro Rail Project represents a transformative intervention within the city's transportation framework. Nevertheless, existing urban mobility conditions within Bhopal indicate significant challenges related to fragmented accessibility systems, increasing private vehicle dependence, parking congestion, weak public transport integration, and inadequate pedestrian infrastructure. These conditions raise important concerns regarding the long-term effectiveness of metro

accessibility if integrated last-mile planning frameworks are not incorporated systematically during the implementation stage.

A major planning issue emerges from the fragmented nature of current station-area accessibility systems. Feeder services within Bhopal are predominantly provided through informal Intermediate Public Transport systems such as shared autos and e-rickshaws operating without coordinated integration frameworks. Similarly, pedestrian infrastructure surrounding major urban corridors remains inconsistent and inadequate in several locations. Parking management systems are also largely unregulated, particularly within commercial and institutional areas experiencing high travel demand.

Without integrated planning interventions, future metro stations may experience operational inefficiencies similar to those observed in several Indian cities where station areas evolved organically without coordinated multimodal accessibility frameworks. Congested station approaches, parking spillovers, unsafe pedestrian conditions, chaotic feeder operations, and weak transfer integration may discourage public transport usage despite improvements in metro infrastructure.

Another critical issue relates to the absence of station area-based planning approaches within conventional urban transport frameworks. Metro systems are often implemented primarily as transportation engineering projects without sufficient integration between transit infrastructure, land-use planning, public realm design, and accessibility management (Bertolini, 1999). Consequently, surrounding urban environments frequently fail to support efficient multimodal accessibility and transit-oriented development objectives.

The present research therefore emerges from the need to understand how feeder systems, parking strategies, pedestrian accessibility, and multimodal integration can be incorporated within coordinated station-area planning frameworks for Bhopal Metro. The study seeks to address a significant planning gap by examining last-mile connectivity not merely as a transport operational concern but as a broader urban accessibility and spatial planning issue.

### 1.5.1 Existing Gaps in Metro Accessibility

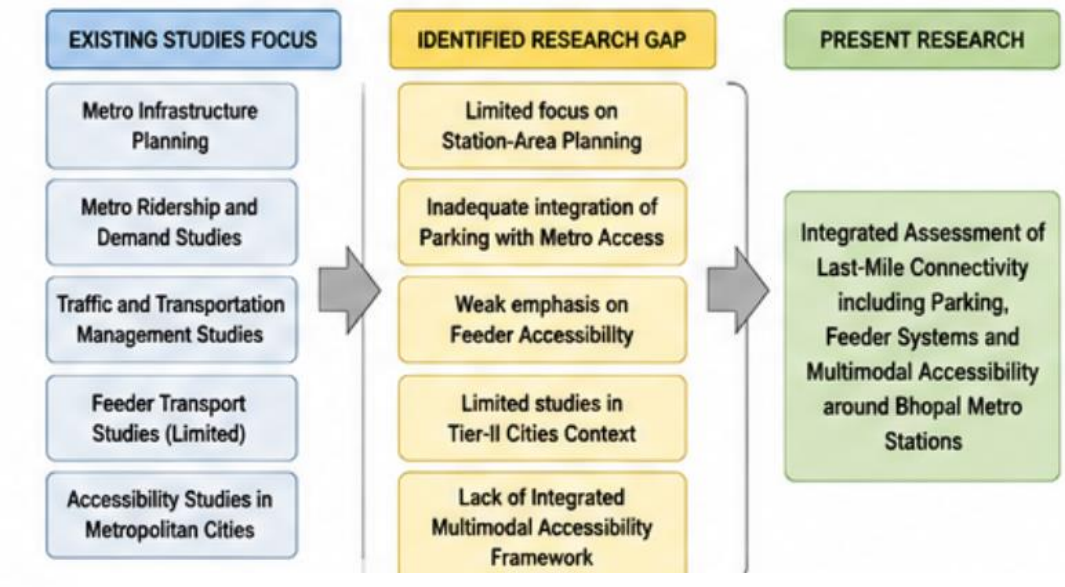



*Figure 4 Research Gap*

Although metro systems are designed to improve urban mobility and reduce dependence on private vehicles, their effectiveness is significantly influenced by the quality of accessibility surrounding station areas. In many Indian cities, metro accessibility remains constrained by fragmented pedestrian environments, weak feeder integration, inadequate transfer infrastructure, and poor multimodal coordination (NIUA, 2021).

One of the most significant accessibility gaps relates to pedestrian infrastructure. Safe and continuous pedestrian movement constitutes the foundation of successful public transport systems because a large proportion of commuters access transit stations by walking. However, several urban corridors within Bhopal currently exhibit discontinuous sidewalks, encroachments, poor streetscape conditions, and inadequate pedestrian crossings. Such deficiencies create accessibility barriers and reduce the comfort and safety of commuters approaching station areas.

Another important accessibility gap involves the lack of integrated feeder systems. Existing Intermediate Public Transport modes provide essential mobility services within Bhopal but generally operate without coordinated planning, designated infrastructure, or route integration with future metro corridors. Consequently, commuters may encounter transfer inconvenience, congestion, and travel uncertainty around station areas.

Universal accessibility also remains an important concern within station-area planning. Many urban transport environments inadequately accommodate the needs of elderly individuals, women, children, and persons with disabilities. The absence of ramps, tactile paving, elevators, accessible crossings, and barrier-free infrastructure reduces equitable access to public transport systems.

Safety and security issues further influence accessibility perception. Poor lighting conditions, traffic conflicts, congested pedestrian environments, and weak surveillance frequently discourage commuters from using public transport systems, particularly during evening hours. These concerns are especially significant within station influence zones expected to experience high pedestrian activity.

These accessibility gaps collectively highlight the need for integrated planning approaches capable of combining pedestrian infrastructure, feeder systems, safety enhancement, and universal accessibility within coordinated station-area frameworks.

### 1.5.2 Parking and Feeder Service Issues

Parking management and feeder integration constitute two of the most critical operational challenges affecting urban transit accessibility within rapidly growing Indian cities. In Bhopal, increasing motorization and dependence on informal transport systems have intensified these challenges, particularly along high-demand urban corridors and commercial centers.

The city currently experiences significant parking spillovers within areas such as MP Nagar, New Market, institutional corridors, and mixed-use commercial zones. Unregulated on-street parking frequently reduces effective road width, obstructs pedestrian movement, and contributes to traffic congestion (Shoup, 2005). Such conditions may intensify around future metro stations if parking demand is not managed through structured planning strategies.

The dominance of two-wheelers within Bhopal's mobility system further complicates parking management challenges. A large proportion of commuters may continue relying on personal vehicles for first-mile accessibility because of limited feeder integration and inadequate non-motorized transport infrastructure. Consequently, metro stations are likely to generate substantial parking demand requiring carefully planned park-and-ride systems and parking regulation frameworks.

Feeder service issues are equally significant within the city's mobility structure. Shared autos and e-rickshaws currently function as major feeder modes connecting residential neighborhoods, commercial areas, and institutional zones. However, these systems operate largely through informal arrangements without designated bays, operational coordination, route rationalization, or integrated transfer infrastructure.

The absence of organized feeder management often results in chaotic circulation conditions around major activity centers. Competition between feeder vehicles, pedestrians, private vehicles, and through traffic creates congestion and reduces transfer efficiency. Such operational conflicts may significantly affect commuter experience around future metro stations if not addressed proactively.

Institutional fragmentation further complicates these issues. Parking regulation, traffic management, metro operations, and feeder services are typically governed by multiple agencies with limited coordination. Consequently, the absence of integrated governance frameworks often reduces the effectiveness of station-area accessibility planning.

The present study therefore seeks to examine how parking systems and feeder services can be strategically integrated within broader multimodal accessibility frameworks for Bhopal Metro.

### 1.5.3 Need for Station Area-Based Planning

The increasing emphasis on sustainable urban mobility has highlighted the importance of station area-based planning within metro development frameworks. Metro stations are not merely passenger boarding points; rather, they function as critical urban nodes where transportation systems, land-use activities, pedestrian movement, public spaces, and economic interactions converge (Bertolini, 1999).

In many Indian cities, however, metro systems have traditionally been implemented primarily as transportation engineering projects with comparatively limited integration between station infrastructure and surrounding urban environments. Consequently, several station areas have evolved incrementally without coordinated planning frameworks addressing feeder integration, pedestrian accessibility, parking management, public realm quality, and land-use organization.

Station area-based planning seeks to address these concerns through integrated and place-based planning approaches. Within this framework, metro stations are conceptualized as multimodal mobility hubs requiring coordinated management of circulation systems, accessibility infrastructure, public spaces, and surrounding development activities.

The need for such planning approaches is particularly significant within rapidly growing Tier-II cities such as Bhopal where infrastructure systems and urban development patterns are still evolving. Since the Bhopal Metro system is currently under implementation, there exists substantial opportunity to proactively integrate station-area planning principles before fragmented accessibility conditions become institutionalized.

One of the major advantages of station area-based planning lies in its ability to improve multimodal integration. Metro stations generate concentrated movement involving pedestrians, feeder vehicles, cyclists, private vehicles, and public transport systems. Without coordinated circulation planning, these interactions may produce operational conflicts and inefficient transfer environments. Integrated station-area frameworks help organize these movement systems through designated feeder bays, pedestrian corridors, parking zones, traffic circulation plans, and public transport integration strategies.

Station-area planning also contributes significantly toward improving pedestrian accessibility and public realm quality. Walkable and safe station environments improve commuter convenience and encourage public transport usage. Streetscape enhancement, barrier-free infrastructure, active public spaces, and universal accessibility collectively contribute toward creating transit-supportive urban environments.

Another important dimension involves the relationship between metro systems and surrounding land-use patterns. Improved accessibility around metro stations often increases development pressure and land value appreciation within surrounding influence zones. Without coordinated planning controls, such growth may lead to unregulated commercial activities, parking spillovers, encroachments, and infrastructure stress.

Transit-oriented development principles further reinforce the importance of station-area planning within sustainable mobility frameworks. Compact mixed-use development around metro stations can reduce travel distances, encourage walking and cycling, increase public transport ridership, and improve land-use efficiency (Suzuki et al., 2013).

The present study therefore recognizes station area-based planning as an essential component of integrated last-mile connectivity within Bhopal Metro. By examining accessibility conditions, feeder systems, parking patterns, and multimodal integration around selected metro stations, the research aims to contribute toward the development of coordinated station-area planning strategies suitable for emerging Tier-II cities.

### 1.6 Aim and Objectives

The present study focuses on understanding and improving last-mile connectivity within the context of the proposed Bhopal Metro Rail Project. The research seeks to examine how integrated station-area planning can improve accessibility through coordinated feeder transport systems, parking management strategies, pedestrian infrastructure, and multimodal integration frameworks.

The study is situated within the broader discourse of sustainable urban mobility, accessibility-based planning, and transit-oriented development. Since Bhopal is currently undergoing a major transition toward metro-based transportation infrastructure, the research aims to contribute toward proactive planning strategies capable of strengthening metro accessibility before full-scale metro operations commence.

### 1.6.1 Aim of the Study

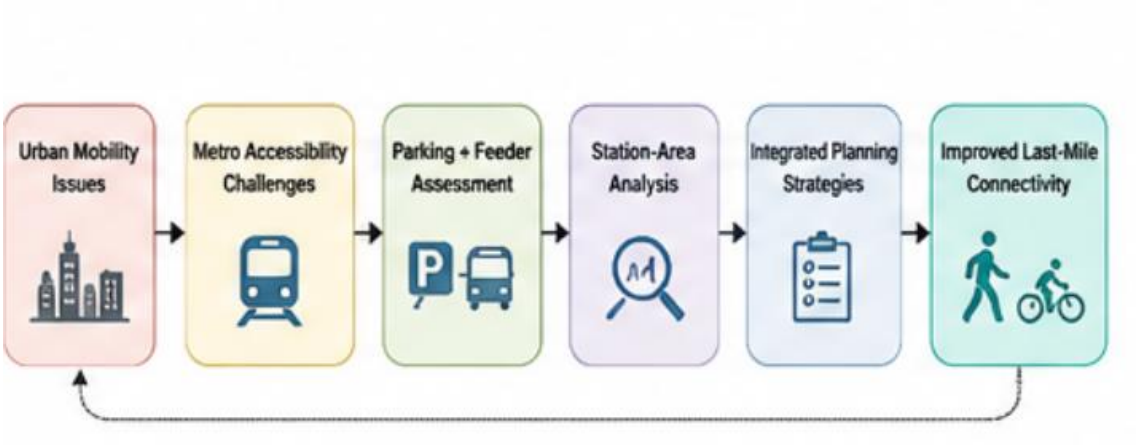



*Figure 5 Conceptual framework*

The
primary aim of the study is:

**"To develop an integrated planning framework for improving last-mile connectivity around selected Bhopal Metro stations through assessment of feeder transport systems and parking management strategies."**

### 1.6.2 Research Objectives:

1. To examine theoretical and policy frameworks related to last-mile connectivity and multimodal urban transport systems.
2. To assess the operational characteristics and spatial distribution of feeder transport systems within selected station influence zones.
3. To evaluate parking demand, utilization patterns, and parking management issues around metro stations.
4. To formulate integrated planning strategies for improving station-area accessibility and last-mile connectivity around Bhopal Metro stations.

### 1.7 Research Questions

The primary research questions include:

1. What are the major accessibility barriers affecting last-mile connectivity around selected Bhopal Metro stations?
2. How effective are the existing feeder transport systems in supporting station accessibility and multimodal integration?

3. What parking-related challenges influence commuter access and circulation around metro station areas?
4. How do commuters perceive accessibility, safety, convenience, comfort, and transfer efficiency within station influence zones?
5. What planning interventions can improve integrated multimodal accessibility and station-area functionality around Bhopal Metro stations?

### 1.8 Scope and Delimitations

The scope of the present study is defined in relation to the thematic focus, spatial coverage, and analytical dimensions associated with last-mile connectivity around metro stations in Bhopal. Since the study examines accessibility systems within the context of an emerging metro city, it emphasizes integrated station-area planning approaches involving feeder systems, parking management, pedestrian accessibility, and multimodal mobility frameworks.

The research primarily focuses on selected metro stations located within the proposed Phase-I corridors of the Bhopal Metro Rail Project. These stations have been selected based on their strategic importance, surrounding land-use characteristics, expected commuter demand, and accessibility conditions. The study concentrates on station influence zones where interactions between metro systems, feeder services, pedestrians, parking activities, and surrounding urban functions are expected to be most significant.

The study adopts a planning-oriented approach emphasizing accessibility enhancement and multimodal integration rather than engineering design or operational rail system analysis. Consequently, the research focuses on station-area conditions, commuter accessibility, and supporting mobility systems rather than metro construction technology or rail engineering parameters.

#### 1.8.1 Spatial Scope

The spatial scope of the study is limited to selected station influence areas within the proposed Bhopal Metro Phase-I corridors. The analysis primarily focuses on accessibility conditions within pedestrian catchments and feeder service zones extending approximately 500 meters to 2 kilometers around selected metro stations.

The study includes assessment of surrounding land-use patterns, feeder routes, pedestrian infrastructure, parking conditions, traffic circulation, and multimodal interactions within these station influence zones. Major commercial, institutional, residential, and mixed-use areas connected to selected metro stations are also considered within the analytical framework.

GIS-based spatial analysis is utilized to understand station catchments, accessibility corridors, and multimodal connectivity patterns surrounding the selected metro stations.

### 1.8.2 Thematic Scope

The thematic scope of the research is centered around the concept of last-mile connectivity and its relationship with metro accessibility. The study specifically examines:

- Feeder transport systems and multimodal integration
- Parking demand and parking management strategies
- Pedestrian accessibility and walkability conditions
- Station-area circulation and transfer efficiency
- Commuter perception regarding accessibility and convenience
- Integrated station-area planning frameworks

The research also incorporates broader dimensions of sustainable urban mobility, accessibility-based planning, transit-oriented development, and multimodal urban transport systems.

The study emphasizes planning and accessibility dimensions rather than detailed traffic engineering analysis or metro operational performance evaluation.

### 1.8.3 Limitations of Study

Although the study seeks to provide a comprehensive assessment of last-mile connectivity around Bhopal Metro stations, certain limitations remain inherent within the research framework.

Firstly, the Bhopal Metro system is currently under implementation and has not yet become fully operational. Consequently, the study relies partially upon projected accessibility conditions, proposed station infrastructure, and anticipated commuter movement patterns rather than actual post-operational ridership behavior.

Secondly, the research is limited to selected metro station areas rather than the complete metro network because of time, resource, and data constraints. Accessibility conditions and commuter behavior may vary across other station locations exhibiting different land-use characteristics and urban contexts.

Thirdly, certain data related to future ridership projections, operational integration mechanisms, and institutional planning frameworks may remain subject to revision during later stages of metro implementation.

Despite these limitations, the study provides important insights into emerging accessibility challenges and contributes toward proactive planning strategies for improving last-mile connectivity within Bhopal.

### 1.9 Research Methodology Framework

Research methodology constitutes a systematic framework through which the objectives of the study are achieved and research questions are addressed. Since the present research examines complex interactions between transport systems, commuter behavior, spatial accessibility, parking patterns, and station-area planning, the study adopts a mixed-method research approach integrating qualitative, quantitative, and spatial analytical techniques.

The methodology is designed to combine field-based assessment, commuter perception analysis, spatial mapping, and planning evaluation within a comprehensive accessibility framework. Both primary and secondary data sources are utilized in order to understand existing conditions, identify planning gaps, and formulate integrated strategies for improving last-mile connectivity around selected metro stations.

The overall methodological structure of the study is organized into sequential stages including literature review, secondary data collection, field surveys, accessibility assessment, spatial analysis, commuter perception analysis, and planning proposal formulation.

#### 1.9.1 Research Approach

The study adopts a mixed-method research approach integrating qualitative and quantitative methods in order to achieve a comprehensive understanding of station-area accessibility conditions and multimodal integration challenges.

The qualitative component of the study focuses on understanding commuter perceptions, planning issues, institutional conditions, and operational challenges associated with feeder systems and parking management. This component includes field observations, photographic documentation, stakeholder interaction, and interpretative assessment of station-area conditions.

The quantitative component involves traffic counts, parking occupancy surveys, commuter questionnaires, accessibility measurements, and modal assessment. Quantitative analysis helps evaluate parking utilization, feeder movement patterns, pedestrian accessibility conditions, and modal interactions around metro stations.

Spatial analysis forms another important methodological dimension of the study. Geographic Information System (GIS)-based mapping techniques are used to analyze station catchments, accessibility zones, land-use patterns, feeder connectivity, and multimodal interaction within station influence areas.

The integration of qualitative, quantitative, and spatial methods enables the study to address both physical accessibility conditions and commuter experience within a comprehensive planning framework.

### 1.9.2 Data Sources and Techniques

The study utilizes both primary and secondary data sources for assessing last-mile connectivity conditions around selected metro stations.

**Primary Data Sources**

Primary data collection involves field-based surveys and observational assessment conducted within selected station influence zones. The primary surveys include:

- Parking occupancy and accumulation surveys
- Feeder transport assessment
- Pedestrian and walkability assessment
- Field observations and photographic documentation

Parking surveys are conducted to evaluate parking demand, utilization patterns, parking duration, and spillover conditions around station areas. Feeder transport assessment focuses on operational characteristics of IPT systems including route patterns, passenger movement, transfer behaviour, and circulation conditions.

Pedestrian and walkability surveys examine sidewalk continuity, crossing facilities, accessibility barriers, safety conditions, and streetscape quality within station catchments. Commuter questionnaires are conducted to understand user perception regarding convenience, accessibility, comfort, safety, and transfer efficiency.

**Secondary Data Sources**

Secondary data is collected from various institutional and planning sources including:

- Comprehensive Mobility Plan (CMP) Bhopal
- Bhopal Metro DPR

- Bhopal Development Plan
- Census of India reports
- MoHUA publications
- NIUA reports
- Urban transport policy documents
- Previous academic studies and journal articles

Secondary data supports analysis related to land-use patterns, transportation networks, demographic trends, metro alignments, policy frameworks, and urban growth characteristics.

**1.10 Significance of the Study**

The present study holds considerable significance within the context of sustainable urban mobility planning, metro accessibility enhancement, and integrated station-area development in emerging Indian cities. As metro rail systems continue to expand across Tier-II urban centers, issues related to last-mile connectivity, multimodal integration, feeder accessibility, and parking management are becoming increasingly important for ensuring the operational effectiveness of public transport systems.

One of the primary contributions of the study lies in its emphasis on last-mile connectivity as a broader urban planning and accessibility issue rather than merely a transport operational concern. The research recognizes that metro systems function effectively only when supported by integrated station-area planning frameworks incorporating pedestrian infrastructure, feeder systems, parking management, public spaces, and multimodal circulation systems. Consequently, the study contributes toward expanding the discourse on accessibility-oriented urban planning within Indian cities.

The study is also significant because it focuses specifically on an emerging Tier-II metro city. Much of the existing literature on metro accessibility and station-area planning in India has concentrated primarily on metropolitan cities such as Delhi, Bengaluru, and Mumbai. Comparatively limited research has examined accessibility challenges and station-area conditions within rapidly growing medium-sized cities undergoing transition toward metro-based transportation systems. The present research therefore contributes important insights regarding accessibility planning within the context of emerging urban centers such as Bhopal.

Another important contribution of the study lies in its integration of parking management and feeder accessibility within a unified planning framework. In many Indian cities, these systems are frequently examined independently despite their interconnected role in influencing station accessibility and commuter behavior. The research therefore attempts to develop a more integrated understanding of how parking systems, feeder networks, pedestrian accessibility, and multimodal transfer conditions collectively influence metro accessibility.

The study also holds practical significance for urban planning authorities, metro agencies, municipal institutions, and transport planners involved in the implementation of the Bhopal Metro Rail Project. Since the metro system is currently under development, the findings of the research may contribute toward proactive planning interventions before operational deficiencies become institutionalized within station areas.

The recommendations derived from the study may assist planning agencies in improving:

- feeder service integration,
- pedestrian accessibility,
- station-area circulation,
- parking regulation,
- and multimodal connectivity frameworks.

The research further contributes toward broader policy objectives associated with sustainable urban mobility, public transport enhancement, congestion reduction, and accessibility improvement. By encouraging integrated station-area planning approaches, the study supports national urban transport priorities emphasized under the National Urban Transport Policy (2006), Metro Rail Policy (2017), and Transit-Oriented Development frameworks.

Academically, the research contributes toward the growing body of literature on station-area planning, accessibility-based transport systems, and multimodal urban mobility within Indian cities. The integration of spatial analysis, commuter perception assessment, and accessibility evaluation within a planning-oriented framework strengthens the interdisciplinary relevance of the study within urban planning and transportation research.

The study is therefore significant both as a contextual planning investigation for Bhopal Metro and as a broader contribution toward integrated last-mile connectivity planning within emerging Indian cities.

# CHAPTER 2

# LITERATURE REVIEW AND POLICY FRAMEWORK

## 2.1 Introduction

Rapid urbanization and motorization in Indian cities have intensified challenges related to congestion, environmental degradation, travel delays, and declining public transport efficiency. In response, metro rail systems have emerged as critical components of sustainable urban mobility strategies in several metropolitan and emerging Tier-II cities. However, the effectiveness of metro systems depends not only upon rail infrastructure and operational efficiency but also upon the accessibility of stations and the quality of last mile connectivity available to commuters (Cervero, 1998). Last mile connectivity refers to the movement of passengers between transit stations and their final destinations through feeder systems, walking, cycling, intermediate public transport (IPT), and parking facilities.

Research across global and Indian contexts demonstrates that inadequate last mile connectivity significantly affects metro ridership and discourages modal shift from private vehicles to public transport (Litman, 2021). In many Indian cities, commuters face difficulties such as discontinuous pedestrian infrastructure, lack of organized feeder systems, unsafe crossings, informal parking, and poor interchange facilities around metro stations (Tiwari, 2015). Consequently, even well-developed metro systems often fail to achieve their full ridership potential.

The relationship between metro accessibility, parking strategies, feeder systems, and station area planning has therefore become an important area of urban transport research. Contemporary planning approaches increasingly emphasize integrated mobility systems combining land use planning, transit-oriented development (TOD), multimodal integration, and sustainable transport infrastructure (Suzuki et al., 2013). Such approaches seek to improve accessibility while reducing automobile dependency and promoting compact urban growth.

In the context of emerging metro systems in Tier-II cities such as Bhopal, integrated planning around stations becomes particularly important because urban transport systems remain transitional and institutional capacities are evolving. The proposed metro development in Bhopal provides an opportunity to establish sustainable accessibility frameworks before automobile dependency intensifies further.

This chapter reviews theoretical concepts, empirical studies, and policy frameworks relevant to last mile connectivity and metro station accessibility. The chapter examines literature concerning accessibility-based planning, TOD, parking management, feeder systems, pedestrian-oriented development, and multimodal integration. International and Indian case studies are reviewed to identify lessons applicable

to Tier-II cities. The chapter further analyzes national transport policies and institutional frameworks shaping urban mobility planning in India and Bhopal. Finally, the chapter identifies research gaps and develops the conceptual framework guiding the present study.

## 2.2 Theoretical Foundations of Urban Mobility

### 2.2.1 Accessibility-Based Planning

Accessibility-based planning represents a shift from conventional transport planning approaches focused primarily on mobility and traffic movement toward a people-oriented framework emphasizing access to opportunities and services. Hansen (1959) defined accessibility as the potential of opportunities for interaction within a transportation system. Geurs and van Wee (2004) further

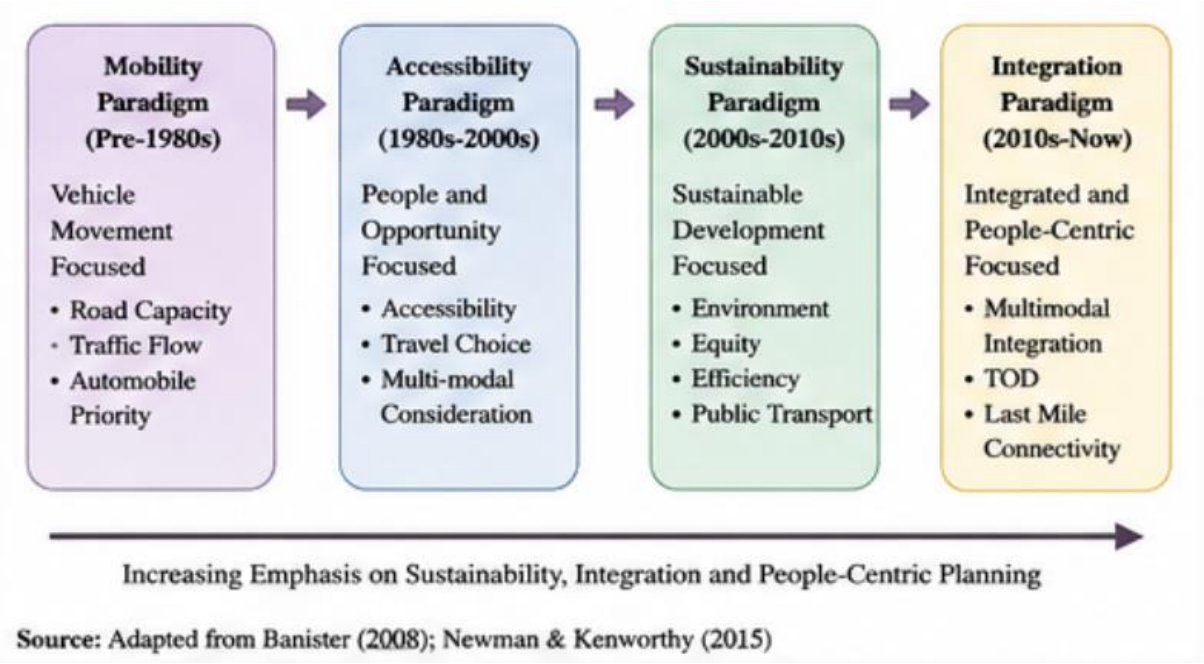



*Figure 6 Conceptual evolution of urban mobility*

conceptualized accessibility as the relationship between land use, transportation systems, temporal constraints, and individual characteristics.

Traditional transport planning prioritized road expansion and vehicular speed, often neglecting equity and accessibility concerns. However, contemporary planning theory recognizes that transportation systems should improve access to employment, education, healthcare, and recreation rather than merely maximizing vehicle movement (Bertolini et al., 2005). Accessibility-based planning therefore integrates transportation and land use systems to reduce travel distances and improve multimodal connectivity.

In metro systems, accessibility largely depends upon the quality of station access infrastructure. Studies indicate that commuters are more likely to use public transport when stations are accessible through safe pedestrian routes, feeder services, cycling facilities, and organized interchange systems (Cervero & Kockelman, 1997). Poor accessibility increases generalized travel costs and discourages transit usage.

For Indian cities, accessibility planning becomes particularly significant because a large proportion of transit users depend upon walking and IPT modes to access stations. Tiwari (2015) observed that inadequate pedestrian infrastructure and unsafe street environments significantly constrain public transport usage in Indian urban areas. Consequently, accessibility planning around metro stations must prioritize universal accessibility, pedestrian safety, feeder integration, and equitable mobility systems.

### 2.2.2 Sustainable Urban Mobility

Sustainable urban mobility refers to transportation systems that are environmentally responsible, socially equitable, and economically efficient. The concept emerged from growing concerns regarding climate change, congestion, fossil fuel consumption, and unsustainable automobile-oriented urban growth (Banister, 2008).

According to the European Commission (2013), sustainable urban mobility seeks to satisfy mobility needs while improving quality of life and minimizing environmental impacts. Sustainable mobility frameworks emphasize public transport systems, non-motorized transport (NMT), compact urban development, reduced emissions, and equitable access.

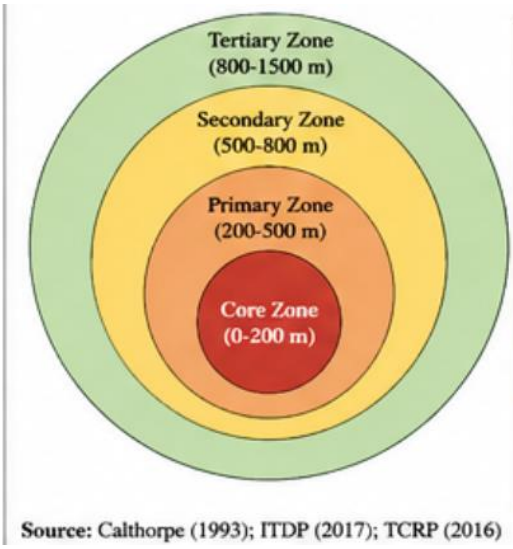
Metro rail systems are widely recognized as sustainable transport infrastructure because they provide high-capacity mobility with comparatively lower emissions and land consumption than private automobiles (Newman & Kenworthy, 1999). However, sustainability outcomes depend heavily upon station accessibility and modal integration. Weak last mile connectivity often forces commuters to rely upon private vehicles, thereby undermining sustainability objectives.

Banister (2008) argued that sustainable mobility requires reducing travel demand while promoting integrated and multimodal transport systems. This includes prioritizing walking, cycling, feeder transit, and transit-oriented development. Similarly, Litman (2021) emphasized that sustainable transport policies should improve accessibility rather than vehicle mobility.

In Indian cities, sustainable urban mobility remains challenging due to rapid motorization, fragmented transport governance, and inadequate pedestrian infrastructure. Nevertheless, metro projects combined

with TOD and NMT integration are increasingly viewed as important mechanisms for achieving sustainable urban development.

### 2.2.3 Transit-Oriented Development (TOD)




| Zone | Characteristics |
|---|---|
| Core Zone (0-200 m) | High pedestrian activity, retail & commercial uses, station entry area |
| Primary Zone (200-500 m) | Mixed land use, high accessibility, feeder service importance |
| Secondary Zone (500-800 m) | Residential areas, moderate accessibility, IPT dominance |
| Tertiary Zone (800-1500 m) | Low density, high parking demand, park & ride relevance |

**Source:** Calthorpe (1993); ITDP (2017); TCRP (2016)

*Figure 7 Station influence zone*

Transit-Oriented Development (TOD) refers to compact, mixed-use, high-density urban development organized around mass transit corridors and stations. Calthorpe (1993) described TOD as a planning strategy integrating land use and transportation to create walkable and transit-supportive urban environments.

TOD principles generally include density, diversity, design, destination accessibility, and reduced distance to transit (Ewing & Cervero, 2010). These principles encourage mixed land use patterns, pedestrian-friendly streets, reduced parking dependency, and efficient public transport accessibility.

International experiences demonstrate that TOD improves transit ridership, reduces automobile dependence, and supports sustainable urban growth (Suzuki et al., 2013). Cities such as Hong Kong, Singapore, and Tokyo successfully integrated metro systems with compact urban development, resulting in high public transport usage and efficient land utilization.

In India, TOD has gained policy importance following the introduction of metro systems in several cities. The Ministry of Housing and Urban Affairs (MoHUA) introduced TOD policies emphasizing mixed-use development, walkability, and densification around transit corridors. However, implementation challenges remain due to fragmented institutional structures, inadequate pedestrian infrastructure, and weak integration between transport and land use planning.

Scholars argue that TOD implementation in Indian cities often focuses excessively on real estate intensification while neglecting pedestrian accessibility and public realm quality (Tiwari & Jain, 2013). Consequently, successful TOD requires integrated planning approaches that prioritize last mile connectivity and multimodal accessibility.

### 2.2.4 Land Use–Transport Integration

Land use and transportation systems are closely interconnected. Urban spatial structure influences travel behavior while transportation infrastructure shapes patterns of urban development (Wegener & Fürst, 1999). Integrated land use–transport planning therefore seeks coordinated development of mobility systems and urban form.

Dispersed urban development patterns increase travel distances and automobile dependence, whereas compact mixed-use development supports public transport viability (Newman & Kenworthy, 1999). Metro systems often stimulate economic growth and land value appreciation around stations; however, unplanned intensification may also generate congestion and parking pressures.

Bertolini (1999) proposed the node-place model to understand metro stations as both transportation nodes and urban places. According to this model, station areas should balance transportation functions with urban development objectives.

Indian cities frequently experience weak integration between land use and transport planning due to institutional fragmentation and outdated planning regulations. Consequently, metro station areas often suffer from incompatible land uses, inadequate pedestrian infrastructure, and unmanaged parking growth. Integrated planning frameworks are therefore essential for improving accessibility and promoting sustainable urban mobility.

### 2.2.5 Multimodal Integration Theory

Multimodal integration refers to the coordination of different transportation modes within a seamless mobility system. Effective multimodal systems enable efficient transfers between metro rail, buses, IPT, walking, cycling, and private vehicles (Vuchic, 2005).

Multimodal integration includes physical integration, operational coordination, fare integration, information systems, and institutional coordination. Physical integration concerns transfer facilities and

station design, whereas operational integration involves synchronized schedules and coordinated services.

Research indicates that multimodal integration significantly improves commuter convenience and transit ridership (Givoni & Banister, 2010). Stations functioning as multimodal interchange hubs reduce transfer time and improve travel reliability.

In Indian cities, multimodal integration remains limited due to fragmented governance structures and inadequate interchange infrastructure. Metro stations often experience conflicts between pedestrians, IPT vehicles, buses, and private vehicles because of poor circulation planning and lack of designated spaces.

Consequently, station area planning must prioritize integrated circulation systems, organized pickup-drop facilities, feeder integration, and pedestrian-oriented design.

## 2.3 Last Mile Connectivity and Metro Accessibility

### 2.3.1 Concepts and Definitions

Last mile connectivity refers to the final segment of a commuter's journey between a transit station and the ultimate destination. The concept includes access and egress movements through walking, cycling, feeder buses, IPT, and private vehicles (Shaheen & Chan, 2016).

Research identifies last mile connectivity as one of the most important determinants of public transport usage. According to Cervero (2001), poor accessibility around transit stations increases generalized travel costs and discourages ridership. Effective last mile systems therefore enhance commuter convenience and improve modal shift toward public transport.

In developing countries, last mile connectivity is strongly influenced by informal and semi-formal transport systems. IPT modes such as auto-rickshaws, shared autos, and e-rickshaws play important roles in extending transit accessibility.

### 2.3.2 Components of Last Mile Connectivity

The major components of last mile connectivity include pedestrian infrastructure, feeder transit systems, IPT services, cycling facilities, parking systems, and information infrastructure.

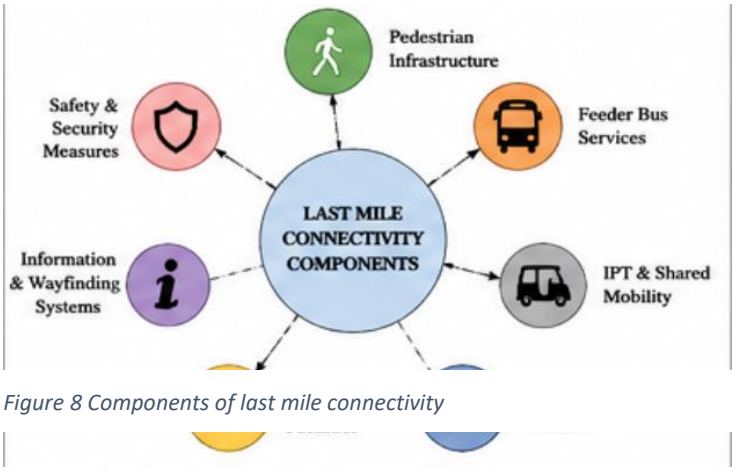



*Figure 8 Components of last mile connectivity*

Pedestrian connectivity remains the most fundamental component because almost all public transport trips involve walking segments. Studies indicate that comfortable walking environments significantly influence transit usage (Gehl, 2010). Essential pedestrian infrastructure includes continuous footpaths, street lighting, shading, safe crossings, universal accessibility features, and traffic calming.

Feeder systems increase metro catchment areas and improve accessibility for peripheral neighborhoods. IPT systems provide flexible and demand-responsive mobility, especially in Indian cities where formal feeder systems are limited.

Cycling infrastructure and public bicycle-sharing systems are increasingly integrated with metro systems globally. Parking facilities, particularly park-and-ride systems, support accessibility for suburban commuters but may also increase automobile dependency if not managed appropriately.

### 2.3.3 Factors Affecting Metro Accessibility

Metro accessibility depends upon multiple spatial, infrastructural, operational, and socio-economic factors. Important determinants include walking distance, travel time, feeder availability, safety, affordability, station design, urban density, and service reliability (Owen & Levinson, 2015).

Research in Indian cities highlights pedestrian safety and infrastructure quality as critical barriers to metro accessibility (Tiwari, 2015). Encroachments, discontinuous footpaths, poor lighting, and unsafe crossings discourage walking and reduce transit attractiveness.

Socio-economic factors also influence accessibility perceptions. Women, elderly persons, and differently-abled commuters often experience greater mobility constraints due to safety concerns and inaccessible infrastructure.

Furthermore, affordability and reliability of feeder systems significantly influence commuter choices. Integrated and reliable feeder systems improve perceived accessibility and encourage public transport adoption.

### 2.3.4 Last Mile and Ridership Behaviour

Numerous studies establish strong relationships between last mile connectivity and transit ridership. Improved accessibility reduces travel inconvenience and increases commuter willingness to shift from private vehicles to public transport (Ewing & Cervero, 2010).

Research on Indian metro systems indicates that commuters prefer transit systems with reliable feeder services, organized interchange facilities, and safe pedestrian access (RITES, 2014). Conversely, inadequate accessibility reduces user satisfaction and limits ridership growth.

Ridership behavior is also influenced by comfort, security, transfer time, and affordability. Women commuters particularly prioritize safety and lighting conditions around stations.

Therefore, improving last mile infrastructure can significantly enhance transit competitiveness and overall system efficiency.

## 2.4 Parking Strategies Around Metro Stations

### 2.4.1 Park-and-Ride Concepts

Park-and-ride systems allow commuters to park private vehicles near transit stations and continue their journeys through public transport. Such systems are particularly useful in peripheral urban areas where feeder transit accessibility remains limited (Willson, 2005).

Park-and-ride facilities reduce traffic volumes entering central urban areas and support transit ridership. However, excessive parking supply may encourage automobile dependence and undermine TOD principles.

Contemporary planning approaches therefore advocate balanced parking provision integrated with sustainable mobility objectives.

### 2.4.2 Parking Demand and Supply Characteristics

Parking demand around metro stations depends upon land use intensity, accessibility conditions, transit quality, income levels, and urban density. Commercial and mixed-use station areas generally experience high parking demand.

Indian cities frequently suffer from inadequate organized parking infrastructure, resulting in informal on-street parking and congestion around stations (Kodransky & Hermann, 2011). Encroached streets reduce pedestrian safety and affect traffic circulation.

Effective parking management requires demand assessment, spatial planning, pricing mechanisms, and enforcement systems.

### 2.4.3 Parking Pricing and Management Strategies

Parking pricing functions as an important travel demand management strategy capable of influencing commuter mode choice. Higher parking charges discourage private vehicle usage and promote public transport adoption (Shoup, 2005).

Modern parking management strategies include dynamic pricing, shared parking, digital parking systems, and time-based regulations. Such approaches aim to optimize land utilization while reducing congestion.

Indian urban transport policies increasingly recognize parking management as a mobility management tool rather than merely infrastructure provision.

### 2.4.4 Parking Impacts on Station Area Mobility

Unregulated parking around metro stations creates congestion, reduces carriageway capacity, and compromises pedestrian movement. Informal parking frequently occupies footpaths and public spaces, creating accessibility barriers.

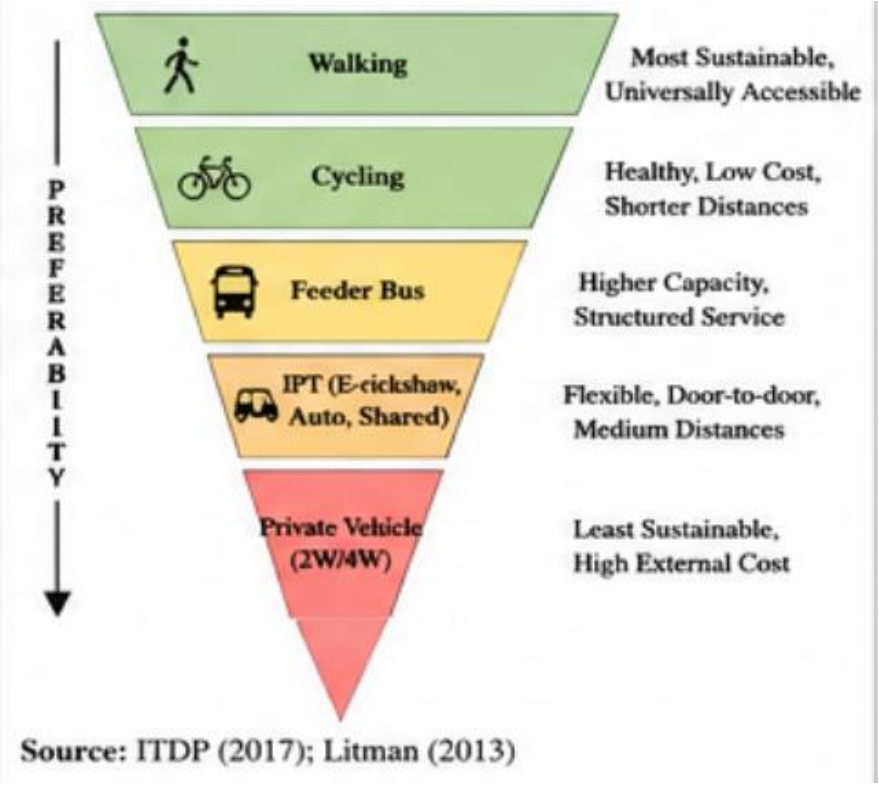
Well-planned parking systems can improve station accessibility and support multimodal integration. However, excessive parking supply may conflict with pedestrian-oriented station planning and TOD objectives.

Therefore, parking strategies should balance commuter accessibility with sustainable mobility goals.

## 2.5 Feeder Services and Intermediate Public Transport

### 2.5.1 Feeder Bus Systems

Feeder bus systems provide organized connectivity between metro stations and surrounding residential or commercial areas. Efficient feeder systems increase station catchment areas and improve public transport accessibility.




Successful feeder systems are characterized by synchronized schedules, route integration, affordable fares, and reduced transfer times (Vuchic, 2005). Nevertheless, many Indian cities continue to experience limited feeder service coverage and operational inefficiencies.

*Figure 9 Hierarchy of last mile modes*

### 2.5.2 IPT and Shared Mobility

Intermediate Public Transport (IPT) modes such as auto-rickshaws, e-rickshaws, shared autos, and taxis constitute essential components of Indian urban mobility systems. IPT services provide flexible and demand-responsive last mile connectivity.

Recent technological advancements introduced app-based mobility platforms and shared mobility systems improving service accessibility and efficiency. However, lack of regulation and designated operating spaces often creates congestion near metro stations.

Scholars emphasize integrating IPT systems into formal transport planning frameworks to improve station accessibility and operational efficiency.

### 2.5.3 Non-Motorized Transport Integration

Walking and cycling represent the most sustainable forms of urban mobility. Integration of NMT infrastructure with metro systems improves accessibility while reducing environmental impacts.

International cities prioritize cycle tracks, bike-sharing systems, pedestrian streets, and traffic calming around transit stations. In contrast, Indian cities frequently lack adequate NMT infrastructure due to automobile-oriented street design and encroachments.

According to MoHUA (2019), pedestrian-oriented planning and NMT integration are essential for improving urban livability and transit accessibility.

### 2.5.4 Service Quality and Accessibility Parameters

Service quality strongly influences commuter perceptions and transit usage. Important accessibility parameters include reliability, safety, comfort, affordability, frequency, convenience, and travel time.

Integrated mobility systems minimizing uncertainty and transfer inconvenience are generally preferred by commuters. Information systems, real-time transit updates, and wayfinding infrastructure further improve accessibility.

## 2.6 Station Area Planning and Design

### 2.6.1 Pedestrian-Oriented Development

Pedestrian-oriented station planning emphasizes safe, comfortable, and active walking environments. Gehl (2010) argued that high-quality public spaces encourage walking and social interaction.

Important elements of pedestrian-oriented development include continuous footpaths, active frontages, safe crossings, lighting, shading, and universal accessibility.

Pedestrian-friendly station areas improve transit usage and enhance urban livability.

### 2.6.2 Universal Accessibility

Universal accessibility ensures mobility systems remain usable for all individuals irrespective of age or physical ability. Barrier-free infrastructure includes ramps, tactile paving, elevators, accessible signage, and safe crossings.

Inclusive station design improves accessibility for elderly persons, children, and differently-abled commuters while enhancing overall commuter convenience.

### 2.6.3 Public Realm and Streetscape Design

The quality of station area public spaces significantly influences commuter perceptions regarding safety and comfort. Streetscape elements such as landscaping, lighting, seating, signage, vending zones, and shading improve public realm quality.

Well-designed station areas encourage pedestrian activity and strengthen urban identity.

### 2.6.4 Multimodal Interchange Planning

Metro stations function as interchange hubs connecting multiple transport modes. Efficient interchange planning minimizes transfer distances and improves operational coordination.

Key principles include segregated circulation systems, organized pickup-drop zones, integrated ticketing, and clear wayfinding infrastructure.

## 2.7 International and National Case Studies

### 2.7.1 International Metro Accessibility Models

Cities such as Singapore, Hong Kong, and Tokyo demonstrate highly integrated transit accessibility systems characterized by compact urban development, seamless multimodal integration, and strong institutional coordination.

Singapore's transit planning integrates pedestrian infrastructure, feeder buses, and land use regulation within station influence areas. Hong Kong successfully integrated rail systems with high-density mixed-use development through the "Rail + Property" model (Suzuki et al., 2013).

Tokyo's railway-oriented urban structure demonstrates the effectiveness of multimodal integration and pedestrian accessibility in promoting public transport ridership.

### 2.7.2 Indian Metro City Experiences

Indian metro cities such as Delhi, Bengaluru, Hyderabad, and Kochi implemented several last mile initiatives including feeder buses, e-rickshaw integration, bicycle-sharing systems, and TOD policies.

The Delhi Metro integrated feeder buses and non-motorized transport improvements around selected stations; however, pedestrian infrastructure challenges persist (DMRC, 2019).

Hyderabad Metro promoted station area development and shared mobility partnerships, while Kochi Metro integrated water transport and bicycle-sharing systems.

### 2.7.3 Lessons for Tier-II Cities

Tier-II cities require context-sensitive mobility strategies considering lower densities, evolving transport systems, and financial constraints. Lessons from metropolitan cities indicate the importance of integrated planning, multimodal accessibility, and institutional coordination.

For Bhopal, proactive planning of feeder systems, parking infrastructure, and pedestrian accessibility before metro expansion can significantly improve future transit efficiency.

## 2.8 Policy and Institutional Framework

### 2.8.1 National Urban Transport Policy (NUTP)

The National Urban Transport Policy (2006) emphasizes moving people rather than vehicles and advocates integrated land use and transportation planning. The policy prioritizes public transport, NMT infrastructure, and sustainable mobility systems.

NUTP recognizes accessibility, equity, and environmental sustainability as key urban transport objectives.

### 2.8.2 Metro Rail Policy

The Metro Rail Policy (2017) emphasizes integrated urban transport planning, multimodal connectivity, TOD, and value capture financing.

The policy highlights feeder systems and station accessibility as essential components of metro planning.

### 2.8.3 TOD Policy and NMT Guidelines

National TOD and NMT guidelines encourage compact mixed-use development and pedestrian-oriented planning around transit corridors.

These frameworks promote walkability, cycling infrastructure, and reduced parking dependency to improve transit accessibility.

### 2.8.4 Parking Policies and Regulatory Framework

Urban parking policies increasingly recognize parking management as a travel demand management strategy. Pricing mechanisms, demand management, and parking regulations are emphasized within contemporary planning frameworks.

### 2.8.5 Institutional Framework in Bhopal

Urban transport planning in Bhopal involves multiple institutions including the municipal corporation, development authority, traffic police, smart city agencies, and metro authorities.

Fragmented institutional responsibilities often create coordination challenges affecting integrated mobility planning and implementation.

## 2.9 Research Gap Identification

Existing literature extensively discusses TOD, metro systems, and sustainable mobility; however, limited studies specifically examine the integrated relationship between parking strategies, feeder systems, and last mile connectivity in Tier-II Indian cities.

Most Indian studies focus on metropolitan contexts such as Delhi and Bengaluru, whereas emerging cities like Bhopal remain underexplored despite rapid urban transformation and proposed metro expansion.

Furthermore, limited research examines the combined influence of parking management, IPT integration, pedestrian accessibility, and feeder services on station accessibility.

The present study therefore addresses these gaps by evaluating parking strategies and feeder systems around metro stations in Bhopal through an integrated accessibility framework.

### 2.10 Conceptual Framework for the Study

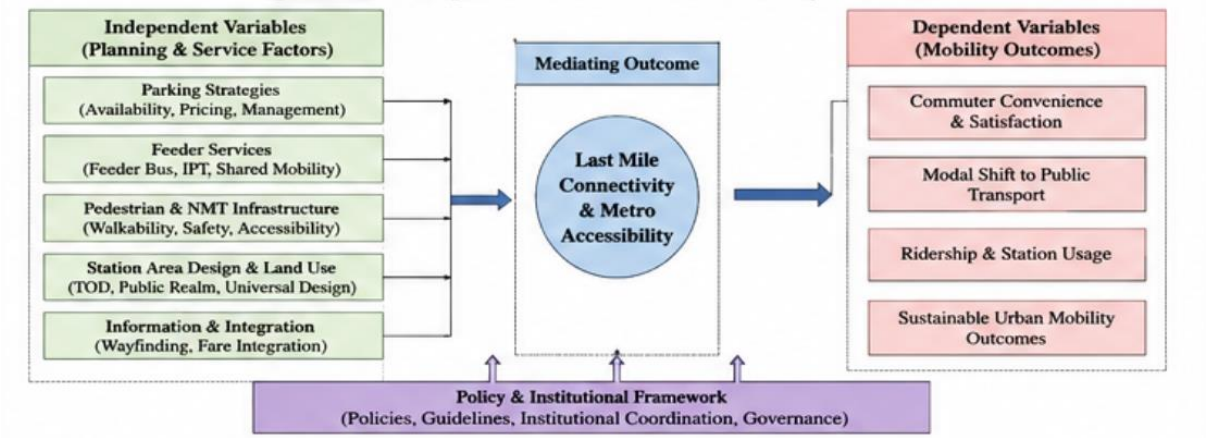



*Figure 10 Conceptual Framework for the Study*

The conceptual frar
parking systems, feeder services, pedestrian infrastructure, and commuter behavior.

The framework assumes that improved last mile connectivity enhances station accessibility and increases public transport ridership. Independent variables include parking availability, feeder service quality, pedestrian infrastructure, IPT integration, and station area design.

Dependent variables include commuter accessibility, modal choice, travel behavior, and station usage patterns.

Institutional coordination and policy implementation act as moderating factors influencing mobility outcomes.

## 2.11 Chapter Summary

This chapter reviewed theoretical concepts, empirical literature, and policy frameworks related to last mile connectivity and metro station accessibility. The review highlighted the significance of accessibility-based planning, TOD, sustainable mobility, and multimodal integration in improving public transport systems.

The chapter further examined literature concerning parking management, feeder systems, IPT integration, NMT infrastructure, and station area planning. International and Indian case studies demonstrated the importance of integrated accessibility planning and institutional coordination.

The analysis identified significant research gaps concerning integrated last mile planning in Tier-II cities such as Bhopal. Based on these findings, the chapter established a conceptual framework guiding the empirical investigation of parking strategies and feeder services around metro stations in Bhopal.

# CHAPTER 3

# STUDY AREA PROFILE AND EXISTING SITUATION ANALYSIS

## 3.1 Introduction to Study Area

Urban transport systems in rapidly growing Indian cities are undergoing significant transformation due to increasing population, motorization, land use intensification and changing mobility patterns. In this context, metro rail systems are increasingly being promoted as sustainable mass transit solutions capable of reducing congestion, travel time and environmental externalities. However, the operational success and ridership efficiency of metro systems are strongly dependent upon the quality of last mile connectivity available between metro stations and surrounding urban areas. The absence of integrated pedestrian infrastructure, organized feeder services, cycling facilities and parking management often limits the accessibility and usability of metro systems, particularly in Tier-II cities where transport systems remain fragmented.

The present study focuses on the city of entity["city","Bhopal","Madhya Pradesh, India"], the capital city of Madhya Pradesh, which is presently witnessing major investments in urban transport infrastructure through the implementation of the Bhopal Metro Rail Project by the Madhya Pradesh Metro Rail Corporation Limited (MPMRCL). The city presents a highly suitable case for studying last mile connectivity due to its dispersed urban structure, mixed land use characteristics, dependence on private and intermediate public transport modes, and the ongoing transition toward mass rapid transit systems.

The chapter provides a comprehensive profile of the study area and examines the existing urban transport conditions relevant to last mile connectivity around proposed metro stations. The chapter includes an analysis of Bhopal's historical growth, demographic structure, economic characteristics, land use distribution and urban transport systems. Further, it evaluates the proposed metro corridors, station influence areas and current accessibility conditions in selected station areas. Particular emphasis is placed on pedestrian infrastructure, feeder services, parking patterns, intermediate public transport operations and traffic management issues affecting metro accessibility.

The chapter also identifies critical challenges associated with station area planning and last mile integration, thereby establishing the contextual foundation for subsequent analytical and planning chapters of the thesis.

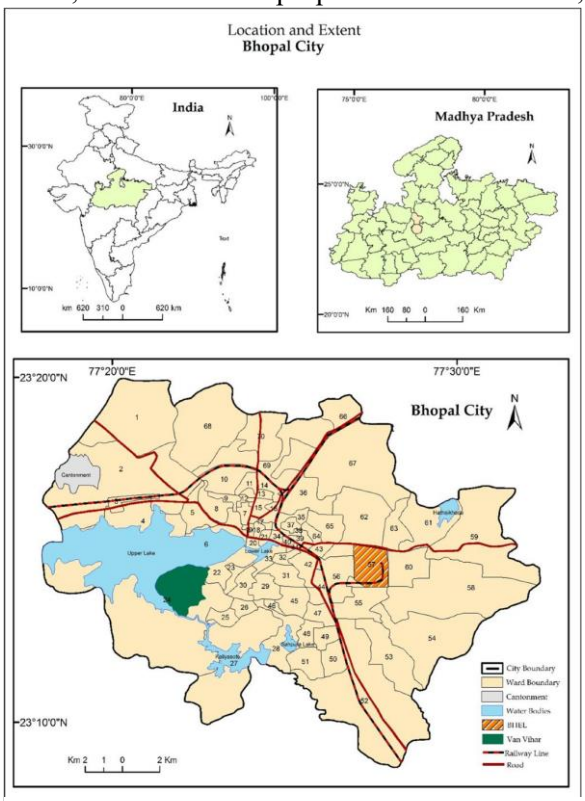



*Figure 11 Regional location of Bhopal*

## 3.2 City Profile of Bhopal

### 3.2.1 Historical Growth and Urban Expansion

entity["city","Bhopal","Madhya Pradesh, India"] has evolved from a historic princely settlement into one of the major administrative, educational and institutional centers of central India. The city was founded during the early eighteenth century by Dost Mohammad Khan and later developed under the rule of the Begums of Bhopal. The historical urban form of the city was initially concentrated around the walled city near Upper Lake, characterized by compact mixed-use neighborhoods, narrow streets and traditional commercial areas.

Following independence, Bhopal emerged as the capital of Madhya Pradesh in 1956, which significantly accelerated administrative and institutional growth. The post-independence planning interventions introduced planned residential colonies, government offices and institutional campuses in areas such as Arera Colony, TT Nagar and Shivaji Nagar. The development of large-scale public institutions, educational campuses and industrial establishments further contributed to urban expansion.

The city experienced substantial physical growth during the 1980s and 1990s due to industrialization, migration and expansion of service-sector activities. Urban growth gradually shifted toward the southern and eastern directions along major transport corridors such as Hoshangabad Road, Raisen Road, Kolar Road and Ayodhya Bypass. Planned residential developments and peri-urban expansion

resulted in the emergence of low-density urban sprawl characterized by increasing travel distances and automobile dependence.

The Bhopal Development Plan and subsequent planning frameworks attempted to regulate urban expansion through zoning regulations and infrastructure proposals. However, the pace of urbanization often exceeded infrastructure provision capacities. The city presently exhibits a combination of historic cores, planned institutional areas, commercial corridors and rapidly developing peripheral zones.

The spatial growth pattern of Bhopal has significant implications for urban mobility and metro accessibility. The dispersed urban structure and uneven distribution of employment centers create long commuting patterns that increase dependence on private vehicles and intermediate public transport. Consequently, efficient last mile connectivity systems become critical for ensuring successful integration between metro stations and surrounding urban activities.

From a transportation planning perspective, Bhopal's urban expansion has generated increasing pressure on road infrastructure, parking facilities and public transport systems. The concentration of institutional and commercial activities along major corridors has also created traffic bottlenecks around key intersections and transit nodes. These conditions strengthen the need for integrated transit-oriented development and station area planning strategies.

### 3.2.2 Demographic Profile

According to Census of India statistics, Bhopal is among the fastest growing urban centers in central India. The city has witnessed steady population growth due to administrative importance, educational opportunities, industrial activities and migration from surrounding districts. The urban agglomeration has experienced demographic expansion across both core city areas and peripheral growth zones.

. Demographic Profile

| Indicator | City (Municipal Corporation) |
|---|---|
| Total Population | 1,798,218 |
| Total Population of UA (if) | 1,886,100 |
| Share of ULB population in District Urban population (%) | 93.80 |
| Population Growth Rate (AEGR) 2001-11 | 2.24 |
| Area (sq. km)* | 285.88 |
| Share of ULB area in district (%)*# | 10.31 |
| Density of population (person per sq. km)* | 6290 |
| Literacy Rate (%) | 83.47 |
| Schedule Caste (%) | 13.46 |
| Schedule Tribes (%) | 2.56 |
| Youth, 15 - 24 years (%) | 21.30 |
| Slum Population (%) | 26.68 |
| Working Age Group, 15-59 years (%) | 65.22 |

ource: Census of India, 2011
District Census Handbook, Census of India, 2011

*Figure 12 Demographic Profile of Bhopal (Source:*

The demographic composition of Bhopal reflects characteristics commonly associated with emerging metropolitan cities. A significant proportion of the population belongs to the working-age group, thereby generating high travel demand associated with employment, education, commerce and daily activities. The concentration of students, government employees and service-sector workers contributes to recurring peak-hour mobility pressures.

Population density patterns in the city vary considerably across different zones. The old city areas near Chowk Bazaar and surrounding localities exhibit high-density mixed-use development with compact street networks. In contrast, newer residential colonies and peri-urban areas display relatively lower densities and automobile-oriented layouts.

The literacy rate of Bhopal is comparatively high due to the presence of major educational institutions including universities, engineering colleges and research centers. The city also functions as an educational hub for surrounding regions, resulting in substantial student movement across the urban area. Educational trips constitute a major component of daily travel demand and influence transport corridor utilization.

Household income variations within the city create differentiated mobility preferences and transport choices. Higher-income groups increasingly depend upon private cars and two-wheelers, while lower and middle-income groups rely on buses, shared auto-rickshaws, e-rickshaws and non-motorized transport modes. This socio-economic diversity creates complex transport demands requiring multimodal integration.

The city's population growth has contributed to increasing vehicle ownership levels, particularly of two-wheelers. Rising motorization has intensified congestion, parking shortages and environmental concerns. At the same time, the demand for efficient public transport systems has also increased. The metro rail project is therefore expected to address future mobility needs by providing high-capacity transit services integrated with feeder and last mile systems.

Demographic trends further indicate continued urban expansion toward peripheral areas, which may increase dependence on multimodal transport systems. The effectiveness of metro systems in such contexts depends upon station accessibility, feeder connectivity and inclusive mobility infrastructure.

### 3.2.3 Economic Structure

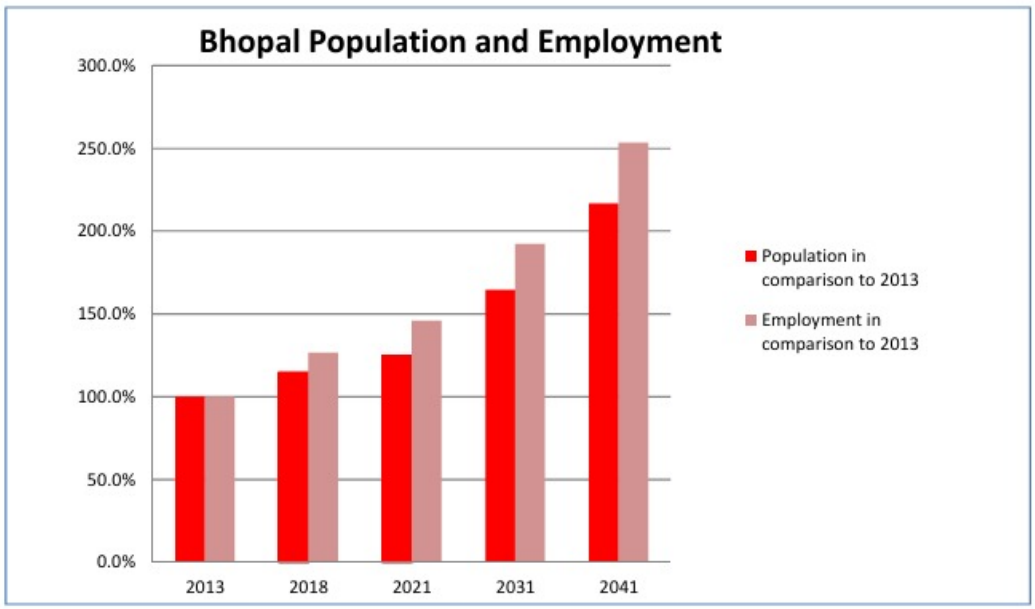



*Figure 13 Economic Structure of Bhopal*

The economy of Bhopal is primarily service-oriented, supported by administrative functions, educational institutions, healthcare services, trade activities and emerging commercial sectors. As the state capital, the city accommodates numerous government offices and administrative establishments that generate substantial employment and travel demand.

Institutional activities form a major component of the city economy. The presence of universities, technical institutions, research organizations and training centers contributes significantly to economic productivity and daily commuting patterns. Major educational institutions attract students and professionals from different parts of the state and country.

Commercial activities are concentrated in areas such as New Market, MP Nagar, Bittan Market, 10 Number Market and various corridor-based developments along arterial roads. MP Nagar functions as one of the primary commercial and business districts of the city, accommodating offices, retail establishments, coaching centers, hospitality facilities and service enterprises. These commercial clusters generate high traffic volumes and parking demand.

Industrial activities in Bhopal include manufacturing, engineering, pharmaceuticals, electrical goods and small-scale industrial units. Industrial estates located in Govindpura and nearby areas contribute to freight movement and worker mobility. However, compared to major industrial metropolitan regions, the city economy remains largely dominated by tertiary-sector activities.

The growth of information technology services, private healthcare and real estate development has also influenced urban transformation in recent decades. Increasing commercialization along transport

corridors has intensified land value appreciation and mixed-use development around major intersections.

The economic structure of the city has direct implications for transport planning and metro ridership patterns. Employment concentrations within commercial and institutional zones generate directional commuting flows during peak hours. Effective metro integration with these activity centers can reduce dependence on private vehicles and improve urban mobility efficiency.

The city's economy also demonstrates growing demand for organized urban transport systems capable of supporting economic productivity. Congestion-related travel delays and inadequate parking management impose economic costs on businesses and commuters. Consequently, investments in integrated metro-based mobility systems are expected to improve accessibility and support sustainable urban growth.

### 3.2.4 Land Use and Urban Form

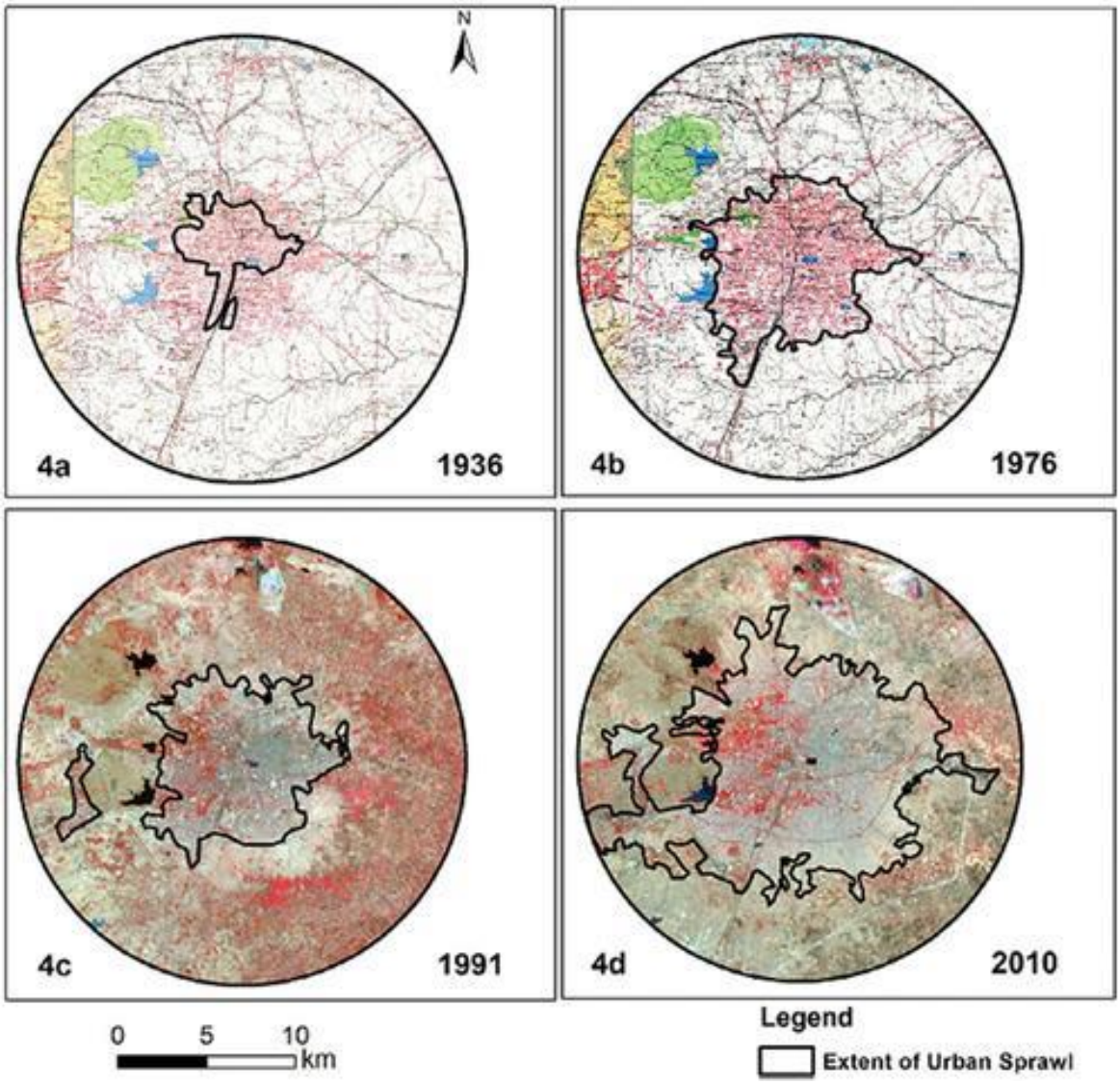



*Figure 14 Urban Growth Pattern of Bhopal (Draft BDP 2021)*

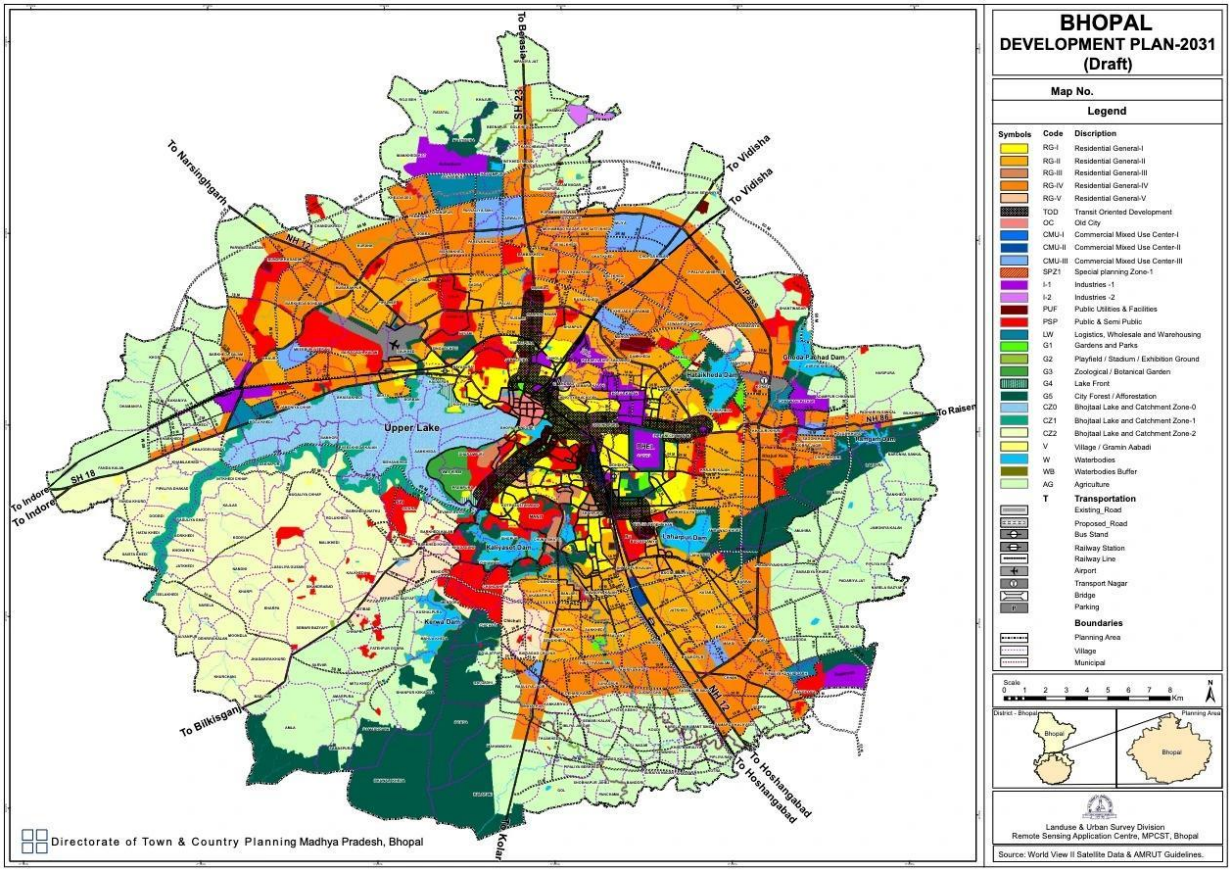



*Figure 15 Proposed land use plan (Draft BDP 2031)*

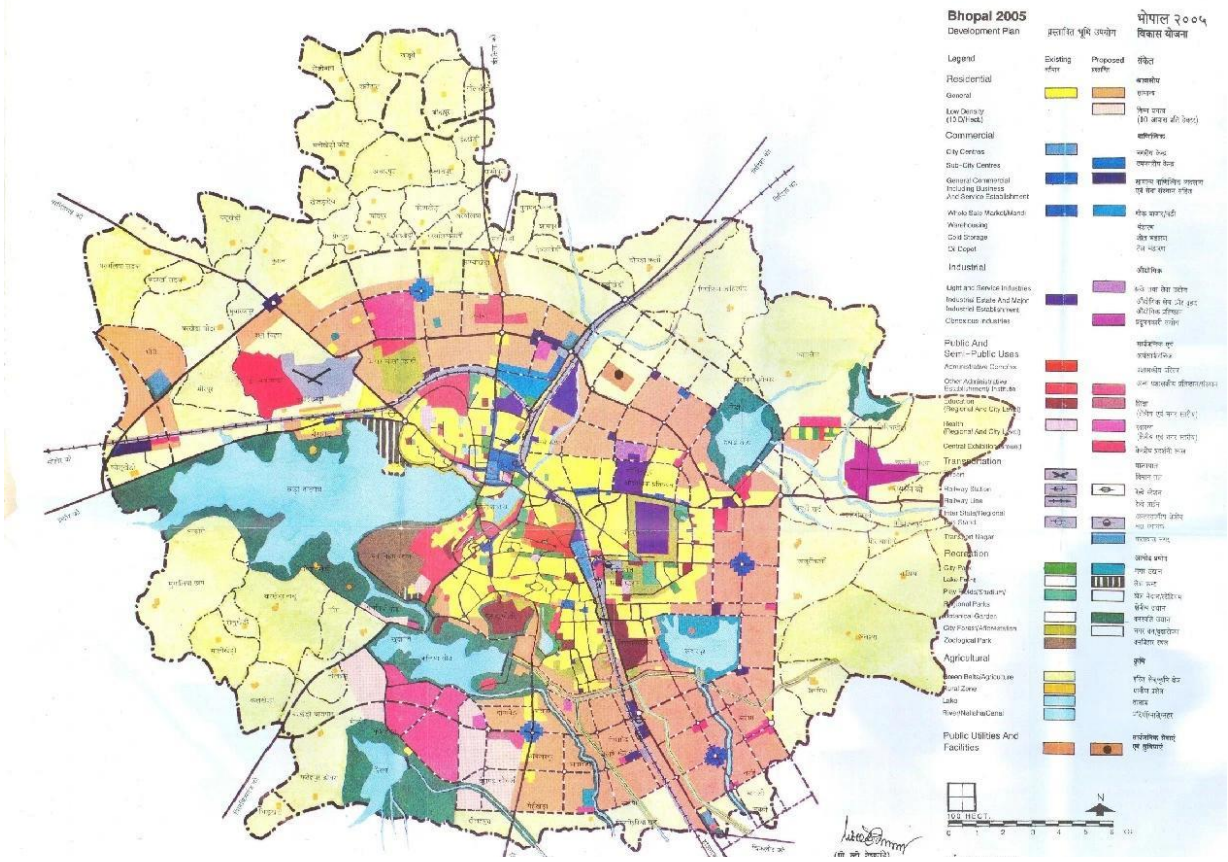



*Figure 16 Land use map of Bhopal Development Plan 2005*

The urban form of Bhopal reflects a combination of historical settlements, planned residential sectors, institutional campuses and corridor-based commercial development. The city is geographically constrained by lakes, undulating topography and environmental zones, which have influenced its spatial structure.

Land use distribution within the city exhibits considerable diversity. Residential land use occupies the largest proportion of urbanized areas, followed by public and semi-public uses, transportation infrastructure, commercial areas and industrial zones. Institutional land use is particularly significant due to the presence of administrative complexes, educational campuses and healthcare facilities.

The old city areas demonstrate compact urban morphology with mixed land use patterns and pedestrian-oriented street networks. In contrast, newer planned colonies such as Arera Colony and Shahpura exhibit wider roads, lower densities and automobile-oriented layouts. Peripheral growth areas along Kolar Road and Hoshangabad Road are characterized by gated housing developments, commercial strips and dispersed land use patterns.

Commercial development in Bhopal has increasingly shifted toward linear corridor-based growth along arterial roads. Such development patterns create localized congestion and accessibility challenges due to ribbon development, uncontrolled parking and inadequate pedestrian infrastructure.

The city's urban form has significant implications for transit accessibility and last mile connectivity. Mixed land use areas generally support walkability and shorter trip distances, whereas low-density peripheral areas increase dependence on motorized transport. The effectiveness of metro systems in Bhopal will therefore depend upon integrated land use and transport planning approaches.

Transit-oriented development principles remain relatively underdeveloped within the existing urban structure. Many activity centers continue to prioritize vehicular access rather than pedestrian accessibility. Station area planning interventions are therefore essential for creating compact, mixed-use and transit-supportive urban environments.

The presence of lakes and environmentally sensitive zones also requires balanced planning approaches that integrate mobility improvements with ecological conservation. Sustainable mobility systems such as walking, cycling and public transport become particularly important within environmentally constrained urban contexts.

### 3.3 Existing Urban Transport System

#### 3.3.1 Road Network and Hierarchy

The road network of Bhopal forms the primary framework for urban mobility and transportation activities. The city road system consists of arterial roads, sub-arterial roads, collector streets and local roads connecting residential, institutional, commercial and industrial areas.

Major arterial corridors include Hoshangabad Road, Raisen Road, VIP Road, Kolar Road, Ayodhya Bypass, Bhadbhada Road and Berasia Road. These corridors accommodate significant traffic volumes and function as major mobility spines linking different parts of the city.

The city road hierarchy displays considerable variation in terms of width, design quality and operational efficiency. Planned areas generally possess wider roads and organized layouts, whereas older areas exhibit narrow streets and constrained right-of-way conditions. Encroachments, on-street parking and informal commercial activities frequently reduce effective carriageway capacity.

Several important intersections within the city experience recurring congestion during peak hours. Junctions located near MP Nagar, Board Office Square, New Market, Jyoti Talkies, Nadra Bus Stand and Bairagarh are particularly affected by traffic delays and mixed traffic conflicts.

The road infrastructure in Bhopal is dominated by heterogeneous traffic conditions involving cars, two-wheelers, buses, auto-rickshaws, bicycles, pedestrians and informal transport modes. Two-wheelers constitute a major proportion of traffic composition due to affordability, convenience and inadequate public transport coverage.

Although flyovers and road widening projects have been implemented at selected locations, congestion levels continue to increase due to rising motorization and corridor-based urban growth. The absence of dedicated bus lanes, cycling tracks and organized parking management further reduces operational efficiency.

Pedestrian infrastructure along major roads remains inconsistent. Footpaths are either discontinuous, encroached or poorly maintained in several areas. Safe crossing facilities are limited, thereby affecting walkability and accessibility around major transit nodes.

The proposed metro system is expected to reduce traffic pressure along key corridors. However, the success of the metro project will depend upon integration with surrounding road networks and efficient station access systems.

### 3.3.2 Public Transport System

Public transport services in Bhopal are presently dominated by city bus operations, supplemented by intermediate public transport modes. The Bhopal City Link Limited (BCLL) operates bus-based public

transport services under urban mobility initiatives introduced during the Smart City Mission and urban transport modernization programs.

The city bus system includes standard buses, mini buses and Bus Rapid Transit System (BRTS)-related operations along selected corridors. The BRTS corridor was developed to improve public transport efficiency and reduce travel time; however, operational and integration challenges have limited its overall effectiveness.

Bus routes connect major residential areas, commercial zones, educational institutions and transport terminals. Nevertheless, route coverage and service frequency remain inadequate in several peripheral areas. Passengers frequently experience issues related to overcrowding, irregular schedules and insufficient multimodal integration.

Bus stops and passenger waiting facilities also vary considerably in quality. Many stops lack adequate shelters, seating arrangements, passenger information systems and universal accessibility features.

The public transport mode share within the city remains lower than desired due to increasing dependence on private vehicles and intermediate public transport. Limited reliability and accessibility reduce the attractiveness of formal public transport systems.

Despite these challenges, public transport remains essential for economically weaker sections, students and daily commuters. The introduction of the metro rail system is expected to strengthen the city's public transport network by providing higher-capacity and faster transit services.

However, metro systems alone cannot address urban mobility challenges unless supported by integrated feeder systems and multimodal accessibility. Effective coordination between buses, IPT modes and metro operations is therefore necessary for creating a comprehensive urban transit network.

### 3.3.3 Intermediate Public Transport

Intermediate Public Transport (IPT) plays a critical role in the mobility structure of Bhopal. Auto-rickshaws, shared auto-rickshaws and e-rickshaws constitute major components of the city's informal and semi-formal transport systems.

IPT modes provide flexible and demand-responsive mobility services, particularly in areas inadequately served by formal public transport. Shared auto-rickshaws operate extensively along major corridors and connect residential areas with commercial centers, educational institutions and transport nodes.

Auto-rickshaws function as important last mile connectors due to their route flexibility and ability to navigate narrow streets and congested areas. In several localities, IPT services operate as the primary mode of public transport accessibility.

However, IPT operations within the city remain largely unorganized. Issues such as unauthorized stopping, route overlaps, traffic obstruction and fare inconsistencies affect operational efficiency. Concentrations of auto-rickshaws near major intersections and commercial areas often contribute to congestion and roadside encroachment.

The growing presence of e-rickshaws reflects changing mobility trends and increasing demand for environmentally sustainable transport options. E-rickshaws are particularly active in local neighborhood-level movement and short-distance trips.

Despite operational challenges, IPT systems offer significant potential for integration with metro stations as feeder services. Organized IPT stands, route rationalization and digital integration can improve accessibility and reduce first and last mile barriers.

The integration of IPT with metro systems is particularly important in Tier-II cities where fixed-route public transport coverage remains limited. Properly managed feeder services can substantially increase metro ridership and accessibility.

### 3.3.4 Traffic and Travel Characteristics

The travel characteristics of Bhopal are shaped by mixed land use patterns, dispersed urban growth and increasing motorization levels. Daily travel demand is generated by administrative, educational, commercial and institutional activities distributed across the city.

Peak-hour traffic congestion is concentrated along major corridors connecting residential areas with employment and commercial centers. Hoshangabad Road, MP Nagar, Board Office Square, New Market and Raisen Road experience particularly high traffic volumes during morning and evening peak periods.

Two-wheelers constitute the dominant mode of private transport due to affordability and maneuverability within congested traffic conditions. The increasing ownership of private cars has further intensified parking demand and roadway congestion.

Trip purposes within the city include work trips, educational trips, shopping trips and institutional travel. Educational institutions generate significant recurring travel demand due to large student populations and concentrated campus locations.

Walking remains an important component of urban mobility, particularly for short-distance trips and access to public transport. However, inadequate pedestrian infrastructure reduces safety and comfort for pedestrians.

Travel speeds along major corridors are often reduced during peak hours due to intersection delays, mixed traffic conditions, roadside parking and informal activities. Traffic management challenges are particularly severe around commercial corridors and transport hubs.

Parking shortages constitute another major urban mobility issue. Unregulated on-street parking frequently reduces carriageway width and disrupts traffic movement. Commercial areas and institutional zones are especially affected by parking spillover.

The implementation of the metro system is expected to influence future travel behavior by shifting a proportion of trips from private vehicles toward public transport. However, this modal shift will depend upon station accessibility, affordability, travel convenience and feeder connectivity.

### 3.4 Overview of Madhya Pradesh Metro Rail Corporation Limited Metro Project

#### 3.4.1 Metro Corridors and Phasing

Proportions of 1st Phase Network (structural)

| Line No. | Name of Corridor/Line | Total Stations | | | | Length in Km | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Elevated | Underground | At Grade | Total | Elevated | Ramp | Underground | At Grade | Total |
| 2 | Karond Square to AIIMS | 14 | 2 | 0 | 16 | 12.58 | 0.62 | 1.79 | 0 | 14.99 |
| 5 | Bhadbhada Square to Ratnagiri Tiraha | 14 | 0 | 0 | 14 | 12.882 | 0 | 0 | 0 | 12.882 |
| | | | | Total | 30 | | | | Total | 27.88 |

Line 5 has one station which shares concourse with line 2

*Figure 17 Metro Phasing (phase 1) SOURCE: METRO DPR PHASE 1 2016*

The Bhopal Metro Rail Project is being implemented by the Madhya Pradesh Metro Rail Corporation Limited (MPMRCL) with the objective of improving urban mobility, reducing congestion and promoting sustainable transportation within the city.

The metro project includes multiple corridors designed to connect major residential, institutional, commercial and transport nodes. The alignment has been planned to serve high-demand corridors and integrate with existing urban development patterns.

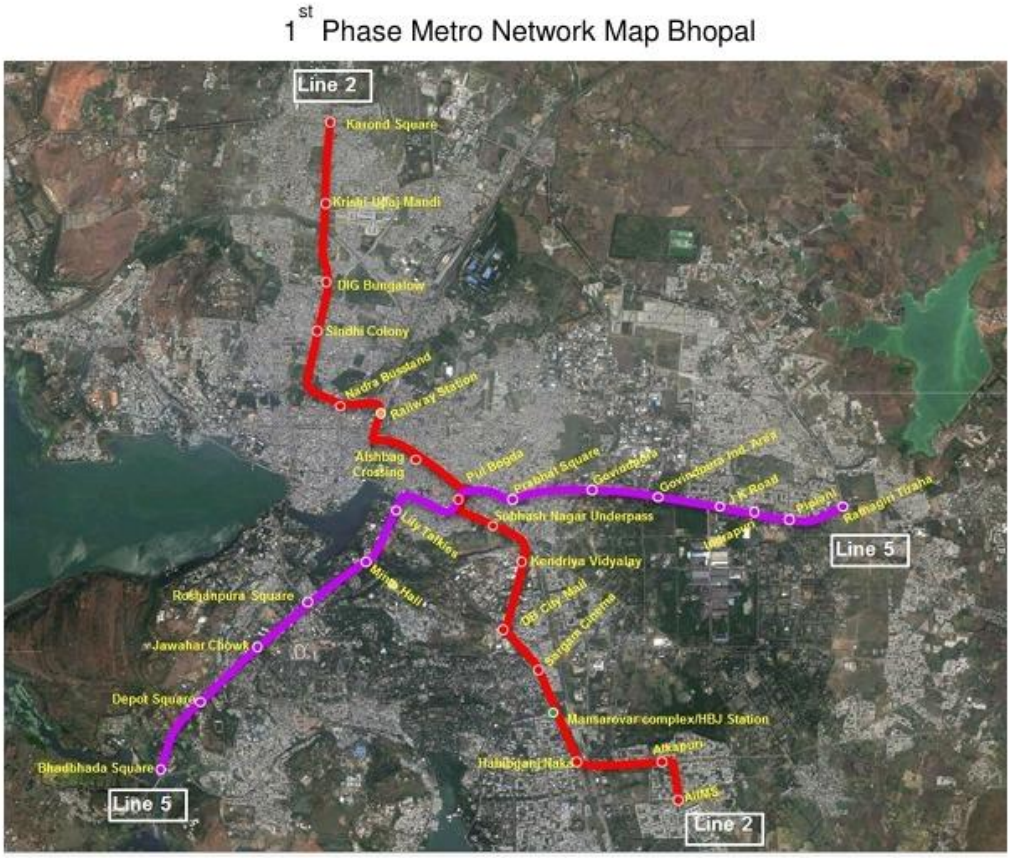
The proposed corridors traverse important areas including AIIMS, Subhash Nagar, MP Nagar, New Market, Bairagarh, Karond and other strategic urban zones. The project incorporates elevated and at-grade sections depending upon corridor characteristics and right-of-way conditions.

The metro system has been planned in phases to ensure gradual implementation and operational efficiency. Priority corridors are being developed initially based on projected ridership demand and strategic importance.

The proposed metro network aims to reduce travel time across major corridors while encouraging modal shift from private vehicles toward public transport. The system is also expected to support future transit-oriented development initiatives and integrated urban growth.

The metro project represents a major transformation in the transport structure of Bhopal. However, the effectiveness of the system will depend upon station accessibility and integration with existing transport networks.

### 3.4.2 Station Locations and Influence Zones




| Line No. | Name of Corridor/Line | Total Stations | | | | Length in Km | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Elevated | Underground | At Grade | Total | Elevated | Ramp | Underground | At Grade | Total |
| 2 | Karond Square to AIIMS | 14 | 2 | 0 | 16 | 12.58 | 0.62 | 1.79 | 0 | 14.99 |
| 5 | Bhadbhada Square to Ratnagiri Tiraha | 14 | 0 | 0 | 14 | 12.882 | 0 | 0 | 0 | 12.882 |
| | | | | Total | 30 | | | | Total | 27.88 |

*Figure 18 First Phase Metro Network Map SOURCE: METRO DPR PHASE 1 2016*

Metro stations have been strategically located to maximize accessibility to residential areas, institutional campuses, commercial centers and transport nodes. The station influence zones generally extend within walking and feeder-access distances surrounding the stations.

Station areas located within commercial corridors such as MP Nagar are expected to generate high ridership due to concentrated employment and business activities. Institutional stations near educational and healthcare facilities are also projected to experience substantial passenger demand.

The influence zone of metro stations typically includes pedestrian catchments, feeder service catchments and park-and-ride accessibility areas. Land use intensity and connectivity within these zones significantly influence station utilization.

Several proposed stations are located near major intersections and existing transport corridors. While such locations improve accessibility potential, they also create challenges related to congestion, parking management and pedestrian movement.

The station influence areas presently exhibit varying levels of infrastructure preparedness. In many locations, pedestrian facilities, cycling infrastructure and organized feeder systems remain inadequate.

Effective station area planning is therefore necessary to improve accessibility and support seamless multimodal integration. Land use restructuring, pedestrian improvements and parking management interventions can enhance station performance and user convenience.

### 3.4.3 Interchange and Integration Potential

The integration potential of the metro system with existing transport modes constitutes a critical determinant of overall network efficiency. Metro stations in Bhopal possess opportunities for integration with buses, IPT systems, pedestrian networks and cycling infrastructure.

Several stations are proposed near existing bus corridors and transport hubs, thereby creating possibilities for multimodal interchange. However, successful integration requires coordinated infrastructure planning and operational management.

The current urban transport environment of Bhopal remains fragmented, with limited physical and operational coordination between different modes. Passengers often experience difficulties in transferring between buses, IPT modes and walking routes.

Integrated interchange facilities can improve user convenience and reduce transfer time. Such facilities may include organized feeder terminals, pedestrian plazas, cycle parking, wayfinding systems and integrated ticketing arrangements.

The metro system also presents opportunities for implementing transit-oriented development principles around station areas. Mixed-use development, higher densities and pedestrian-friendly environments can support increased ridership and sustainable mobility.

The integration potential of metro stations is particularly important in a city such as Bhopal where public transport dependence remains moderate and private vehicle ownership is increasing. Efficient interchange systems can improve public transport attractiveness and reduce reliance on personal vehicles.

### 3.5 Selection of Sample Metro Stations

#### 3.5.1 Selection Criteria

The selection of sample metro stations for the present study was undertaken to ensure representation of diverse urban contexts, land use characteristics and transport conditions. The selected stations reflect varying functional roles within the urban structure of Bhopal.

The selection criteria included the following parameters:

1. Land use diversity within the station influence zone.
2. Presence of commercial, institutional or residential activity concentrations.
3. Traffic intensity and congestion levels.
4. Availability of public transport and IPT services.
5. Existing pedestrian and parking conditions.
6. Strategic significance within the metro corridor.
7. Potential for multimodal integration.

Stations exhibiting contrasting urban environments were selected to facilitate comparative analysis of last mile connectivity conditions. The selected sample stations collectively represent commercial, institutional and mixed-use urban contexts.

The selected stations also demonstrate varying accessibility challenges, thereby enabling assessment of different planning interventions and integration strategies.

#### 3.5.2 Typology of Stations

The selected metro stations can broadly be categorized into the following typologies:

**Commercial-Oriented Stations**

Commercial stations are located within high-intensity business and retail zones characterized by significant pedestrian activity, traffic congestion and parking demand. Stations near MP Nagar and New Market fall within this category.

These stations are expected to experience high passenger turnover due to employment and commercial activities. However, they also face challenges related to encroachment, limited pedestrian space and unregulated parking.

**Institutional Stations**

Institutional stations are located near educational institutions, healthcare facilities and administrative complexes. Such stations generate concentrated peak-hour travel demand associated with students, employees and visitors.

Institutional station areas often possess relatively wider roads and campus-based development patterns, though pedestrian accessibility and feeder integration may remain inadequate.

**Residential and Mixed-Use Stations**

Residential stations primarily serve surrounding housing areas and neighborhood-level activities. These stations require efficient feeder connectivity due to dispersed residential catchments.

Mixed-use station areas combine residential, commercial and institutional functions and therefore generate multidirectional travel demand throughout the day.

The station typology framework assists in understanding the relationship between land use characteristics and last mile connectivity requirements.

### 3.5.3 Commercial, Residential and Institutional Catchments

The catchment characteristics of metro stations significantly influence accessibility patterns and ridership potential. Commercial catchments generally demonstrate high pedestrian volumes and short-duration trips associated with shopping, employment and business activities.

Residential catchments generate recurring daily commuting demand and require strong feeder connectivity due to the dispersed nature of housing areas. The quality of neighborhood-level pedestrian and cycling infrastructure becomes particularly important in such contexts.

Institutional catchments are characterized by periodic peak-hour movement associated with educational schedules, office timings and healthcare visits. These catchments require organized pedestrian circulation and efficient drop-off systems.

The selected station areas in Bhopal exhibit overlapping land use influences, thereby creating complex travel patterns. Mixed land use environments can potentially support higher metro ridership due to diversified trip generation.

However, existing infrastructure conditions in several station catchments remain inadequate for supporting efficient multimodal accessibility. Pedestrian discontinuity, traffic congestion and informal parking activities reduce overall accessibility quality.

The analysis of catchment characteristics therefore provides a basis for identifying context-specific planning interventions for different station types.

### 3.6 Existing Last Mile Connectivity Conditions

#### 3.6.1 Pedestrian Infrastructure

Pedestrian infrastructure forms the most critical component of last mile connectivity because every public transport trip begins and ends with walking. The quality of pedestrian facilities around metro stations directly influences user convenience, accessibility and ridership potential.

The existing pedestrian environment in many parts of Bhopal remains inadequate and fragmented. Footpaths along major roads are often discontinuous, encroached or poorly maintained. Informal vending, utility installations and parked vehicles frequently obstruct pedestrian movement.

In commercial areas such as MP Nagar and New Market, pedestrian congestion is particularly severe due to mixed traffic conditions and high activity intensity. Several stretches lack adequate walking width and safe crossing facilities.

Universal accessibility features such as ramps, tactile paving and barrier-free pathways are limited. This affects mobility for elderly persons, children and persons with disabilities.

Pedestrian crossings at major intersections are often unsafe due to inadequate signal coordination, high vehicular speeds and limited refuge spaces. The absence of grade-separated crossings near busy corridors further increases pedestrian risk.

Street lighting, shading and streetscape quality also vary considerably across different areas. Poor environmental conditions reduce walkability and discourage public transport usage.

Despite these challenges, the compact urban structure of several station areas provides opportunities for improving walkability through pedestrian-oriented design interventions. Continuous footpaths, safe

crossings, universal accessibility measures and streetscape enhancements can significantly improve station accessibility.

The success of metro systems in Indian cities increasingly depends upon creating safe and comfortable pedestrian environments. In the context of Bhopal, pedestrian infrastructure improvement should therefore be prioritized as a core component of station area planning.

### 3.6.2 Cycling and NMT Infrastructure

Non-motorized transport (NMT), particularly walking and cycling, represents an environmentally sustainable mode of urban mobility. However, cycling infrastructure within Bhopal remains limited and fragmented.

Dedicated cycling tracks are largely absent along major corridors. Cyclists often share carriageways with fast-moving mixed traffic, thereby increasing safety risks. The absence of secure cycle parking and end-of-trip facilities further discourages cycling.

Several residential and institutional areas possess potential for short-distance cycling trips due to moderate travel distances and relatively lower traffic intensity. Nevertheless, inadequate infrastructure and safety concerns limit cycling adoption.

The city's climatic conditions and topographical variations also influence cycling behavior. However, the increasing availability of electric cycles and shared mobility systems presents opportunities for promoting cycling as a feeder mode.

NMT integration with metro stations can substantially improve accessibility within station influence zones. Cycle-sharing systems, dedicated lanes and secure parking facilities can strengthen multimodal connectivity.

Transit-oriented planning approaches emphasize the importance of walkable and cycle-friendly station areas. In Bhopal, the introduction of integrated NMT infrastructure around metro stations can improve sustainability and reduce dependence on motorized feeder modes.

The promotion of cycling infrastructure can also support environmental objectives by reducing vehicular emissions and energy consumption.

### 3.6.3 Existing Parking Conditions

Parking management constitutes a major challenge within several commercial and institutional areas of Bhopal. Increasing vehicle ownership and inadequate off-street parking provision have resulted in extensive on-street parking practices.

Commercial corridors such as MP Nagar and New Market experience significant parking spillover onto carriageways and pedestrian spaces. Informal parking activities frequently reduce effective road width and contribute to traffic congestion.

Institutional areas also experience peak-hour parking pressure due to concentrated visitor and employee demand. The absence of structured parking management systems leads to inefficient space utilization.

Parking around future metro stations represents a critical planning concern because uncontrolled parking can obstruct pedestrian access and reduce station efficiency. At the same time, strategically planned park-and-ride facilities may support metro ridership from peripheral areas.

The current parking system in the city remains largely fragmented and inadequately regulated. Pricing mechanisms, digital management systems and enforcement measures remain limited.

Integrated parking management strategies are therefore necessary within metro station influence zones. Such strategies may include multilevel parking facilities, shared parking systems, demand-based pricing and restrictions on on-street parking.

Parking policies should also prioritize pedestrian movement and public transport accessibility rather than encouraging excessive automobile dependence.

### 3.6.4 Feeder Services and IPT Operations

Feeder connectivity constitutes a critical determinant of metro accessibility, particularly in cities characterized by dispersed land use patterns. Existing feeder services in Bhopal are primarily dependent on IPT modes such as auto-rickshaws and e-rickshaws.

Although these modes provide flexible connectivity, their operations remain largely uncoordinated. Lack of designated pickup and drop-off areas near major transport nodes often creates congestion and roadside conflicts.

Bus-based feeder services remain limited in coverage and frequency. Peripheral residential areas frequently lack efficient formal feeder systems connecting to major transport corridors.

The absence of integrated scheduling and ticketing between different modes reduces convenience for passengers. Passengers often rely on multiple informal transfers, increasing travel uncertainty and time.

Metro station areas require organized feeder integration systems capable of supporting seamless multimodal mobility. Feeder planning should consider passenger demand, route rationalization, service frequency and universal accessibility.

Electric feeder systems and shared mobility services also present opportunities for sustainable last mile connectivity. Such systems can reduce environmental impacts while improving accessibility.

The integration of IPT and feeder systems with metro operations is particularly important in Bhopal due to the dispersed nature of urban growth and limited formal public transport penetration.

### 3.6.5 Traffic Congestion and Encroachments

Traffic congestion constitutes one of the most significant urban mobility challenges within Bhopal. Major corridors and intersections experience recurring delays due to increasing vehicle ownership, mixed traffic conditions and inadequate traffic management.

Commercial areas and transport nodes are particularly affected by congestion arising from roadside parking, informal vending and unregulated IPT operations. Encroachments onto footpaths and carriageways reduce effective mobility space and create conflicts between pedestrians and vehicles.

Several future metro station areas presently exhibit inadequate traffic circulation systems. The concentration of commercial activities near intersections further intensifies congestion pressures.

Encroachments also reduce pedestrian safety and accessibility. Informal commercial activities frequently occupy sidewalks and public spaces, forcing pedestrians onto carriageways.

Traffic congestion around station areas may reduce the effectiveness of metro systems if not addressed through integrated planning interventions. Efficient traffic circulation, parking management and pedestrian prioritization are therefore essential.

Integrated station area planning should include measures such as traffic calming, pedestrianization, organized vending zones and intersection redesign. Such interventions can improve accessibility while reducing conflicts between different road users.

The management of congestion and encroachments is particularly important for ensuring comfortable and efficient access to metro stations.

## 3.7 Key Issues and Challenges in Station Areas

The analysis of existing conditions within the selected station areas reveals several interconnected issues affecting last mile connectivity and metro accessibility.

## Fragmented Multimodal Integration

The existing urban transport system demonstrates limited integration between buses, IPT modes, pedestrians and future metro infrastructure. Passengers often experience discontinuity during mode transfers due to inadequate interchange facilities and uncoordinated operations.

### Inadequate Pedestrian Infrastructure

Footpaths, pedestrian crossings and universal accessibility facilities remain insufficient in several station areas. Unsafe walking conditions discourage public transport usage and reduce accessibility for vulnerable groups.

### Traffic Congestion and Mixed Traffic Conditions

High traffic volumes, roadside parking and heterogeneous traffic composition contribute to congestion around major corridors and intersections. Congested environments reduce travel reliability and accessibility.

### Unorganized IPT Operations

Although IPT modes provide essential mobility services, their operations remain poorly regulated. Random stopping, roadside waiting and route overlaps create traffic conflicts and inefficient circulation.

### Parking Spillover and Encroachment

Unregulated on-street parking and encroachments reduce effective roadway capacity and obstruct pedestrian movement. Commercial areas are particularly affected by parking pressure.

### Limited Cycling Infrastructure

The absence of dedicated cycling facilities limits opportunities for sustainable non-motorized feeder connectivity.

### Weak Transit-Oriented Development Integration

Several station influence zones presently lack transit-supportive land use patterns and pedestrian-oriented urban design. Land use and transport planning integration remains limited.

**Institutional and Governance Challenges**

Multiple agencies are involved in transport planning, traffic management and infrastructure provision. Coordination challenges frequently affect implementation efficiency.

The identified issues indicate the need for integrated planning approaches combining infrastructure improvements, policy interventions and institutional coordination. Station area planning should prioritize pedestrian accessibility, multimodal integration and sustainable mobility systems.

### 3.8 Chapter Summary

This chapter presented a comprehensive profile of the study area and examined the existing urban transport and last mile connectivity conditions within Bhopal. The analysis demonstrated that the city has experienced significant urban growth characterized by corridor-based expansion, increasing motorization and changing mobility patterns.

The city profile highlighted the historical evolution, demographic characteristics, economic structure and land use patterns influencing transportation demand within Bhopal. The analysis revealed that dispersed urban growth and increasing dependence on private vehicles have intensified congestion and accessibility challenges.

The chapter further examined the existing urban transport system, including road networks, public transport services, IPT operations and traffic characteristics. The findings indicated that although IPT systems provide substantial mobility support, multimodal integration and formal public transport accessibility remain limited.

The overview of the Bhopal Metro Rail Project demonstrated the strategic significance of metro investments in improving urban mobility. However, the analysis emphasized that metro success will depend upon effective last mile connectivity and station area integration.

The assessment of selected metro station areas revealed significant challenges related to pedestrian infrastructure, cycling facilities, parking management, feeder services and traffic congestion. Existing accessibility conditions remain fragmented and insufficient for supporting seamless multimodal mobility.

The chapter identified major issues including inadequate pedestrian facilities, unorganized IPT operations, congestion, parking spillover and weak transit-oriented integration. These findings establish the contextual basis for subsequent analytical chapters focusing on assessment methodologies, user

perceptions and planning interventions for improving last mile connectivity around metro stations in Bhopal.

# Chapter 4: Research Methodology and Analytical Framework

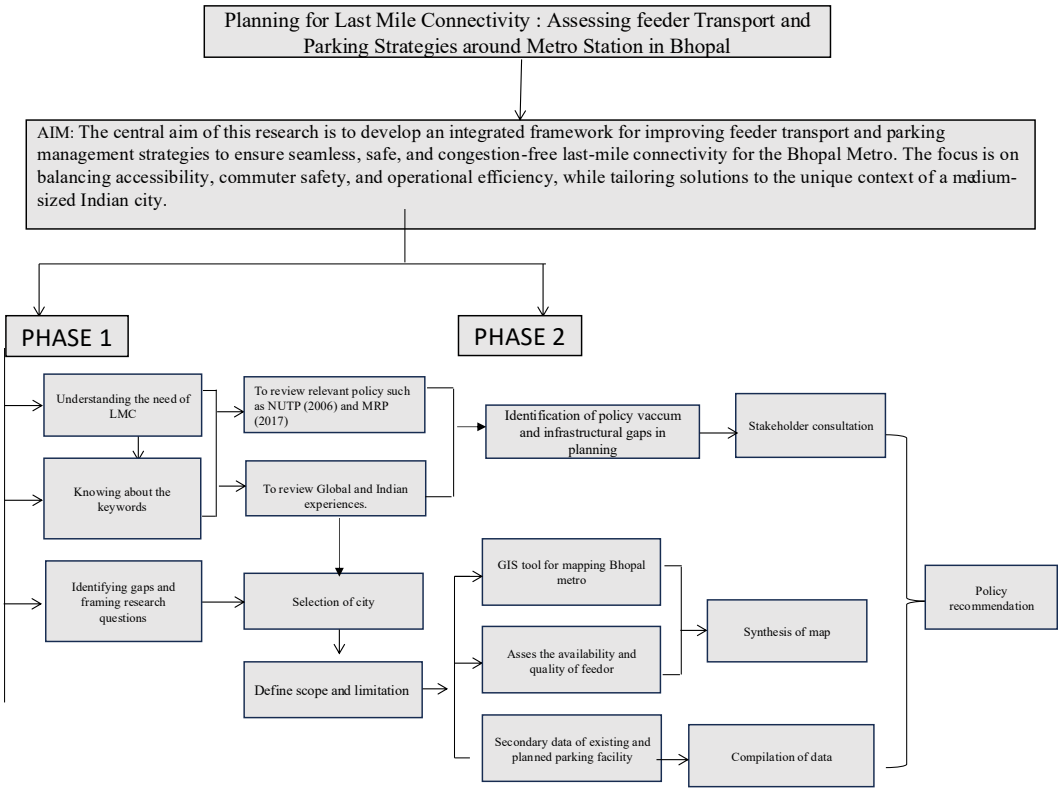



*Figure 19 Methodology Phase 1*

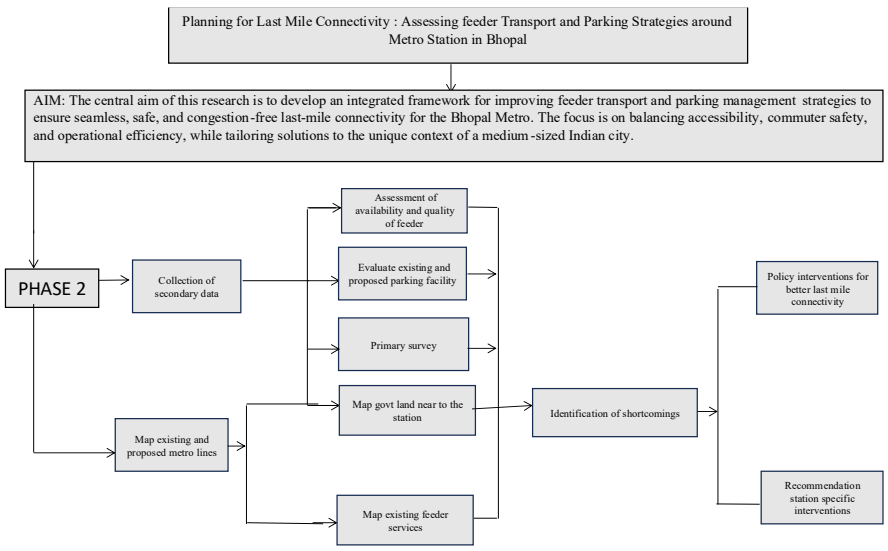



*Figure 20 Methodology Phase 2*

## 4.1 Introduction

This chapter presents the research methodology and analytical framework adopted for the study titled *"Planning for Last Mile Connectivity: Assessment of Parking Strategies and Feeder Services around Metro Stations in Bhopal."* The chapter establishes the systematic procedures used for data collection, spatial analysis, assessment of accessibility conditions, evaluation of parking infrastructure, and analysis of feeder transport systems around selected metro station areas in Bhopal.

The methodology has been designed to examine the interrelationship between metro transit systems and supporting last mile connectivity infrastructure. The study recognizes that the efficiency of urban rail systems is significantly influenced by accessibility conditions, feeder transport integration, pedestrian mobility, and parking management within station influence zones. Therefore, the methodology integrates transportation planning techniques, spatial analysis tools, field-based surveys, and statistical methods to evaluate existing conditions and identify critical mobility gaps.

The chapter further explains the research design, sampling framework, survey techniques, GIS-based analytical methods, indicator development process, and statistical tools adopted for assessment. A mixed-method research approach combining quantitative and qualitative techniques has been employed to ensure comprehensive analysis of both physical infrastructure and commuter perceptions.

The overall methodological framework is structured to support evidence-based planning interventions for improving multimodal accessibility and sustainable urban mobility around metro stations. Similar methodological approaches have been widely adopted in transit-oriented development studies, urban accessibility research, and public transport integration assessments (Cervero, 1998; Vuchic, 2005; Litman, 2021).

## 4.2 Research Design and Approach

### 4.2.1 Exploratory and Analytical Research

The present research adopts both exploratory and analytical approaches to understand and evaluate last mile connectivity conditions around metro stations. The exploratory dimension focuses on identifying the nature, extent, and operational characteristics of accessibility issues related to metro transit systems. Since metro-based mobility systems in emerging Indian cities are undergoing rapid transformation, exploratory research becomes essential for understanding commuter behavior, travel patterns, parking demand, and feeder transport dependency.

The analytical component of the study involves systematic assessment of existing mobility conditions using measurable indicators and spatial analysis techniques. The study evaluates pedestrian accessibility, parking efficiency, feeder transport performance, and multimodal integration around selected station areas. Quantitative analysis is used to assess travel behavior, parking occupancy, accessibility levels, and user satisfaction, while spatial analysis is employed to understand service coverage and mobility gaps.

The research further adopts a case study-based planning approach wherein selected metro station influence zones are examined in detail. This enables contextual understanding of urban form, land use characteristics, transport infrastructure, and socio-economic activity patterns influencing last mile connectivity.

### 4.2.2 Mixed-Method Approach

The study adopts a mixed-method research approach integrating both quantitative and qualitative methods for comprehensive assessment. Quantitative methods are used to generate measurable and comparable datasets related to accessibility, parking utilization, pedestrian movement, and feeder service performance. Qualitative methods are employed to understand commuter perceptions, institutional challenges, operational constraints, and governance-related issues.

The quantitative component includes:

- User questionnaire surveys
- Parking occupancy analysis
- Traffic and pedestrian counts
- GIS-based accessibility assessment
- Composite index development
- Ranking and prioritization analysis

The qualitative component includes:

- Stakeholder interviews
- Institutional consultations
- Observational field studies
- Policy and literature review

The mixed-method approach improves analytical reliability by enabling triangulation of data obtained from multiple sources. According to Creswell (2014), integration of qualitative and quantitative techniques enhances the validity and practical applicability of planning research.

## 4.3 Development of Assessment Framework

The analytical framework for the study has been developed based on principles of integrated urban mobility, transit-oriented development, and sustainable transportation planning. The framework focuses on assessing the relationship between metro infrastructure and supporting last mile connectivity systems within station influence areas.

The framework is structured around three major assessment dimensions:

1. Last Mile Connectivity Assessment
2. Parking Strategy Assessment
3. Feeder Service Assessment

Each component is evaluated through a set of indicators representing accessibility, operational efficiency, user convenience, and spatial integration.

### 4.3.1 Indicators for Last Mile Connectivity

The last mile connectivity indicators are formulated to assess the quality of access between metro stations and surrounding urban areas. The indicators are derived from principles of walkability, multimodal integration, accessibility planning, and pedestrian-oriented development.

These indicators help evaluate the accessibility performance and pedestrian friendliness of station areas.

#### 4.3.2 Indicators for Parking Assessment

Parking assessment indicators are developed to examine the adequacy, efficiency, and management of parking systems around metro stations. The assessment considers both formal and informal parking conditions influencing commuter access patterns.

The assessment further examines the relationship between parking availability and metro ridership behavior.

#### 4.3.3 Indicators for Feeder Service Assessment

Feeder transport assessment focuses on evaluating the efficiency, accessibility, and operational integration of supporting transport systems connecting commuters to metro stations.

## 4.4 Data Requirements and Sources

The study utilizes primary, secondary, and spatial datasets to evaluate existing mobility conditions around metro stations.

### 4.4.1 Primary Data

Primary data collection forms a major component of the study and involves extensive field-based surveys conducted around selected metro station areas.

The primary datasets include:

- User questionnaire surveys
- Parking inventory surveys
- Traffic volume counts
- Pedestrian movement surveys
- Feeder transport surveys
- Stakeholder interviews
- Field observations and photographic documentation

Primary data collection enables assessment of real-time mobility conditions, commuter behavior, and operational challenges.

### 4.4.2 Secondary Data

Secondary data is collected from government agencies, institutional reports, planning documents, and academic sources.

Major secondary data sources include:

- Bhopal Metro Rail Corporation Limited reports
- Comprehensive Mobility Plan of Bhopal
- Development Plan documents
- Smart City Mission reports
- Census of India data
- Urban transport policy documents
- Research journals and technical reports

Secondary data provides contextual understanding of transport infrastructure, land use patterns, and urban growth trends.

### 4.4.3 Spatial and GIS Data

Spatial datasets are used for accessibility mapping and network analysis. GIS-based datasets include:

- Road network maps
- Metro alignment and station layers
- Land use maps
- Transit route maps
- Population density layers
- Parking location maps
- Pedestrian network data

Spatial analysis supports visualization and interpretation of accessibility conditions.

## 4.5 Sampling Design

The sampling framework is designed to ensure representative and reliable data collection across selected metro station areas.

### 4.5.1 User Surveys

User surveys are conducted among metro commuters, pedestrians, feeder transport users, and local residents using stratified random sampling techniques.

The survey captures information related to:

- Socio-economic characteristics
- Travel purpose and frequency
- Modal choice behavior
- Last mile travel patterns
- Parking usage
- Accessibility challenges
- User satisfaction levels

The sample size is determined based on station ridership intensity and commuter diversity.

### 4.5.2 Stakeholder Surveys

Stakeholder consultations are conducted with representatives from transport agencies, planning authorities, metro administration, and feeder transport operators.

The major stakeholders include:

- Metro authorities
- Municipal officials
- Traffic police
- Bus operators
- Auto-rickshaw unions
- Urban planning professionals

The interviews provide institutional perspectives on operational and policy-level challenges.

### 4.5.3 Spatial Sampling of Station Areas

Spatial sampling is carried out within station influence zones using walkable catchment areas. A radius of approximately 500–800 meters is considered for detailed assessment based on accepted TOD planning standards.

Station areas are categorized into:

- Commercial influence zones
- Residential influence zones
- Mixed-use areas
- Peripheral station areas

This classification supports comparative analysis across different urban contexts.

## 4.6 Survey and Data Collection Techniques

### 4.6.1 Household/User Questionnaire Survey

Structured questionnaire surveys are administered to commuters and local users. Both closed-ended and perception-based questions are included to evaluate mobility behavior and accessibility conditions.

The survey focuses on:

- Access and egress modes
- Travel time
- Parking preference
- Feeder transport dependency
- Safety perception
- Overall satisfaction

Likert-scale analysis is used to assess commuter perceptions.

### 4.6.2 Parking Inventory Survey

Parking inventory surveys are conducted to evaluate parking supply, occupancy levels, and parking management conditions around metro stations.

The survey includes assessment of:

- On-street parking
- Off-street parking
- Illegal parking zones
- Vehicle turnover rates
- Peak-hour parking demand
- Bicycle parking facilities

Occupancy analysis is conducted during both peak and non-peak periods.

### 4.6.3 Feeder Service Survey

The feeder service survey evaluates operational efficiency and accessibility of supporting transport systems such as buses, auto-rickshaws, e-rickshaws, and shared mobility modes.

The survey assesses:

- Route coverage
- Frequency of services
- Passenger load conditions
- Waiting time
- Fare structure
- Connectivity with metro stations

The survey helps identify spatial and operational gaps in feeder transport systems.

### 4.6.4 Traffic and Pedestrian Counts

Traffic volume counts and pedestrian movement surveys are conducted at selected station access points and adjoining intersections.

The assessment includes:

- Classified traffic counts
- Peak-hour traffic intensity
- Pedestrian flow analysis
- Crossing movement patterns
- Conflict point identification
- Pedestrian delay assessment

These surveys support analysis of station area mobility efficiency and congestion levels.

#### 4.6.5 Stakeholder Interviews

Semi-structured interviews are conducted to understand governance mechanisms, implementation challenges, and policy constraints related to last mile connectivity systems.

The interviews focus on:

- Parking management policies
- Feeder integration mechanisms
- Infrastructure funding
- Inter-agency coordination
- Operational bottlenecks
- Future mobility planning initiatives

Stakeholder inputs provide qualitative depth to the analysis.

### 4.7 GIS and Spatial Analysis

GIS-based spatial analysis forms a critical component of the research methodology.

#### 4.7.1 Catchment Delineation

Station catchments are delineated using network-based accessibility analysis rather than simple radial buffers. Walkable service areas are mapped using actual pedestrian networks and street connectivity patterns.

The analysis identifies:

- Accessible population zones
- Connectivity barriers
- Service gaps

- Walkability limitations

### 4.7.2 Walkability Analysis

Walkability assessment is conducted using indicators related to pedestrian infrastructure quality and street environment conditions.

The analysis considers:

- Footpath continuity
- Sidewalk width
- Crossing facilities
- Encroachments
- Street lighting
- Universal accessibility

Walkability scores are prepared for comparative assessment of station areas.

### 4.7.3 Accessibility Mapping

GIS-based accessibility mapping is used to evaluate spatial connectivity between metro stations and surrounding urban activity areas.

The analysis includes:

- Travel time mapping
- Connectivity analysis
- Population accessibility assessment
- Transit integration mapping
- Service distribution analysis

Accessibility mapping helps identify underserved urban areas.

### 4.7.4 Service Area and Network Analysis

Network analysis techniques are used to evaluate feeder transport coverage and multimodal accessibility conditions.

The analysis examines:

- Service radius

- Route efficiency
- Travel impedance
- Transit accessibility zones
- Connectivity hierarchy

Service area analysis supports identification of critical mobility gaps.

## 4.8 Data Analysis Methods

### 4.8.1 Descriptive Statistical Analysis

Descriptive statistical techniques are used for analyzing survey data and commuter responses.

The analysis includes:

- Frequency distribution
- Mean and median values
- Percentage analysis
- Standard deviation
- Comparative tabulation

These techniques support interpretation of mobility behavior and accessibility conditions.

### 4.8.2 Comparative Assessment

Comparative analysis is conducted across selected metro station areas to evaluate variations in accessibility quality, parking efficiency, feeder transport availability, and walkability conditions.

The comparative framework helps identify:

- High-performing station areas
- Deficient accessibility zones
- Infrastructure gaps
- Planning priorities

### 4.8.3 Composite Index Development

A composite index is developed to assess overall last mile connectivity performance around metro stations. Multiple indicators related to accessibility, parking, feeder services, and walkability are integrated using weighted scoring methods.

The composite index formulation is expressed as:

$$CI = \sum_{i=1}^{n} w_i \, x_i$$

Where:

- $CI$= Composite Index
- $w_i$= Weight assigned to indicator
- $x_i$= Normalized indicator score

The composite index enables objective comparison between station areas.

### 4.8.4 Ranking and Prioritization Techniques

Ranking techniques are used to prioritize station areas requiring immediate intervention. Weighted indicators and normalized scores are used to prepare prioritization matrices.

The ranking framework supports planning recommendations related to:

- Pedestrian infrastructure improvement
- Parking management strategies
- Feeder transport enhancement
- Accessibility improvement measures
- Transit-oriented development interventions

## m4.9 Limitations of Methodology

Despite efforts to ensure methodological rigor, certain limitations exist within the study.

- The study is limited to selected metro station influence areas within Bhopal.
- Travel behavior and commuter perceptions may vary across different time periods.
- Availability of institutional transport data may be limited.
- Informal transport systems are dynamic and difficult to comprehensively document.
- Seasonal variations may influence traffic and pedestrian movement patterns.

However, integration of field surveys, GIS analysis, and stakeholder consultations enhances the reliability and validity of the research outcomes.

## 4.10 Chapter Summary

This chapter presented the research methodology and analytical framework adopted for assessing last mile connectivity around metro stations in Bhopal. The methodology integrates exploratory and analytical research approaches using mixed-method techniques involving field surveys, GIS analysis, statistical assessment, and stakeholder consultations.

The chapter explained the indicator framework, sampling methods, survey techniques, spatial analysis procedures, and data analysis tools adopted for evaluating accessibility, parking systems, and feeder transport integration. The methodological framework provides a structured basis for identifying mobility gaps and formulating sustainable planning interventions for improving multimodal accessibility and urban mobility systems around metro stations in Bhopal.

# Chapter 5: Assessment of Parking Strategies and Feeder Services

## 5.1 Introduction

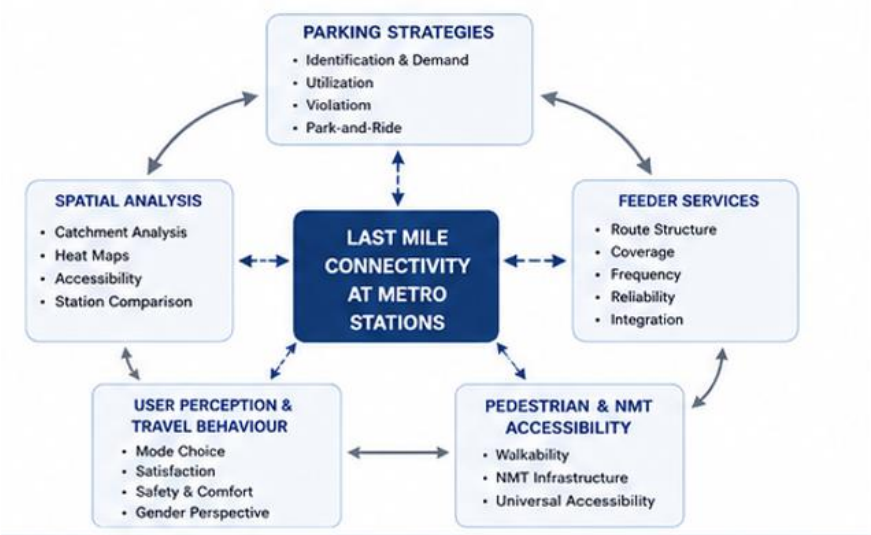



*Figure 21 Assessment components*

The operational efficiency and long-term sustainability of urban metro systems are significantly influenced by the quality of last mile connectivity available within station influence areas. Although metro rail systems provide high-capacity and time-efficient public transportation, their effectiveness is often constrained when commuters experience difficulty in accessing stations from surrounding residential, commercial, institutional, and employment areas. In rapidly urbanizing Indian cities, the challenge of seamless first and last mile integration has therefore emerged as one of the most critical dimensions of sustainable urban mobility planning.

In the context of entity ["city","Bhopal","Madhya Pradesh, India"], the proposed metro system is expected to play an important role in restructuring urban mobility patterns and reducing dependence on private vehicles. However, the success of the metro system will not depend solely upon rail infrastructure but also upon the quality of feeder services, parking management systems, pedestrian accessibility, and multimodal integration around station areas. Existing mobility conditions within Bhopal continue to reflect increasing motorization, fragmented public transport systems, inadequate pedestrian facilities, and unregulated parking practices. Such deficiencies adversely affect accessibility to public transportation and reduce the overall efficiency of urban movement patterns.

This chapter presents a comprehensive assessment of parking strategies and feeder services around selected metro stations in Bhopal. The analysis evaluates parking demand characteristics, feeder service performance, pedestrian and non-motorized transport accessibility, user perception, and spatial accessibility conditions. The chapter further develops a Last Mile Connectivity Index (LMCI) to comparatively evaluate station-level accessibility performance.

The assessment has been carried out through a combination of primary and secondary data collection methods including parking occupancy surveys, feeder route inventory surveys, pedestrian infrastructure audits, user perception surveys, GIS-based accessibility mapping, traffic observations, and field reconnaissance studies. The selected station areas represent diverse urban typologies such as commercial corridors, mixed land-use zones, institutional sectors, and emerging residential areas, thereby enabling comparative understanding of accessibility challenges across different urban contexts.

The chapter therefore attempts to establish an integrated understanding of how parking systems, feeder mobility services, pedestrian accessibility, and commuter behaviour collectively influence the effectiveness of metro accessibility within Bhopal. The findings generated through this analysis form the basis for the planning strategies and recommendations proposed in the subsequent chapter.

## 5.2 Assessment of Existing Parking Conditions




*Figure 22 Parking Strategy assessment flow*

### 5.2.1 Parking Supply and Demand Analysis

Parking availability around metro stations plays a crucial role in encouraging commuters to shift from private vehicles towards public transportation systems. Inadequate parking infrastructure or poorly managed parking environments often result in traffic congestion, spillover parking, and reduced accessibility around station areas. The assessment of parking supply and demand around selected metro stations in Bhopal revealed substantial imbalances between formal parking capacity and actual parking demand.

The parking assessment was undertaken through detailed occupancy and accumulation surveys conducted during peak and off-peak periods. The survey methodology included inventory mapping of available parking spaces, classified vehicle counts, parking duration analysis, turnover observations, and peak-hour occupancy assessment. The findings indicated that parking demand around metro station areas is strongly influenced by surrounding land-use intensity, road hierarchy, and concentration of commercial and institutional activities.

Commercial and mixed-use corridors such as MP Nagar and New Market demonstrated significantly higher parking pressure compared to residential sectors. Two-wheelers constituted the dominant

category of parked vehicles, reflecting the widespread dependence on motorcycles and scooters for daily commuting within the city. Car parking demand was concentrated near commercial centres and institutional corridors where longer-duration parking activity was observed.

The assessment further revealed that most existing parking systems surrounding proposed metro stations currently operate in an unorganized and informal manner. Roadside parking occupies substantial portions of carriageways and pedestrian pathways, thereby reducing effective road width and obstructing pedestrian movement. In several station areas, parking demand exceeded formal parking supply during peak periods, particularly during office hours and evening commercial activity.

Peak-hour parking occupancy was found to be highest between 9:00 AM and 11:00 AM and again during the evening period between 5:00 PM and 8:00 PM. Commercially active corridors recorded occupancy levels exceeding eighty percent during these periods, indicating critical parking pressure and inadequate organized parking infrastructure.

The study also demonstrated that commuters preferred parking locations closer to station entry points even when such spaces were informal or unauthorized. This behaviour reflects the importance of walking convenience, safety, and reduced transfer effort in determining parking preferences. The findings therefore indicate the urgent requirement for integrated parking management strategies linked with station area planning and multimodal accessibility improvement.

### 5.2.2 On-Street and Off-Street Parking Assessment

The assessment of on-street and off-street parking systems revealed considerable variation in management efficiency, accessibility, and user preference across different station influence areas. On-street parking currently dominates most metro station surroundings due to the limited availability of organized off-street parking infrastructure.

Field observations revealed that on-street parking is largely characterized by random vehicle arrangement, lack of demarcated parking bays, encroachment onto pedestrian spaces, and weak enforcement mechanisms. In many commercial corridors, vehicles were parked along both sides of the carriageway without formal regulation, thereby reducing roadway efficiency and increasing traffic conflicts near intersections and access points.

The absence of structured pricing mechanisms and parking control measures further contributed to inefficient parking turnover and unauthorized occupation of public space. Informal parking management practices were also observed in several locations where roadside parking operations were controlled without institutional oversight.

Off-street parking facilities were comparatively limited in number and capacity. Existing parking lots near commercial areas lacked proper pedestrian integration with metro station access points, reducing their usability for commuters. In many cases, users continued to prefer roadside parking despite the availability of off-street facilities because of shorter walking distances and the absence of parking charges.

The assessment also highlighted the absence of integrated Park-and-Ride systems within most station areas. International and national metro systems demonstrate that structured parking integrated with public transport stations can substantially improve transit ridership and reduce dependence on private vehicles. However, current parking management conditions in Bhopal remain fragmented and automobile-oriented.

### 5.2.3 Peak Hour Utilization Characteristics

The analysis of peak-hour parking utilization was undertaken to understand temporal variations in parking demand and turnover characteristics. The findings revealed that parking demand patterns varied significantly according to surrounding land-use activities.

Commercial corridors experienced prolonged parking duration due to office and retail activities, whereas institutional areas demonstrated comparatively shorter parking cycles associated with student and employee movement. Mixed-use corridors exhibited continuous parking activity throughout the day due to overlapping commercial and residential travel patterns.

The study further indicated that morning parking peaks were primarily associated with office and institutional trips, while evening peaks reflected shopping, recreational, and commercial activity. Weekend parking demand was also observed to increase substantially near commercial centres and public activity zones.

High parking occupancy during peak periods generated additional circulation traffic as drivers searched for vacant parking spaces. This phenomenon contributed to localized congestion, increased travel delay, and reduced accessibility around station approaches. Parking demand was also found to be highly concentrated within a short walking radius from station entry points, demonstrating the strong relationship between parking behaviour and pedestrian convenience.

The findings therefore emphasize the need for dynamic parking management systems incorporating demand-responsive pricing, structured parking supply, and intelligent parking guidance mechanisms.

### 5.2.4 Parking Violations and Spillover Effects

Parking violations emerged as a major urban mobility concern within station influence areas. Illegal parking, double parking, occupation of intersections, and parking on pedestrian pathways were frequently observed during field surveys.

The spillover effects of such parking practices were found to be severe in commercial and mixed-use corridors. Encroachment onto sidewalks reduced pedestrian safety and forced pedestrians to walk along carriageways, thereby increasing conflict between vehicular and pedestrian movement. Spillover parking also obstructed bus movement, reduced roadway efficiency, and contributed to visual and environmental degradation within station areas.

Weak enforcement mechanisms further aggravated parking violations. The absence of proper parking signage, lane markings, surveillance systems, and institutional monitoring resulted in recurring non-compliance. In several commercial corridors, insufficient formal parking capacity pushed vehicles into adjacent residential streets, leading to increased traffic intrusion, safety concerns, and environmental disturbance.

The findings suggest that parking management around metro stations must be integrated with broader urban mobility and public realm improvement strategies in order to improve overall accessibility and pedestrian comfort.

### 5.2.5 Evaluation of Park-and-Ride Facilities

Park-and-Ride systems serve as an important mechanism for integrating private vehicle trips with mass transit systems. However, the assessment revealed that dedicated Park-and-Ride infrastructure around proposed metro stations in Bhopal remains extremely limited.

Existing parking areas lack multimodal integration, secure parking environments, bicycle parking infrastructure, passenger information systems, and organized pedestrian connectivity. The absence of structured Park-and-Ride facilities may therefore reduce metro ridership potential among commuters residing in peripheral and low-density areas where direct feeder service accessibility remains inadequate.

The assessment identified several station locations with potential for future Park-and-Ride development based on land availability, regional road connectivity, and projected travel demand concentration. Properly designed Park-and-Ride systems can significantly reduce congestion within central urban areas by intercepting private vehicle trips before entry into dense commercial zones.

However, the study also recognizes that poorly planned Park-and-Ride systems may increase automobile dependence if not integrated with sustainable mobility objectives. Therefore, future Park-

and-Ride development in Bhopal should prioritize multimodal integration, pedestrian continuity, electric vehicle infrastructure, bicycle accessibility, and transit-oriented development principles.

### 5.3 Assessment of Feeder Services




*Figure 23 Feerder service assessment framework*

Feeder transport systems constitute one of the most critical components of effective last mile connectivity because they connect metro stations with surrounding residential, commercial, institutional, and employment areas. The assessment of feeder services around selected metro stations in Bhopal was undertaken through route inventory surveys, operational observations, commuter interaction surveys, and GIS-based accessibility mapping.

The existing feeder mobility structure within Bhopal primarily consists of city bus services, mini buses, auto-rickshaws, e-rickshaws, shared tempos, and app-based mobility services. However, the analysis revealed that these systems currently operate in a fragmented and corridor-oriented manner with limited operational coordination and weak multimodal integration.

Most feeder routes are concentrated along major arterial roads and commercial corridors, whereas peripheral residential sectors continue to experience inadequate public transport accessibility. The route structure largely follows a radial mobility pattern centred around major commercial and institutional activity nodes. Such a structure provides accessibility along high-demand corridors but limits coverage within low-density peripheral areas.

Intermediate Public Transport (IPT) systems such as auto-rickshaws and e-rickshaws currently function as the most dominant last mile mobility modes due to their operational flexibility and high service penetration. However, these systems remain largely informal and weakly regulated. The absence of designated stopping areas, fare regulation, and route coordination reduces their efficiency and contributes to traffic congestion around station areas.

The assessment further indicated that feeder accessibility varies significantly according to station typology. Commercial and institutional stations demonstrated relatively better feeder availability due

to concentrated travel demand, whereas residential station areas exhibited lower route density and weaker service frequency. The findings therefore indicate the need for integrated feeder restructuring based upon route rationalization, service hierarchy, and multimodal coordination.

### 5.3.2 Catchment Coverage and Accessibility

Catchment analysis was undertaken to evaluate the spatial coverage and accessibility performance of feeder services around selected metro stations. The assessment considered walkable access distance, feeder route penetration, population coverage, and service availability within station influence zones.

A walkable catchment radius of approximately 500 metres and a feeder service catchment extending between three and five kilometres were adopted for the analysis. GIS-based mapping demonstrated substantial variation in accessibility levels across different station areas.

Commercial and centrally located urban corridors exhibited comparatively higher feeder accessibility due to greater route density and stronger public transport concentration. In contrast, peripheral residential areas demonstrated weak feeder coverage and limited service penetration. Several low-income residential sectors and urban fringe developments were located outside effective feeder service catchments, thereby reducing accessibility to future metro infrastructure.

The analysis further revealed that feeder accessibility is strongly influenced by street network continuity, road hierarchy, pedestrian infrastructure quality, and traffic congestion conditions. In many locations, inadequate pedestrian connectivity between feeder stops and station entry points reduced the effectiveness of otherwise accessible feeder routes.

The findings suggest that integrated station area planning is necessary to improve accessibility continuity between feeder systems, pedestrian networks, and metro station infrastructure.

### 5.3.3 Frequency and Reliability Assessment

Service frequency and operational reliability represent major determinants of public transport attractiveness and commuter satisfaction. The feeder service assessment revealed substantial inconsistencies in headways, waiting times, and schedule adherence across different feeder modes operating within the city.

Public bus services demonstrated relatively lower operational flexibility and longer waiting times compared to IPT systems. However, buses provided higher passenger carrying capacity and comparatively lower travel costs. Operational limitations associated with bus systems included irregular headways, peak-hour overcrowding, traffic-related delays, and limited off-peak frequency.

Auto-rickshaws and e-rickshaws offered greater operational flexibility and shorter waiting times, but their services were characterized by fare inconsistency, route deviation, and weak regulation. Shared mobility services and app-based transport systems demonstrated growing importance among middle-income commuters; however, their accessibility remained concentrated within economically active urban areas.

The assessment revealed that commuters generally prioritized reliability, predictability, and reduced waiting time over travel speed while selecting feeder modes. Reliability challenges were found to be strongly associated with mixed traffic conditions and the absence of dedicated feeder corridors.

The findings therefore indicate that future metro integration strategies must emphasize operational synchronization between metro systems and feeder services through improved scheduling, route coordination, and real-time passenger information systems.

### 5.3.4 Operational and Integration Issues

The assessment identified several operational and institutional barriers affecting the integration of feeder services with future metro systems in Bhopal. One of the most significant challenges relates to the absence of unified transport planning and weak inter-agency coordination.

Physical integration between feeder stops and metro station entrances was observed to be inadequate in several locations. Long transfer distances, poor wayfinding systems, inadequate waiting areas, and lack of sheltered pedestrian pathways reduced commuter convenience and increased transfer difficulty.

Operational coordination between buses, IPT systems, and future metro schedules was also found to be weak. The absence of synchronized feeder operations may significantly increase transfer waiting times and reduce passenger confidence in multimodal travel systems.

The assessment further observed that informal feeder systems operate independently without institutional regulation or operational integration. Although such systems provide flexibility and route adaptability, they also contribute to congestion, inconsistent service quality, and inefficient curbside management.

The findings therefore emphasize the need for integrated urban mobility planning frameworks capable of improving multimodal coordination, operational efficiency, and passenger experience.

### 5.3.5 IPT and Shared Mobility Performance

Intermediate Public Transport systems currently perform a dominant role in last mile mobility within Bhopal. Auto-rickshaws, e-rickshaws, and shared tempos provide flexible and demand-responsive mobility services across both formal and informal urban sectors.

The assessment revealed that IPT systems offer several operational advantages including flexible routing, relatively low waiting times, accessibility to narrow streets, and high service penetration within dense urban areas. These characteristics make IPT systems particularly important in areas where formal public transport accessibility remains limited.

However, several operational concerns were also identified during the assessment. Fare irregularities, unsafe driving behaviour, overloading, traffic obstruction near station areas, and absence of designated pick-up and drop-off infrastructure were commonly observed.

E-rickshaws emerged as an environmentally sustainable alternative for short-distance feeder mobility. Their increasing adoption demonstrates substantial potential for low-emission feeder integration within future metro systems. App-based mobility services also showed growing importance among middle-income commuters due to convenience and reliability; however, affordability constraints continue to limit their widespread accessibility.

The findings therefore indicate that regulated IPT integration with metro systems can significantly improve last mile connectivity while simultaneously reducing dependence on private vehicles.

## 5.4 Pedestrian and NMT Accessibility Assessment




*Figure 24 Pedestrian and NMT Accessibility Assessment Framework*

### 5.4.1 Footpath and Crossing Infrastructure

Pedestrian accessibility constitutes one of the most important determinants of successful metro-oriented mobility systems. The assessment of pedestrian infrastructure around selected metro stations revealed inadequate and discontinuous walking environments that significantly affect accessibility efficiency.

Field observations identified several deficiencies including encroached footpaths, discontinuous sidewalks, poor pavement quality, lack of tactile paving, inadequate street lighting, and unsafe pedestrian crossings. Commercial corridors experienced severe pedestrian obstruction due to roadside vending, informal parking, and unauthorized occupation of pedestrian spaces.

In several locations, sidewalks were either absent or too narrow to accommodate pedestrian movement comfortably. Pedestrian crossings were limited and often poorly designed, resulting in unsafe interaction between vehicles and pedestrians. High traffic speeds and inadequate crossing intervals further reduced pedestrian safety near station areas.

Universal accessibility infrastructure such as ramps, tactile surfaces, auditory signals, and barrier-free pedestrian facilities remained largely absent across most surveyed locations. Such deficiencies substantially affect accessibility for elderly persons, children, and persons with disabilities.

The findings indicate that improvement of pedestrian infrastructure is essential for increasing effective metro accessibility and reducing dependence on motorized last mile movement.

### 5.4.2 Walkability Conditions

Walkability assessment was conducted using indicators related to pedestrian comfort, continuity, safety, accessibility, environmental quality, and urban design characteristics. The analysis revealed that most station influence areas currently exhibit poor-to-moderate walkability conditions.

Major commercial corridors demonstrated comparatively high pedestrian activity but suffered from severe infrastructure deficiencies. Encroached sidewalks, informal roadside parking, deteriorated pavement conditions, lack of shading, inadequate crossings, and high vehicular traffic speeds significantly reduced pedestrian comfort.

The assessment further demonstrated that effective pedestrian catchment areas were substantially smaller than theoretical walking radii because of poor environmental quality and safety concerns. Pedestrian movement was especially difficult near major intersections where vehicular prioritization dominated street design.

The commuter perception survey indicated that users were generally willing to walk distances between five hundred and seven hundred metres if pedestrian environments were safe, continuous, shaded, and visually active. However, deteriorated pedestrian conditions significantly reduced willingness to walk.

Women respondents particularly emphasized the importance of street lighting, surveillance, active street edges, and shaded pathways in determining perceived walkability. The findings therefore indicate

that improvement of walkability conditions can significantly enhance metro accessibility while simultaneously promoting sustainable and low-carbon urban mobility systems.

### 5.4.3 Cycling Infrastructure Assessment

Cycling infrastructure within station influence areas remains extremely limited. The assessment identified a near absence of dedicated cycle tracks, bicycle parking facilities, and integrated cycling networks.

The major barriers affecting cycling mobility included lack of dedicated infrastructure, traffic safety concerns, roadway encroachment, inadequate parking facilities, and absence of cycle-sharing systems. Despite these limitations, relatively short urban trip lengths and flat terrain conditions within several corridors indicate strong potential for bicycle integration.

International experiences demonstrate that integration between bicycle infrastructure and metro systems can substantially improve sustainable last mile accessibility. Therefore, the development of dedicated cycling infrastructure, bicycle parking, and cycle-sharing systems should form an integral component of future station area planning strategies within Bhopal.

### 5.4.4 Universal Accessibility Assessment

Universal accessibility ensures equitable mobility access for women, elderly persons, children, and persons with disabilities. The assessment revealed substantial deficiencies in inclusive infrastructure provision around most metro station areas.

Major deficiencies included absence of ramps, lack of tactile paving, uneven walking surfaces, inadequate seating facilities, inaccessible crossings, poor lighting, and weak surveillance conditions. Women respondents expressed concerns regarding personal safety during evening hours because of poorly lit streets and inactive public spaces.

Elderly users identified long walking distances and lack of resting facilities as major barriers affecting station accessibility. Persons with disabilities reported significant difficulty due to inadequate barrier-free infrastructure and poor pedestrian continuity.

The findings emphasize the importance of inclusive station area planning based upon universal accessibility principles and human-centred urban design approaches.

## 5.5 User Perception and Travel Behaviour Analysis




*Figure 25 User Perception and Travel Behaviour Analysis Framework*

### 5.5.1 Socio-Economic Profile of Respondents

User perception surveys were conducted to understand commuter mobility behaviour, accessibility concerns, and willingness to shift toward metro-oriented travel systems. The respondent profile represented a diverse socio-economic composition including students, office employees, business owners, daily wage workers, homemakers, and service sector employees.

The majority of respondents belonged to middle-income households and demonstrated high dependence on two-wheelers for daily commuting. Public transport usage remained moderate, whereas acceptance of e-rickshaw services showed increasing trends among younger commuters.

The survey further indicated rising concern regarding travel expenditure, congestion, and parking difficulties. Younger respondents demonstrated comparatively greater willingness to shift toward metro-based travel provided that feeder connectivity and pedestrian accessibility conditions improve.

### 5.5.2 Existing Mode Choice Behaviour

The travel behaviour assessment revealed that mode choice within Bhopal is strongly influenced by travel time reliability, accessibility convenience, travel cost, parking availability, safety, comfort, and transfer convenience.

Two-wheelers emerged as the dominant commuting mode because of their flexibility and ability to navigate congested urban corridors. Auto-rickshaws and IPT systems also demonstrated substantial importance for short-distance and last mile travel.

Public transport users highlighted long waiting times, weak feeder integration, and unreliable service frequency as major constraints affecting public transport usage. Women commuters demonstrated greater sensitivity toward safety, comfort, surveillance, and accessibility conditions compared to male respondents.

The findings further revealed that commuters are willing to shift toward metro systems if supported by reliable feeder services, safe pedestrian infrastructure, integrated ticketing systems, organized parking, and reduced transfer time.

The analysis therefore indicates that modal shift potential within Bhopal depends not only upon metro infrastructure but also upon the overall quality of multimodal integration and last mile accessibility.

### 5.5.3 Perception of Parking Facilities

Respondents expressed considerable dissatisfaction regarding existing parking conditions around major commercial and institutional areas. The primary concerns included lack of organized parking, parking congestion, unauthorized parking charges, insufficient parking availability, and safety-related issues.

Several respondents supported the introduction of structured Park-and-Ride systems integrated with metro stations. However, users also emphasized that such facilities should remain affordable and pedestrian-friendly in order to encourage widespread utilization.

The survey further revealed that commuters generally prefer parking environments offering convenience, safety, and minimum walking effort. This indicates the strong relationship between parking behaviour and pedestrian accessibility conditions.

### 5.5.4 Perception of Feeder Service Quality

The perception survey revealed mixed opinions regarding feeder service quality within the city. Positive perceptions included flexibility of IPT systems, availability of e-rickshaw services, and relatively affordable travel costs.

However, several negative concerns were also identified including poor reliability, traffic delays, fare inconsistency, lack of comfort, overcrowding, and weak service integration. Respondents expressed strong preference for integrated feeder systems offering predictable schedules, organized interchange facilities, and unified ticketing mechanisms.

The findings therefore demonstrate that improving feeder reliability and operational integration can significantly enhance commuter confidence in metro-based travel systems.

### 5.5.5 Safety, Comfort and Accessibility Concerns

Safety emerged as one of the most significant determinants of commuter satisfaction within station influence areas. The survey identified unsafe pedestrian crossings, traffic conflicts, poor lighting, weak surveillance, and inadequate waiting areas as major concerns.

Heat exposure and lack of shaded pedestrian pathways were also identified as critical comfort-related issues affecting willingness to walk. Accessibility concerns were particularly severe for elderly persons and persons with disabilities who experienced difficulty due to poor pedestrian infrastructure and lack of universal accessibility measures.

The findings indicate that improvement of safety, comfort, and environmental quality is essential for enhancing effective metro accessibility and commuter satisfaction.

### 5.5.6 Gender and Vulnerable User Perspectives

The assessment highlighted several gender-based and socially differentiated mobility concerns within station influence areas. Women commuters emphasized the importance of safe walking environments, improved street lighting, reliable public transport services, and better surveillance systems.

Persons with disabilities reported substantial accessibility barriers due to poor infrastructure design, lack of ramps, discontinuous sidewalks, and inaccessible crossings. Elderly users identified long walking distances and absence of resting spaces as major mobility constraints.

The findings therefore reinforce the importance of inclusive planning approaches that prioritize safety, accessibility, comfort, and equitable mobility opportunities for vulnerable user groups.

## 5.6 Spatial Analysis of Last Mile Connectivity




*Figure 26 Spatial Analysis Framework for Last Mile Connectivity*

### 5.6.1 Walk Catchment Analysis

Walk catchment analysis was undertaken using GIS-based spatial mapping techniques to evaluate pedestrian accessibility around selected metro stations. The analysis considered street network continuity, pedestrian infrastructure quality, intersection density, and physical barriers affecting pedestrian movement.

The assessment revealed that effective pedestrian catchment areas were substantially smaller than theoretical walking radii because of poor infrastructure conditions and environmental barriers. Several areas located within nominal walking distance remained effectively inaccessible due to missing sidewalks, wide road crossings, encroachments, and fragmented street networks.

The findings indicate that improvement of pedestrian continuity and public realm quality can significantly increase effective station accessibility.

### 5.6.2 Feeder Service Catchment Analysis

Feeder service catchment mapping demonstrated uneven accessibility distribution across the study area. Central corridors exhibited overlapping feeder coverage due to higher route density, whereas peripheral residential sectors remained underserved.

The analysis identified substantial gaps in multimodal accessibility within newly developing urban areas and low-density peripheral sectors. Such gaps may significantly reduce metro accessibility among economically vulnerable populations.

The findings emphasize the importance of feeder restructuring and integrated accessibility planning within future metro influence areas.

### 5.6.3 Accessibility Heat Maps

Accessibility heat maps were prepared to visualize variations in last mile accessibility across station influence areas. High accessibility zones were concentrated near commercial corridors, major intersections, and existing public transport routes.

Low accessibility zones were primarily located within peripheral residential sectors, urban fringe developments, and low-density corridors characterized by weak feeder connectivity and poor pedestrian infrastructure.

The spatial analysis demonstrated a strong relationship between land-use intensity and accessibility performance. Areas with mixed land use and higher activity concentration generally demonstrated comparatively better accessibility conditions.

### 5.6.4 Station-Wise Comparative Analysis

Comparative station analysis highlighted substantial variation in connectivity performance among different station typologies. Stations located within mixed-use and commercially active corridors

demonstrated comparatively stronger accessibility performance due to higher route density, better pedestrian activity, and greater IPT availability.

Peripheral station areas exhibited weaker accessibility because of fragmented pedestrian infrastructure, limited feeder coverage, and lower public transport concentration.

The findings indicate that station area planning strategies must be context-sensitive and responsive to surrounding land-use characteristics and mobility demand patterns.

### 5.7 Development of Last Mile Connectivity Index

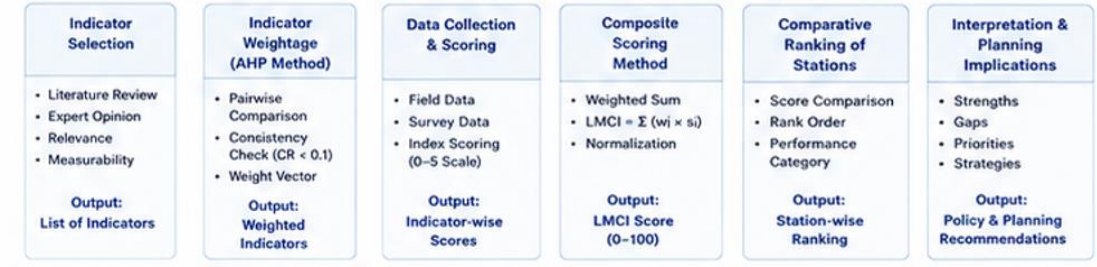



*Figure 27 Development of Last Mile Connectivity Index*

## 5.7.1 Indicator Weightage

In order to comparatively evaluate station-level accessibility performance, a composite Last Mile Connectivity Index was developed integrating physical infrastructure, operational performance, accessibility conditions, and commuter perception indicators.

The development of the index was based upon literature review, expert consultation, user perception surveys, field observations, and GIS-based accessibility analysis. The framework incorporated indicators related to walkability, feeder service quality, parking management, safety, non-motorized transport infrastructure, universal accessibility, and operational integration.

Weightages were assigned using an Analytical Hierarchy Process based prioritization approach supported by expert opinion and commuter perception analysis. Higher weightage was assigned to pedestrian accessibility and feeder service integration because of their critical influence on metro accessibility.

### 5.7.2 Composite Scoring Method

The Last Mile Connectivity Index was computed using a weighted composite scoring methodology integrating both qualitative and quantitative variables. The methodology included indicator selection, data normalization, weight allocation, composite score generation, and comparative station ranking.

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The weighted scoring approach enabled integration of infrastructure quality, operational efficiency, commuter perception, and spatial accessibility into a unified planning framework. The methodology also supports future scalability and comparative evaluation across additional metro corridors.

### 5.7.3 Comparative Ranking of Stations

The LMCI results demonstrated substantial variation in accessibility performance among selected metro stations. Commercial and centrally located stations generally achieved comparatively higher scores because of stronger feeder availability, higher pedestrian activity, and better accessibility concentration.

Peripheral stations demonstrated lower performance due to inadequate multimodal integration, fragmented pedestrian infrastructure, and weaker feeder service penetration.

The index therefore provides an important analytical tool for identifying accessibility disparities, prioritizing infrastructure investments, and supporting evidence-based mobility planning.

## 5.8 Identification of Critical Gaps and Deficiencies

The integrated assessment of parking systems, feeder services, pedestrian infrastructure, and commuter perception revealed several structural and operational deficiencies affecting last mile connectivity around proposed metro stations in Bhopal.

The assessment highlighted inadequate pedestrian infrastructure, fragmented feeder systems, weak parking management, lack of cycling infrastructure, poor multimodal integration, and limited universal accessibility provision.

Institutional fragmentation also emerged as a major barrier affecting coordinated mobility planning. Different components of the urban transport system are currently managed by multiple agencies with limited operational coordination and inconsistent infrastructure standards.

The analysis further demonstrated substantial accessibility disparities across station influence areas. Peripheral residential sectors remain inadequately connected to high-capacity transit corridors because of poor feeder penetration, fragmented street networks, and automobile-oriented urban development patterns.

Women, elderly persons, and persons with disabilities experience disproportionately higher accessibility barriers because of unsafe pedestrian environments, poor lighting, lack of barrier-free infrastructure, and inadequate public realm quality.

The findings therefore indicate that successful metro implementation within Bhopal cannot rely solely upon rail infrastructure investment. Instead, integrated and multimodal accessibility planning is essential for improving station accessibility, reducing private vehicle dependence, and promoting sustainable urban mobility systems.

## 5.9 Summary




*Figure 28 assessment to action- planning implications*

This chapter presented a comprehensive assessment of parking strategies, feeder services, pedestrian accessibility, and multimodal integration around selected metro stations in Bhopal. The analysis highlighted substantial challenges associated with parking management, feeder route integration, pedestrian infrastructure quality, and non-motorized transport accessibility.

The parking assessment revealed increasing dependence on informal roadside parking, inadequate organized parking supply, and severe spillover effects within station influence areas. The feeder service assessment demonstrated fragmented route structures, weak operational integration, and inadequate multimodal coordination.

The pedestrian and NMT assessment identified major deficiencies in footpath continuity, crossing infrastructure, cycling facilities, and universal accessibility provisions. User perception analysis further highlighted concerns related to safety, comfort, parking availability, feeder reliability, and accessibility conditions.

Spatial accessibility analysis demonstrated uneven distribution of connectivity performance across different station typologies. The Last Mile Connectivity Index developed within this study enabled comparative evaluation of station-level accessibility conditions and identification of priority intervention areas.

Overall, the findings demonstrate that successful metro implementation in Bhopal requires integrated, inclusive, and user-centric last mile connectivity planning emphasizing multimodal integration, pedestrian-oriented design, sustainable mobility systems, and equitable accessibility frameworks.

# CHAPTER 6 PLANNING PROPOSALS AND STRATEGIC FRAMEWORK

## 6.1 Introduction

The operational success of an urban metro system is not determined solely by the efficiency of the rail corridor, but by the quality of accessibility that connects commuters to the system. In rapidly growing Indian cities, metro infrastructure frequently underperforms because station accessibility remains fragmented, unsafe, poorly integrated, and heavily dependent upon informal mobility systems. Consequently, first and last mile connectivity has emerged as one of the most critical determinants influencing metro ridership, commuter convenience, and long-term sustainability of public transport systems.

In the context of Bhopal, the introduction of the metro corridor represents a significant opportunity to restructure urban mobility patterns toward a more integrated, sustainable, and transit-oriented urban structure. The proposed metro network has the potential to reduce travel time, strengthen accessibility, improve regional connectivity, and encourage a gradual shift away from automobile-oriented mobility patterns. However, field investigations undertaken during the study revealed that the areas surrounding proposed metro stations presently suffer from fragmented pedestrian infrastructure, weak feeder integration, inadequate non-motorized transport systems, unregulated parking conditions, unsafe crossings, and poor multimodal coordination.

The analysis undertaken in the preceding chapters established that although a substantial proportion of commuters demonstrate willingness to shift toward metro-based mobility, the absence of efficient last mile accessibility may significantly reduce the effective catchment area of stations. Under such conditions, the metro system risks functioning merely as an isolated transit corridor rather than as an integrated urban mobility network.

The chapter therefore proposes a comprehensive planning and strategic framework for improving last mile connectivity around metro station areas in Bhopal. Unlike conventional transport proposals that focus primarily upon traffic engineering interventions, the proposed framework adopts an integrated planning perspective combining transportation planning, station area design, land use restructuring, public realm enhancement, multimodal integration, parking management, environmental sustainability, and governance coordination.

The proposals are derived from primary household surveys, commuter perception analysis, field-based infrastructure assessment, accessibility mapping, station typology analysis, mobility corridor evaluation, and Transit-Oriented Development (TOD) principles. The chapter additionally draws upon

national and international best practices related to multimodal accessibility, pedestrian-oriented planning, public transport integration, and sustainable urban mobility frameworks.

The proposed framework conceptualizes metro stations not merely as transportation nodes but as multifunctional urban interfaces capable of supporting mobility integration, economic activity, public interaction, and sustainable urban restructuring. The planning approach therefore seeks to transform station influence zones into accessible, inclusive, walkable, and transit-supportive urban environments capable of strengthening both metro ridership and overall urban livability.

### 6.2 Vision and Planning Objectives

*Table 1 Planning Vision and Strategic Objectives Framework*

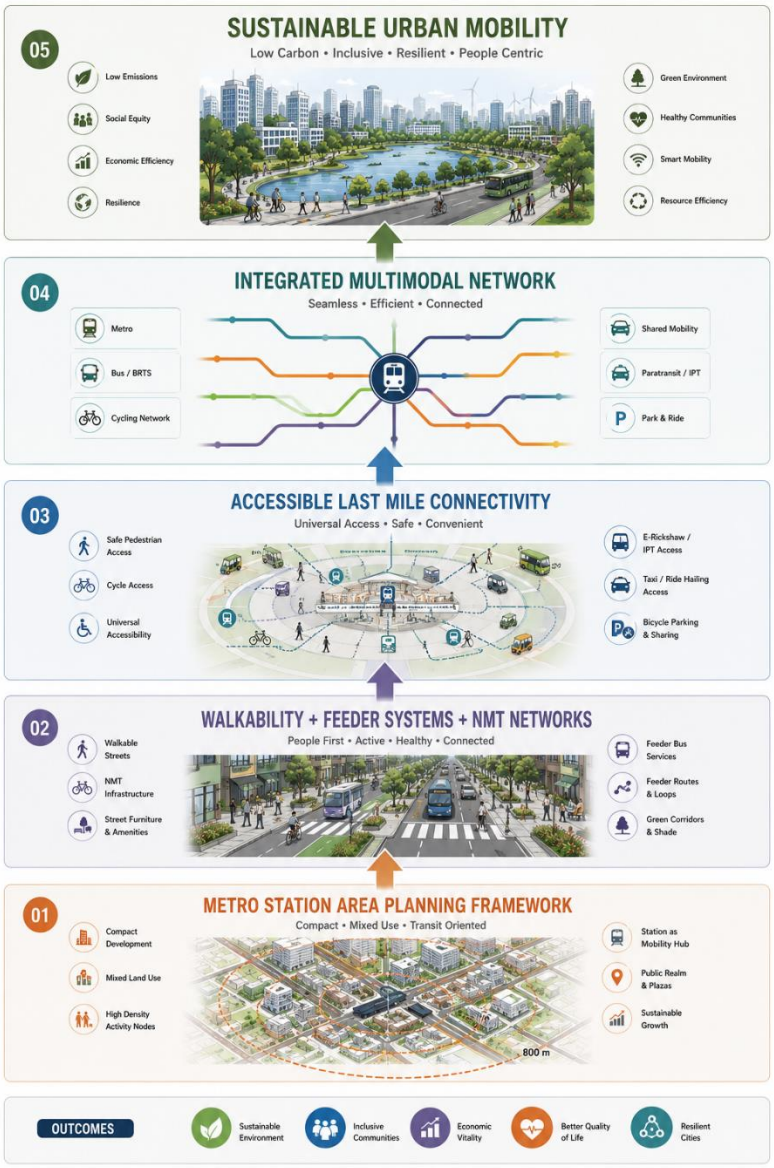
| Planning Dimension | Strategic Objective | Expected Mobility Outcome |
|---|---|---|
| Accessibility | Improve pedestrian and feeder connectivity | Enhanced metro catchment area |
| Sustainability | Promote NMT and public transport integration | Reduced private vehicle dependency |
| Inclusiveness | Ensure universal accessibility | Improved equitable mobility |
| Efficiency | Integrate multimodal systems | Reduced transfer delays |
| Urban Development | Promote TOD and mixed-use growth | Compact urban development |

### 6.2.1 Planning Vision

The planning vision formulated for the study is:

"To develop an integrated, accessible, sustainable, and transit-oriented last mile connectivity framework for Bhopal Metro that enhances multimodal accessibility, promotes public transport usage, minimizes private vehicle dependency, and supports inclusive urban development."

The proposed vision aligns with the principles of the National Urban Transport Policy (NUTP), Smart City Mission objectives, Sustainable Development Goal 11, and Transit-Oriented Development frameworks emphasizing integrated urban mobility planning. The vision further recognizes that efficient metro accessibility is not solely a transportation issue but a broader urban planning challenge involving land use organization, public realm quality, environmental sustainability, social inclusiveness, and institutional coordination.




The planning framework therefore seeks to establish metro station areas as people-oriented urban mobility districts characterized by safe pedestrian infrastructure, multimodal integration, active public spaces, organized feeder systems, and sustainable mobility networks.

*Figure 29 HIERARICHAL PLANNING FRAMEWORK*

### 6.2.2 Planning Objectives

The primary objective of the proposed framework is to establish an integrated mobility structure capable of improving accessibility and strengthening metro dependency within Bhopal. The framework prioritizes pedestrian accessibility as the fundamental layer of metro integration and seeks to create continuous, universally accessible, and safe walking environments within station influence zones.

A second objective involves strengthening non-motorized mobility through integrated cycling systems, public bicycle sharing networks, and active mobility corridors connecting metro stations with surrounding residential, institutional, and commercial areas. Since a substantial proportion of urban trips within Bhopal fall within short-distance travel ranges, improving walking and cycling infrastructure possesses significant potential for strengthening sustainable mobility.

The framework additionally aims to improve feeder connectivity through coordinated integration of buses, intermediate public transport systems, shared mobility platforms, and electric shuttle services. Particular emphasis is placed upon reducing transfer inconvenience and improving multimodal accessibility within station influence zones.

Another major objective concerns rationalization of parking systems through parking pricing mechanisms, structured parking management, and travel demand strategies capable of discouraging excessive private vehicle dependency within high-accessibility urban districts.

The framework also seeks to encourage Transit-Oriented Development and mixed-use urban restructuring around metro stations in order to promote compact, walkable, and transit-supportive urban growth. Simultaneously, the proposals aim to improve public realm quality, environmental sustainability, urban safety, and social inclusiveness through integrated streetscape enhancement and station area redevelopment.

Finally, the framework emphasizes the importance of coordinated governance mechanisms capable of integrating transportation planning, station area development, land use regulation, and multimodal mobility management within a unified planning structure.

### 6.3 Strategic Planning Framework for Last Mile Connectivity

The proposed strategic framework is conceived as a multidimensional urban mobility structure integrating transportation planning, land use restructuring, public realm enhancement, environmental sustainability, mobility management, and institutional governance within metro influence zones of Bhopal. Unlike conventional transport planning approaches that focus primarily on vehicular circulation, the framework recognizes metro station areas as integrated urban environments where mobility systems interact with economic activity, social interaction, public spaces, and everyday urban life.

The framework adopts a ‘People First Mobility’ approach wherein priority is assigned according to a hierarchy of sustainable movement systems. Pedestrians and non-motorized users constitute the highest

priority group, followed by public transport systems, shared mobility networks, and finally private motorized vehicles. Such prioritization is essential for reducing automobile dependency and promoting sustainable urban mobility within rapidly urbanizing Indian cities.

The strategic planning framework is structured around six interrelated planning dimensions:

1. Pedestrian and Universal Accessibility Systems;
2. Non-Motorized and Active Mobility Networks;
3. Integrated Feeder and Multimodal Transit Systems;
4. Parking and Travel Demand Management;
5. Station Area Development and TOD Integration;
6. Institutional, Financial, and Governance Mechanisms.

The framework additionally recognizes that metro stations function within significantly different spatial and mobility contexts. Consequently, planning interventions cannot remain uniform across all station areas. The study therefore adopts a station typology-based planning approach wherein interventions are determined according to land use intensity, commuter demand characteristics, accessibility conditions, and corridor-level mobility patterns.

*Table 2 Station Typology and Planning Characteristics*

| Station Typology | Dominant Land Use | Major Mobility Concern | Proposed Planning Focus |
|---|---|---|---|
| Commercial Stations | Retail and offices | Congestion and parking pressure | Pedestrianization and multimodal integration |
| Institutional Stations | Educational and healthcare zones | Peak-hour commuter movement | Feeder integration and cycling systems |
| Residential Stations | Housing sectors | Last mile accessibility | Neighborhood feeder systems |
| Interchange Stations | Mixed regional mobility | Transfer efficiency | Integrated mobility hubs |
| Peripheral Stations | Urban edge development | Regional access dependency | Park-and-ride systems |

### 6.3.1 Station Typology-Based Planning Approach

One of the major shortcomings observed within conventional metro planning approaches in Indian cities is the tendency to implement uniform mobility interventions across stations possessing significantly different urban conditions and commuter characteristics. In reality, each metro station functions within a unique spatial context influenced by surrounding land use, commuter intensity, economic activity, road hierarchy, and public space conditions. Consequently, a context-sensitive planning approach becomes essential for improving operational efficiency and strengthening long-term metro integration.




*Figure 30 Integrated mobility for sustainable Cities*

Commercial stations located within high-intensity activity districts such as MP Nagar and New Market are expected to generate substantial pedestrian movement and continuous public activity throughout the day. Such stations should therefore prioritize pedestrian accessibility, public realm enhancement, parking restraint, shared mobility integration, and multimodal circulation management rather than expansion of automobile-oriented infrastructure. These station areas possess strong potential to evolve into pedestrian-oriented transit districts characterized by active street edges, organized vending systems, improved streetscape quality, and reduced vehicular dominance.

Institutional stations located near educational campuses, hospitals, and administrative zones require a different planning response focused on organized feeder systems, cycling infrastructure, universal accessibility measures, and structured IPT integration. Since such corridors generate recurring commuter flows associated with students, employees, patients, and visitors, reliable and inclusive mobility systems become essential.

Residential catchment stations should focus upon strengthening neighborhood-level accessibility through feeder mobility systems, safe pedestrian infrastructure, public bicycle networks, and intermediate parking management. Similarly, interchange stations should function as integrated multimodal mobility hubs incorporating feeder buses, IPT systems, structured parking, public plazas, and high-capacity passenger circulation infrastructure.

Peripheral stations located near the urban edge should incorporate park-and-ride systems and regional feeder integration while simultaneously discouraging automobile-dependent urban sprawl. The station

typology-based framework therefore allows planning interventions to respond directly to actual urban conditions and mobility demand patterns.

### 6.3.2 Integrated Mobility Planning Structure

The proposed mobility structure is organized around a layered accessibility framework comprising primary pedestrian zones, secondary multimodal accessibility areas, and extended transit catchments. The immediate station influence zone extending approximately 250 m from station entrances should function as a pedestrian-priority environment characterized by wide obstruction-free footpaths, universal accessibility infrastructure, public plazas, organized vending, and traffic calming measures.

The secondary accessibility zone extending between 250–500 m should support cycling systems, organized IPT integration, shared mobility infrastructure, and feeder service access. The extended catchment area between 500–800 m should subsequently integrate feeder buses, park-and-ride systems, regional mobility interfaces, and TOD-oriented mixed-use development.

Such a layered accessibility framework strengthens multimodal integration while simultaneously increasing the functional catchment area of metro stations.

### 6.3.3 Transit-Oriented Mobility Corridors

The study additionally proposes the development of integrated transit-oriented mobility corridors connecting major metro stations with surrounding urban activity generators including MP Nagar, institutional clusters, BRTS corridors, lakefront areas, and residential sectors. These corridors should function not merely as transportation routes but as integrated public movement environments characterized by pedestrian infrastructure, cycling systems, landscape integration, universal accessibility, and multimodal connectivity.

The corridor-based planning approach improves continuity of movement while simultaneously strengthening integration between metro systems and surrounding urban fabric.

## 6.4 Station Area Planning Proposals

Metro station areas function as critical interfaces between the transit system and the surrounding city. Consequently, station area planning must extend beyond transportation engineering and incorporate accessibility, urban design, public safety, environmental quality, and public realm enhancement.

The proposed framework divides station influence areas into three spatial categories comprising the primary influence zone (0–250 m), secondary influence zone (250–500 m), and extended catchment zone (500–800 m). Planning interventions are subsequently structured according to the mobility and spatial requirements of each zone.

### 6.4.1 Pedestrian Priority Improvements

Field investigations revealed that pedestrian infrastructure surrounding several proposed metro station areas within Bhopal remains fragmented, discontinuous, and highly vulnerable to encroachment by informal activities and parked vehicles. Since walking constitutes the primary access mode for a

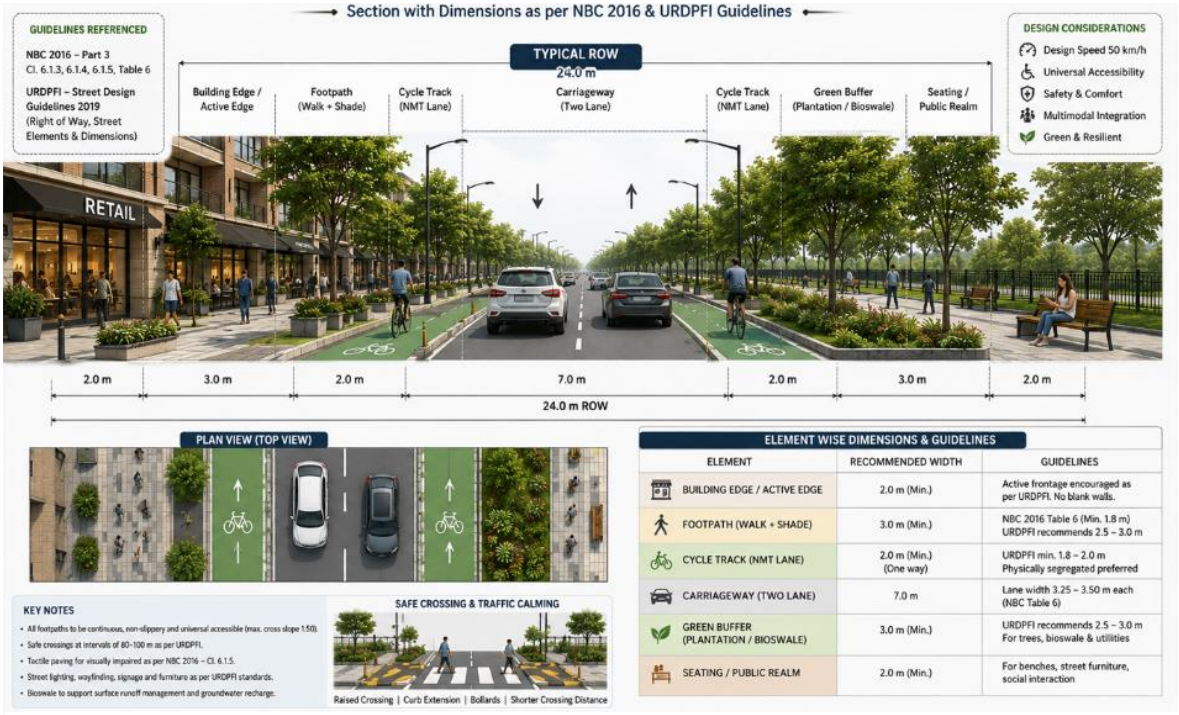



*Figure 31 complete street framework*

substantial proportion of metro commuters, pedestrian infrastructure must form the foundation of all last mile connectivity interventions.

The study therefore proposes the development of continuous, obstruction-free, and universally accessible pedestrian systems within station influence zones. Footpaths should maintain adequate effective width to accommodate peak commuter movement and incorporate tactile guidance systems,




*Figure 32 complete street framework - 45 m road*

should additionally be organized in a manner that minimizes obstruction of pedestrian movement.

Major intersections and mobility corridors should incorporate signalized pedestrian crossings, refuge islands, zebra markings, raised table crossings, and pedestrian countdown systems in order to reduce conflicts between vehicular and pedestrian movement. At high-traffic locations, grade-separated crossings may additionally be introduced wherever feasible.

The study further recommends transformation of selected commercial corridors surrounding metro stations into pedestrian-priority mobility streets. Areas such as MP Nagar and New Market possess substantial potential for pedestrian-oriented redevelopment due to their high commercial intensity and mixed-use activity. These corridors should gradually evolve into walkable urban environments characterized by traffic calming, organized vending, reduced vehicular dominance, and improved streetscape treatment.

Considering Bhopal's climatic conditions, thermal comfort emerges as another major determinant influencing walkability. Consequently, the proposals recommend avenue plantation, shaded walkways, urban canopies, and landscape buffers capable of improving pedestrian comfort during extreme weather conditions.

### 6.4.2 Non-Motorized Transport Infrastructure

The development of Non-Motorized Transport infrastructure constitutes one of the most important components of sustainable last mile connectivity planning. Although a significant proportion of urban trips within Bhopal fall within short-distance travel ranges, the existing mobility environment remains heavily dominated by motorized movement systems.

The feasibility of NMT infrastructure varies significantly according to corridor width, surrounding land use, traffic conditions, and right-of-way availability. Therefore, the framework adopts a context-sensitive approach rather than proposing uniform infrastructure standards across all station areas.

Institutional corridors and newly developed sectors possessing comparatively larger right-of-way availability should incorporate segregated cycling tracks as part of complete street retrofitting initiatives. Conversely, congested commercial areas may instead adopt shared mobility streets, traffic calming interventions, and tactical cycling infrastructure due to severe space limitations.

The framework additionally proposes Public Bicycle Sharing systems integrated directly with metro stations, institutional clusters, commercial corridors, and public spaces. Secure bicycle parking systems, digital docking infrastructure, and smart mobility integration should also be incorporated within station environments.

From an environmental perspective, strengthening NMT systems can significantly reduce short-distance motorized trips, improve accessibility efficiency, and support long-term sustainable urban mobility transformation within Bhopal.

*Table 3 Proposed NMT Infrastructure Strategy*

| Corridor Type | Proposed NMT Intervention | Feasibility Consideration |
|---|---|---|
| Institutional Corridors | Segregated cycle tracks | Higher ROW availability |
| Commercial Areas | Shared mobility streets | Limited corridor width |
| Residential Streets | Traffic-calmed cycling routes | Moderate traffic intensity |
| Metro Influence Zones | Public bicycle systems | High short-trip potential |

### 6.4.3 Universal Accessibility Measures

Universal accessibility constitutes a fundamental component of inclusive urban mobility planning. Transportation infrastructure within Indian cities frequently remains inadequately responsive toward the requirements of elderly persons, children, and persons with disabilities, thereby reducing equitable access to public transportation systems.

The field investigations identified several accessibility-related deficiencies surrounding proposed metro station areas including discontinuous pedestrian surfaces, inadequate kerb ramps, unsafe crossings, and absence of tactile guidance systems. The framework therefore proposes integration of universal accessibility across all station area interventions.

Pedestrian pathways should incorporate tactile paving, anti-skid surfaces, wheelchair-accessible ramps, and adequate pathway dimensions. Metro access points, transit plazas, and feeder interchange areas should additionally integrate elevators, escalators, universally recognizable signage systems, and audio guidance infrastructure.

The framework recognizes that universal accessibility should not be treated merely as a compliance-oriented design requirement but rather as a broader social equity objective capable of improving mobility conditions for all commuter groups.

### 6.4.4 Public Realm and Streetscape Enhancement

The quality of public realm surrounding metro stations significantly influences commuter perception, pedestrian comfort, public safety, and urban identity. In many Indian cities, station areas remain characterized by fragmented streetscapes, encroached public spaces, visual disorder, and inadequate spatial organization.

The study therefore proposes a comprehensive public realm enhancement strategy wherein metro station areas are reimagined as vibrant urban mobility districts rather than purely transportation infrastructure zones. Streetscape improvement should involve coordinated integration of pedestrian infrastructure, landscape systems, lighting, public seating, signage, vending organization, and urban design treatment.

Particular attention should be assigned to high-intensity commercial areas such as MP Nagar where continuous public activity generates strong potential for pedestrian-oriented redevelopment. The framework recognizes that informal vending forms an important component of urban economic activity and therefore recommends organized vending zones rather than displacement-oriented interventions.

Landscape infrastructure including avenue plantation, shaded seating, bioswales, and green buffers should additionally be integrated within station areas in order to improve thermal comfort and environmental quality.

### 6.5 Parking Management Strategies

The field investigations identified unmanaged parking as one of the most significant barriers affecting station accessibility and traffic circulation around metro corridors. Unregulated on-street parking reduces effective carriageway width, obstructs pedestrian movement, and contributes substantially toward localized congestion.

The proposed parking framework therefore adopts a demand management approach rather than indiscriminate expansion of parking supply. Parking interventions are differentiated according to station typology, surrounding land use, and commuter characteristics.

| Station Category | Parking Approach | Expected Outcome |
|---|---|---|
| Commercial Stations | Parking restraint and pricing | Reduced congestion |
| Institutional Stations | Shared parking systems | Efficient land utilization |
| Peripheral Stations | Park-and-ride facilities | Reduced inner-city traffic |
| Interchange Stations | Structured parking integration | Better multimodal transfers |

*Table 4 Parking Management Strategy by Station Type*

#### 6.5.1 Rationalization of Parking Supply

Commercial stations should discourage excessive private vehicle parking through controlled parking supply, parking pricing systems, and pedestrian-priority circulation. In contrast, peripheral stations may incorporate structured parking and park-and-ride facilities capable of intercepting incoming automobile traffic before entry into congested urban areas.

Parking areas should additionally be categorized into regulated parking zones, short-duration parking zones, paid parking corridors, and restricted parking areas. Organized enforcement systems remain essential for ensuring obstruction-free pedestrian pathways and station access roads.

#### 6.5.2 Smart Parking Systems

The framework additionally proposes introduction of smart parking technologies including sensor-based parking monitoring, digital payment systems, real-time occupancy information, CCTV-based surveillance, and integrated mobility applications. Such systems can substantially reduce parking search behavior and improve operational efficiency within station influence zones.




### 6.5.3 Parking Pricing and Demand Management

Parking pricing remains one of the most effective mechanisms for influencing travel behavior and reducing automobile dependency. Differential pricing systems, peak-hour pricing, long-duration parking penalties, and integrated transit incentives should therefore form a major component of station area parking management.

*Figure 34 Parking demand management*

### 6.5.4 Park-and-Ride Strategy Framework

Peripheral metro stations should integrate park-and-ride systems capable of attracting suburban commuters and reducing traffic inflow toward inner-city areas. Such facilities should however be carefully planned in order to prevent excessive automobile dependency.

## 6.6 Feeder Service Improvement Strategies

Efficient feeder systems constitute one of the most important determinants influencing metro accessibility and ridership performance. Since the spatial structure of Bhopal is characterized by dispersed urban growth, institutional corridors, and low-to-medium density residential sectors, feeder integration becomes essential for extending metro accessibility beyond walkable catchments.

*Table 5 Proposed Feeder Service Structure*

| Feeder Type | Operational Area | Vehicle Type | Planning Objective |
|---|---|---|---|
| Metro Shuttle | Commercial districts | Electric mini-bus | High-frequency connectivity |
| Institutional Feeder | AIIMS and campuses | Mid-size feeder bus | Peak-hour movement |
| IPT Integration | Residential catchments | E-rickshaw/Auto | Flexible last mile access |
| Shared Mobility | Mixed-use areas | Shared EV systems | Demand-responsive mobility |

### 6.6.1 Feeder Route Rationalization

The framework proposes a hierarchical feeder route structure aligned with station typology, land use intensity, and commuter demand characteristics. Commercial stations experiencing high pedestrian turnover may rely upon smaller electric shuttle systems and organized IPT integration due to constrained right-of-way conditions. Institutional corridors, however, may support medium-capacity feeder buses operating on structured schedules.

The framework recognizes that auto-rickshaws and e-rickshaws already perform an important informal feeder role within Bhopal. Consequently, the objective is not replacement of informal systems but their gradual integration through designated feeder bays, digital registration systems, route rationalization, and passenger information infrastructure.

### 6.6.2 Integration with Bus and IPT Networks

The metro system should function as part of a larger integrated urban mobility network rather than an isolated transportation corridor. Major stations should therefore evolve into multimodal interchange environments integrating buses, IPT systems, public bicycle networks, pedestrian plazas, and shared mobility services.

### 6.6.3 Shared Mobility Integration

Shared mobility systems including shared bicycles, app-based shuttle services, electric micro-transit systems, and shared e-mobility platforms possess considerable potential for strengthening last mile accessibility. However, successful integration requires designated docking infrastructure, regulated pickup zones, operational guidelines, and digital integration platforms.

### 6.6.4 Multimodal Integration Measures

Multimodal integration should occur through coordinated physical, operational, and informational systems. Barrier-free transfers, integrated signage, unified ticketing, common smart cards, and real-time passenger information systems can substantially improve commuter convenience and public transport efficiency.

## 6.7 Transit-Oriented Development and Station Area Strategies

The metro corridor provides a major opportunity to restructure urban growth within Bhopal toward a more compact, accessible, and transit-oriented urban form. TOD should therefore be understood not

merely as a density enhancement strategy but as a broader urban restructuring framework integrating transportation systems, land use planning, and public realm enhancement.

*Table 6 TOD Planning Framework*

| TOD Zone | Development Character | Mobility Priority |
|---|---|---|
| 0–500 m Zone | High-density mixed use | Walking and transit |
| 500–800 m Zone | Medium-density mixed use | Cycling and feeder systems |
| Beyond 800 m | Transitional urban growth | Regional feeder connectivity |

### 6.7.1 TOD Influence Zones

The primary TOD influence zone extending approximately 500 m from metro stations should prioritize mixed-use development, pedestrian-oriented design, active commercial frontages, and reduced parking dependency. The secondary influence zone extending between 500–800 m should support moderate-density growth integrated with feeder systems and active mobility networks.

The framework recognizes that TOD implementation within existing urban environments may encounter practical constraints including fragmented land ownership, infrastructure limitations, and existing built form conditions. Consequently, TOD implementation within Bhopal should initially prioritize corridor retrofitting, public realm enhancement, and strategic redevelopment rather than large-scale displacement-oriented interventions.

### 6.7.2 Land Use Integration

Land use and transport integration remains essential for reducing trip lengths and encouraging transit usage. Metro station areas should therefore function as integrated urban activity centers supporting residential, commercial, institutional, and recreational functions within walkable distances.

### 6.7.3 Mixed Use and Mobility Nodes

Major metro stations such as MP Nagar possess substantial potential to evolve into multimodal economic and activity nodes integrating commercial development, public spaces, office functions, retail corridors, and community infrastructure.

### 6.7.4 Active Mobility Corridors

The study additionally proposes development of active mobility corridors connecting metro stations with educational institutions, public spaces, commercial districts, and bus terminals. These corridors should incorporate wide pedestrian pathways, cycling infrastructure, green buffers, universal accessibility systems, and streetscape enhancement.




*Figure 35 Transit oriented development Model*

### 6.8 Institutional and Governance Framework

Institutional fragmentation remains one of the most significant barriers affecting integrated urban mobility planning within Indian cities. Metro systems, pedestrian infrastructure, parking management, feeder services, land use regulation, and public realm management are frequently administered by separate agencies operating through isolated governance structures.

The study therefore proposes establishment of a Unified Metro Mobility Coordination Cell functioning as an integrated planning and implementation platform responsible for mobility coordination, data sharing, feeder management, TOD regulation, and station area development.

The proposed institutional structure should additionally support preparation of unified station area design guidelines ensuring consistency in accessibility standards, streetscape quality, signage systems, and multimodal integration.

Public consultation mechanisms and participatory planning systems should also form an integral component of governance implementation in order to reduce stakeholder conflicts and improve acceptance of mobility reforms.

### 6.9 Implementation Strategy

The implementation framework should adopt a phased approach based upon mobility demand intensity, financial feasibility, and corridor-level accessibility priorities.

**Short-Term Interventions**

Short-term proposals should focus on tactical pedestrian improvements, organized IPT integration, temporary streetscape enhancement, pilot feeder systems, and parking regulation within high-priority station areas.

**Medium-Term Interventions**

Medium-term interventions should involve development of cycling infrastructure, multimodal interchange systems, smart parking infrastructure, public bicycle sharing systems, and integrated feeder services.

**Long-Term Interventions**

Long-term strategies should focus upon TOD restructuring, station area redevelopment, multimodal mobility hubs, integrated digital mobility platforms, and large-scale corridor retrofitting.

### 6.10 Financial and Operational Framework

Implementation of integrated mobility infrastructure requires diversified financial mechanisms capable of supporting both capital investment and long-term operational sustainability.

Potential funding sources include government infrastructure grants, Smart City Mission funding, PPP-based mobility projects, land value capture mechanisms, parking revenue systems, and commercial station area redevelopment.

Public–Private Partnerships may particularly support implementation of structured parking systems, shared mobility platforms, digital parking infrastructure, and public bicycle sharing networks.

The study additionally recommends adoption of value capture financing mechanisms within high-accessibility TOD corridors in order to recover part of the land value appreciation generated by metro investment.

### 6.11 Expected Outcomes and Planning Implications

The integrated planning framework proposed in the study is expected to generate significant transportation, environmental, economic, and social benefits within Bhopal.

Improved pedestrian infrastructure, feeder integration, multimodal accessibility systems, and organized station circulation are expected to increase metro ridership and reduce private vehicle dependency. Simultaneously, promotion of walking, cycling, and electric feeder systems may contribute toward reduction of vehicular emissions and improvement of environmental quality.

The TOD framework possesses substantial potential for stimulating commercial growth, mixed-use redevelopment, and corridor-level economic intensification. Improved accessibility may additionally strengthen access to employment opportunities, educational institutions, healthcare facilities, and public services for diverse socio-economic groups.

Public realm enhancement, pedestrian safety improvement, and organized streetscape systems are also expected to improve urban livability and commuter experience.

However, successful realization of these outcomes will depend substantially upon implementation quality, institutional coordination, long-term maintenance systems, stakeholder participation, and continuity of governance mechanisms.

The proposed framework therefore represents not merely a transportation strategy but a broader urban restructuring approach aimed at establishing Bhopal as a sustainable, accessible, multimodal, and transit-oriented city.

### 6.12 Summary

The chapter presented a comprehensive planning and strategic framework for improving last mile connectivity around Bhopal Metro stations through integrated mobility planning, multimodal accessibility enhancement, TOD-based urban restructuring, and public realm transformation. The

proposals emphasized pedestrian priority, feeder integration, parking demand management, non-motorized mobility systems, universal accessibility, and coordinated governance mechanisms.

The framework additionally recognized the importance of station typology-based interventions and context-sensitive planning approaches capable of responding to varied land use and commuter characteristics across metro corridors. Through integration of transportation planning, urban design, environmental sustainability, and institutional coordination, the proposed framework seeks to establish a people-oriented and transit-supportive urban mobility structure for Bhopal.




*Figure 36 Proposed cycle routes*

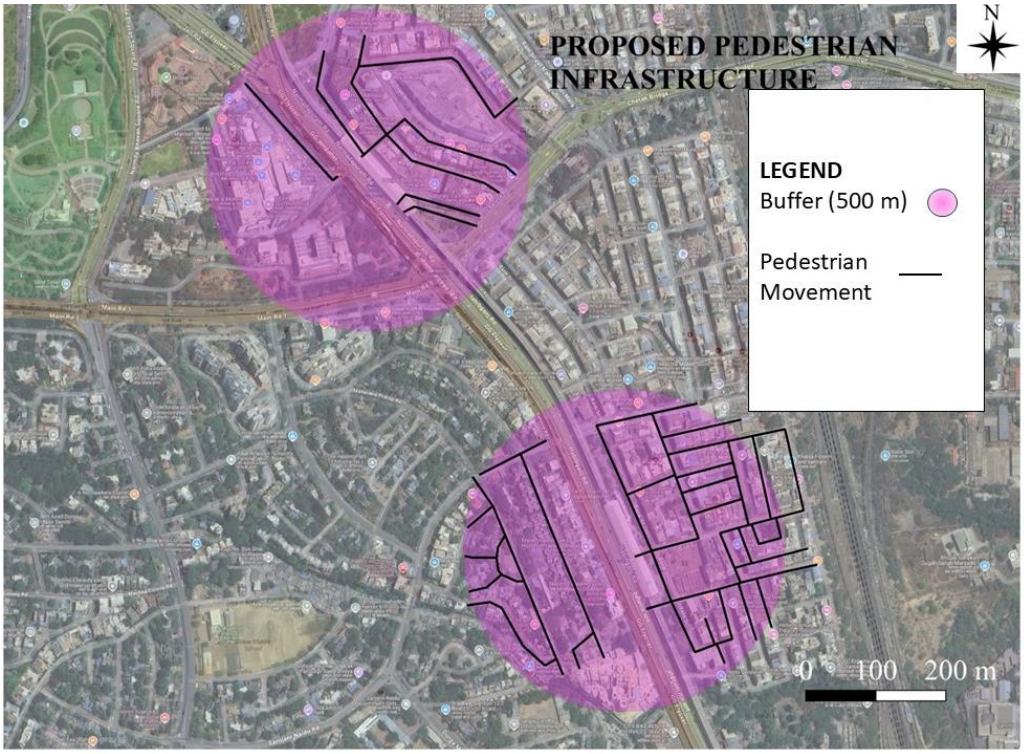



*Figure 37 Proposed pedestrian infrastructure*

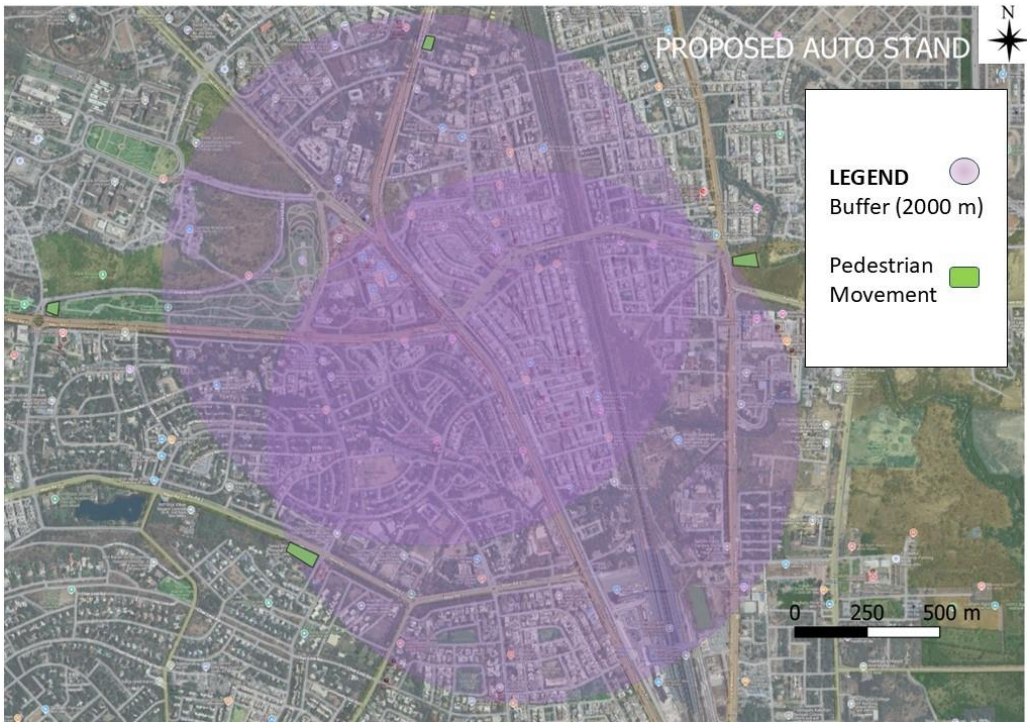



*Figure 38 Proposed auto stand*

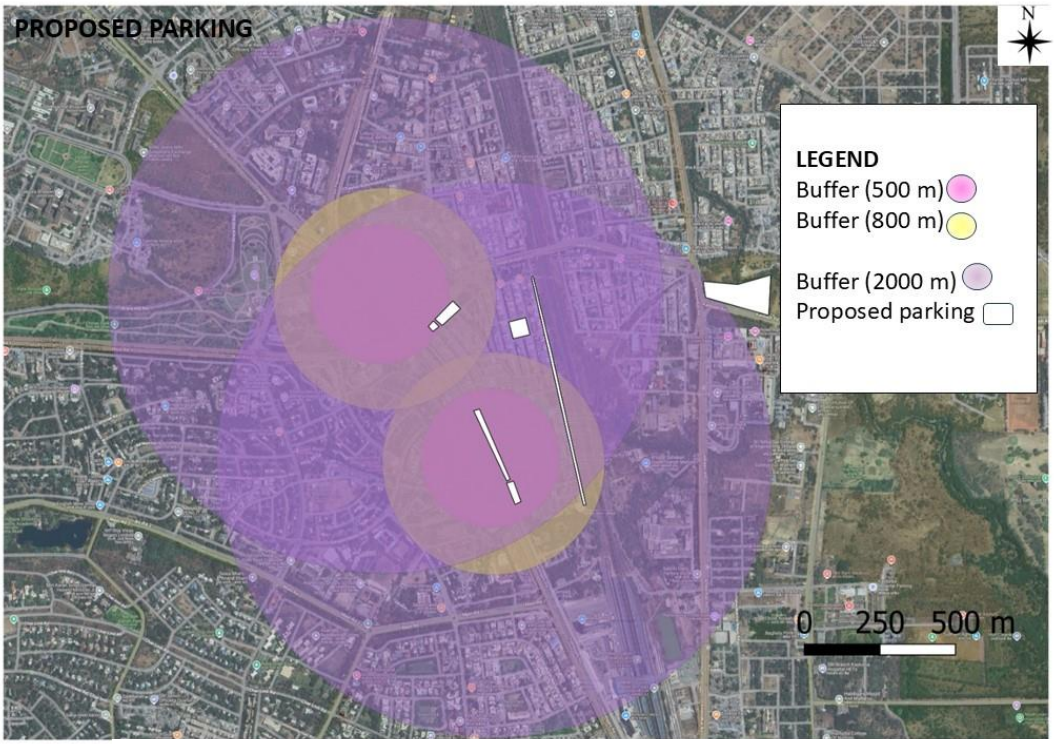



*Figure 37 Proposed parking*

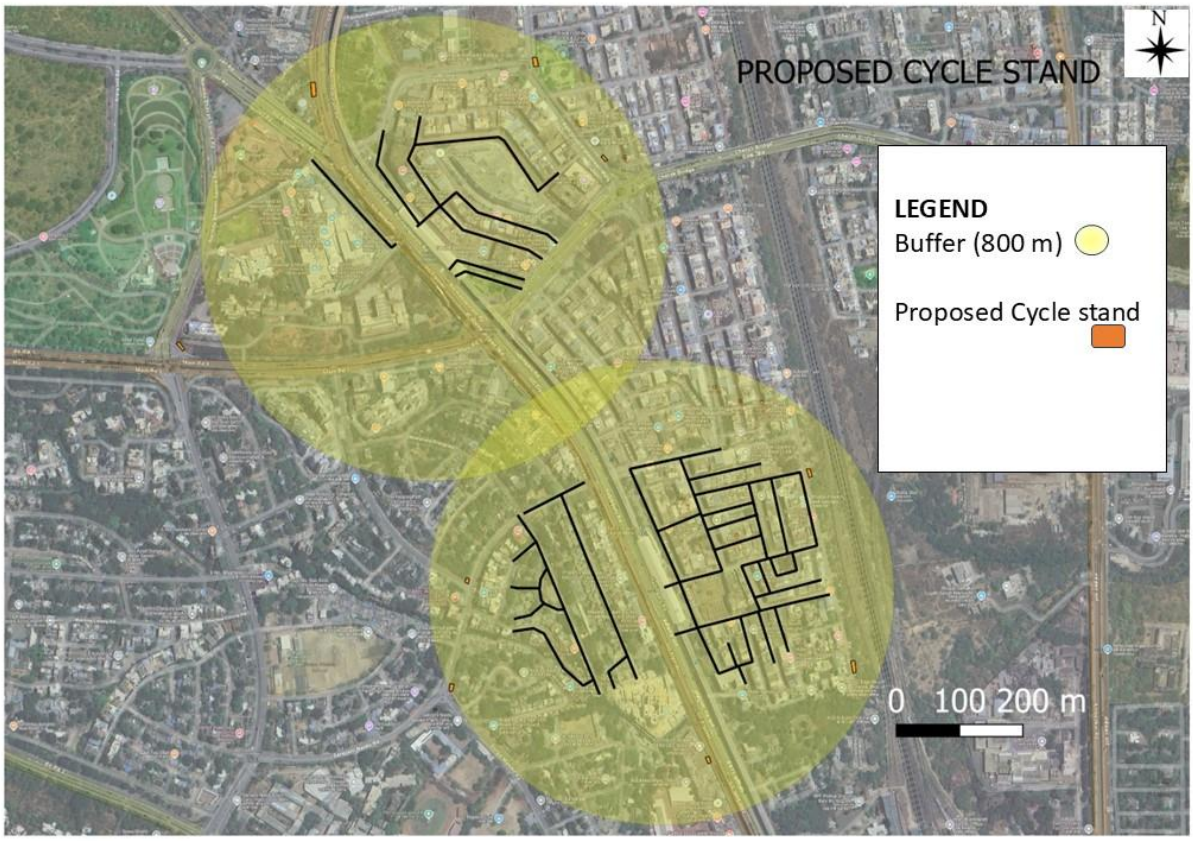



*Figure 38 Proposed cycle stand*

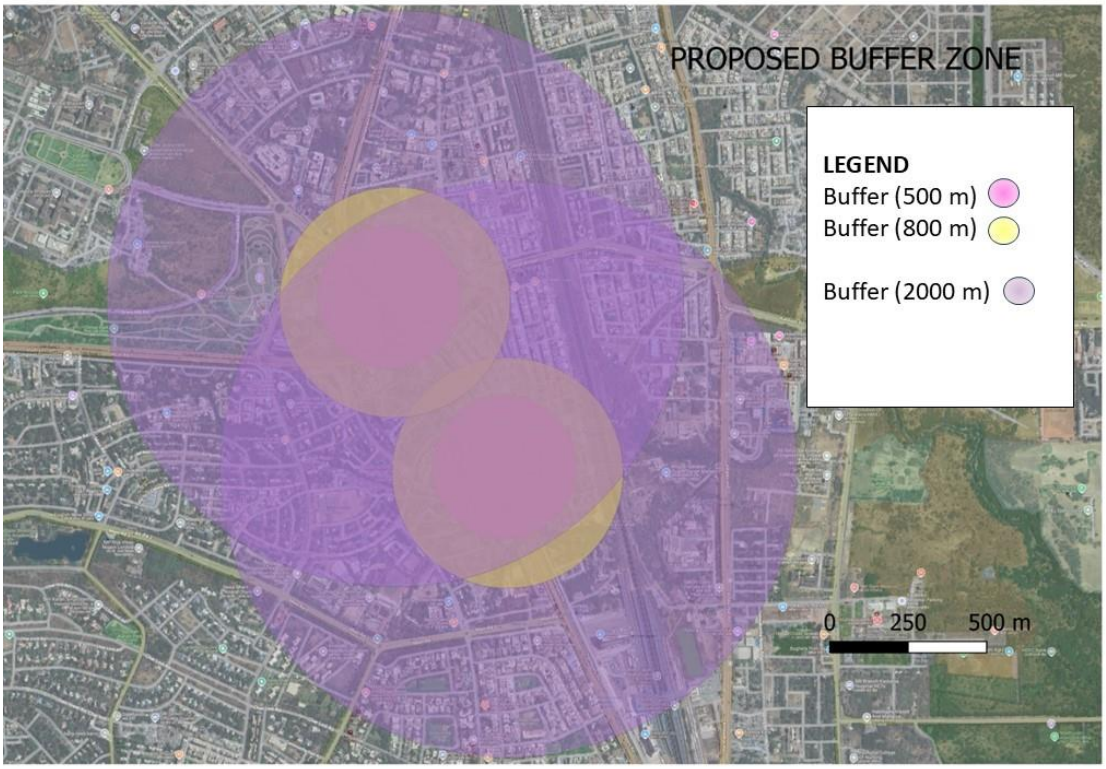



*Figure 39 Proposed buffer zone*

# Chapter 7: Conclusion and Recommendations

## 7.1 Major Findings of the Study

- The present research entitled *"Planning for Last Mile Connectivity: Assessment of Parking Strategies and Feeder Services around Metro Stations in Bhopal"* was undertaken to examine the effectiveness of existing and proposed last mile connectivity systems associated with the emerging metro network in Bhopal. The study investigated the relationship between metro accessibility, feeder services, parking management, pedestrian infrastructure, and multimodal integration in the context of a rapidly transforming Tier-II Indian city. Based on primary surveys, commuter perception analysis, station area observations, policy review, and spatial assessment, several critical findings emerged.
- The study identified that last mile connectivity remains one of the most significant determinants influencing metro ridership potential in Bhopal. While the metro system has been conceptualized as a high-capacity sustainable transit solution for the city, the accessibility gap between metro stations and final destinations poses a major challenge in achieving seamless mobility. A large proportion of potential users indicated that difficulty in reaching metro stations from residential areas, employment centres, educational institutions, and commercial nodes may discourage regular usage of metro services.
- The findings revealed that existing feeder transport systems in Bhopal are fragmented, informal, and poorly integrated with the planned metro infrastructure. Intermediate public transport (IPT) modes such as auto-rickshaws, shared e-rickshaws, vans, and informal shuttle services currently perform the role of last mile connectors in the city. However, these services lack route rationalization, fare integration, scheduling mechanisms, passenger information systems, and designated pick-up/drop-off infrastructure near metro stations.
- The study further found that the absence of integrated mobility planning around station areas may reduce the operational efficiency and ridership performance of the metro system. Most station influence zones exhibit inadequate pedestrian infrastructure, discontinuous footpaths, encroachment issues, insufficient universal accessibility features, and limited cycling facilities. Such deficiencies reduce walkability and adversely affect commuter convenience.
- Another important finding concerns parking management around metro stations. The assessment revealed that parking demand is likely to increase significantly in station influence areas once metro operations commence. However, the existing parking environment in Bhopal is characterized by unregulated on-street parking, inefficient land utilization, weak enforcement mechanisms, and absence of integrated park-and-ride systems. Without appropriate parking strategies, station areas may experience congestion, traffic conflicts, and deterioration of urban public spaces.

- The research identified considerable variation in accessibility conditions across different metro station typologies. Stations located within high-density commercial corridors demonstrated greater multimodal interaction and higher demand for organized feeder systems, while peripheral stations exhibited stronger dependence on private vehicles and informal transport services. This variation indicates the need for context-specific planning interventions rather than adopting a uniform strategy for all metro stations.
- The commuter perception survey indicated that affordability, travel time savings, reliability, safety, and comfort are the most important factors influencing modal shift toward metro transit. Respondents expressed willingness to use metro services if efficient and affordable feeder systems are made available within reasonable walking distances. Female commuters particularly emphasized concerns regarding safety, lighting, surveillance, and accessibility during early morning and late evening hours.
- The study also established that integration between land use planning and transit planning remains limited in Bhopal. Several emerging growth corridors continue to develop in an automobile-oriented manner with low pedestrian priority and inadequate public transport accessibility. This disconnect between urban expansion and transit-oriented planning may weaken the long-term sustainability objectives associated with metro development.
- Spatial analysis of station influence areas demonstrated that transit-oriented development (TOD) opportunities exist around selected metro stations, especially near mixed-use corridors, institutional zones, and commercial centres. However, policy implementation mechanisms, development control regulations, and coordinated institutional frameworks are currently inadequate to fully realize TOD potential.
- Another major finding relates to governance and institutional coordination. Multiple agencies including metro authorities, municipal bodies, transport departments, traffic police, and urban development agencies operate with limited coordination mechanisms. The absence of an integrated mobility governance framework creates overlaps in responsibilities and delays in infrastructure implementation.
- The research further revealed that non-motorized transport (NMT) infrastructure in Bhopal remains underdeveloped despite increasing policy emphasis on sustainable urban mobility. Dedicated cycling tracks, shaded pedestrian pathways, universal accessibility provisions, and safe street crossings are either absent or discontinuous in most station influence zones. This condition restricts the possibility of achieving low-carbon multimodal mobility.
- The study additionally observed that technological integration in urban transport systems is at an early stage in Bhopal. Smart ticketing, integrated fare systems, real-time passenger information, mobility-as-a-service (MaaS) platforms, and app-based feeder integration mechanisms are not yet fully institutionalized.

- The findings also highlighted socio-economic disparities in mobility access. Lower-income groups are more dependent on walking, shared mobility, and informal transport services for daily commuting. Therefore, any future last mile connectivity strategy must prioritize affordability and equitable accessibility rather than focusing solely on infrastructure provision.
- Overall, the study confirmed that successful metro implementation in Bhopal depends not only on rail infrastructure development but also on the creation of an integrated, accessible, affordable, and sustainable last mile connectivity ecosystem.

- **7.2 Achievement of Research Objectives**
- The study was structured around a set of research objectives intended to assess the existing and proposed last mile connectivity conditions associated with the Bhopal Metro system. The objectives were comprehensively addressed through literature review, spatial analysis, commuter surveys, stakeholder consultations, station area assessment, policy evaluation, and comparative analysis.

Objective 1: To examine the concept and significance of last mile connectivity in urban transit systems

- This objective was achieved through an extensive review of national and international literature related to sustainable urban mobility, transit-oriented development, multimodal integration, feeder systems, parking management, and non-motorized transport planning. The review established that last mile connectivity is a critical component of successful urban transit systems and directly influences ridership, accessibility, and modal integration.
- The literature analysis further demonstrated that cities with effective last mile connectivity systems experience higher public transport usage, reduced automobile dependence, lower congestion levels, and improved environmental sustainability. The study contextualized these findings within the framework of Indian metropolitan and Tier-II cities.

Objective 2: To analyze the existing transport and mobility conditions around metro station influence areas in Bhopal

- This objective was fulfilled through field surveys, land use assessment, traffic observations, pedestrian audits, parking surveys, and GIS-based spatial analysis. The study identified major accessibility gaps, traffic bottlenecks, parking conflicts, inadequate pedestrian infrastructure, and deficiencies in feeder transport integration.
- Station influence areas were evaluated based on parameters such as connectivity, walkability, multimodal access, parking availability, land use characteristics, traffic volume, and commuter

activity patterns. The analysis provided a comprehensive understanding of existing urban mobility conditions surrounding metro corridors.

Objective 3: To assess commuter perception regarding feeder services and parking facilities

- The commuter perception survey successfully captured user opinions related to accessibility, convenience, affordability, safety, reliability, comfort, and willingness to shift toward metro-based travel. The survey findings indicated that commuters strongly value efficient feeder systems and integrated mobility infrastructure.
- The analysis also highlighted concerns regarding pedestrian safety, inadequate parking management, lack of organized feeder services, and poor first-and-last mile integration. The survey provided valuable user-centric insights that informed the formulation of planning recommendations.

Objective 4: To evaluate existing and proposed parking strategies around metro stations

- This objective was addressed through parking demand assessment, observation of on-street and off-street parking conditions, analysis of traffic circulation patterns, and review of parking management policies. The research identified major issues including encroachment, inefficient utilization of parking spaces, absence of structured park-and-ride facilities, and lack of parking pricing mechanisms.
- The study further evaluated the role of parking strategies in supporting multimodal transit integration and reducing congestion within station influence zones.

Objective 5: To propose planning strategies for improving last mile connectivity in Bhopal

- The final objective was comprehensively achieved through the formulation of policy recommendations, integrated planning strategies, institutional frameworks, and mobility improvement proposals. The recommendations focused on multimodal integration, feeder service rationalization, NMT infrastructure enhancement, TOD-based planning, parking management reforms, technological integration, and governance coordination.
- The proposed framework was designed specifically for the socio-economic and spatial context of Bhopal while maintaining relevance for other Tier-II Indian cities.
- Therefore, all research objectives outlined in the study were successfully addressed through systematic investigation and analysis.

### 7.3 Conclusions on Last Mile Connectivity in Bhopal

- The study concludes that last mile connectivity constitutes the most critical missing link in the realization of an efficient and sustainable metro-based urban transport system in Bhopal. Although metro rail infrastructure has the potential to transform urban mobility patterns within the city, its long-term success depends heavily upon the quality of integration between metro stations and surrounding urban areas.
- The current mobility structure of Bhopal is characterized by fragmented transport systems, increasing dependence on private vehicles, inadequate public transport integration, and weak pedestrian infrastructure. These conditions pose serious challenges for the operational efficiency and ridership sustainability of the metro network.
- One of the key conclusions emerging from the study is that infrastructure-centric transit planning alone cannot ensure successful urban mobility transformation. Metro systems must be supported by comprehensive accessibility planning frameworks that integrate feeder transport, pedestrian movement, cycling infrastructure, parking management, and land use planning.
- The research concludes that Bhopal presently lacks an integrated multimodal transport framework capable of supporting seamless mobility transitions between metro services and local travel modes. Existing feeder systems operate largely in an informal manner with minimal institutional coordination. Unless feeder integration is strengthened through route planning, service standardization, fare integration, and infrastructure provision, the metro system may fail to achieve its intended ridership potential.
- The study also concludes that walkability conditions within station influence areas are inadequate for supporting transit-oriented mobility. In many locations, pedestrians encounter discontinuous footpaths, unsafe crossings, encroachments, inadequate lighting, absence of universal accessibility features, and conflicts with vehicular traffic. Such deficiencies discourage walking as a viable mode of access to metro stations.
- Parking management emerged as another critical concern. The absence of integrated parking strategies may lead to uncontrolled traffic congestion around metro stations. Without structured park-and-ride facilities, demand-responsive parking policies, and effective enforcement mechanisms, station areas may experience severe operational inefficiencies.
- The study further concludes that transit-oriented development remains an underutilized opportunity within Bhopal. Several metro station influence zones possess the potential for mixed-use, compact, pedestrian-friendly urban development. However, institutional fragmentation, limited regulatory support, and lack of coordinated planning continue to hinder TOD implementation.
- Another important conclusion relates to equity and inclusiveness in mobility planning. Lower-income groups, students, women, elderly persons, and differently abled commuters depend significantly on affordable and accessible transport systems. Therefore, last mile connectivity planning must prioritize universal accessibility, affordability, safety, and social inclusion.

- The study additionally concludes that Tier-II cities like Bhopal require context-sensitive mobility strategies rather than direct replication of metropolitan transport models. Urban form, travel behaviour, economic structure, institutional capacity, and socio-cultural conditions differ significantly from large metropolitan cities. Hence, planning interventions must be adapted to local realities.
- The research also emphasizes that sustainable urban mobility cannot be achieved through isolated infrastructure investments alone. Effective governance coordination, integrated policy frameworks, financial sustainability mechanisms, public participation, and institutional accountability are equally essential.
- Finally, the study concludes that last mile connectivity should not be treated merely as a supplementary component of metro planning but rather as a central pillar of urban mobility policy. Integrated and inclusive last mile connectivity systems have the potential to significantly improve public transport ridership, reduce congestion, enhance environmental sustainability, and improve overall urban quality of life in Bhopal.

### 7.3.1 Synthesis of Key Survey Findings and Analytical Outcomes

| Parameter Assessed | Major Observation | Planning Implication |
|---|---|---|
| Feeder Service Availability | Fragmented and informal feeder systems dominate station areas | Need for integrated feeder network planning |
| Pedestrian Accessibility | Discontinuous footpaths and unsafe crossings observed | Priority for walkability improvement |
| Parking Conditions | High dependence on unregulated on-street parking | Requirement of structured parking management |
| Non-Motorized Transport | Limited cycling and pedestrian infrastructure | Integration of NMT within station planning |
| Institutional Coordination | Weak inter-agency coordination mechanisms | Need for unified mobility governance |
| Commuter Perception | Safety, affordability, and reliability highly valued | User-centric transit planning required |

| | | |
|---|---|---|
| TOD Potential | High potential near mixed-use corridors | Need for TOD-based land use integration |

- The above analytical findings collectively demonstrate that successful implementation of metro systems in Tier-II cities requires integrated planning approaches that combine transport infrastructure, accessibility planning, institutional coordination, and sustainable urban design interventions.
- 
- The empirical analysis conducted during the study revealed several critical mobility trends associated with metro station accessibility in Bhopal. The commuter perception survey indicated that a substantial proportion of respondents considered inadequate feeder connectivity as a major barrier to metro usage. Many respondents expressed preference for metro-based travel only if reliable, affordable, and time-efficient feeder services were available within convenient walking distances.
- Field observations further revealed that pedestrian infrastructure around several station influence areas remains fragmented and discontinuous. In multiple locations, footpaths were either encroached upon or physically inaccessible for elderly persons and differently abled users. Lack of shaded pathways, inadequate lighting, and unsafe road crossing conditions significantly reduced pedestrian comfort.
- Parking assessment conducted around key station areas demonstrated high dependence on informal and unregulated on-street parking. Commercial corridors exhibited severe parking spillover effects leading to traffic congestion and obstruction of pedestrian movement. The absence of structured parking management systems and designated park-and-ride facilities was identified as a major operational challenge.
- The study additionally found that intermediate public transport modes such as auto-rickshaws and e-rickshaws currently function as the primary last mile connectors in Bhopal. However, these services operate with minimal institutional regulation, inconsistent fare structures, and limited route integration.
- Commuters identified affordability, reliability, safety, travel time reduction, and comfort as the most important determinants influencing modal shift toward metro systems. Female respondents particularly emphasized the need for improved surveillance, lighting, and secure waiting areas within station zones.
- Spatial analysis further highlighted the existence of strong transit-oriented development potential around selected station influence areas, especially near mixed-use commercial corridors and institutional zones. However, implementation constraints related to governance coordination, land use regulation, and infrastructure integration continue to limit TOD realization.

- Overall, the analytical findings reinforce the conclusion that successful metro implementation in Bhopal depends fundamentally upon integrated and inclusive last mile connectivity systems.

### 7.4 Policy Recommendations

Policy Linkages with National Urban Mobility Frameworks

- The recommendations proposed in this study are aligned with major national urban transport and planning policies including the National Urban Transport Policy (NUTP, 2006), Metro Rail Policy (2017), Transit-Oriented Development Policy Framework, Smart Cities Mission, AMRUT Mission, and Sustainable Development Goal (SDG) targets related to sustainable urban mobility and inclusive urban development.
- The proposed interventions emphasize integrated land use and transport planning, promotion of public transport systems, reduction of automobile dependence, enhancement of non-motorized transport infrastructure, and development of equitable urban mobility systems. These principles are consistent with national planning priorities promoting accessibility-based urban development.
- The recommendations also support the broader objective of creating climate-responsive and people-oriented cities through integrated multimodal transport systems.

### 7.4 Vision Framework for Last Mile Connectivity in Bhopal

Vision Statement: “To develop an integrated, inclusive, accessible, and sustainable last mile connectivity system for Bhopal Metro that promotes seamless multimodal mobility, reduces automobile dependence, enhances urban liveability, and supports transit-oriented urban development in the context of a rapidly growing Tier-II city.”

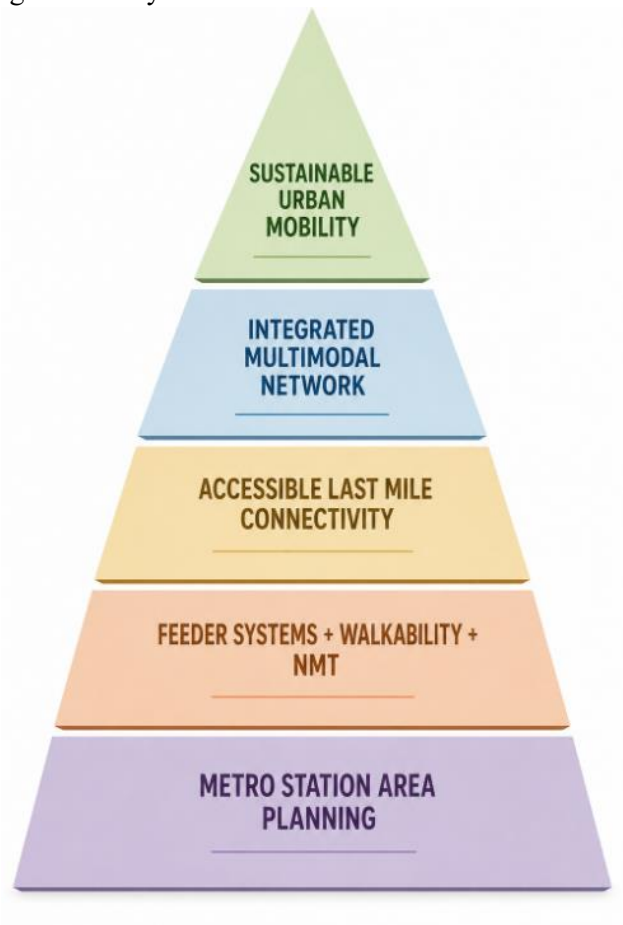



*Figure 40 : Strategic Vision Pyramid for Sustainable Metro Accessibility*

### 7.4.1 Recommendations for Metro Agencies

- Integrated Feeder Service Planning

Metro agencies should develop an integrated feeder transport network connecting metro stations with residential areas, institutional zones, commercial centres, and major activity nodes. Feeder services should include electric buses, mini-buses, e-rickshaws, shuttle vans, and shared mobility systems.

Dedicated feeder routes should be planned based on catchment analysis, commuter demand patterns, and station typologies. Route rationalization and service frequency optimization are essential to minimize waiting time and improve reliability.

- Multimodal Integration Infrastructure

Metro stations should function as multimodal mobility hubs rather than isolated transit points. Station design must incorporate designated spaces for feeder vehicles, pedestrian circulation, bicycle parking, pick-up/drop-off zones, and para-transit integration.

Integrated interchange facilities should minimize walking distances between different transport modes and ensure universal accessibility.

- Smart Mobility Systems

Metro agencies should introduce integrated smart ticketing systems enabling seamless transfers between metro services and feeder transport modes. Mobile applications providing real-time passenger information, route planning, digital payments, and multimodal trip integration should be developed.

- Park-and-Ride Facilities

Structured park-and-ride systems should be developed near peripheral metro stations to reduce private vehicle entry into congested urban cores. Parking design should prioritize efficient land utilization, safety, surveillance, and accessibility.

Dynamic parking pricing mechanisms may be adopted to discourage excessive automobile dependence.

- Universal Accessibility Measures

Metro infrastructure should ensure accessibility for elderly persons, women, children, and differently abled users. Elevators, ramps, tactile paving, accessible signage, lighting systems, and surveillance mechanisms should be incorporated within all station areas.

Integration with Non-Motorized Transport

Metro agencies should prioritize pedestrian and cycling connectivity within station influence zones. Continuous footpaths, shaded walkways, safe crossings, cycle tracks, bicycle-sharing facilities, and traffic calming measures should be integrated into station planning.

- Transit-Oriented Development (TOD)

Metro agencies should collaborate with planning authorities to promote TOD principles around station areas. Higher density mixed-use development, reduced parking dependency, active street frontages, and pedestrian-oriented urban design should be encouraged.

### 7.4.2 Recommendations for Urban Local Bodies

- Pedestrian Infrastructure Improvement

Urban local bodies should prioritize the development of safe, continuous, and universally accessible pedestrian infrastructure around metro stations. Footpaths should be obstruction-free, adequately shaded, well-lit, and designed according to universal accessibility standards.

- Integrated Land Use Planning

Municipal authorities should align urban development plans with metro transit corridors. Land use zoning regulations should support mixed-use development, higher density residential growth, and transit-supportive urban form within station influence areas.

- Street Design Reforms

Complete street principles should be adopted in station influence zones to ensure equitable allocation of road space among pedestrians, cyclists, public transport users, and private vehicles.

Traffic calming measures including raised crossings, pedestrian refuge islands, reduced turning radii, and speed management systems should be implemented.

- Parking Regulation and Enforcement

Urban local bodies should establish parking management frameworks incorporating parking pricing, digital parking systems, enforcement mechanisms, and restrictions on indiscriminate on-street parking.

Structured parking facilities should be developed strategically to reduce congestion and protect public spaces.

- Public Realm Enhancement

Public spaces around metro stations should be improved through landscaping, street furniture, lighting, signage, vending management, and place-making interventions. High-quality public realms can enhance station attractiveness and pedestrian comfort.

- Environmental Sustainability Measures

Urban local bodies should integrate green infrastructure within station areas through urban greening, rainwater harvesting, permeable pavements, and climate-responsive urban design strategies.

### 7.4.3 Recommendations for Transport Authorities

- Institutional Coordination Framework

Transport authorities should establish integrated governance mechanisms involving metro agencies, municipal corporations, traffic police, urban development authorities, and regional transport departments.

A unified urban mobility authority may be considered for coordinated decision-making, infrastructure implementation, and policy integration.

- Public Transport Integration

Bus systems, IPT services, and metro services should be integrated through synchronized schedules, unified fare systems, and common mobility platforms.

Transport authorities should encourage electric feeder systems and low-emission mobility solutions.

- Regulation of Intermediate Public Transport (IPT)

Auto-rickshaws, shared mobility systems, and e-rickshaws should be formally integrated into urban mobility planning. Licensing, route allocation, fare regulation, safety standards, and operational management frameworks should be strengthened.

- Data-Driven Mobility Planning

Transport authorities should adopt GIS-based planning, passenger data analytics, mobility surveys, and smart transport technologies to improve decision-making and service optimization.

- Gender-Sensitive Mobility Planning

Transport planning should incorporate gender-sensitive design measures including surveillance systems, emergency response mechanisms, lighting improvements, and safe waiting areas.

- Promotion of Sustainable Mobility

Policies encouraging walking, cycling, electric mobility, shared transport, and public transport usage should be prioritized over automobile-oriented infrastructure expansion.

### 7.4.4 Implementation Framework for Last Mile Connectivity Improvement

*Table 7 : Institutional and Phasing Framework for Last Mile Connectivity Improvement in Bhopal*

| Identified Issue | Proposed Planning Strategy | Responsible Agency | Implementation Horizon |
|---|---|---|---|
| Inadequate feeder connectivity | Introduction of integrated electric feeder systems and route rationalization | Metro Rail Authority & Transport Department | Short-Term |
| Poor pedestrian infrastructure | Development of continuous universal-access footpaths and safe crossings | Municipal Corporation | Short to Medium-Term |
| Unregulated parking around stations | Smart parking management and structured park-and-ride systems | Urban Local Body & Traffic Police | Medium-Term |
| Weak multimodal integration | Development of integrated interchange hubs | Metro Authority & Urban Development Agency | Medium-Term |
| Lack of cycling infrastructure | Dedicated cycle tracks and public bicycle sharing systems | Municipal Corporation | Medium-Term |
| Institutional fragmentation | Establishment of unified urban mobility coordination framework | State Government & Transport Authorities | Long-Term |
| Limited TOD implementation | Revision of land use regulations and TOD policy integration | Town & Country | Long-Term |

| | | | |
|---|---|---|---|
| | | Planning Department | |
| Safety concerns among commuters | Enhanced lighting, surveillance, and gender-sensitive design measures | Metro Authority & Municipal Bodies | Short-Term |
| Dependence on private vehicles | Promotion of public transport incentives and parking pricing | Transport Authorities | Long-Term |
| Limited technological integration | Smart ticketing, MaaS platforms, and real-time passenger information systems | Metro Rail Authority | Medium-Term |

### 7.5 Planning Implications for Tier-II Cities

#### 7.5.1 Bhopal-Specific Planning Implications

- The study identified several location-specific mobility challenges and opportunities within major urban corridors of Bhopal. Station influence areas near MP Nagar, Rani Kamlapati Railway Station, AIIMS corridor, New Market, and institutional zones demonstrated high potential for multimodal integration due to mixed land use concentration and high commuter activity.
- Commercial corridors such as MP Nagar and New Market exhibited significant parking pressure and pedestrian congestion, indicating the need for structured parking management, improved walkability, and enhanced feeder transport integration.
- The AIIMS and institutional corridors revealed growing dependence on intermediate public transport systems and shared mobility modes due to increasing educational and healthcare-related travel demand.
- The study further observed that overlap between Bhopal Metro corridors and existing BRTS infrastructure presents important opportunities for integrated public transport planning and multimodal interchange development.
- TOD-based planning interventions around high-intensity station areas may support compact urban development while reducing dependence on private vehicles.

- These observations reinforce the need for location-sensitive mobility planning strategies within Bhopal rather than standardized infrastructure approaches.
- The findings of this research hold significant implications for urban planning practice in Tier-II Indian cities experiencing rapid urbanization and emerging transit infrastructure development.
- Tier-II cities are increasingly witnessing spatial expansion, rising motorization, traffic congestion, environmental degradation, and mobility inequalities. Many such cities are investing in metro systems and mass transit infrastructure as part of broader urban modernization strategies. However, inadequate attention to last mile connectivity may undermine the effectiveness of these investments.
- The study demonstrates that mobility challenges in Tier-II cities differ substantially from those observed in metropolitan regions. Informal transport systems, mixed land use patterns, institutional limitations, and financial constraints require context-sensitive planning approaches.
- One major implication is the need to integrate transport planning with land use planning from the early stages of urban development. Transit corridors should guide urban growth patterns through TOD-based planning frameworks.
- Another implication concerns the importance of multimodal integration. Metro systems alone cannot solve urban mobility challenges unless supported by feeder systems, NMT infrastructure, and integrated governance frameworks.
- The research also highlights the growing importance of equitable mobility planning. Tier-II cities contain large populations dependent on affordable public and informal transport systems. Therefore, mobility planning must prioritize accessibility, affordability, and social inclusion.
- The study further suggests that intermediate public transport modes should not be viewed as temporary or informal solutions but rather as essential components of integrated urban mobility systems.
- From a governance perspective, Tier-II cities require stronger institutional coordination mechanisms and capacity-building initiatives to manage complex urban transport systems effectively.
- Another important implication relates to sustainability. As Tier-II cities continue to urbanize, mobility planning decisions made today will significantly influence future environmental outcomes, energy consumption patterns, and urban liveability.
- Therefore, the experience of Bhopal offers important lessons for other emerging Indian cities seeking to develop sustainable, inclusive, and transit-oriented urban mobility systems.

### 7.6 Contribution to Urban Planning Practice and Research

- The present study contributes to the field of urban planning and transport research in several important ways.
- First, the research provides a comprehensive understanding of last mile connectivity challenges in the context of a Tier-II Indian city. While substantial literature exists on metropolitan transit systems, relatively limited research has focused specifically on intermediate cities such as Bhopal.
- Second, the study integrates multiple dimensions of mobility planning including feeder systems, parking strategies, pedestrian infrastructure, non-motorized transport, commuter perception, station area planning, and governance frameworks within a single analytical framework.
- Third, the research contributes to policy discourse by highlighting the importance of multimodal integration and accessibility planning in ensuring metro system success.
- Fourth, the study emphasizes the role of informal and intermediate public transport systems within urban mobility ecosystems. This perspective is particularly relevant for Indian cities where IPT modes constitute a major component of daily commuting.
- Fifth, the research proposes context-specific planning recommendations tailored to the socio-economic and spatial realities of Bhopal. These recommendations may serve as a reference framework for similar Tier-II cities.
- The study also contributes methodologically through the integration of primary surveys, spatial analysis, commuter perception assessment, and policy review.
- From a practical planning perspective, the findings may assist policymakers, transport agencies, urban planners, and municipal authorities in designing more effective and inclusive mobility strategies.
- Additionally, the research reinforces the importance of adopting sustainable urban mobility principles within emerging Indian cities undergoing rapid transformation.

### 7.7 Limitations of the Study

- Despite comprehensive analysis and systematic investigation, the study has certain limitations that should be acknowledged.
- The first limitation relates to the evolving nature of the Bhopal Metro project. Since portions of the metro infrastructure are still under development, certain operational characteristics, commuter behaviour patterns, and ridership trends could not be fully assessed.
- Second, the study was limited by time and resource constraints associated with primary data collection. Although extensive field surveys were conducted, a larger sample size across wider spatial coverage may provide more comprehensive insights.

- Third, the study focused primarily on selected station influence areas and corridors. Therefore, certain localized mobility dynamics may not have been fully captured.
- Fourth, the analysis of future ridership behaviour relied partly on commuter perception and anticipated travel patterns rather than fully operational metro data.
- Fifth, detailed financial feasibility analysis of proposed recommendations was beyond the scope of the study.
- Another limitation concerns the dynamic nature of urban mobility systems. Travel behaviour, land use patterns, and transport technologies continue to evolve rapidly, which may influence future mobility conditions.
- The study also faced limitations regarding availability of updated secondary data related to transport demand, parking utilization, and station-level mobility patterns.
- Despite these limitations, the research provides a robust analytical framework and valuable planning insights for understanding last mile connectivity challenges in Bhopal.

### 7.8 Scope for Future Research

- The study opens several avenues for future research in the field of urban mobility and transit planning.
- Future studies may undertake longitudinal assessment of commuter behaviour after the operationalization of the Bhopal Metro system. Such studies would provide deeper understanding of modal shift patterns, ridership trends, and changing accessibility conditions.
- Research may also explore advanced transit-oriented development strategies around metro corridors and evaluate their socio-economic and environmental impacts.
- Further studies can examine the role of emerging technologies including autonomous mobility, mobility-as-a-service (MaaS), smart ticketing, artificial intelligence-based transport management, and shared electric mobility systems.
- Comparative analysis between multiple Tier-II Indian cities may generate broader policy insights regarding sustainable mobility planning and metro integration.
- Future research may additionally focus on gender-sensitive mobility planning, accessibility for differently abled users, and inclusive urban design approaches.
- Detailed financial and economic feasibility analysis of feeder systems, parking infrastructure, and multimodal integration projects would also be valuable.
- Environmental impact assessment related to reduced vehicular emissions, energy efficiency, and climate resilience associated with improved last mile connectivity may form another important area of investigation.
- Future studies may further integrate advanced GIS modelling, transport simulation techniques, and big data analytics for more sophisticated mobility analysis.

- Research on governance reforms, institutional coordination models, and public-private partnership frameworks may also contribute significantly to urban transport planning practice.
- Thus, the field of last mile connectivity planning continues to offer substantial opportunities for interdisciplinary research and policy innovation.

### 7.8.1 Conceptual Planning Framework for Integrated Last Mile Connectivity in Bhopal

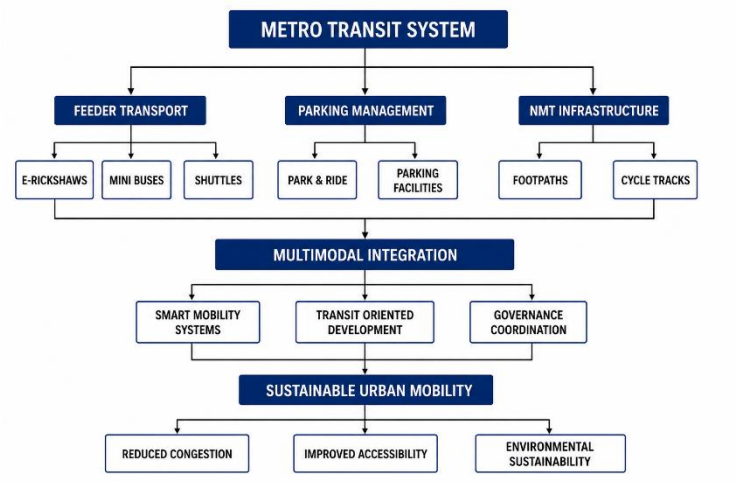



*Figure 41 Conceptual Planning Framework for Integrated Last Mile Connectivity in Bhopal*

## 7.9 Concluding Remarks

- The institutional framework highlights the importance of coordinated governance mechanisms in achieving integrated last mile connectivity and sustainable urban mobility outcomes.
- Urban mobility systems are fundamental to the economic productivity, social inclusiveness, and environmental sustainability of contemporary cities. In rapidly urbanizing Tier-II cities such as Bhopal, the development of metro systems represents a transformative opportunity to reshape urban transport patterns and promote sustainable mobility.
- However, the effectiveness of metro systems depends not merely on rail infrastructure but on the quality of integration between transit systems and everyday urban life. Last mile connectivity acts as the critical interface connecting commuters to the broader mobility network.
- The present study demonstrates that Bhopal possesses significant potential to develop an integrated, sustainable, and inclusive urban mobility system centred around metro transit. Nevertheless, achieving this vision requires coordinated planning interventions involving

feeder integration, pedestrian infrastructure improvement, parking management, multimodal accessibility, institutional coordination, and transit-oriented development.

- The study emphasizes that mobility planning should move beyond automobile-centric approaches toward people-oriented urban development models prioritizing accessibility, equity, and sustainability.
- If effectively implemented, the recommendations proposed in this study can contribute toward enhancing metro ridership, reducing congestion, improving environmental quality, strengthening public transport accessibility, and creating more liveable urban environments.
- The experience of Bhopal further illustrates broader lessons for emerging Indian cities undergoing mobility transitions. Sustainable urban futures will depend increasingly upon integrated transport systems capable of balancing economic growth, environmental responsibility, and social equity.
- In conclusion, last mile connectivity should be recognized not as a peripheral transport issue but as a central planning priority essential for achieving efficient, inclusive, and sustainable urban mobility.

### 7.9.1 Final Planning Synthesis

- The overall research framework developed through this study establishes that metro accessibility in Bhopal cannot be addressed through isolated infrastructure interventions alone. Instead, an integrated planning structure involving feeder systems, parking management, non-motorized transport, land use integration, institutional coordination, and smart mobility systems is essential for achieving sustainable urban mobility outcomes.

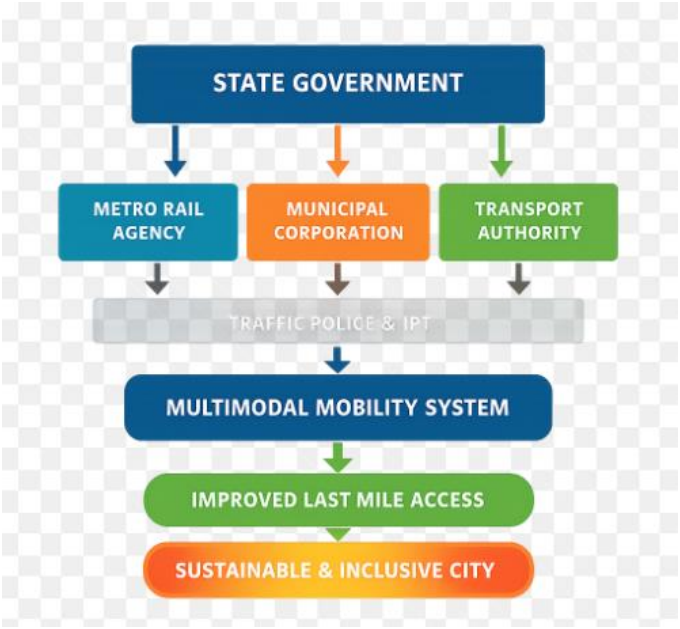



*Figure 42 : Integrated Institutional Coordination Framework for Last Mile Connectivity*

- The study further reinforces that Tier-II Indian cities require context-sensitive and people-oriented mobility planning approaches rather than automobile-centric development models. The proposed planning framework therefore attempts to bridge the gap between transport infrastructure investment and actual commuter accessibility.

- From an urban planning perspective, the research highlights that future city development must prioritize accessibility over mobility, integration over fragmentation, and sustainability over automobile dependence. If implemented effectively, the recommendations proposed in this study can contribute significantly toward creating a more inclusive, efficient, and environmentally sustainable urban transport system in Bhopal.

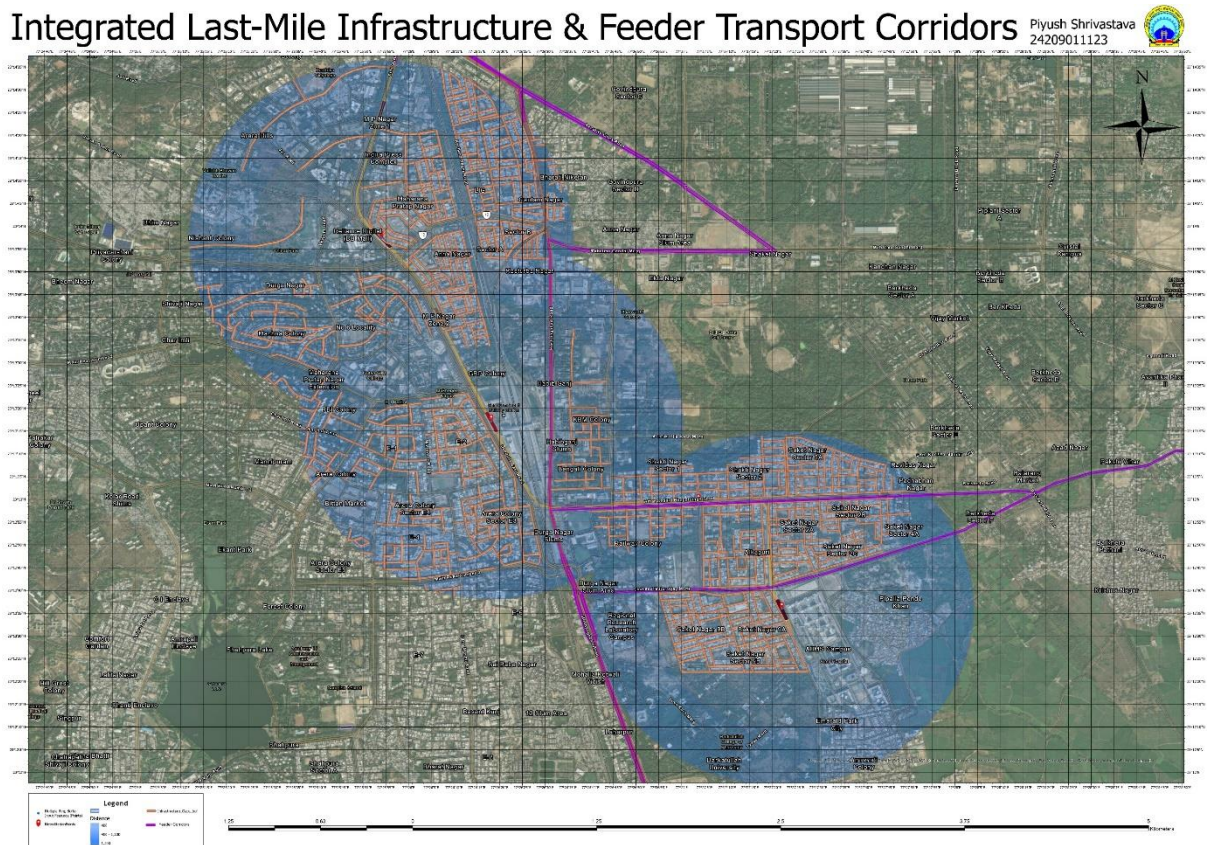



*Figure 43 Integrated Last-Mile Infrastructure and Feeder Transport Corridors*

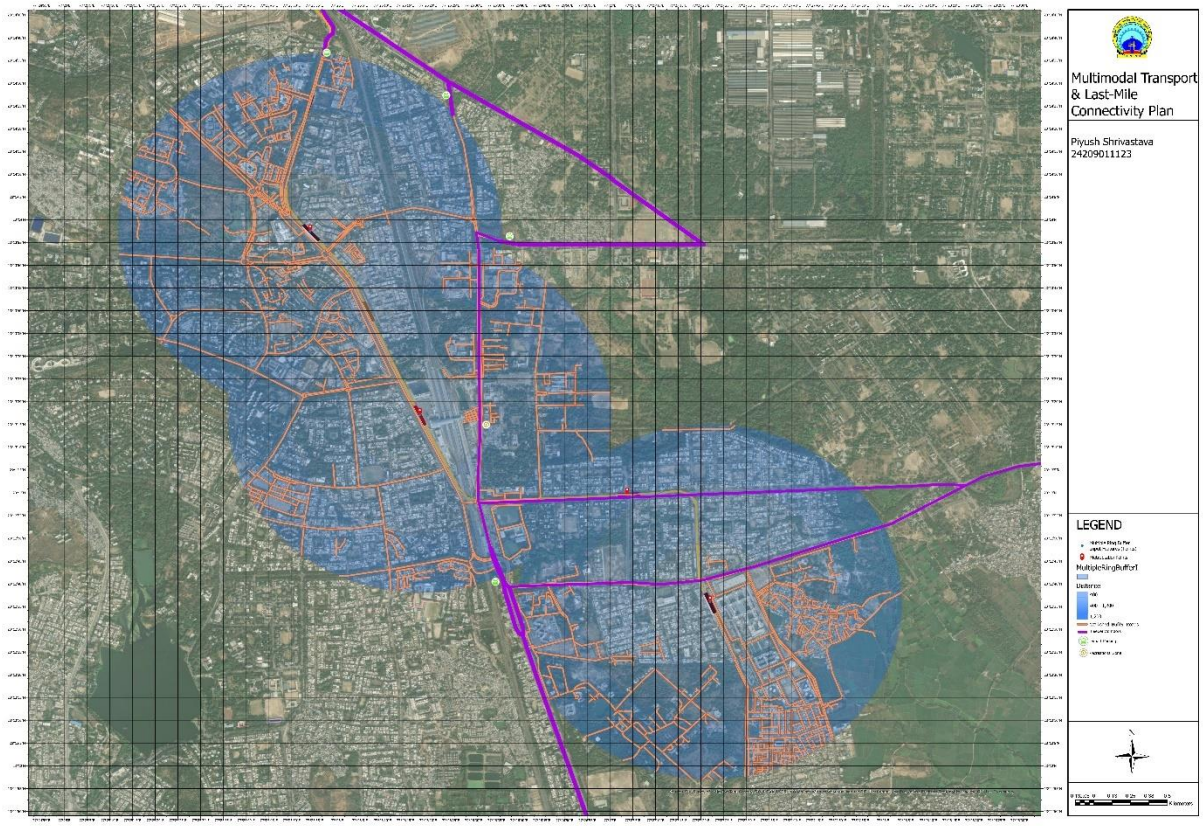



*Figure 44 Multimodal Transport & Last Mile Connectivity Plan*

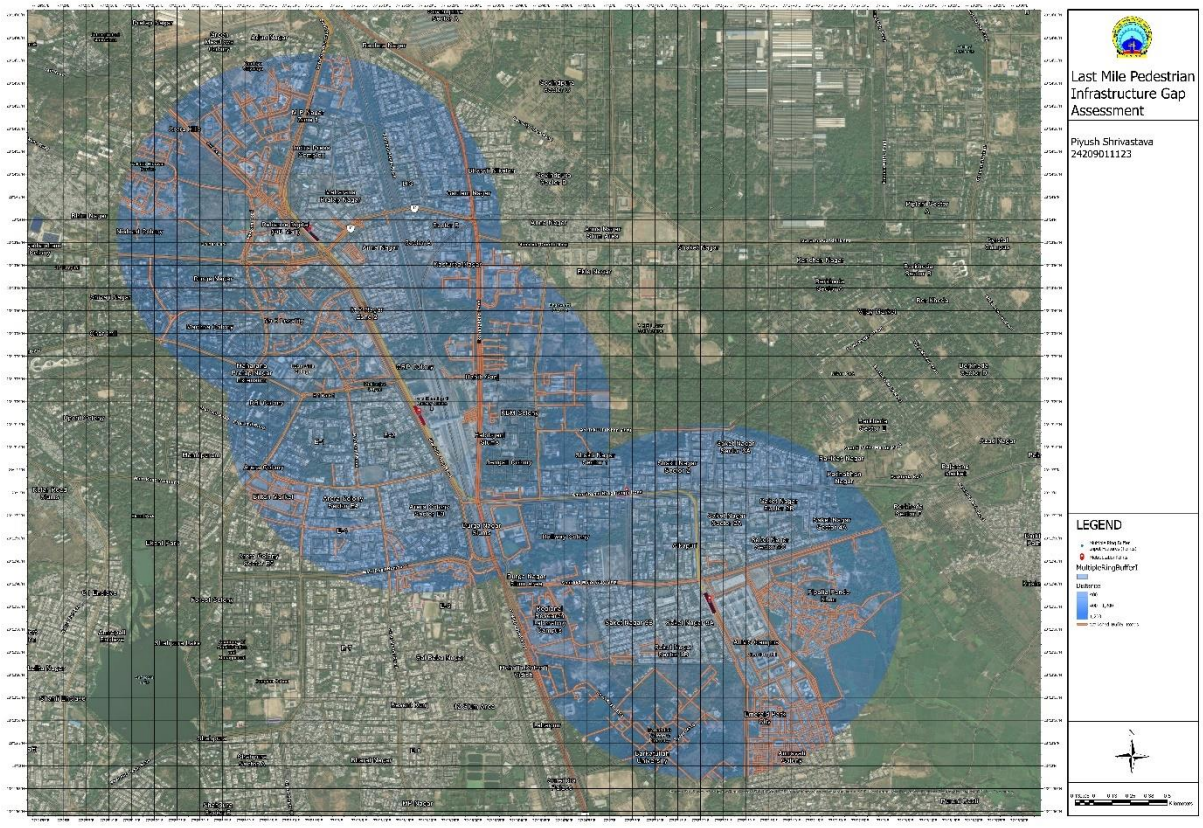



*Figure 45 Last Mile Pedestrian Infrastructure Gap Assessment*

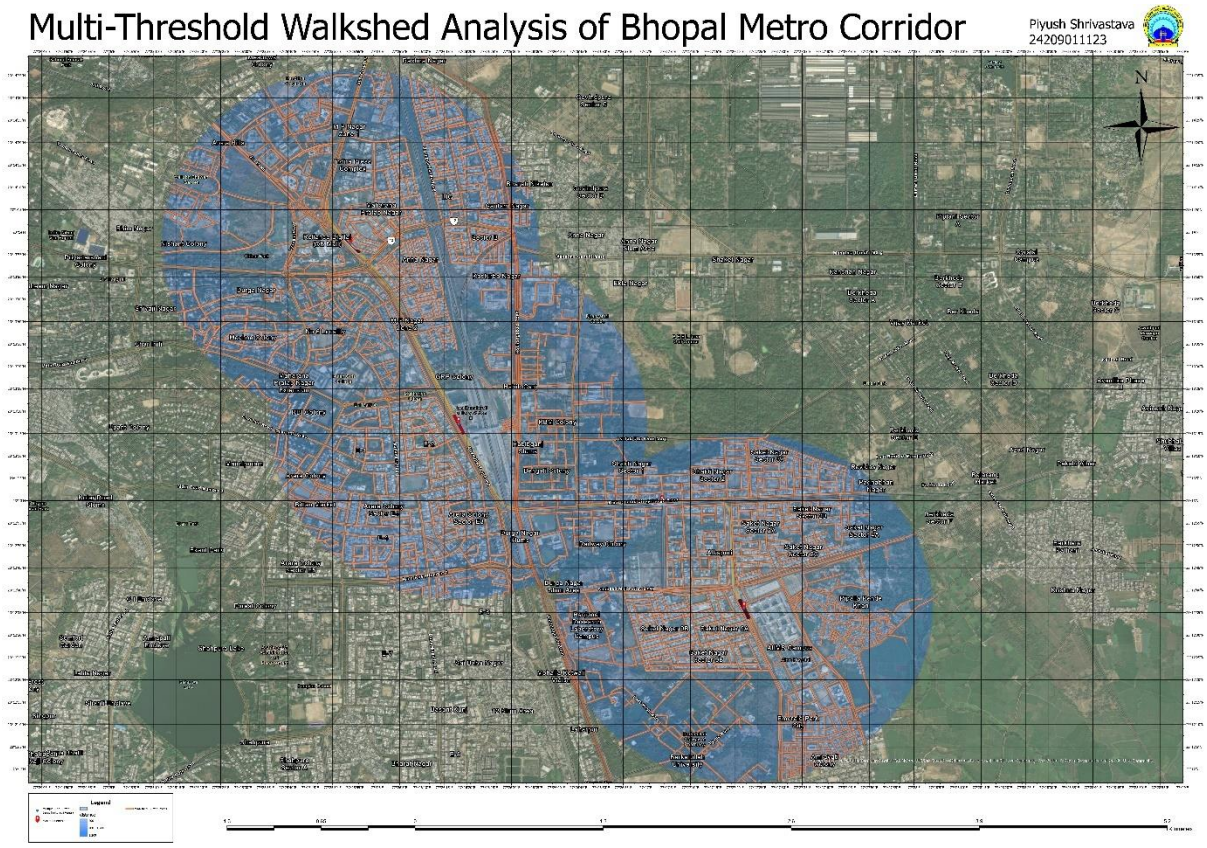



*Figure 46 Multi-Threshold Walkshed Analysis of Bhopal Metro Corridor*




*Figure 47 Pedestrian Catchment Map*

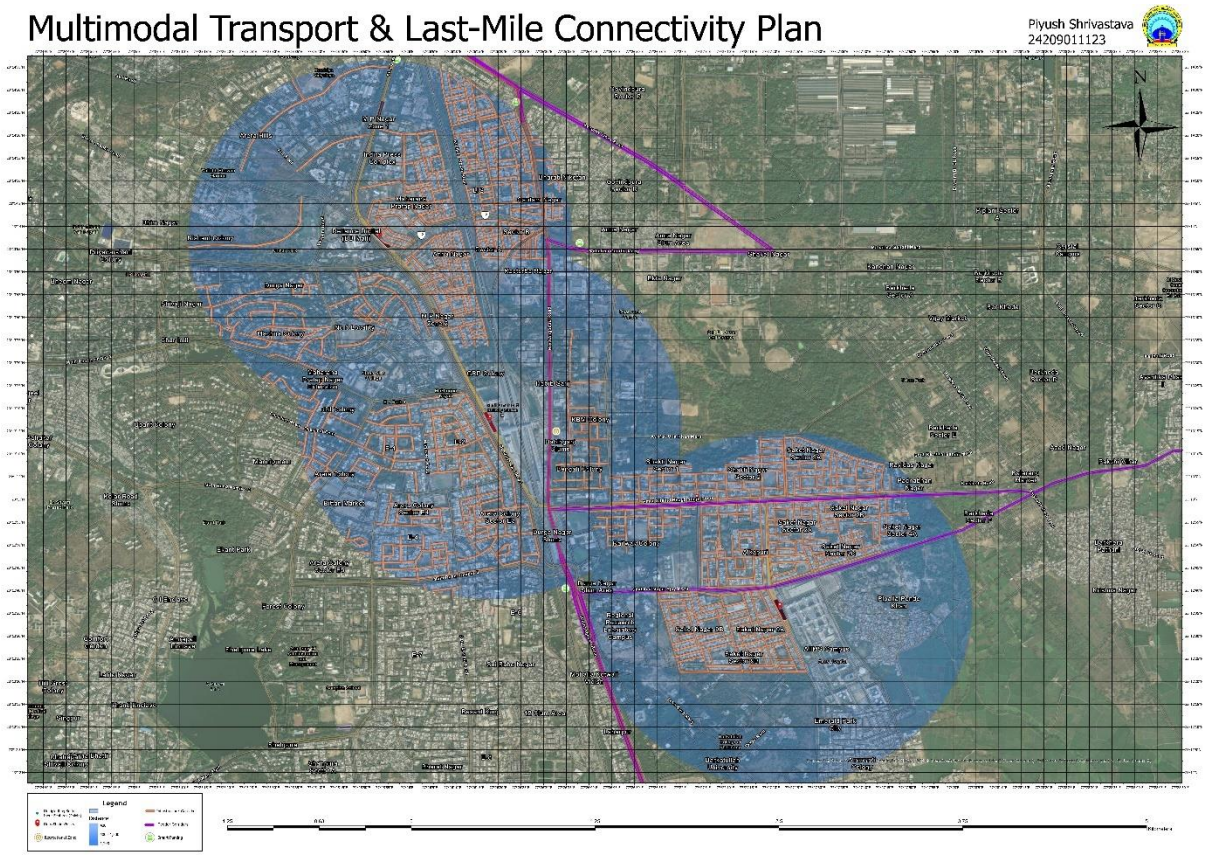



*Figure 48 Comprehensive Multimodal Transport and Last-Mile Connectivity Plan*

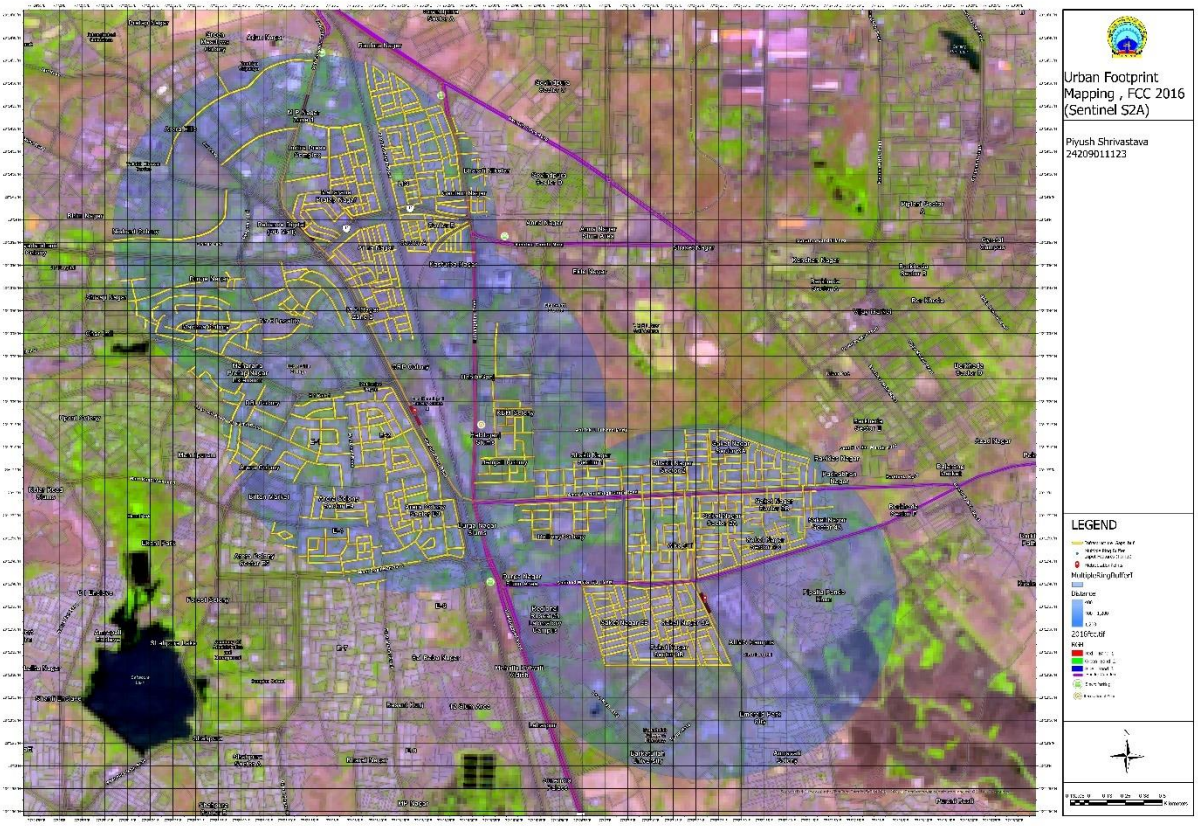



*Figure 50 Urban Footprint Mapping Using Sentinel S2A FCC 2016*

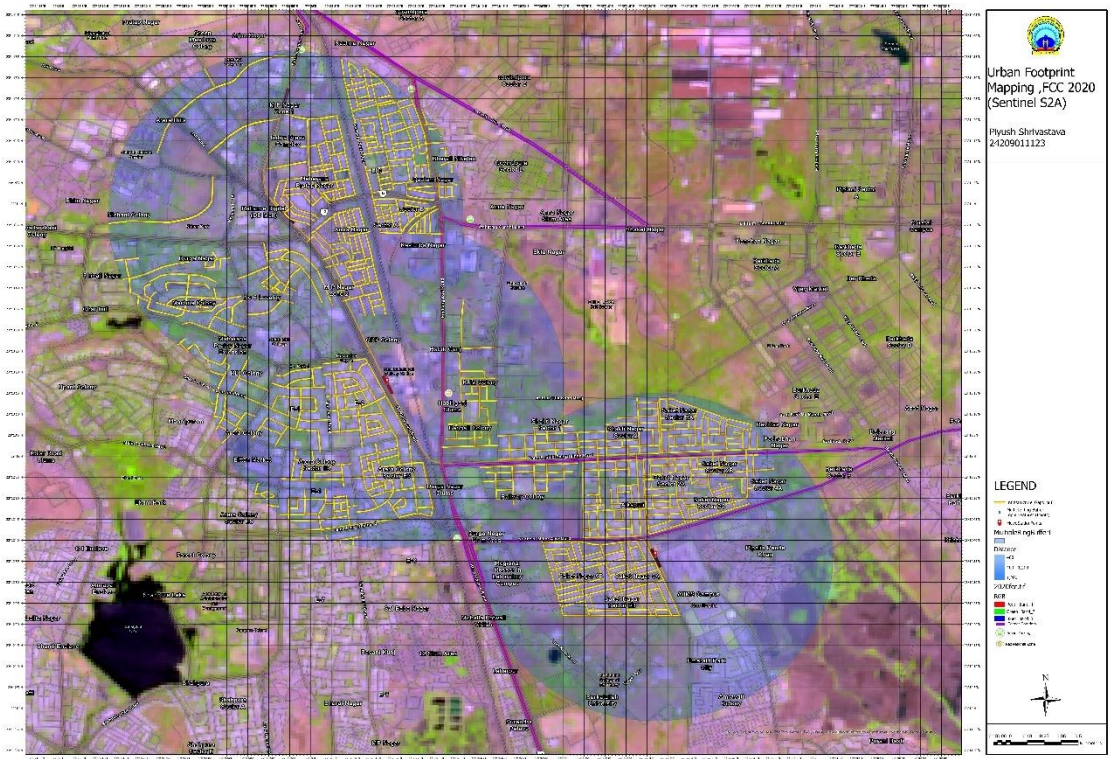



*Figure 49 Urban Footprint Mapping Using Sentinel 2A FCC 2020*

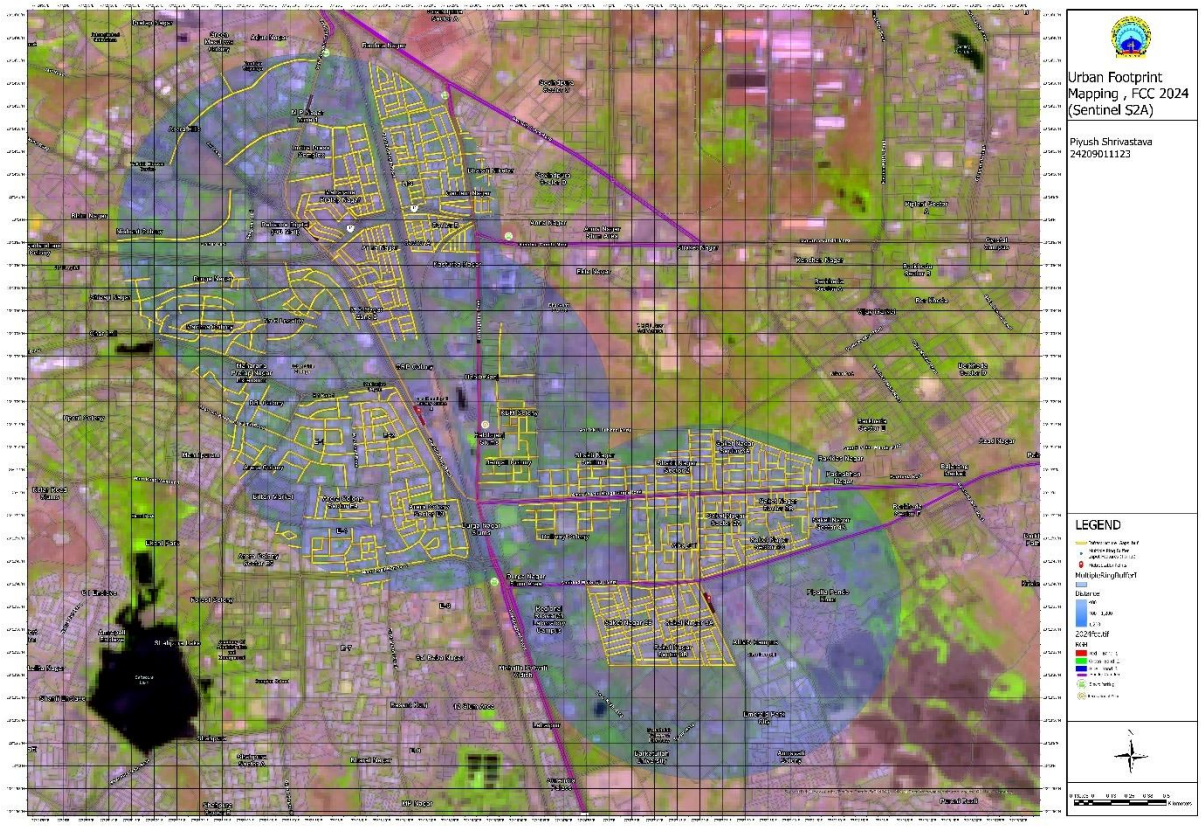



*Figure 51 Urban Footprint Mapping Using Sentinel 2A FCC 2024*

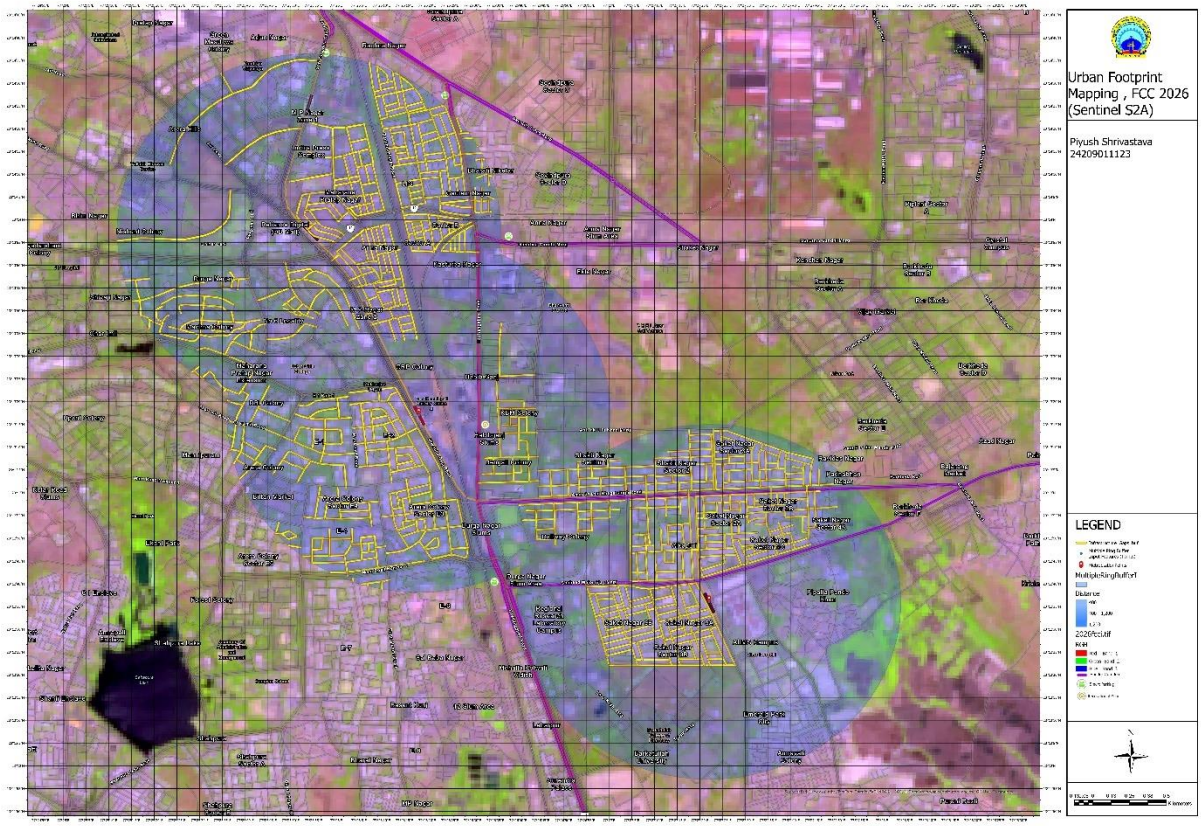



*Figure 53 Urban Footprint Mapping Using Sentinel 2A FCC 2026*

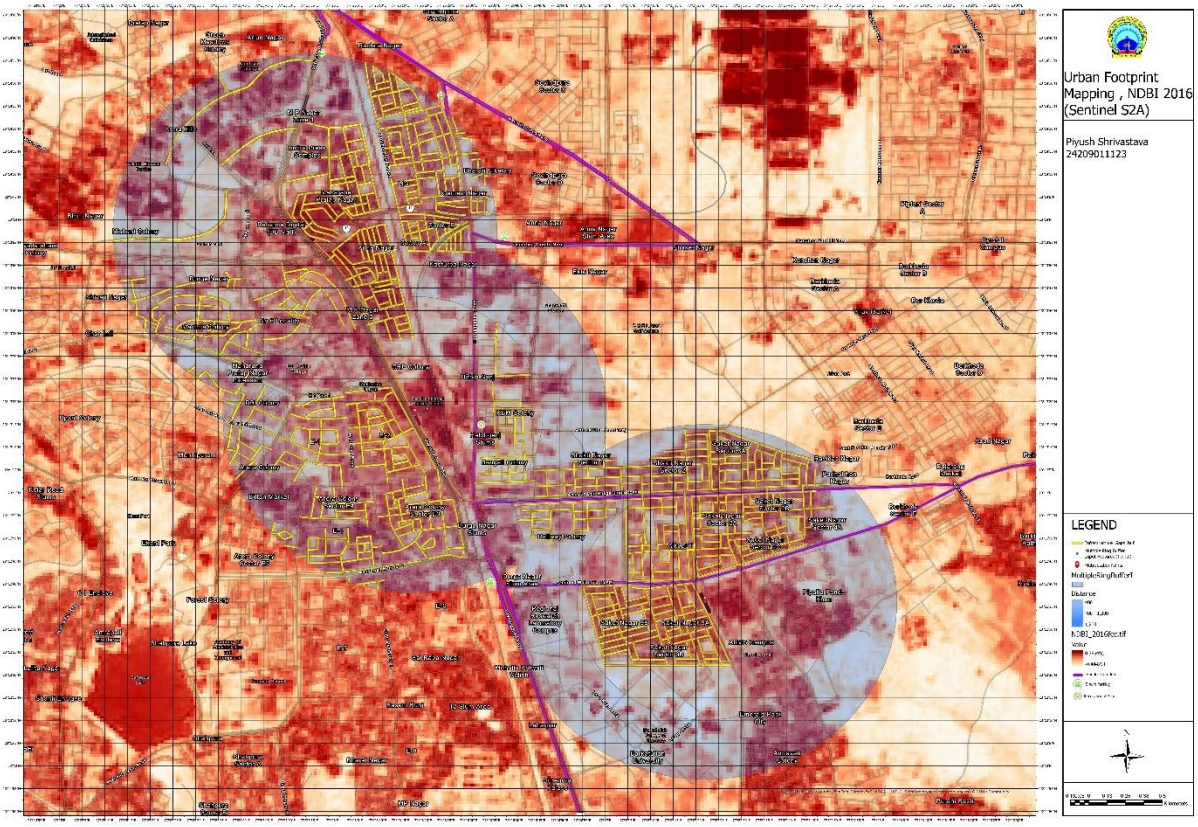



*Figure 52 Urban Footprint Mapping Using Sentinel 2A NDBI 2016*

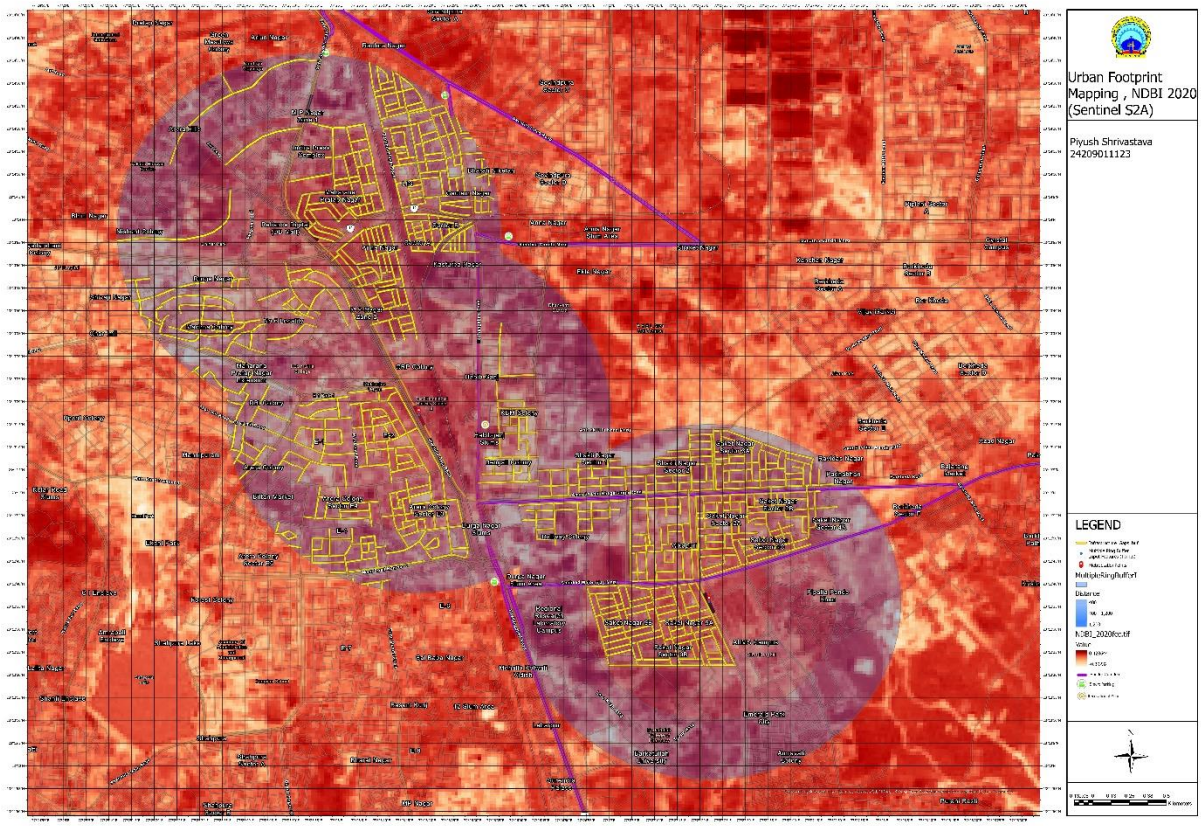



*Figure 54 Urban Footprint Mapping Using Sentinel 2A NDBI 2020*

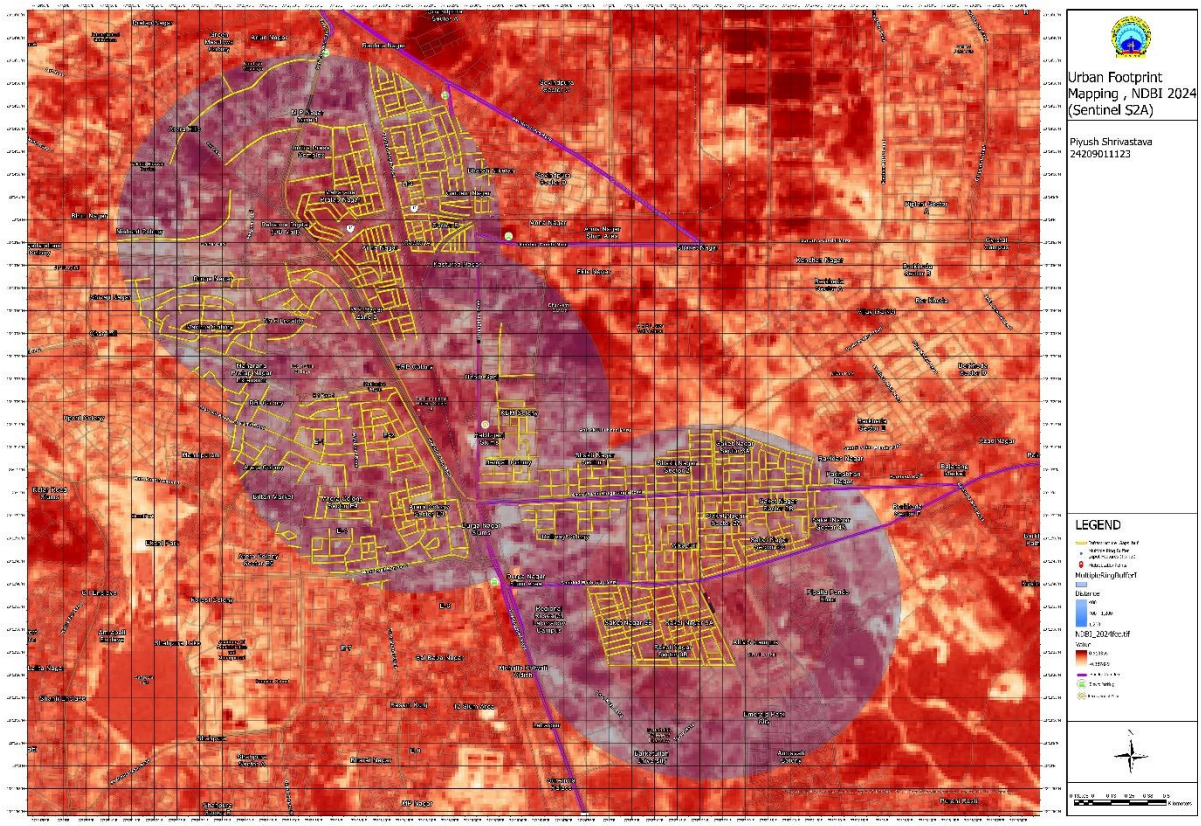



*Figure 55 Urban Footprint Mapping Using Sentinel 2A NDBI 2024*

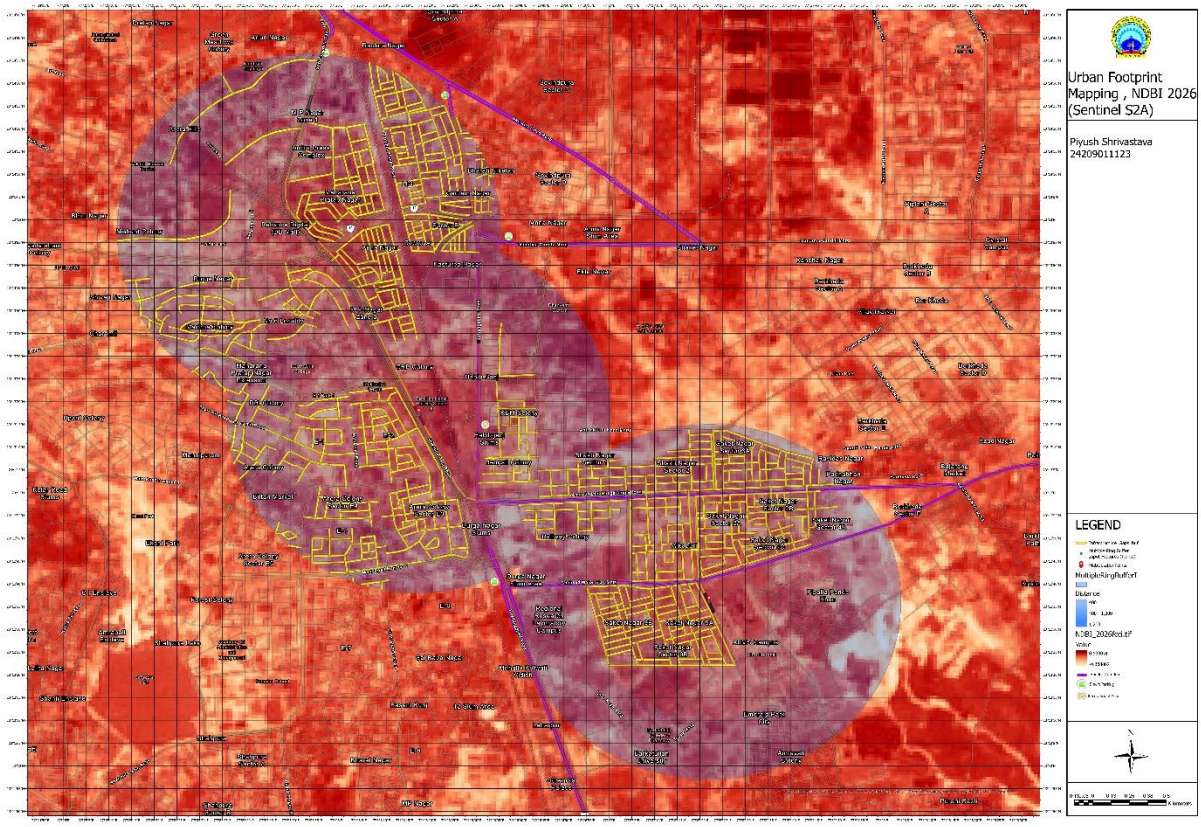



*Figure 56 Urban Footprint Mapping Using Sentinel 2A NDBI 2026*

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