IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

Strategy to Enhance Last mile connectivity of Metro rail transit system in India

Ar. Hasan Saif[1], Ar. Anupam[2]

MURP 2nd Year Scholar, Faculty of Architecture and Planning, A.K.T.U., Lucknow, India[1]

Assistant Professor, Faculty of Architecture and Planning, A.K.T.U., Lucknow, India[2]

Abstract: The rapid pace of urbanization in India has amplified the need for efficient public transportation systems. Metro rail networks play a vital role in addressing mobility challenges; however, their effectiveness is often hindered by inadequate last-mile connectivity (LMC). This study explores strategic interventions to enhance LMC in Indian cities through an evaluation of current challenges and a review of best practices from both domestic and international contexts. Using case studies from Delhi, Bangalore, Singapore, and Norway, this research identifies core barriers including infrastructure limitations, affordability issues, and institutional fragmentation. The findings underscore the significance of integrated, multimodal, and user-centered approaches. Recommendations include the adoption of unified ticketing, electric feeder services, pedestrian and cycling infrastructure upgrades, and stakeholder collaboration. Improving LMC not only supports increased metro ridership but also contributes to sustainable and inclusive urban mobility.

Keywords: Last-Mile Connectivity, Metro Rail Transit, Urban Mobility, Multimodal Integration, Sustainable Transport, Public Transit Access, Non-Motorized Transport, Transport Policy

I. INTRODUCTION

1.1 Introduction

Urbanization is a defining characteristic of the 21st century, with cities around the world experiencing unprecedented growth. In India, this rapid urbanization has led to increased demand for efficient public transportation systems.

Last-mile connectivity refers to the final leg of a commuter's journey, where they travel from the metro station to their ultimate destination. This segment of the journey is often fraught with difficulties, including inadequate transport options, poor pedestrian infrastructure, and safety concerns.

The importance of enhancing last-mile connectivity cannot be overstated. It is essential not only for improving the overall user experience but also for promoting the use of public transport as a viable alternative to private vehicles. Effective last-mile solutions can lead to reduced traffic congestion, lower emissions, and improved air quality, contributing to the broader goals of sustainable urban development.

1.2 Background

The Indian urban landscape is characterized by rapid motorization, leading to congestion, increased fuel consumption, and environmental degradation. Metro rail systems have been developed in several cities, including Delhi, Bangalore, Mumbai, and Lucknow, to alleviate these issues. However, the lack of seamless LMC solutions undermines their effectiveness.

Key challenges include:
Inadequate Infrastructure: Poorly maintained pedestrian pathways and limited cycling lanes.
High Dependency on Personal Vehicles: Many commuters rely on private vehicles due to inefficient feeder services.

Safety Concerns: Issues such as poor lighting and unsafe pathways deter usage, especially among vulnerable groups like women and the elderly.

Innovative solutions, such as shared mobility services and integrated multimodal systems, present opportunities to address these gaps. Lessons from global best practices, including the Station Access and Mobility Program (STAMP) in Bangalore and built environment studies in Singapore, highlight the potential of strategic interventions.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

1.3 Need for the Study

Urbanization and Transportation Demand
India is experiencing rapid urbanization, leading to increased travel demand and congestion in urban areas. The total number of registered motor vehicles has grown significantly, resulting in higher fuel consumption and environmental degradation.

Current Challenges in India
Inadequate Infrastructure: Many metro stations lack proper pedestrian pathways, cycling lanes, and integration with other transport modes

High Dependency on Personal Vehicles: A significant portion of commuters relies on personal vehicles due to the lack of efficient last-mile options.

Poor Integration of Transport Modes: There is often a disconnect between metro services and other forms of transport, such as buses and non-motorized transport (NMT)

Potential for Innovation and New Mobility Solutions
The rise of new mobility enterprises, characterized by mobile applications delivering real-time information and on-demand shared mobility, presents an opportunity to bridge the last-mile gap

1.4 Aims

To study accessible, efficient, user friendly and seamless connectivity to metro rail system.

1.5 Objectives

- To study the existing last-mile connectivity infrastructure and services around selected metro stations.
- To study the travel behaviour, preferences, and challenges faced by metro users for their last-mile journeys.
- To review successful strategies and policies from best practices case studies for improving last-mile connectivity in metro rail transit systems.

1.6 Scope of the Study

To study various last-mile solutions such as pedestrian pathways, bike-sharing, and micro-mobility options.

1.7 Limitations

- The study will primarily focus on selected Indian tier-I & tier-II cities with operational metro rail systems, such as Delhi, Bangalore, Mumbai, and Lucknow.
- Focus on Selected Modes: explore various modes of transport, it may not cover all possible last-mile solutions comprehensively, particularly in peri-urban areas
- Rely on secondary data.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

1.8 Methodology

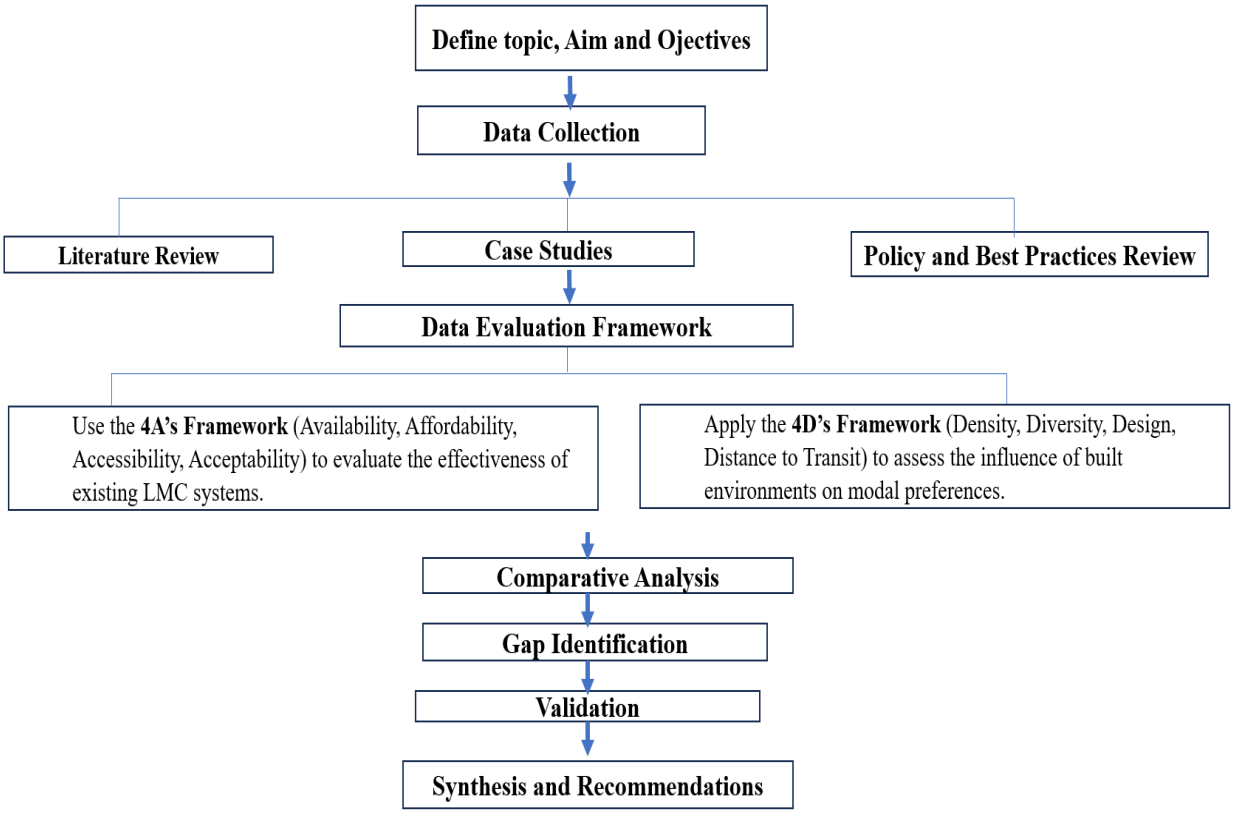

Fig. 1 Methodology flow diagram

II. LITERATURE REVIEW

Several scholars and transport studies highlight the pivotal role of LMC in determining the effectiveness of public transit systems. Chatterjee and Paul (2022) emphasize the necessity for integrating transport planning with land use policies to enhance LMC. Their review highlights key Indian policies such as the National Urban Transport Policy (NUTP) that advocate for sustainable transport and multimodal integration.

Azmi et al. (2021) examined LMC for the Lucknow Metro, revealing that bicycle integration and pedestrian improvements can significantly boost metro accessibility. They argued for better walkability around stations, noting that 60% of respondents were willing to walk up to 500 meters if safe and shaded pathways were provided. Similarly, Khan and Kakirde (2021) support the use of non-motorized transport (NMT) like cycle tracks and pedestrian zones as scalable and inclusive LMC options in tier-II cities.

Kanuri et al. (2018) studied Bangalore's STAMP initiative, which introduced app-based solutions such as motorbike rentals and parking platforms to improve station access. They observed a measurable shift in user preference toward shared mobility. Mo et al. (2018) focused on Singapore and found that built environment factors—particularly land use mix and pedestrian accessibility—strongly influence first- and last-mile choices.

Hoen et al. (2024) evaluated user preferences in Norway's Sluppen Business Park and found that commuters are price-sensitive and infrastructure-dependent. The study concluded that users would shift from personal cars to transit if safe, affordable, and efficient LMC options were available.

Chidambara and Gupta (2018) emphasized the role of urban design and walkability in metro ridership in Delhi, citing pedestrian safety, continuity of sidewalks, and accessibility for differently-abled persons as critical success factors. Murari and Murthy (2024) extended this discussion to institutional coordination, noting that lack of integrated transport authorities hinders effective multimodal service delivery.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

Despite increasing interest in LMC, gaps remain. Most studies are either city-specific or limited to technical assessments. Few offer comprehensive, comparative insights between global north and south cities, or explore the policy and behavioral dimensions of LMC in a systematic manner. This paper attempts to address this by synthesizing best practices and offering a framework-based strategy applicable to Indian metro systems.

III. CASE STUDIES

Case Study 1: Bangalore – STAMP Initiative and Innovation-Driven Mobility

The Bangalore Metro (Namma Metro) is India's third-longest metro system but has faced underwhelming ridership largely due to poor last-mile integration. In response, the **Station Access and Mobility Program (STAMP)**, launched by WRI India in collaboration with the Directorate of Urban Land Transport, aimed to improve station access through innovation challenges and pilot programs.

Key pilots around Baiyappanahalli and Indiranagar stations included **bike-sharing, carpooling apps, ride-hailing partnerships, and digital parking solutions**. These pilots improved user satisfaction and reduced overall commute times. However, long-term implementation was hindered by limited government buy-in and lack of scaling.

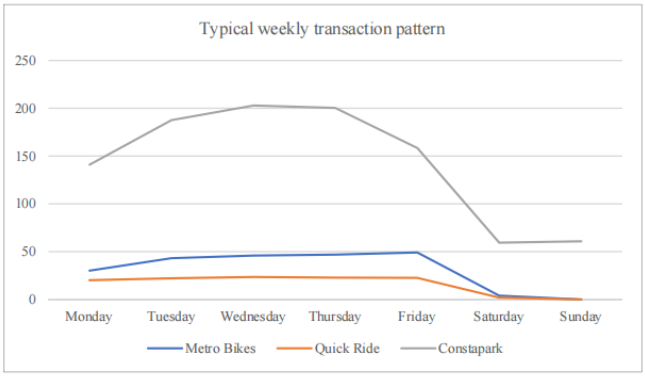

Fig. 2 Typical weekly transaction pattern

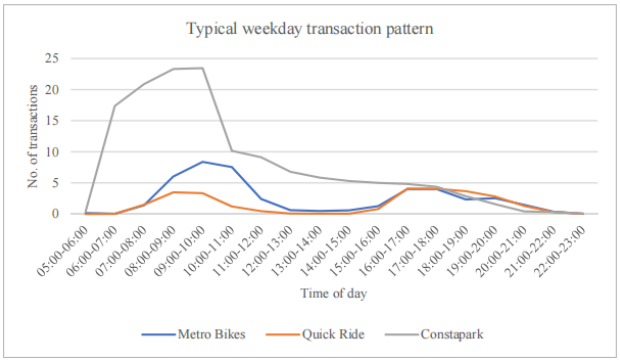

Fig. 3 Typical weekly transaction pattern

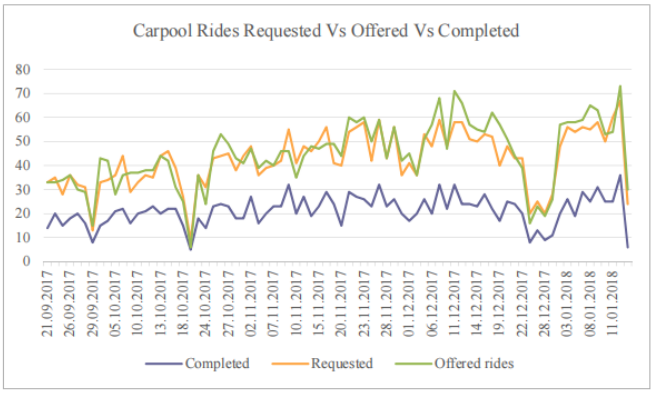

Fig. 4 Typical weekly transaction pattern

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

4A's Analysis:

- *Availability*: High potential with tech-enabled platforms but uneven deployment
- *Accessibility*: Often blocked by informal street vendors and poor footpaths
- *Affordability*: Competitive pricing vs. autos; however, not always inclusive
- *Acceptability*: Positive among youth, but low adoption by elderly and women

4D's Insight: High-density areas and mixed land use helped adoption, but poor pedestrian design limited effectiveness.

Case Study 2: Delhi – Institutional Gaps in an Expansive Network

The Delhi Metro is one of the most expansive in Asia, covering over 390 km. While operational efficiency and punctuality are strong, LMC remains a persistent issue. Of its 254 stations, fewer than 10% are serviced by formal feeder buses. Instead, users rely on informal systems—e-rickshaws and shared autos—which lack regulation, safety, and pricing controls.

Pedestrian access is highly inconsistent. Many stations are disconnected from footpaths, and walkways are encroached or poorly maintained. DMRC's efforts to address this through Public Bicycle Sharing (PBS) and pedestrian skywalks are sporadic and localized.

4A's Analysis:

- *Availability*: Feeder coverage is highly inadequate
- *Accessibility*: Major gaps for differently-abled and elderly
- *Affordability*: High IPT dependency increases cost for low-income groups
- *Acceptability*: Safety and predictability are key deterrents

4D's Insight: Despite high density and demand, poor street-level design and lack of institutional integration (e.g., no functioning UMTA) hinder effective LMC.

Case Study 3: Singapore – Seamless Integration and Policy Consistency

Singapore's MRT system is globally praised for its well-integrated last-mile network. It includes **feeder bus systems (Loop Services), walkable neighborhoods, cycling tracks**, and a unified fare system (EZ-Link). The city adopts **Transit-Oriented Development (TOD)** principles, ensuring that housing, schools, and retail centers are located within walking distance of MRT stations.

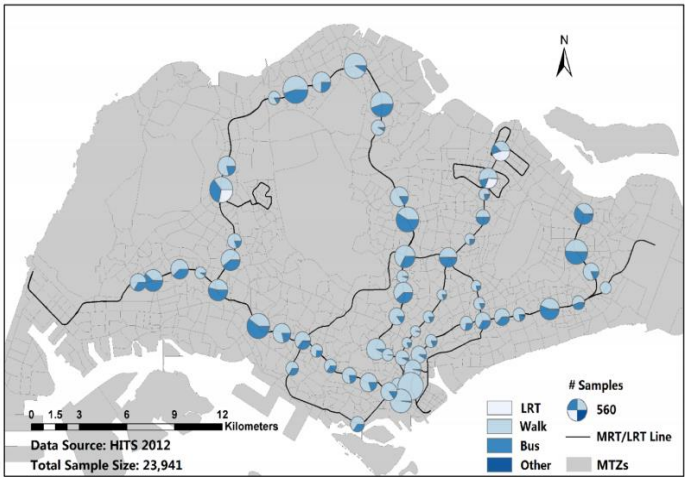

Fig. 5 Modal share of first- and last-mile trips

The MRT network maintains covered walkways, clear signage, tactile paths for the visually impaired, and escalator/elevator accessibility at all stations. According to the **Household Interview Travel Survey (2017)**, 69% of MRT users walked for their last mile.

4A's Analysis:

- *Availability*: Ubiquitous coverage through coordinated modes
- *Accessibility*: Universally designed infrastructure
- *Affordability*: Unified pricing across all transport modes
- *Acceptability*: Very high due to reliability, safety, and design

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

4D's Insight: Density and diversity are optimally used with excellent urban design and minimal distance to transit.

Case Study 4: Sluppen Business Park, Norway – Challenges in Low-Density Urban Fabric

Sluppen is a commercial district in Trondheim, Norway, that highlights challenges in low-density, car-dependent environments. Despite nearby bus services, car usage remains dominant due to lack of pedestrian paths, poor connectivity to transit stops, and cultural preference for driving.

A survey of 244 employees revealed **33% were willing to shift to shared mobility** (e-bikes, shuttles) if pricing and convenience matched private vehicle use. The Sluppen Mobility Hub pilot introduced bike parking, e-scooters, and a digital map of transit options. However, uptake remained modest.

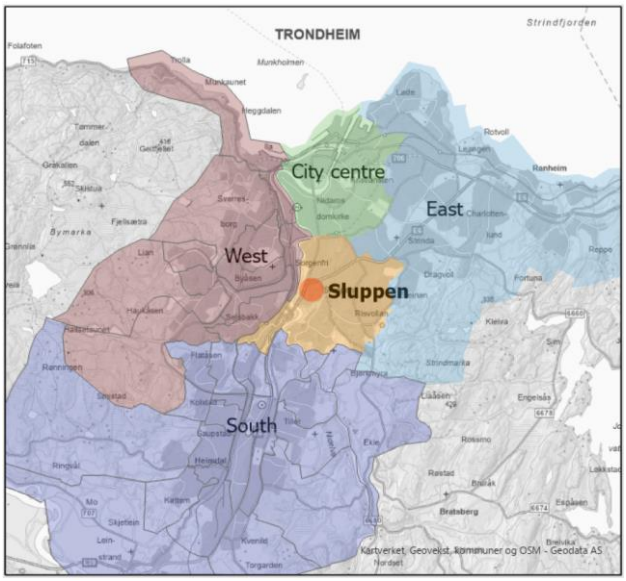

Fig. 6 Map of residential locations in Sluppen

4A's Analysis:

- *Availability*: Services are emerging but not always reliable
- *Accessibility*: Weak pedestrian and cycle infrastructure
- *Affordability*: High sensitivity to price changes
- *Acceptability*: Mixed; depends on age, gender, and parking incentives

4D's Insight: Low density and poor design inhibit effective last-mile behavior shift.

Summary Insights:

Across the four case studies, **common success factors** for effective LMC include:

- Multimodal integration (shared mobility + metro)
- User-centered design (safety, ease of use)
- Institutional coordination (UMTA, PPP models)
- Contextual pricing strategies

Failures or limitations generally stem from:

- Fragmented policy and operations
- Poor pedestrian infrastructure
- Lack of consistent funding or scaling of pilots

IV. ANALYSIS & DISCUSSION

The cross-case analysis reveals that the success of last-mile connectivity (LMC) in metro systems is highly contingent on how well cities address four key dimensions: **infrastructure quality**, **multimodal integration**, **user inclusivity**, and **institutional coordination**. Applying the **4A's and 4D's frameworks**, we can extract actionable insights and identify where Indian cities lag compared to international best practices.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

Infrastructure and Design Deficiencies

In Indian cities like Delhi and Bangalore, LMC often breaks down due to inadequate physical infrastructure—encroached footpaths, disconnected sidewalks, and poorly maintained station surroundings. In contrast, Singapore's MRT stations are embedded within walkable, mixed-use neighborhoods designed to prioritize pedestrians and cyclists. The **'Design' and 'Distance to Transit'** elements of the 4D's framework are especially relevant here.

Integration Gaps

The lack of multimodal planning in Delhi (with few formal feeder services and weak regulation of informal modes) highlights institutional fragmentation. Singapore, on the other hand, integrates buses, rail, and non-motorized modes under a unified fare and service design. Even Bangalore's STAMP pilots, although innovative, lacked city-level policy coordination, which limited scalability. This underscores the importance of having a **Unified Metropolitan Transport Authority (UMTA)** for seamless planning and implementation.

Affordability and Inclusivity

Affordability emerges as a key barrier in both India and Norway. While shared modes like e-rickshaws are cheaper than private vehicles, inconsistent pricing, lack of subsidies, and safety concerns deter regular use. In Sluppen, user behavior was highly price-sensitive, indicating that **behavioral economics** plays a crucial role in LMC adoption. Delhi's example shows that unregulated pricing in informal modes disproportionately affects low-income and female users.

Behavioral and Cultural Factors

Cultural attitudes also influence LMC choices. In Sluppen, car usage is deeply ingrained due to suburban land use and low-density planning. In Indian cities, gendered mobility—where safety and social norms affect travel behavior—plays a significant role in whether people choose metro + feeder combinations. These nuances highlight the need to **design LMC systems with demographic sensitivity**, using disaggregated data and participatory planning.

Technology as an Enabler

Technology-driven LMC solutions, such as ride-hailing integration, mobile-based navigation, and digital parking (as in STAMP), show potential to bridge connectivity gaps. However, digital literacy, smartphone access, and user trust are essential to ensure **equitable adoption**. Cities must pair tech solutions with public awareness campaigns and inclusive design.

V. RECOMMENDATIONS

Based on the comparative analysis and framework-based evaluation, this study proposes a set of strategic recommendations tailored for Indian cities aiming to enhance last-mile connectivity (LMC) in metro systems. These strategies emphasize **integration, affordability, user safety, and institutional collaboration**:

1. Integrated Multimodal Planning

- Establish **Unified Metropolitan Transport Authorities (UMTAs)** in all metro cities to coordinate services across metro, bus, shared mobility, and NMT (Non-Motorized Transport).
- Promote **multimodal hubs** near metro stations, integrating feeder buses, bike-sharing docks, auto stands, and pedestrian access within 100–300m walking distance.
- Encourage **Transit-Oriented Development (TOD)** policies by aligning land use and density regulations to support walkable, mixed-use station areas.

2. Affordable and Inclusive Mobility Options

- Implement **tiered fare structures** and subsidized passes for low-income groups, students, and women to ensure affordability of feeder and shared modes.
- Regulate pricing and safety standards for informal modes like e-rickshaws and shared autos through partnerships and formalization programs.
- Encourage **public-private partnerships (PPPs)** for operating low-cost electric feeder buses or e-bike systems.

3. Pedestrian and Cycling Infrastructure Enhancement

- Redesign footpaths, crossings, and lighting near stations to ensure **continuous, safe pedestrian corridors**.
- Implement **complete street policies** with cycle lanes and pedestrian zones in a 1 km catchment area around stations.
- Adopt **universal design principles** to accommodate elderly, differently-abled, and other vulnerable users.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 4, April 2025

DOI: 10.17148/IARJSET.2025.12490

4. Technology and Data-Driven Solutions

- Deploy **real-time tracking apps**, digital ticketing, and journey planners that integrate metro + feeder + NMT options.
- Use data analytics from travel apps and surveys to plan services based on **peak demand and user preferences**.
- Promote open data sharing between metro agencies, urban local bodies, and private operators to support innovation.

5. Behavioral and Community Engagement

- Conduct **awareness campaigns** to promote LMC options and encourage behavioral shift away from private vehicles.
- Involve local communities and RWAs (Resident Welfare Associations) in planning last-mile interventions.
- Pilot **gender-sensitive audits** around metro stations and incorporate user feedback in design upgrades.

6. Institutional and Funding Reforms

- Allocate dedicated funding for LMC in metro project budgets (at least 10% of total capital cost).
- Link metro expansion approvals to **demonstrated LMC planning**, ensuring feeder services are operational from day one.
- Encourage **inter-departmental coordination** through MOUs among urban development, transport, and municipal agencies.

These recommendations are not one-size-fits-all but offer a **modular strategy** that can be adapted based on city size, urban form, and resource availability. When implemented collectively, they can dramatically improve metro ridership, reduce vehicular congestion, and promote inclusive, sustainable urban mobility.

VI. CONCLUSION

As Indian cities continue to expand and invest in metro rail systems, the issue of last-mile connectivity (LMC) emerges as a critical determinant of overall transit success. This study highlights that without seamless, safe, and affordable connections between metro stations and final destinations, even the most advanced rail infrastructure risks being underutilized.

Through a comparative analysis of Delhi, Bangalore, Singapore, and Sluppen (Norway), it becomes evident that **physical infrastructure**, **multimodal integration**, **institutional capacity**, and **user inclusivity** must all be addressed to achieve effective LMC. While Indian metro systems show great potential, they are frequently hampered by fragmented governance, unregulated informal modes, and poorly designed public spaces.

Lessons from international cases emphasize the importance of **planning metro systems as part of a holistic mobility ecosystem**, where walking, cycling, feeder transit, and shared mobility are seamlessly integrated. Singapore's design-first approach and Norway's behavior-focused strategy both offer valuable perspectives. However, these must be contextually adapted to Indian conditions, considering resource limitations and diverse user needs.

The recommendations proposed in this paper—ranging from institutional reforms to infrastructure upgrades and behavioral campaigns—are not isolated fixes, but **part of a comprehensive strategy to enhance urban mobility and sustainability**.

Strengthening last-mile connectivity will not only boost metro ridership but also contribute to broader goals such as **reduced congestion, lower emissions, greater social equity, and improved quality of urban life**. It is essential that policymakers, planners, and citizens alike recognize LMC as an enabler of inclusive growth and take coordinated steps to realize its full potential.

REFERENCES

[1]. Azmi, Z., Hasan, M., & Rizwan, M. (2021). *Assessment of Last Mile Connectivity for Lucknow Metro: A Case Study.* International Journal of Transportation Engineering and Traffic System, 7(2), 35–42.

[2]. Chatterjee, A., & Paul, S. (2022). *Land Use and Transport Integration for Last-Mile Access: An Indian Policy Perspective.* Journal of Urban Mobility, 4(1), 18–27.

[3]. Khan, M. A., & Kakirde, D. V. (2021). *Non-Motorized Transport as Last-Mile Solution in Tier-II Cities.* Urban Mobility Review, 8(3), 56–65.

DOI: 10.17148/IARJSET.2025.12490

[4]. Kanuri, C., Martens, C., & Jain, D. (2018). *Advancing Last-Mile Connectivity in Indian Cities through Innovation: The STAMP Experience.* WRI India Technical Report.

[5]. Mo, H., Wong, Y. D., & Huang, X. (2018). *Influence of Built Environment on Last-Mile Mode Choice: Singapore MRT Case.* Transportation Research Procedia, 25, 5040–5056.

[6]. Hoen, C., Bakken, T., & Sørensen, R. (2024). *Mobility Choices in Low-Density Employment Zones: A Norwegian Case Study.* Journal of Transport Geography, 112, 103124.

[7]. Chidambara, A., & Gupta, N. (2018). *Walkability and Metro Accessibility in Delhi: An Empirical Evaluation.* Indian Journal of Transport Policy, 6(4), 88–99.

[8]. Murari, R., & Murthy, A. (2024). *Institutional Coordination and Urban Transit Integration in India.* Journal of Sustainable Transportation Systems, 10(1), 23–35.

[9]. WRI India (2019). *STAMP: Station Access and Mobility Program – Summary Report.* World Resources Institute India.

[10]. Ministry of Housing and Urban Affairs (2014). *National Urban Transport Policy (Revised).* Government of India.

[11]. Delhi Metro Rail Corporation (DMRC). (2022). *Annual Report and Performance Indicators.* Retrieved from https://www.delhimetrorail.com/

[12]. Land Transport Authority, Singapore. (2020). *Public Transport Journey Planner Data and Land Use Policies.* https://www.lta.gov.sg/

