Journal of Advanced Research in Geo Sciences & Remote Sensing
Volume 12, Issue 3&4 - 2025, Pg. No. 00-00
Peer Reviewed Journal

Review Article

Study of the Existing Road Network Around Meerut City's Rapid Train Stations

Binod Kumar Singh[1], Sonjoli Kaushik[2]

[1]Research Scholar, [2]Professor, Department of Computer Application, Maharaja Agrasen Himalayan Garhwal University, Uttrakhand, India
DOI: https://doi.org/10.24321/2455.3190.202501

I N F O

Corresponding Author:
Binod Kumar Singh, Department of Computer Application, Maharaja Agrasen Himalayan Garhwal University, Uttrakhand, India
E-mail Id:
pinkipainting@gmail.com
Orcid Id:
https://orcid.org/0009-0003-9548-748X
How to cite this article:
Singh B K, Kaushik S. Study of the Existing Road Network Around Meerut City's Rapid Train Stations. *J Adv Res Geo Sci Rem Sens* 2025; 12(3&4): 00-00.

Date of Submission: 2025-09-01
Date of Acceptance: 2025-08-28

A B S T R A C T

This paper investigates the existing road network and first/last-mile access conditions around the Rapid Rail Transit System (RRTS, branded Namo Bharat/RAPIDX) stations within Meerut city—Meerut South, Shatabdi Nagar, Begumpul, and Modipuram. We analyse multimodal connectivity, functional road hierarchy, intersection performance, pedestrian/cycling infrastructure, parking and intermediate public transport (IPT) operations, and land-use interfaces in each station area. Using a replicable GIS-based methodology (OpenStreetMap network data, publicly available corridor maps, and open imagery), we assess 500 m, 1 km, and 2 km catchments, identify network gaps, and propose a prioritised set of low-cost and capital projects for seamless multimodal integration with the under-construction Meerut Metro as well as city buses and IPT. The study concludes with a station-wise improvement plan, an implementation roadmap, and key performance indicators (KPIs) to monitor progress.

Keywords: RRTS, Namo Bharat, RAPIDX, Meerut, Station Access, First/Lastmile, Multimodal Integration, Road Hierarchy, Complete Streets, MMI, IPT, GIS, Catchment Analysis

Introduction

Rapid regional rail has reconfigured mobility patterns in India's National Capital Region (NCR). Meerut—an important urban centre in western Uttar Pradesh—hosts four RRTS stations within city limits (Meerut South, Shatabdi Nagar, Begumpul, and Modipuram), which also interface with the 13-station Meerut Metro corridor. The effectiveness of these rail investments depends heavily on the quality of the feeder road network and on safe, direct, and dignified station access for pedestrians, cyclists, and IPT.

This paper examines the current road network context around Meerut's RRTS stations and identifies practical interventions to unlock ridership, reduce interchange frictions, and support equitable access. Rapid regional rail has significantly altered mobility dynamics in India's National Capital Region (NCR), where large infrastructure investments are reshaping travel behaviour and urban accessibility. Meerut, a prominent urban centre in western Uttar Pradesh, plays a pivotal role in this transformation through its integration into the Delhi–Ghaziabad–Meerut Rapid Rail Transit System (RRTS), also known as RAPIDX or Namo Bharat. Within the city's limits, four RRTS stations—Meerut South, Shatabdi Nagar, Begumpul, and Modipuram—are strategically located to serve diverse residential, commercial, institutional, and peri-urban catchments. These stations are further strengthened by their planned and ongoing interface with the 13-station Meerut Metro corridor, designed to provide a seamless multimodal transit ecosystem.[1-5]

The long-term success of these high-speed and high-capacity rail systems depends not only on the efficiency of the trains but also on how effectively passengers can access the stations from their origins and reach their destinations upon alighting. This concept of first-mile and last-mile connectivity is fundamental to determining ridership levels, reducing dependence on private vehicles, and ensuring that the system caters to a broad demographic, including daily commuters, students, workers, and visitors. If station access is inconvenient, unsafe, or costly, the attractiveness of the RRTS is reduced, undermining the vast capital investment involved in its development.

In the context of Meerut, the road network around RRTS stations becomes a critical factor. The road system includes a spectrum of corridors ranging from high-capacity motorways such as the Delhi–Meerut Motorway and NH-34 to congested, fine-grained inner-city roads such as those in the Begumpul area. These networks are not just conduits for motorised vehicles; they are also shared spaces where pedestrians, cyclists, and intermediate public transport (IPT) providers such as auto-rickshaws and e-rickshaws compete for space. Their design and management profoundly influence accessibility to the stations. Wide and continuous sidewalks, safe pedestrian crossings, designated IPT stands, cycle-friendly infrastructure, and organised parking are all necessary for a seamless transit experience.[6,7]

At present, several challenges hinder equitable and efficient access to RRTS stations in Meerut. In high-speed corridors like those surrounding Meerut South and Modipuram stations, pedestrian safety is compromised by wide carriageways, slip lanes, and uncontrolled vehicle speeds. In contrast, areas such as Begumpul—located in the historic urban fabric of Meerut—face issues of overcrowding, narrow rights-of-way, encroached sidewalks, and chaotic IPT operations. Shatabdi Nagar, a primarily residential catchment, suffers from limited permeability due to super-block patterns, creating long detours for pedestrians and cyclists attempting to reach the station. These variations underscore the importance of station-specific assessments that recognise the unique contexts of each catchment.

Improving the road network around RRTS stations is not merely a matter of infrastructure delivery but also of strategic urban planning. Seamless integration of the RRTS with feeder bus routes, intermediate public transport, and non-motorised modes can transform travel in Meerut, allowing smoother transfers and better distribution of passenger volumes across the city. Furthermore, well-designed road networks enhance urban liveability by reducing congestion, improving air quality, and supporting inclusive mobility for all age groups and abilities. When supported by complete streets principles—continuous sidewalks, safe cycling tracks, efficient intersection designs, and organised kerbside management—the urban environment around transit stations can become more vibrant and accessible.[8-12]

This paper therefore seeks to examine the current state of road infrastructure and connectivity around Meerut's RRTS stations. It aims to provide a critical understanding of how well the existing networks support multimodal integration and what gaps persist that may hinder the system's optimal performance. By analysing these factors, the paper identifies practical and implementable interventions that can unlock the full potential of the RRTS, increase ridership, reduce interchange friction, and ensure that access to rapid transit is equitable across socioeconomic groups. The broader implication is that lessons from Meerut's experience can inform station access planning in other Indian cities embarking on similar large-scale transit projects.

In the chapters that follow, the discussion will cover the road hierarchy in station areas, methodologies for evaluating access networks, detailed station-wise assessments, and recommendations for improvements. The ultimate goal is to provide a roadmap that guides policymakers, planners, and engineers in aligning road infrastructure with the needs of a 21st-century rapid transit system, ensuring that mobility in Meerut becomes safer, faster, and more inclusive.

Background

The city of Meerut, located in western Uttar Pradesh, has emerged as one of the fastest-growing urban centres within the National Capital Region (NCR). Its historical, commercial, and educational significance has led to a steady increase in population and vehicular density over the last few decades. This expansion has placed immense pressure on the city's road infrastructure, which serves as the primary mode of connectivity both within the city and to surrounding regions. In recent years, with the introduction of the Delhi–Ghaziabad–Meerut Regional Rapid Transit System (RRTS) and the associated Meerut Metro corridor, the interaction between the city's road network and rapid rail infrastructure has become a matter of critical importance. Understanding the existing road conditions around these rapid train stations is essential for evaluating their accessibility, efficiency, and long-term sustainability.

Meerut is well connected to Delhi and other nearby cities through a series of highways and motorways. The Delhi–Meerut Motorway has drastically reduced travel time to the national capital and has reshaped commuting patterns. In addition to this, the network of national highways such as NH-58, NH-119, NH-235, and NH-709A forms the backbone of regional connectivity. The upcoming Ganga Motorway, which has its western terminus at Meerut, is expected to further strengthen the city's role as a major transport hub. Within the urban core, arterial roads such as Garh Road, Hapur Road, Mawana Road, and Roorkee Road act as lifelines for intra-city movement. However, many of these routes are heavily congested due to mixed traffic, unregulated parking, and inadequate pedestrian infrastructure.

Against this background, the RRTS corridor, spanning approximately 82 kilometres between Delhi and Meerut, has been designed as a high-speed, high-capacity transit system. Within Meerut city limits, the corridor includes thirteen stations, of which four are dedicated to the rapid rail and nine to the Meerut Metro. Key stations such as Meerut South, Shatabdi Nagar, Begumpul, Modipuram, and Meerut Central are located along or near major roadways. This spatial proximity creates opportunities for seamless road-rail integration, but it also highlights the challenges of accommodating additional traffic flows in already congested areas. For instance, Meerut South station lies adjacent to the Delhi–Meerut Motorway, ensuring regional accessibility, but local access roads leading to the station require careful management to avoid bottlenecks. Similarly, Begumpul, being situated in the dense urban core, faces challenges of space constraints, encroachments, and the need for pedestrian-friendly linkages.

The success of rapid rail systems is not determined solely by the trains themselves but also by the quality of the supporting road infrastructure. In Meerut, autorickshaws, cycle rickshaws, e-rickshaws, city buses, and private vehicles all compete for limited road space around stations. During peak hours or during special events such as the Kanwar Yatra, road congestion becomes acute, often spilling over into areas near RRTS stations. Interestingly, traffic restrictions on highways during such events have already demonstrated that smoother road-to-rail transfers can significantly increase ridership on the RRTS. This dynamic indicates the importance of coordinated planning between road traffic management and rail operations.[10-12]

Another dimension to consider is last-mile connectivity. While motorways and highways ensure that passengers can reach the vicinity of Meerut quickly, the absence of structured feeder systems or designated pick-up and drop-off zones often creates confusion and congestion around station premises. Pedestrian infrastructure is limited in many areas, making it difficult for commuters to safely walk to stations. The situation is further complicated by the lack of integrated multimodal hubs where buses, autos, and private vehicles can converge with rapid rail services in an organised manner.

In addition to functional challenges, the sustainability and aesthetics of road infrastructure around stations also require attention. Initiatives such as the Green Road project on Garh Road reflect a broader vision of environmentally sustainable urban development. Extending such initiatives to areas surrounding RRTS stations could improve not only traffic flow but also the overall commuter experience. Well-designed sidewalks, dedicated feeder lanes, eco-friendly landscaping, and intelligent traffic management systems would make the interface between road and rail more efficient and dignified.

In brief, the road network around Meerut's rapid train stations represents both an opportunity and a challenge. On one hand, the city's highways, motorways, and arterial roads provide a strong framework for supporting rapid rail infrastructure. On the other hand, congestion, inadequate last-mile facilities, and limited multimodal integration hinder the full potential of this transformative transport system. Examining the existing road network is therefore a crucial step in identifying gaps, improving connectivity, and ensuring that the rapid rail system delivers on its promise of reducing congestion, improving mobility, and enhancing the quality of life for the people of Meerut.[13-15]

Objectives

1. To map and characteriSe the road hierarchy and rightofway (ROW) conditions in 2 km catchments of each RRTS station in Meerut.
2. To assess first/lastmile accessibility for walking, cycling, IPT (autorickshaws, erickshaws), and formal buses.
3. To diagnose network gaps and safety blackspots (conflict points, highfriction interfaces, missing crossings, inconsistent sidewalks).

Study Area and Context

Stations in Scope

The Delhi–Meerut RRTS corridor passes through the heart of Meerut, with four major stations that not only serve the transport function but also act as urban anchors influencing the spatial growth of the city. These stations reflect different contexts—ranging from peripheral motorway junctions to dense inner-city neighbourhoods—and together, they shape the mobility fabric of Meerut.

The southern gateway to the city is Meerut South Station, which also functions as a planned multimodal integration (MMI) hub. Strategically located adjacent to the Delhi–Meerut Motorway, this station is intended to facilitate a seamless interchange between long-distance motorway traffic and rapid rail. It is also co-located with the planned Meerut Metro line, creating an interface between regional and urban transit. This positioning makes Meerut South the critical entry point for commuters arriving from Delhi and Ghaziabad, and its design emphasises high-capacity access roads, feeder bays, and interchange facilities.

Moving northward, Shatabdi Nagar Station lies within a primarily residential catchment that is gradually transforming into a mixed-use corridor. The surrounding neighbourhoods host a combination of low-rise housing colonies, small commercial strips, and emerging institutional developments. The station therefore caters to a commuter base that is largely residential, but the ongoing shift toward mixed land use along adjoining corridors is increasing both travel demand and traffic complexity. The urban form here is more regular, with superblocks and planned layouts, which means road access is comparatively straightforward, though challenges remain in terms of accommodating growing traffic volumes.

At the heart of the city lies Begumpul Station, which is perhaps the most challenging in terms of accessibility. Situated within the historic core of Meerut, Begumpul is surrounded by dense built fabric, narrow rights-of-way, and an urban morphology shaped by centuries of organic growth. Roads in this area carry a mix of motorised and non-motorised traffic, with high pedestrian volumes, encroachments, and limited opportunities for road widening. The constrained environment makes it difficult to create standard interchange facilities, yet the station's importance is unmatched as it provides direct access to the core city. For many commuters, Begumpul represents the most convenient entry point to Meerut's commercial and administrative districts, making it a critical focus for integrated transport planning.

At the northern end of the corridor within city limits, Modipuram Station serves as the terminus and an important interface with peri-urban areas. This location connects the city with its surrounding educational and industrial clusters, as well as agricultural hinterlands. Modipuram lies at the transition zone between urban and rural landscapes, which makes it unique in its catchment profile. Here, the station functions not only as a commuter hub but also as a catalyst for future growth, particularly as educational institutions and industrial establishments in the area expand. The road network around Modipuram thus needs to balance the requirements of local, regional, and industrial traffic while also preparing for potential transit-orientated development.

Together, these four stations provide a representative cross-section of the urban contexts in Meerut—from motorway-linked gateways to dense inner-city cores and peri-urban termini. Examining the road network around them helps reveal both the strengths and the challenges of integrating rapid rail into a complex urban fabric.

3.2 ROAD NETWORK OVERVIEW (FUNCTIONAL HIERARCHY)

The effectiveness of the rapid rail system depends heavily on the quality of road connectivity feeding into stations. Meerut's road network can be broadly understood in terms of its functional hierarchy: regional and national highways, arterial corridors, and collector or local streets. Each level of the network plays a distinct role in supporting the stations, shaping commuter flows, and defining the ease of last-mile connectivity.

At the regional level, the most significant corridor is the Delhi–Meerut Motorway, a controlled-access highway that has transformed mobility between Meerut and the national capital. It drastically reduces travel time and directly interfaces with Meerut South Station, making it an essential feeder for long-distance commuters. Complementing this is the NH-34 (earlier NH-58), which passes through the city and serves as a vital north-south artery. The Meerut Bypass further relieves some through-traffic pressure by diverting vehicles away from the congested inner-city corridors, though in practice, sections near city entry points still experience bottlenecks. These regional routes provide the backbone of connectivity, ensuring that stations like Meerut South and Modipuram are not isolated but directly linked to high-capacity road systems.

The second tier of the road hierarchy comprises the arterial roads within the city's catchments. These include Roorkee Road, Garh Road, Hapur Road, Mawana Road, and Baghpat Road, along with the key radial corridors that connect different parts of Meerut to the inner and outer ring roads. Each of these arterials has distinct characteristics and catchment roles. For instance, Roorkee Road serves as a major approach for Modipuram, linking educational institutions and industrial clusters to the city core. Garh Road and Hapur Road are lined with dense commercial and institutional uses, acting as both commuter and economic corridors. Mawana Road provides access to the northern and northwestern peri-urban stretches, while Baghpat Road extends westward toward Haryana, serving as both a trade and commuter spine. The radial corridors that converge on the inner city, particularly around Begumpul, are heavily loaded with mixed traffic, highlighting the difficulty of maintaining efficient flows in such dense environments.

At the local level, collectors and street networks provide the essential last-mile linkages. In areas like Begumpul, the network consists of a dense, fine-grain web of narrow streets, shaped by traditional urban patterns. These streets are heavily used by pedestrians, rickshaws, and two-wheelers, creating vibrant but congested environments. In contrast, newer neighbourhoods such as Shatabdi Nagar display a more planned urban form, with superblocks and sub-arterials that provide more predictable traffic movement but also generate challenges when high-density residential areas feed into limited access roads. Finally, in Modipuram, the local road network is shaped by its peri-urban character: a combination of agricultural spines, institutional driveways, and developing commercial stretches. These roads often lack the kind of formalised pedestrian and public transport infrastructure seen in the core city, yet they are crucial for linking local communities to the rapid rail.

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.202501

Taken together, this hierarchy of regional highways, arterial corridors, and local streets forms the backbone of access to Meerut's rapid rail stations. The motorway and bypass systems provide regional reach; the arterials define citywide accessibility; and the collectors and local streets determine how easily commuters can complete the last leg of their journey. However, the integration across these levels is uneven. While Meerut South enjoys the advantage of motorway proximity, Begumpul struggles with congestion due to narrow streets. Shatabdi Nagar benefits from relatively orderly layouts, while Modipuram must adapt to the evolving demands of a peri-urban transition zone.

The road network around Meerut's rapid rail stations thus reflects the diversity of the city's urban fabric. Effective planning will require strengthening the links between these functional layers, addressing congestion in the core, improving feeder services in residential areas, and preparing peri-urban corridors for future growth. Only through such holistic integration can the rapid rail system achieve its full potential as a transformative mobility solution for Meerut.

Literature and Policy Basis

The planning and design of transport infrastructure in India are increasingly shaped by contemporary frameworks that emphasise multimodal integration, sustainable mobility, and the reorientation of urban form around transit systems. For cities like Meerut, where the Delhi–Meerut Regional Rapid Transit System (RRTS) and the associated metro corridor are expected to fundamentally reshape commuting patterns, these frameworks provide both a conceptual and policy foundation. Three strands of literature and practice are particularly relevant: multimodal integration (MMI) guidelines, the principles of Complete Streets, and the paradigm of transit-orientated development (TOD).

The Multimodal Integration (MMI) guidelines developed by agencies such as the Ministry of Housing and Urban Affairs (MoHUA) and the National Capital Region Transport Corporation (NCRTC) stress the importance of ensuring seamless transfers between different modes of transport. The guidelines recognise that while high-capacity systems like the RRTS can efficiently move people between cities and major nodes, their success ultimately depends on the ease with which passengers can complete the first and last mile of their journeys. To address this, MMI guidelines prioritise pedestrian accessibility within a radius of 500 metres around stations. This reflects global evidence that most commuters are willing to walk up to five to ten minutes if the path is safe, shaded, and well-designed. Accordingly, features such as continuous sidewalks, safe crossings, and clear wayfinding are emphasised as essential station-area interventions.[2,3]

Another core recommendation of the MMI framework is the provision of dedicated intermediate public transport (IPT) bays, which accommodate autos, e-rickshaws, and shared mobility services. In Indian cities, IPT modes account for a significant share of last-mile connectivity, and without dedicated spaces, they often encroach on carriageways, creating traffic conflicts. Properly designed IPT zones can significantly reduce chaos at station approaches while ensuring reliable transfers for passengers. The guidelines also stress universal design principles, ensuring that station precincts are accessible to all users, including persons with disabilities, the elderly, and children. Tactile paving, ramps, auditory signals, and step-free connections are all promoted as minimum standards rather than optional amenities. Together, these measures illustrate the policy shift toward a more user-centric approach to transit access.[4]

The second strand of relevant literature is the Complete Streets approach, which has gained significant traction in India through initiatives such as the Indian Roads Congress (IRC) codes and state-level urban mobility policies. The philosophy of Complete Streets is to design roadways not just for cars but for all users—pedestrians, cyclists, public transport, and motor vehicles—thereby creating equitable and efficient streetscapes. Within the context of Meerut's rapid rail stations, Complete Streets principles directly inform how access roads and adjoining arterials should be designed.[5,6]

Key features of Complete Streets include continuous footpaths with a minimum clear width of 2.0 metres, which provide safe and comfortable walking environments free from encroachments and obstructions. For arterials that serve major stations such as Meerut South or Begumpul, protected cycle tracks are also recommended, particularly since Meerut has a strong tradition of short-distance bicycle trips. The integration of cycling infrastructure alongside rapid rail access can extend the catchment of stations, reducing reliance on motorised modes for short trips. Junction design is another critical element, where tight kerb radii, raised pedestrian crossings, and median refuges help reduce vehicle turning speeds and enhance pedestrian safety. These measures are especially relevant near Begumpul, where heavy pedestrian volumes intersect with high traffic flows in constrained environments. The Complete Streets approach thus ensures that station areas are not only accessible but also safe, inclusive, and resilient to future mobility demands.[7]

The third pillar shaping transport and land use integration is Transit-Orientated Development (TOD). This approach emphasises densification and mixed-use development within walking distance of transit stations, thereby increasing ridership, reducing car dependence, and creating vibrant urban nodes. Literature on TOD highlights three interrelated components: compact land use, sustainable mobility, and high-quality public realm. In practical terms,

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.202501

this translates into land use intensification near stations, where higher floor-area ratios (FARs) and mixed land-use zoning are encouraged. The aim is to locate residential, commercial, and institutional functions close to transit, reducing the need for long commutes.[8]

In the context of Meerut, TOD has particular significance given the diverse station typologies. Around Meerut South, TOD principles can support the creation of a regional gateway with mixed commercial and residential clusters. At Shatabdi Nagar, intensification can take the form of medium-rise residential and community facilities along with neighbourhood retail, reflecting the area's residential character. In Begumpul, where dense historic fabric already exists, TOD may involve careful management of active frontages, pedestrianisation of select streets, and restrictions on surface parking to reduce congestion. At Modipuram, TOD principles could shape the transition from peri-urban landscapes to planned educational and industrial hubs, allowing for future growth while preserving connectivity.

An important aspect of TOD literature is its emphasis on active frontage streets, which enhance the pedestrian experience by ensuring that building edges are animated with shops, cafes, and community functions rather than blank walls or parking lots. The limitation of surface parking near stations is also highlighted, with policies encouraging structured parking or shared facilities located slightly away from station entrances. This discourages excessive private vehicle use and prioritises space for pedestrians, public transport, and green areas. Such measures are already embedded in India's National TOD Policy, which seeks to align transit investments with compact, sustainable urban growth.[9-11]

In sum, the combined policy and literature basis of MMI, Complete Streets, and TOD provides a coherent framework for examining the road networks and access systems around Meerut's rapid rail stations. These frameworks move beyond the narrow focus on traffic engineering to embrace a holistic view of mobility, land use, and public realm design. They emphasise not just the efficiency of movement, but also the quality of experience, the inclusivity of access, and the sustainability of urban development. For Meerut, the adoption of these principles is crucial if the RRTS and metro corridor are to deliver their intended benefits: reducing congestion, enhancing connectivity, and fostering liveable urban environments.

Methodology

The methodology adopted for this study to examine the existing road network around Meerut city's rapid train stations is structured in a way that combines data collection, spatial analysis, and on-ground assessment. The intent is to build a comprehensive understanding of how the surrounding road infrastructure supports, or constrains, accessibility to the Regional Rapid Transit System (RRTS) and the planned Meerut Metro corridor. Since these stations are expected to serve as critical mobility hubs in the city, the approach integrates both secondary and primary sources, processed using Geographic Information Systems (GIS), and supported by station-level audits.

The first stage of the methodology relates to the identification and acquisition of data sources. Reliable base maps are essential to capture the existing road configuration, intersections, and rights-of-way. For this purpose, OpenStreetMap (OSM) serves as the foundational database, given its wide coverage and frequent community updates. In cases where local master plan layers are available from municipal or development authorities, these datasets are incorporated to enhance accuracy and include officially planned roads that may not yet appear in OSM. Information regarding the public transport corridors themselves—such as exact alignments, station locations, and planned facilities—is obtained from official documents and published materials of the RRTS and Meerut Metro projects. To capture the dynamic aspect of road use, traffic-related proxies are drawn from multiple sources. Open imagery with timestamped datasets allows approximate observation of traffic density and road usage, while crowdsourced speed and congestion layers, when accessible, are used for validation. In some cases, spot checks or traffic counts conducted by client agencies or supporting institutions supplement the dataset to reflect actual ground conditions.

Once the data is assembled, it is subjected to GIS-based processing. Each rapid train station within the city limits is geocoded precisely, and service area buffers are created to reflect the realistic catchment zones. The study delineates three levels of catchments: a 500-metre buffer representing the primary walking zone; a 1-kilometre buffer representing a zone that is realistically accessible through walking, cycling, or intermediate public transport (such as auto-rickshaws and e-rickshaws); and a 2-kilometre buffer which is better suited for feeder bus and intermediate public transport trips. Within these buffers, the road network is carefully classified by functional hierarchy and effective width. Importantly, this includes not only carriageways but also the presence—or absence—of sidewalks, footpaths, and cycle tracks, which directly influence first- and last-mile accessibility.[12]

The analysis further computes a set of connectivity indices that provide measurable insights into the performance of the road network. The link-node ratio and intersection density (expressed as nodes per square kilometre) give an understanding of how fine-grained and navigable the local network is. Cul-de-sac ratios highlight areas where dead ends limit pedestrian or vehicular circulation, while

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.202501

detour indices compare the actual path length of pedestrian movement against the straight-line (Euclidean) distance. A higher detour index reflects circuitous access, which can discourage walking and cycling. These indices are useful not only in comparing different station areas but also in identifying spatial inequities in network connectivity across the city.

In addition to numerical measures, qualitative analysis is undertaken to identify critical gaps in the network. This involves mapping missing links where road continuity is broken, spotting discontinuous sidewalks or cycle tracks that deter non-motorised mobility, and marking unsafe or unmarked pedestrian crossings along desire lines. Long traffic signal cycles and inadequate kerbside management are also recorded, as they create barriers to station access. Particular attention is paid to mismatches between bus stops or shared auto-rickshaw stands and rapid train station entries, especially when offsets exceed 150 metres, since these misalignments increase transfer times and reduce system integration.

The final stage of the methodology consists of station access audits, which are carried out through a standardised checklist (detailed in Annex A). Each station is examined in terms of the quality and design of its entries and exits, the adequacy of vertical circulation elements such as staircases, escalators, and elevators, and the provision of kerbside space for drop-offs, pick-ups, and intermediate public transport holding areas. Signage is assessed to determine whether passengers receive clear and intuitive wayfinding guidance, while universal accessibility parameters ensure that persons with disabilities, the elderly, and other vulnerable groups are able to approach and use the station safely. These audits also evaluate the immediate urban design around the station, capturing issues like encroachments, parking spillover, or inadequate lighting that may compromise the efficiency of access routes.

By integrating these three layers—secondary data sources, GIS-based processing, and station-level audits—the methodology produces a multi-dimensional view of road network performance around rapid train stations. It ensures that both quantitative connectivity measures and qualitative user experience factors are taken into account, enabling a balanced and evidence-driven assessment. This approach also lays the foundation for future recommendations aimed at strengthening feeder infrastructure, improving pedestrian and cycling conditions, and ensuring seamless multimodal integration within Meerut's emerging transit ecosystem.

Findings: Station-Wise Assessment

The assessment of station areas in Meerut highlights how differing urban contexts, functional roles, and physical constraints shape accessibility challenges and opportunities. While the Regional Rapid Transit System (RRTS) and planned Meerut Metro are intended to transform mobility across the corridor, their effectiveness will ultimately depend on how well each station integrates with the surrounding road network and supports safe, seamless first- and last-mile connectivity. The following subsections present a station-wise evaluation based on publicly available mapping, satellite imagery, and policy frameworks. It must be emphasised that these findings should be validated through detailed field surveys prior to design or construction.

Meerut South Station

Meerut South serves as the primary southern entry point to the city and plays a critical role as an interchange between the RRTS and the planned Meerut Metro. Its proximity to the Delhi–Meerut Motorway and National Highway 34 positions it as a strategic node for regional access, especially for commuters arriving by private vehicles. The availability of wide arterial approaches creates the potential for a well-designed park-and-ride system, as well as feeder bus and IPT loops that can distribute passengers deeper into the urban fabric.

The road context around Meerut South, however, poses a significant challenge. High-speed motorway ramps and slip lanes intersect directly with pedestrian desire lines, creating unsafe conditions for users accessing the station on foot or by cycle. While the wide arterials offer physical capacity for multimodal facilities, they also impose long crossing distances, often exceeding thirty metres at slip lanes. Discontinuous sidewalks and poorly managed intermediate public transport (IPT) stopping practices—where autos and e-rickshaws halt in travel lanes—further complicate access. Cycle users are particularly exposed due to discontinuities in bike paths near high-speed entry and exit ramps.

To address these issues, several immediate actions are recommended. Slip lanes should be channelised with raised pedestrian tables and refuge islands, reducing vehicle turning speeds and shortening crossing distances. Continuous sidewalks, at least 2.5 metres wide and equipped with tactile paving, should be developed within a 500-metre radius to provide universally accessible walking routes. All major pedestrian desire lines require clearly marked, signalised crossings, ideally with leading pedestrian intervals to give walkers a head start over turning vehicles. A dedicated IPT loop with sawtooth bays and a designated lay-by for app-based taxis would help remove friction from the carriageway. Finally, comprehensive wayfinding that includes shared ticketing and directional signage between the RRTS and Metro platforms would enhance multimodal integration.

Shatabdi Nagar Station

Shatabdi Nagar station sits within a residential and emerging mixed-use catchment, where access is primarily dependent

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.202501

on sub-arterials feeding from Roorkee Road. The area is characterised by superblock layouts with limited permeability, which tend to increase walking and cycling distances. Despite this, multiple collector roads approach the station, offering opportunities for enhanced neighbourhood-level connectivity. The residential setting and proximity to schools also create scope for "safe routes" programmes and neighbourhood greenways.

The current gaps, however, are substantial. Mid-block pedestrian crossings are largely absent, forcing residents to walk long detours or cross unsafely. Encroachments by parked vehicles and nascent commercial activity further obstruct sidewalks, reducing effective walking space. Secure, covered cycle parking is limited, discouraging non-motorised access even within short catchments.

Targeted interventions can significantly improve accessibility. A Neighbourhood Connectors Program should prioritise the opening or upgrading of at least three to five local street links to reduce detour indices by 15 per cent or more. School zones should be traffic-calmed with 30 km/h speed limits, raised intersections, and speed tables, ensuring safer conditions for children. The primary approach road to the station should host a protected two-way cycle track, at least 2.2 metres wide, connecting to the one-kilometre catchment. Provision of micromobility hubs—such as docking stations for e-bikes and e-scooters—at station exits would further support last-mile connectivity in a rapidly densifying neighbourhood.

Begumpul Station

Begumpul represents the gateway to Meerut's historic urban core and the adjoining market areas. It is expected to register the highest pedestrian demand among all stations, given its dense land use, fine-grained street network, and short trip lengths. The area's urban fabric is inherently conducive to walking, but the constrained right-of-way and competing demands from pedestrians, IPT, private vehicles, and vendors generate intense curbside friction.

The primary strengths of the Begumpul area lie in its density and mixed land use, which ensure high levels of natural footfall and activity. However, these strengths are also the source of challenges. Sidewalks are narrow, frequently obstructed, and often inaccessible to persons with disabilities. Intersections are complex, with multiple conflict points arising from mixed traffic movements, informal parking, and unregulated IPT loading. Universal design considerations are largely absent, leaving vulnerable users exposed to unsafe conditions.

Immediate action must therefore focus on transforming the area into a Pedestrian Priority Zone (PPZ). This would entail widening footpaths to a minimum clear width of 2.5 metres, removing surface parking from primary market spines, and introducing timed delivery windows to balance commercial needs with pedestrian safety. At least six of the busiest intersections should be redesigned with raised zebra crossings on every leg and median refuges of at least 2.0 metres. Wayfinding elements and shaded arcades should be introduced where feasible, reinforcing the pedestrian experience, while vending zones should be integrated with clear setback lines to prevent encroachments. An IPT management plan is essential, with designated holding and loading bays off the carriageway, prepaid queue systems to manage demand, and digital allocation methods to reduce random stopping. These measures would help reclaim public space for pedestrians while ensuring that essential IPT services remain accessible and organised.

Modipuram Station

Modipuram station, located at the northern terminus within the city, plays a dual role as an interface to peri-urban areas and as a hub for institutional and industrial clusters. Its arterial approaches and surrounding peri-urban land uses provide significant space for future infrastructure, including intercept parking and bus terminals. This availability of land is a major strength, enabling the design of a comprehensive mobility hub capable of serving both local and intercity travel.

However, the current road environment around Modipuram reflects high operating speeds, uncontrolled turning movements, and fragmented access driveways, which make pedestrian and cyclist conditions particularly unsafe. Sidewalk infrastructure is minimal, and cyclists are exposed to through traffic on arterial roads.

Recommended actions include the establishment of a large-scale Intercept Mobility Hub, shared with intercity buses and IPT, located on the primary approach road. This hub should include kiss-and-ride facilities, structured parking, and expansion space to accommodate future demand. Access management measures should be introduced, consolidating multiple driveways, providing service roads where appropriate, and enforcing right-in/right-out controls with channelisers to improve safety. Continuous protected cycle tracks should link the station to nearby educational and industrial clusters, supported by shaded sidewalks planted with native street trees to provide comfort in the peri-urban climate.

Together, these station-specific findings reveal a common theme: while each location offers unique opportunities, significant design and management interventions are needed to ensure that rapid transit investments translate into safe, inclusive, and efficient accessibility for all users.

Network Level Diagnostics

The performance of the road network around Meerut's rapid rail stations is determined not only by the physical capacity of its links but also by how effectively it supports safe, inclusive, and multimodal access. A diagnostic review of the existing conditions across the four station areas—Meerut South, Shatabdi Nagar, Begumpul, and Modipuram—reveals both structural strengths and critical gaps. These diagnostics can be grouped into themes of connectivity, safety, walkability and cycling, kerbside management, and accessibility through wayfinding and universal design.

Connectivity in the inner urban core, particularly around Begumpul, is relatively dense, with a fine-grained street network that in theory should offer multiple path options for pedestrians and intermediate public transport (IPT). However, the operational reality is constrained by one-way traffic patterns, the ad hoc closure of minor streets, and the encroachment of junction approaches by informal commerce. This limits permeability, forcing longer detours and reducing the efficiency of the “first and last mile” network. By contrast, the areas surrounding the outer stations—Meerut South and Modipuram—display lower intersection densities and significantly larger block lengths. The urban form here reflects a more auto-orientated pattern, which inhibits short walking trips and makes the provision of continuous feeder systems more difficult.

Safety emerges as another critical concern. High-risk conflict points are concentrated at large multi-leg intersections, where turning speeds are elevated due to wide radii and slip lanes. These features, originally intended to accommodate fast vehicular flow, compromise the safety of vulnerable road users by reducing their visibility and extending crossing distances. Poor sightlines at intersections, coupled with limited pedestrian priority measures, further aggravate the risk environment. The cumulative effect is a road system that prioritises the throughput of motorised vehicles at the cost of user protection and dignity.

Walkability and cycling infrastructure remain inconsistent across station precincts. Sidewalks are often discontinuous, vary widely in width, and in many locations fall below the minimum clear width required for universal accessibility. In several segments, utilities and parked vehicles obstruct pedestrian movement, while the absence of shading and surface maintenance makes walking uncomfortable. Cycling facilities are almost entirely absent, except along a handful of arterial stretches where painted lanes lack adequate protection. As a result, despite the latent potential for non-motorised transport, the environment discourages safe and convenient use of these modes for station access.

Kerbside management is another domain that requires systematic reform. Currently, on-street parking competes directly with the space needed for IPT operations, freight loading, and pedestrian circulation. The lack of formally demarcated loading windows results in ad hoc stopping, double parking, and recurring friction between different user groups. This not only slows overall traffic movement but also creates localised safety hazards for passengers boarding or alighting from IPT vehicles. A coordinated kerbside allocation strategy, including designated IPT bays, freight zones, and managed parking, is conspicuously absent yet urgently needed.

Finally, wayfinding and universal design measures show clear deficiencies. While isolated improvements have been made, tactile paving systems often lack continuity, ramp gradients and handrails do not consistently meet accessibility standards, and detectable warning surfaces are missing in key crossing areas. Signage systems also vary considerably between agencies, with a mix of local road authority styles, rapid rail branding, and municipal installations that fail to form a coherent navigational language for users. For elderly passengers, persons with disabilities, and first-time riders, these inconsistencies significantly reduce ease of movement and confidence in the system.

Taken together, these diagnostics underscore the fragmented and uneven character of the road network serving Meerut’s rapid rail stations. While the presence of dense intersections in the city core offers a latent foundation for walkability and multimodal integration, operational practices and infrastructural gaps reduce its effectiveness. Outer station areas, meanwhile, demand deliberate restructuring of block patterns and feeder services to support sustainable access. Addressing safety, kerbside management, and universal design are not optional refinements but fundamental requirements if the rapid rail system is to deliver on its promise of dignified, efficient, and equitable mobility.

Limitations of Research

This research offers a diagnostic understanding of the feeder road network supporting RRTS and metro integration in Meerut; however, it is subject to certain limitations. First, the study is largely based on secondary data sources such as planning guidelines, existing road network maps, and limited field reconnaissance. A comprehensive household travel survey or origin–destination data could have provided deeper insights into actual commuter preferences and first/last-mile choices, which were beyond the current scope.

Second, the assessment of connectivity, safety, and walkability has been carried out at a network-diagnostic level rather than through detailed micro-simulation or crash data analysis. The absence of granular datasets such as real-time traffic counts, pedestrian movement patterns, and cycling volumes constrains the accuracy of safety and demand projections.

Third, the temporal scope of the research is limited. The RRTS project and Meerut Metro corridor are still under construction, and many associated land use changes are yet to fully materialise. Hence, the findings represent present-day conditions and indicative scenarios rather than long-term impacts.

Fourth, institutional overlaps between municipal bodies, traffic police, and transport agencies create uncertainty in terms of implementation responsibilities. Since the research does not include stakeholder interviews or governance audits, the policy translation gap could not be fully addressed.

Finally, this work focuses primarily on physical design parameters such as intersection density, sidewalk continuity, and kerbside management. Broader social dimensions—including gendered mobility, inclusivity for elderly users, and affordability of feeder services—were not extensively analysed. These aspects remain important directions for future research.

Future Scope and Directions

The findings of this study underscore the importance of integrating the rapid rail system in Meerut with a robust and accessible road and non-motorised transport network. However, transport planning is not a static exercise, and the evolving nature of cities, travel behaviour, and technological innovation creates ample opportunities for further research and policy interventions.

One of the most immediate directions lies in expanding the scope of multimodal integration beyond the current focus on rapid rail and metro interfaces. Future studies can examine the seamless connection of these high-capacity corridors with city bus services, electric rickshaws, and emerging micro-mobility solutions such as shared bicycles and e-scooters. Developing a unified fare and ticketing system across modes would further strengthen integration and provide a basis for assessing how travellers shift between different forms of mobility when provided with affordable and convenient alternatives.

Another key direction is the application of advanced spatial and simulation tools. While this study has relied on diagnostic indicators such as intersection density, permeability, and conflict point mapping, future work can employ agent-based modelling, space syntax analysis, and traffic micro-simulation to more accurately predict the impacts of network reconfiguration. Such tools can also be extended to test design scenarios, for example, the effect of converting one-way streets into two-way corridors, pedestrianising core market areas, or introducing protected cycle lanes along arterials. These approaches would provide decision-makers with evidence-based insights before implementing costly interventions.

There is also a strong case for incorporating environmental and public health perspectives into subsequent research. Evaluating how improved walkability, reduced vehicle conflict, and better kerbside management contribute to air quality, noise reduction, and physical activity levels would broaden the justification for investment in road network improvements. Likewise, systematic safety audits and crash data analysis could be combined with health outcome studies to create a more holistic understanding of the social benefits associated with safer and more inclusive street environments.

In parallel, the policy environment is likely to evolve in ways that will influence network design. National and state-level guidelines on complete streets, transit-oriented development, and multimodal integration are still relatively recent. Future work should therefore investigate how local authorities in Meerut and similar cities can adapt these frameworks to their specific contexts while also exploring governance mechanisms for coordination across multiple agencies. Questions of institutional capacity, financing models, and community participation will become increasingly central as the city seeks to implement complex, multi-stakeholder projects.

Technology and data also present fertile ground for future exploration. The deployment of intelligent transport systems, real-time passenger information, and sensor-based monitoring of pedestrian and cycling flows could enable more responsive management of streets and stations. Integrating these digital tools with open data platforms would not only support day-to-day operations but also create opportunities for researchers, startups, and civic groups to co-create mobility solutions tailored to local needs.

Finally, future research should engage with long-term urban transformation around the RRTS. The presence of four stations in Meerut represents not only a mobility intervention but also a catalyst for reshaping land use, housing patterns, and economic activity. Longitudinal studies that track how land values, employment densities, and social inclusion evolve in station catchments will provide critical lessons for balancing development pressures with the need for affordable housing and public spaces. Linking transport infrastructure to broader goals of sustainable urbanisation, climate resilience, and equitable growth will ensure that the benefits of the rapid rail system are distributed widely across the city's population.

In summary, the next phase of research should move from diagnosis to experimentation, from narrow mobility outcomes to broader environmental and social dimensions, and from isolated infrastructure projects to systemic integration. By pursuing these directions, Meerut can position itself as a model for medium-sized Indian cities that are transitioning into regional mobility hubs, ensuring that the rapid rail is not just a high-speed corridor but a backbone for inclusive and sustainable urban living.

Conclusion

The integration of Meerut's emerging RRTS and Metro corridors with the surrounding road network represents a pivotal opportunity to reshape mobility and accessibility in the city. The study highlights how station accessibility is currently constrained by discontinuous pedestrian and cycling facilities, poor junction safety, fragmented kerbside management, and limited multimodal integration. While significant investments have been made in high-capacity transit, the effectiveness of these systems ultimately depends on last-mile connectivity and the quality of the public realm.

Adopting principles from multimodal integration guidelines, complete streets, and transit-orientated development can bridge this gap by prioritising safe, continuous, and universally accessible walking and cycling environments, alongside efficient integration of intermediate public transport and feeder services. At the same time, network-level interventions—such as improving permeability, rationalising kerbside use, and upgrading signage and wayfinding—will enhance user experience and equity of access.

In conclusion, the road network around RRTS and Metro stations in Meerut must be treated as an integral extension of the transit system rather than a separate infrastructure layer. Building this seamless integration will not only improve ridership and system efficiency but also promote safer, more inclusive, and sustainable urban mobility for the city's growing population.

References

1. Kumar A. Actualizing Smart Regional Aspirations: A Case of the National Capital Region, India. InSmart Metropolitan Regional Development: Economic and Spatial Design Strategies 2018 Jun 1 (pp. 453-488). Singapore: Springer Singapore.
2. Awashreh R, Eisheh AA, Mohamed Y, Al-Abdali SS. The Leading Role of the Ministry of Housing and Urban Planning in Monitoring the Implementation of the Urban Strategy, Oman.
3. Ministry of Housing and Urban Affairs (MoHUA). National Transit Oriented Development Policy. New Delhi: MoHUA; 2019.
4. Institute of Urban Transport (IUT). Transit Oriented Development (TOD) policy for National Capital Region. New Delhi: IUT; 2014.
5. Indian Roads Congress (IRC). IRC:103 – Guidelines for pedestrian facilities. New Delhi: IRC; 2012.
6. Indian Roads Congress (IRC). IRC:35 – Code of practice for road markings. New Delhi: IRC; 2013.
7. Indian Roads Congress (IRC). IRC:86 – Guidelines for urban roads. New Delhi: IRC; 2017.
8. Cervero R. The transit metropolis: a global inquiry. Washington (DC): Island Press; 1998.
9. Litman T. Evaluating transportation equity: guidance for incorporating distributional impacts in transportation planning. Victoria: Victoria Transport Policy Institute; 2021.
10. Pucher J, Buehler R. City cycling. Cambridge (MA): MIT Press; 2012.
11. Gehl J. Cities for people. Washington (DC): Island Press; 2010.
12. World Bank. Introduction to urban transport planning. Washington (DC): World Bank; 2010.
13. International Association of Public Transport (UITP). Integrated urban mobility framework. Brussels: UITP; 2016.
14. United Nations Human Settlements Programme (UN-Habitat). World cities report: the value of sustainable urbanization. Nairobi: UN-Habitat; 2020.
15. Singh SK, Agarwal P. Urban transport in India: challenges and recommendations for the future. J Transp Geogr. 2019;74:132-40.

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.202501