Spatial Planning Study on Integrating Non-Motorized Transport with Multimodal Urban Mobility Systems: Evidence from the Kochi Metro Corridor, India

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Abstract — Non-Motorized Transport (NMT) constitutes a critical but often neglected component of sustainable multimodal urban mobility systems. This paper presents a spatial planning study examining the integration of NMT, primarily walking and cycling, with multimodal urban transport along the Kochi Metro corridor in Kerala, India. Employing a mixed-methods approach combining secondary data review, international case study analysis, and a primary survey of 75 respondents, the study evaluates existing spatial accessibility, infrastructure quality, safety perceptions, and comfort levels of NMT users. Findings indicate that while walking is the dominant mode for first- and last-mile connectivity, significant deficits persist in pedestrian infrastructure, safety provisions, and modal integration. A positive correlation is established between perceived safety, walking comfort, and NMT usage frequency. Cross-tabulation analysis reveals gender and age disparities in NMT dependence and safety perceptions. Drawing on global lessons from Copenhagen, Amsterdam, and Pune, the paper proposes a set of spatial planning recommendations addressing infrastructure, land use, governance, and behavioral dimensions.

Keywords: Non-Motorized Transport, Multimodal Urban Mobility, First and Last Mile Connectivity, Kochi Metro, Pedestrian Infrastructure, Spatial Planning, Sustainable Urban Transport

I. Introduction

Rapid urbanization across Indian cities has intensified pressure on existing transport systems, with motorized vehicles increasingly dominating street space to the detriment of walking and cycling. Multimodal urban mobility, the seamless integration of metro rail, buses, suburban rail, paratransit, cycling, walking, and shared mobility, has emerged as the preferred paradigm for sustainable urban transport [1]. The effectiveness of such systems critically depends on the quality of first- and last-mile connectivity, which is predominantly served by Non-Motorized Transport (NMT).

NMT encompasses all modes of transport that do not rely on motorized engines, including walking, cycling, cycle rickshaws, handcarts, and tricycles for persons with disabilities [2]. In the Indian context, NMT extends to a broad spectrum of street users engaged in both commuting and commercial activities. Despite its universal relevance and zero-emission advantage, NMT infrastructure in most Indian cities remains poorly planned, unsafe, and spatially disconnected from major public transport nodes [3].

This paper focuses on the Kochi Metro corridor, stretching from Aluva in the north to Tripunithura in the south, as a representative multimodal transport spine in India. Kochi is Kerala's only city with a comprehensive multimodal network integrating metro rail, suburban rail, KSRTC bus services, Water Metro, and emerging cycling infrastructure. Despite this diversity, first- and last-mile connectivity gaps remain a key challenge for NMT users. The study evaluates spatial integration of NMT with this multimodal system and proposes recommendations to enhance connectivity and accessibility.

II. Background and Conceptual Framework

A. Non-Motorized Transport in Indian Cities

NMT in the Indian context is classified into commuting and commercial modes. Commuting NMT includes walking, the most universal and widely practiced mode, cycling for short trips typically ranging from 3 to 5 km, and non-motorized vehicles for persons with special needs. Commercial NMT includes cycle rickshaws for last-mile travel, goods transport vehicles, and vending carts for the informal economy. These modes collectively serve critical urban mobility functions, yet face persistent marginalization in transport planning [2].

The Ministry of Urban Development has articulated NMT Guiding Principles centered on creating streets that are safe, accessible, inclusive, efficient, and sustainable. These include interconnected NMT networks, complete streets design, bicycle-friendliness, walkability, universal accessibility, safety, security, wayfinding, and protection from encroachment. Supportive principles address mixed land use, transit priority, parking management, and cycling culture development [2].

B. First and Last Mile Connectivity

First and last mile connectivity refers to the links between passengers' origins or destinations and the nearest public transit node. Deficiencies in this connectivity, characterized by inadequate infrastructure, safety concerns, and poor integration with main transit, discourage commuters from using mass transit, redirecting them toward private vehicles [4]. NMT is broadly recognized as the most effective and sustainable mode to bridge this gap, being affordable, zero-emission, and contributory to public health and social inclusivity [5]. In dense Indian cities, short trip lengths make walking and cycling the most suitable feeder modes to transit nodes [6].

C. NMT and Multimodal Integration

NMT serves multiple functions within multimodal systems: enhancing accessibility to transit nodes; promoting sustainable, low-carbon urban mobility; ensuring affordability and social equity for low-income groups; improving urban livability and public health through active travel; and strengthening spatial integration through Transit-Oriented Development (TOD) principles [7], [8]. At the policy level, integrating NMT aligns with India's National Urban Transport Policy (2006, revised 2023) and programs such as the Smart Cities Mission, AMRUT, and the National Cycling Plan.

III. Research Questions and Objectives

This study addresses two primary research questions: (i) How spatially accessible and connected is NMT infrastructure to public transport modes within multimodal urban mobility systems? (ii) What spatial planning recommendations can improve first and last-mile connectivity through better integration of NMT with multimodal transport systems?

The aim is to evaluate the spatial integration of NMT with multimodal urban mobility systems and to propose recommendations to enhance overall accessibility and connectivity. The specific objectives are to: (i) review the role and importance of NMT in supporting multimodal urban transport; (ii) examine spatial accessibility and connectivity between NMT infrastructure and major public transport modes; (iii) identify spatial and planning barriers limiting effective NMT integration; (iv) analyze user experiences and challenges; and (v) propose spatial planning recommendations.

IV. Literature Review

A systematic review of literature spanning NMT integration, multimodal transport planning, and urban spatial analysis was conducted. Key findings are synthesized across global, African, and Indian contexts.

Risimati et al. [9] studying Johannesburg found that cycling activities are spatially separated from public transport infrastructure and that most transit stations have limited NMT accessibility. They recommend planning around 500 m catchment areas and implementing bike-sharing systems to strengthen multimodal integration. Roig-Costa et al. [10] in Barcelona demonstrated that shared micromobility services promote multimodal travel, advocating for Mobility-as-a-Service (MaaS) platforms, gender-sensitive design, and last-mile transit connections.

In the Indian context, Jain [11] documented a continuous decline in NMT modal share in Pune from 1998 to 2014 due to rising motorization and absent NMT infrastructure policy. Tanwar and Agarwal [12] confirmed through case studies of Delhi and Ahmedabad that coordinated multimodal integration can address congestion, pollution, and inequity. Dawda and Desai [13] highlighted Kochi's Water Metro as a successful integration model while acknowledging challenges of fragmented governance and financial constraints.

Mitullah et al. [14] and Zulu [15] emphasized that urban transport planning in sub-Saharan Africa remains car-centric, necessitating a paradigm shift toward walking and cycling. NIUA [16] guidelines for Indian cities underscore the need for dedicated NMT infrastructure, institutional support, and community participation. Oviedo and Sabogal-Cardona [17] demonstrated in Bogotá that modal shifts from cars to bicycles yield significant societal sustainability gains.

The literature collectively establishes that NMT integration with multimodal systems requires coordinated spatial planning, quality infrastructure, safety assurance, and land-use policies supporting compact, transit-oriented development.

V. International Case Studies

A. Copenhagen, Denmark

Copenhagen (population ~1.4 million, area 179.8 km²) is internationally recognized as the cycling capital of the world, with nearly 62% of daily commuters using bicycles. Following a post-war decline in cycling from 60% in the 1940s to under 20% by the 1960s, the city initiated a long-term NMT reintegration strategy from the 1980s.

Policy frameworks include the Copenhagen City Bicycle Plan (1997), Bicycle Strategy (2011–2025), and the transit-oriented “Finger Plan” urban form. Infrastructure investments encompassed segregated cycle tracks, Cycle Superhighways, pedestrianized zones, bicycle parking at transit stations, and real-time multimodal trip planning. Intermodal connectivity is assured through bicycles permitted in metro and trains, unified ticketing via the Rejsekort system, and Mobility Hubs. Outcomes include reduction of over 90,000 tons of CO_2 annually and a social return of approximately 5 DKK per 1 DKK invested in cycling infrastructure.

B. Amsterdam, Netherlands

Amsterdam (area 219.3 km², population ~934,000) achieves over 40% of all trips by bicycle with over 60% of residents cycling daily, while walking contributes 27% of all trips. Cycling infrastructure follows a hierarchical network structure: an Urban Network linking major centers and transport nodes; a District Network connecting neighborhoods to facilities; and a Neighborhood Network providing local accessibility and feeder connections [19].

Key takeaways include: bicycle parking hubs and pedestrian-friendly zones around major transit stations promote first- and last-mile connectivity; compact mixed-use land use reduces trip distances; and continuous monitoring helps refine strategies. Challenges include narrow historic streets, intersection conflicts, limited bicycle parking near stations, and incomplete network links in peripheral areas.

C. Pune, Maharashtra, India

Pune, once the Cycling Capital of Maharashtra with over 50% cycling modal share in the 1950s–1970s, experienced a decline to approximately 3% by 2016 due to rapid motorization. Under its Comprehensive Bicycle Plan, Pune aims to raise cycling’s modal share to 25% by 2031 through an 824 km cycle network, a ₹286 crore investment, 798 Public Bicycle Sharing stations with 13,100 cycles, and integration with metro and BRT [20]. Key lessons for Indian cities include the importance of dedicated institutional mechanisms, integration with comprehensive mobility plans, and sustained investment backed by national policy.

D. Comparative Analysis

While European cities benefit from mature cycling cultures, extensive segregated infrastructure, and strong intermodal connectivity, Indian cities like Pune face challenges of behavioral change, fragmented governance, and incremental infrastructure investments. Common threads across successful NMT integration globally include: dedicated policy frameworks; hierarchical continuous NMT network design; secure parking at transit nodes; intermodal ticketing and information systems; gender-sensitive universally accessible design; and sustained institutional commitment.

VI. METHODOLOGY

The study adopted a mixed-methods research design comprising three parallel tracks: a systematic literature review and comparative case study analysis; validation of the conceptual framework through site-specific analysis; and synthesis of findings to generate spatial planning recommendations.

A. Study Area

The Kochi Metro corridor was selected based on its modal diversity, urban density, representative challenges, and scalability of findings to similar Indian cities. The corridor stretches approximately 27.96 km from Aluva to Tripunithura, serving 25 stations and a catchment population of 200,000–250,000. Kochi is the only city in Kerala with a comprehensive multimodal transport network. The Vyttila Mobility Hub serves as a key multimodal interchange.

B. Primary Data Collection

A structured primary survey was conducted with 75 respondents selected through random sampling along the corridor. The survey instrument covered five thematic areas: (i) demographics: age, gender, occupation, and vehicle ownership; (ii) travel patterns: purpose of commute, timing, primary modes, and walking distances; (iii) NMT infrastructure assessment: sidewalk and cycle lane availability, parking facilities, and walking infrastructure ratings; (iv) public transport access: integration of walking facilities with transit; and (v) safety and comfort: perceived safety from vehicles by day and night, walking comfort, and desired improvements.

C. Data Analysis

Quantitative data were analyzed using cross-tabulation to examine relationships between variables including walking frequency, walking distance, safety perceptions, comfort levels, demographics, and vehicle ownership. Findings were interpreted thematically and linked to NMT dependence and travel behavior insights. Secondary data were reviewed from KMRL reports, Census data, and existing transport plans.

VII. RESULTS AND ANALYSIS

A. Demographic Profile

The survey sample comprised 57.3% male and 42.7% female respondents, with 52% aged between 18 and 25 years and 30.7% aged 25-40. Working professionals constituted 53.3% of respondents and students 26.7%. Regarding vehicle ownership, 45.3% own a single vehicle, 29.3% own two vehicles, and 17.3% own none.

Cross-tabulation reveals that younger respondents (18-25 years) and working professionals are the most frequent walkers, using walking primarily as a connecting mode. Female respondents report higher walking frequency than males. Respondents with no vehicle show the highest NMT dependence, relying on public buses for primary commuting and walking for first/last-mile connectivity. Elderly respondents and multi-vehicle owners walk least.

B. Travel Patterns and NMT Usage

Work-related trips constitute the dominant commute purpose (56%), with morning peak hours (8-11 AM) accounting for 57.3% of commute timing. Bus is the primary commute mode for 33.3% of respondents, followed by two-wheelers (41.3%) and metro (13.3%). Walking is used daily by 49.3%, weekly by 14.7%, and occasionally by 25.3%.

The primary purpose for walking is accessing public transport (42.7%), followed by commuting to school or college (24%), running errands (18.7%), and work (14.7%). Analysis of walking distance shows that 35% walk less than 1 km, 29% walk 1-2 km, and 9% walk 2–3 km. Walking frequency declines systematically as trip length increases, confirming that NMT is predominantly functional for short-distance and feeder trips.

C. NMT Infrastructure Quality

Sidewalk and cycle lane availability was rated poor (scores 1 or 2 out of 5) by 52% of respondents, with only 17.3% rating availability excellent. Walking infrastructure quality for lighting, shading, and surface quality indicates moderate to poor ratings for a majority. Regarding parking facilities, 38.7% report availability but limited numbers, 20% find them poorly maintained, and 32% report no availability at all.

D. Public Transport Integration

Integration between public transport and walking facilities is perceived as poor or non-existent by 57.3% of respondents, with only 9.3% rating it well-integrated. Walking constitutes the primary mode to reach primary commute mode for 49.3% of respondents. A striking 92% of respondents affirm that improved walking infrastructure would positively impact their public transport usage.

E. Safety and Comfort Perceptions

Cross-tabulation of perceived safety from vehicles with walking frequency reveals a strong positive correlation: 79% of respondents who feel safe walk regularly, compared to only 21% who feel unsafe. Night-time safety perceptions show a pronounced gradient: 36% of daily walkers feel safe at night versus only 13% among those who feel unsafe at night. A significant gender disparity is identified: 24% of female respondents report feeling unsafe while walking at night compared to only 9% of males.

Walking comfort correlates strongly with walking frequency: 85% of comfortable respondents walk regularly compared to only 15% of those reporting no comfort. Distance is the most significant barrier overall (44%), followed by safety concerns (26.7%), lack of continuous pathways (22.7%), unfavorable weather (18.7%), and insufficient shade (14.7%). The most requested improvements are wider sidewalks (52%), improved NMT-PT connectivity (42.7%), safer crossings (40%), reduced traffic speeds (40%), and better lighting (37.3%).

VIII. Spatial Planning Recommendations

A. Pedestrian Infrastructure and Complete Streets

Implement Complete Streets policy along the corridor, incorporating wide footpaths (minimum 2 m in medium-activity zones and 3.2 m in high-activity zones), protected cycle lanes, and raised pedestrian crossings. Ensure universal accessibility through ramps at all curb cuts, tactile paving, and obstruction-free walkways. Install shaded corridors with tree planting, rain shelters, and resting areas at 200–300 m intervals near high-volume streets.

B. Safety and Security Improvements

Introduce Safe Walking Corridors with adequate street lighting, CCTV surveillance, and emergency help points, particularly on routes identified as unsafe by female respondents. Implement traffic calming including speed limits (20-30 km/h in pedestrian zones), raised intersections, and curb extensions near schools, markets, and transit nodes. Provide physical separation between pedestrian walkways and motorized traffic through bollards and raised platforms along arterial roads.

C. Multimodal Integration and Mobility Hubs

Redesign transit access zones around metro stations as pedestrian-priority areas, minimizing vehicle conflicts within 100–200 m of station entrances. Establish Multimodal Mobility Hubs at key nodes including Aluva, Ernakulam South, and Vyttila, combining metro access, bus bays, Water Metro connections, bicycle parking, and walking plazas. Provide secure cycle-parking clusters (minimum 20–30 racks per station) at all metro stations. Upgrade bus stops with shelters, seating, adequate lighting, and real-time transit information.

D. Land Use and Spatial Planning

Promote compact mixed-use development within the 500 m walkable catchment of metro stations through zoning incentives, ensuring basic services are accessible within walkable distances under 2 km. Integrate NMT corridor planning into the Kochi Metropolitan area's Comprehensive Mobility Plan. Apply TOD standards at all station areas with active frontages, mixed land uses, reduced parking requirements, and pedestrian-scale block sizes. Implement parking management strategies to reduce private vehicle dependency near transit nodes.

E. Inclusive and Gender-Sensitive Design

Develop Age-Friendly Walking Zones near residential areas with benches, shading, gentle gradients, and clear tactile guidance. Address gender safety disparities through active-frontage street design, well-lit surveilled pathways, women's safety help points, and accessible incident reporting systems. Introduce affordable shared mobility options including e-scooters and rental bicycles at mobility hubs. Prioritize NMT investment in lower-income areas where dependence on walking and public transport is highest.

IX. Discussion

The findings from the Kochi Metro corridor present a pattern consistent with NMT challenges documented in developing country cities globally. Walking serves as the backbone of first- and last-mile connectivity, yet the supporting infrastructure is inadequate, discontinuous, and unsafe, particularly for women and elderly users. The strong positive correlations between safety perceptions, walking comfort, and NMT frequency align with international evidence [9], [17] and confirm that NMT adoption is structurally constrained by planning failures rather than being purely a behavioral choice.

The gender disparity in night-time safety perceptions (24% of female respondents feeling unsafe vs. 9% of males) echoes findings from African and South Asian cities and reinforces the need for gender-responsive planning approaches. The finding that 92% of respondents expect improved walking infrastructure to positively impact public transport usage provides robust justification for NMT investment as a transit ridership-enhancement strategy.

Comparing Kochi with the case study cities, the Kochi Metro corridor offers a strong multimodal transit backbone that Copenhagen and Amsterdam took decades to develop. The challenge is not modal availability but the spatial quality of connections between modes, particularly the pedestrian and cycling environment. Lessons from Pune's institutional model suggest that similar arrangements are necessary for sustained NMT planning in Kochi. Study limitations include the sample size of 75, which may not fully capture the diverse travel behaviors along the 27.96 km corridor, and the primary focus on walking over cycling.

X. Conclusions

This study demonstrates that NMT plays a vital but under-supported role in multimodal urban mobility, with walking serving as the primary first- and last-mile connector for a significant proportion of Kochi Metro users. Quantitative analysis establishes strong positive relationships between walking frequency and perceived safety, comfort, and infrastructure quality, confirming that improved NMT environments directly translate to greater walking activity and higher public transport ridership.

The spatial planning recommendations proposed span pedestrian infrastructure design, safety enhancements, multimodal integration, land use planning, and inclusive design, drawing on international best practices while remaining contextually grounded in Indian urban governance realities. Implementation requires coordinated action across urban local bodies, metro authorities, transport departments, and planning agencies, guided by a dedicated NMT planning mechanism.

The study contributes to the evidence base on NMT-transit integration in Indian cities and offers a replicable analytical framework for other mid-sized Indian cities developing metro or BRT systems. Future research should include station-wise pedestrian demand-supply analysis, cycling infrastructure planning, and longitudinal assessment of NMT behavior change following infrastructure improvements.

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