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Integration of Transport Planning in the Urban Fringes of South-East BDPA

Bhagyeswari Patra
School of Infrastructure and Planning
Odisha University of Technology and Research,
Bhubaneswar, India

Mr. Santosh Kumar
School of Infrastructure and Planning
Odisha University of Technology and Research,
Bhubaneswar, India

Dr. Piyush Ranjan Rout
School of Infrastructure and Planning
Odisha University of Technology and Research,
Bhubaneswar, India

Abstract **- Rapid peri-urban expansion in Indian metropolitan regions has intensified mobility challenges within fringe territories where transport infrastructure development frequently lags behind spatial growth and land use transformation. The South-East Bhubaneswar Development Plan Area (BDPA) represents one such rapidly transforming peri-urban corridor characterized by dispersed settlement structures, corridor-oriented development, increasing commuter dependency, and fragmented mobility systems. This study examines the existing transport structure, multimodal accessibility conditions, non-motorized transport (NMT) infrastructure, and land use–transport interaction across Balianta, Balipatna, Pratapsasan, Balakati, and Kantapada within the South-East BDPA region.**

The study adopts an integrated transport planning framework combining primary mobility surveys, field-based infrastructure audits, corridor assessment, accessibility analysis, transport hierarchy evaluation, and spatial interpretation. The analytical framework evaluates modal dependency, public transport accessibility, last-mile connectivity, road hierarchy efficiency, travel behavior, and transport-linked spatial growth patterns within the peri-urban mobility system.

The findings reveal a predominantly mono-centric commuting structure, with nearly 70% of daily movement directed toward Bhubaneswar for employment, education, and service access. Approximately 60% of commuters experience travel durations between 30–60 minutes, while nearly 63% travel more than 500 m to access formal public transport services, indicating substantial last-mile accessibility gaps. Public transport systems remain characterized by moderate-to-low service frequency (75%), weak feeder integration, and limited penetration into peripheral settlements, thereby increasing dependence on private two-wheelers and intermediate public transport systems. The study additionally identifies excessive dependence on NH-316 and associated radial corridors, fragmented east–west connectivity, inadequate pedestrian and cycling infrastructure, ribbon development pressure, and growing transport–land use conflicts across emerging fringe corridors.

The study proposes an integrated transport planning framework emphasizing multimodal mobility integration, complete streets, feeder transit systems, transit-oriented development (TOD), climate-responsive mobility infrastructure, rural–urban accessibility enhancement, and transport-linked land use regulation. Strategic interventions including mobility hubs, complete street redesign, non-motorized transport corridors, east–west connector systems, smart mobility infrastructure, and TOD-based growth management are proposed to improve accessibility, reduce congestion, strengthen multimodal integration, and support sustainable peri-urban mobility systems.

The study contributes toward emerging planning discourse concerning peri-urban mobility, transport–land use integration, sustainable transport systems, and climate-responsive urban development within rapidly urbanizing metropolitan fringe regions of the Global South.

Keywords **-** ***Peri-Urban Mobility; Integrated Transport Planning; Multimodal Accessibility; Sustainable Transport; Transit-Oriented Development; Non-Motorized Transport; Bhubaneswar***

I. INTRODUCTION

The increasing expansion of metropolitan regions into peri-urban territories has generated complex mobility challenges associated with fragmented transport systems, accessibility imbalance, corridor-oriented growth, and inadequate infrastructure integration. Rapid transformation of fringe settlements into urban growth corridors has intensified dependence on regional transport networks while simultaneously increasing pressure on public transport systems, non-motorized mobility, and last-mile connectivity. In response to these emerging challenges, integrated transport planning has become essential for developing sustainable, accessible, and climate-responsive mobility systems capable of supporting balanced peri-urban development. The following sections discuss the emerging mobility dynamics within rapidly urbanizing fringe regions, the significance of sustainable and multimodal transport planning, the existing transport planning gaps within the South-East BDPA region, and the research gaps addressed through the present study.

A. Peri-Urbanization and Emerging Mobility Challenges

Rapid urbanization across Indian metropolitan regions has significantly transformed peri-urban landscapes into dynamic transition zones characterized by changing land use patterns, increasing commuter dependency, and expanding mobility demand. Urban fringe areas increasingly function as interfaces

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between urban and rural systems where residential expansion, institutional growth, transportation corridors, and mixed land use transformation collectively generate new mobility pressures. However, transportation infrastructure development within these rapidly transforming fringe regions frequently fails to progress at the same pace as urban growth, resulting in fragmented transport systems, accessibility inequities, and inefficient mobility structures.

In rapidly expanding metropolitan regions such as Bhubaneswar, peri-urban settlements are increasingly integrated into the broader urban economy through daily commuting networks associated with employment, education, trade, and service accessibility. Consequently, fringe mobility systems are becoming increasingly corridor-dependent and motorized, particularly within regions where public transport penetration and non-motorized infrastructure remain weak. Simultaneously, unregulated ribbon development, dispersed settlement expansion, and transport-induced sprawl continue to intensify pressure on existing road networks and regional mobility corridors.

The growing dependence on private two-wheelers and informal intermediate public transport systems further reflects the inability of conventional transport planning systems to adequately address peri-urban accessibility requirements. In many Indian fringe regions, transport systems remain structurally fragmented due to weak multimodal integration, poor feeder connectivity, inadequate pedestrian infrastructure, and limited transport–land use coordination. These conditions collectively contribute toward congestion, safety risks, environmental degradation, and accessibility imbalance within rapidly urbanizing metropolitan peripheries.

B. Sustainable Mobility and Integrated Transport Planning

Contemporary transport planning discourse increasingly emphasizes sustainable mobility approaches capable of integrating accessibility, environmental sustainability, multimodal systems, and equitable mobility within urban development frameworks. Sustainable transport systems prioritize accessibility rather than merely vehicular movement and promote integrated mobility structures involving public transport, non-motorized transport (NMT), feeder systems, and climate-responsive infrastructure.

Integrated transport planning further recognizes the importance of coordinating land use patterns, transport corridors, settlement growth, and mobility systems in order to reduce travel demand, improve accessibility efficiency, and strengthen multimodal integration. Concepts such as Transit-Oriented Development (TOD), Complete Streets, walkability planning, active mobility systems, and mobility hierarchy frameworks increasingly influence contemporary approaches toward sustainable urban and peri-urban transport development.

Non-motorized transport systems additionally play a critical role within peri-urban environments where a substantial proportion of trips remain short-distance and locally oriented. Walking and cycling therefore function as essential mobility components within fringe regions, particularly for low-income populations, students, vendors, and local commuters. However, existing transport planning frameworks within rapidly urbanizing Indian cities continue to prioritize highway expansion and vehicular traffic movement while inadequately addressing pedestrian accessibility, cycling infrastructure, and inclusive mobility systems.

C. South-East BDPA Context and Transport Planning Gaps

The South-East Bhubaneswar Development Plan Area (BDPA) represents one of the most rapidly transforming peri-urban growth corridors within the Bhubaneswar metropolitan region. The settlements of Balianta, Balipatna, Pratapsasan, Balakati, and Kantapada collectively form the eastern urban fringe zone characterized by increasing residential growth, commercial activity, peri-urban transformation, and strong commuter dependency on Bhubaneswar.

The regional transport structure is primarily organized around NH-316 and associated radial corridors connecting fringe settlements with the metropolitan core. While regional accessibility toward Bhubaneswar remains relatively strong, internal connectivity between settlements remains fragmented due to discontinuous road hierarchy, weak east–west linkage systems, and inadequate feeder mobility infrastructure. Pedestrian and cycling facilities remain severely deficient despite substantial short-distance travel demand and relatively suitable conditions for active mobility systems within several semi-urban stretches.

Public transport accessibility additionally remains corridor-dependent with limited service penetration into peripheral settlements. Consequently, users frequently rely on private two-wheelers, shared mobility systems, and informal transport networks to access employment centers, educational institutions, and urban services. Simultaneously, ribbon development along major corridors and unregulated roadside expansion have intensified transport–land use conflicts, congestion pressure, parking inefficiencies, and operational safety risks.

Despite increasing mobility pressure within the South-East BDPA region, limited research has examined integrated transport planning, multimodal accessibility, and sustainable mobility restructuring within the peri-urban fringe areas of Bhubaneswar. Existing planning approaches continue to focus primarily on highway-oriented development while providing limited emphasis on multimodal systems, accessibility equity, and transport-linked spatial planning within rapidly transforming fringe territories.

D. Research Gap

Existing literature extensively discusses sustainable urban mobility, Transit-Oriented Development (TOD), multimodal accessibility, and non-motorized transport systems within metropolitan environments. However, limited studies specifically examine integrated transport planning within rapidly urbanizing peri-urban corridors where fragmented settlement structures, transport-induced sprawl, and corridor-oriented urbanization significantly influence mobility conditions.

The South-East BDPA region therefore represents an important case for examining how integrated transport planning frameworks can improve accessibility, strengthen multimodal systems, and support sustainable peri-urban mobility development within rapidly urbanizing Indian metropolitan regions.

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E. Aim and Objectives

The study aims to evaluate the existing mobility structure and transport infrastructure conditions within the urban fringes of South-East BDPA and develop an integrated transport planning framework for sustainable and accessible peri-urban mobility development.

The objectives of the study include:

- To examine the existing transport infrastructure and mobility conditions within South-East BDPA.
- To assess multimodal accessibility, transport hierarchy efficiency, and last-mile connectivity gaps across the study area.
- To analyze transport–land use interaction, commuter dependency patterns, and mobility behavior within rapidly urbanizing fringe settlements.
- To develop an integrated transport planning framework emphasizing sustainable mobility, multimodal integration, and transport-linked spatial development.

II. LITERATURE REVIEW

The literature on sustainable mobility and integrated transport planning increasingly emphasizes the importance of multimodal accessibility, transport–land use coordination, non-motorized mobility systems, and inclusive infrastructure within rapidly urbanizing metropolitan regions. Contemporary research recognizes that peri-urban fringe areas experience unique mobility challenges associated with fragmented transport networks, corridor-oriented urbanization, weak last-mile connectivity, and increasing dependence on private motorized transport. Existing studies further highlight the significance of Transit-Oriented Development (TOD), Complete Streets, and accessibility-oriented planning approaches in improving mobility efficiency and reducing transport inequity within emerging urban growth corridors. The following sections review the major theoretical concepts, empirical studies, and planning approaches related to sustainable transport systems, peri-urban mobility, and integrated transport planning relevant to the South-East BDPA region.

A. Sustainable Urban Mobility and Integrated Transport Systems

The concept of sustainable urban mobility has emerged as a central component of contemporary urban and regional planning discourse, particularly in rapidly urbanizing metropolitan regions experiencing increasing congestion, environmental degradation, and accessibility inequality. Sustainable mobility frameworks emphasize the movement of people rather than vehicles and promote transport systems that are accessible, efficient, environmentally responsive, socially inclusive, and economically sustainable. Contemporary transport planning approaches therefore increasingly prioritize multimodal accessibility, public transport integration, non-motorized mobility systems, and transport-linked spatial development.

TABLE I. **EMPIRICAL LITERATURE STUDY**

Author / Year	Journal / Source	Methodology	Tools & Techniques	Parameters Identified	Key Findings	Relevance to Present Study
Panda & Behera (2022)	Journal of Transport Geography	Spatial analysis	GIS mapping, accessibility index	Connectivity, transit access, fringe expansion	Identified weak last-mile connectivity and fragmented networks in fringe zones	Direct local evidence for transport integration gaps in South East BDPA
Mohanty et al. (2021)	Urban India Journal	Mixed-method	GIS + household surveys	Land use mix, trip length, modal share	Urban sprawl leads to longer trips and increased dependence on private vehicles	Highlights need for integrated land use–transport planning in BDPA
ITDP (2023)	Sustainable Mobility Report	Policy + data analysis	GTFS data, route mapping	Modal share, accessibility, last-mile connectivity	Strong transit systems fail in fringe areas due to poor integration	Supports need for multimodal integration in peri-urban BDPA
UN-Habitat (2020)	Global Urban Mobility Report	Comparative analysis	Policy review, spatial indicators	Accessibility, equity, mobility patterns	Peripheral areas globally face poor accessibility and transport exclusion	Provides global validation of fringe transport challenges
Cervero (2013)	Transport Policy Journal	Empirical analysis	Land use–transport modeling	Density, accessibility, transit proximity	Integrated TOD improves accessibility and reduces travel demand	Offers strategic framework for integrating transport and land use in BDPA fringe

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Peter Newman and Jeffrey Kenworthy significantly contributed toward the conceptualization of sustainable urban mobility by emphasizing the relationship between automobile dependency, urban form, and transport efficiency. Their work highlights the importance of compact urban development, public transport prioritization, and non-motorized transport systems in reducing automobile dependence and improving mobility sustainability. Similarly, sustainable transport frameworks proposed by UN-Habitat advocate a mobility hierarchy prioritizing pedestrians, cyclists, and public transport over private motorized vehicles in order to create equitable and resilient urban mobility systems.

Integrated transport planning further emphasizes the coordination of transportation systems with land use planning, regional development, and settlement structure. The framework recognizes that transportation infrastructure significantly influences urban expansion patterns, accessibility conditions, and spatial growth dynamics. Consequently, effective mobility systems require coordinated planning approaches capable of integrating transportation corridors, land use structures, economic activity zones, and residential development patterns within rapidly urbanizing metropolitan regions.

B. Transit-Oriented Development and Transport–Land Use Integration

Transit-Oriented Development (TOD) has emerged as one of the most influential frameworks within sustainable mobility planning. Peter Calthorpe conceptualized TOD as a planning approach integrating compact mixed-use development with high-quality public transport systems in order to reduce travel demand and improve accessibility efficiency. TOD promotes walkable urban environments, multimodal integration, higher-density development around transit corridors, and reduced dependency on private motorized transport.

The relationship between transport systems and land use patterns is particularly significant within peri-urban regions where urban expansion frequently occurs along transportation corridors. Unregulated ribbon development, corridor-oriented urbanization, and dispersed settlement growth often intensify travel distances, congestion pressure, and infrastructure inefficiency. Integrated transport–land use planning therefore becomes essential for controlling transport-induced sprawl and improving regional accessibility structures.

Existing studies indicate that peri-urban fringe regions frequently experience weak coordination between transportation systems and spatial growth patterns, resulting in fragmented accessibility networks and inefficient mobility systems. Consequently, coordinated transport-linked zoning regulations, corridor-based planning strategies, and transit-oriented growth management frameworks are increasingly recognized as important mechanisms for sustainable peri-urban development.

C. Non-Motorized Transport and Complete Streets

Non-motorized transport (NMT) systems constitute an essential component of sustainable mobility planning, particularly within peri-urban and semi-urban regions where a significant proportion of daily trips remain short-distance and locally oriented. Walking and cycling contribute toward reduced vehicular dependency, improved public health, lower emissions, enhanced accessibility, and socially inclusive mobility systems. Despite these benefits, pedestrian and cycling infrastructure frequently remain underdeveloped within rapidly urbanizing metropolitan fringe regions.

The Complete Streets concept, developed through the National Complete Streets Coalition and advanced by scholars such as Barbara McCann and Jeff Speck, advocates designing streets for all users rather than prioritizing vehicular traffic alone. Complete Streets frameworks integrate pedestrian pathways, cycling infrastructure, traffic calming systems, universal accessibility features, public transport integration, landscaping, and safer crossing facilities within street design structures.

Research conducted within Indian cities indicates that existing transport planning systems continue to prioritize carriageway expansion and vehicular throughput while inadequately addressing pedestrian safety, cycling accessibility, and inclusive mobility requirements. Such deficiencies become particularly severe within peri-urban growth corridors where mixed traffic conditions, ribbon development, roadside encroachments, and discontinuous infrastructure collectively reduce mobility efficiency and safety.

D. Peri-Urban Mobility Systems and Accessibility Challenges

Peri-urban transport systems demonstrate mobility characteristics significantly different from compact urban cores due to dispersed settlement structures, mixed land use transition, and rural–urban interaction dynamics. Fringe regions frequently depend on radial corridors and highway-oriented connectivity systems linking peripheral settlements with metropolitan cores. However, internal connectivity between peri-urban settlements often remains fragmented due to weak collector roads, inadequate feeder systems, and poor multimodal integration.

Existing studies focusing on Indian metropolitan fringe regions identify increasing dependence on private two-wheelers and informal intermediate public transport systems due to weak public transport penetration and poor last-mile connectivity. Accessibility imbalance additionally emerges as a major issue within peripheral settlements where residents frequently travel long distances to access public transport nodes, employment centers, educational institutions, and urban services.

Panda and Behera (2022), in their study on Bhubaneswar's peri-urban transport systems, identified fragmented transport networks, weak feeder integration, and inadequate accessibility structures within fringe settlements. Similarly, Mohanty et al. (2021) highlighted how uncontrolled peri-urban expansion and transport-induced sprawl significantly increase travel demand and private vehicle dependency within emerging metropolitan corridors.

Global studies additionally demonstrate that peri-urban regions frequently experience transport exclusion due to inadequate multimodal accessibility and weak integration between formal transit systems and local mobility networks. Consequently, integrated mobility planning, feeder systems, and corridor-based accessibility frameworks are increasingly emphasized within contemporary peri-urban transport planning discourse.

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E. Inferences from Literature

The literature review reveals that existing studies extensively discuss sustainable mobility, Transit-Oriented Development (TOD), public transport systems, and non-motorized transport infrastructure within metropolitan environments. However, limited research specifically examines integrated transport planning within rapidly urbanizing peri-urban fringe regions characterized by corridor-oriented urbanization, fragmented settlement structures, and multimodal accessibility imbalance.

Furthermore, insufficient attention has been given to transport hierarchy restructuring, last-mile connectivity gaps, corridor dependency, mobility inequity, and transport–land use interaction within emerging fringe territories such as the South-East BDPA region. Existing planning approaches additionally provide limited focus on climate-responsive mobility systems, rural–urban accessibility integration, and multimodal restructuring within peri-urban metropolitan corridors.

Therefore, a substantial research gap exists concerning the development of integrated transport planning frameworks capable of supporting sustainable and accessible mobility systems within rapidly transforming urban fringe regions. The present study attempts to address this gap through an integrated analysis of mobility structure, multimodal accessibility, transport hierarchy efficiency, and transport-linked spatial planning within the South-East BDPA region of Bhubaneswar.

III. STUDY AREA PROFILE

The South-East Bhubaneswar Development Plan Area (BDPA) represents one of the most rapidly transforming peri-urban growth corridors within the Bhubaneswar metropolitan region. Located along the eastern and south-eastern fringe of Bhubaneswar, the study area comprises the planning zones of Balianta, Balipatna, Pratapsasan, Balakati, and Kantapada. These settlements collectively function as transitional rural–urban territories experiencing increasing residential expansion, corridor-oriented growth, commercial transformation, and rising commuter dependency on the metropolitan core.

The region demonstrates a strategically important spatial location influenced by major regional mobility corridors including NH-316, SH-13, and associated arterial linkages connecting Bhubaneswar with Puri, Cuttack, and adjoining peri-urban settlements. NH-316 functions as the dominant north–south mobility spine organizing regional movement patterns and facilitating strong directional connectivity between fringe settlements and the Bhubaneswar urban core. Secondary corridors and local road networks support intra-settlement mobility; however, connectivity between internal fringe settlements remains fragmented and discontinuous in several locations.

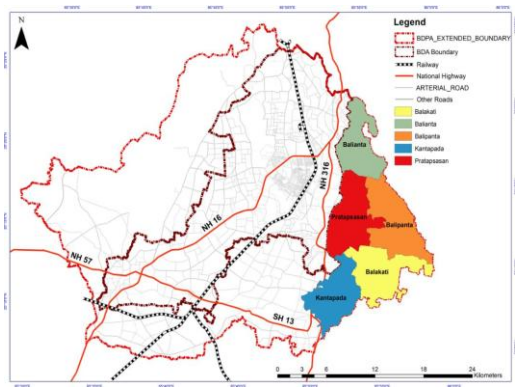

Fig. 1. Study Area BDA - 5 Blocks

The study area exhibits a mixed settlement morphology characterized by compact villages, semi-urban clusters, corridor-based expansion, ribbon development, agricultural landscapes, and emerging residential enclaves. Balianta and Balipatna represent rapidly expanding peri-urban growth corridors experiencing increasing development pressure due to proximity with Bhubaneswar and improving highway accessibility. Pratapsasan functions as a strategically located semi-urban transition node with strong potential for multimodal mobility integration, while Balakati demonstrates a relatively compact settlement structure favorable for walkable neighborhood development. Kantapada, located toward the southern fringe, retains predominantly rural characteristics with comparatively weaker accessibility and lower connectivity to the metropolitan core.

The mobility structure of the South-East BDPA region remains strongly mono-centric and corridor-dependent. A substantial proportion of daily movement is directed toward Bhubaneswar for employment, education, healthcare, trade, and administrative services. Consequently, radial commuting patterns dominate the regional transport system and generate peak-hour pressure on NH-316 and associated arterial corridors. The absence of strong east–west connectors and feeder mobility systems further intensifies dependency on primary corridors and contributes toward network imbalance within the regional transport hierarchy.

The study area additionally demonstrates increasing transport–land use conflicts associated with ribbon development, roadside commercial activity, mixed traffic conditions, informal parking, and weak pedestrian infrastructure. Several corridors currently experience operational inefficiencies due to unstructured edge activity, inadequate street hierarchy, limited multimodal integration, and growing motorization pressure. Non-motorized transport infrastructure remains fragmented despite the prevalence of short-distance local trips and significant dependence on walking, cycling, and intermediate public transport systems within several settlements.

Demographically, the study area represents a rapidly evolving peri-urban landscape characterized by increasing population growth, changing occupational structures, and expanding commuter dependency. According to Census 2011, Balianta recorded a population of approximately 91,728, while Balipatna accounted for nearly 132,796 persons. Pratapsasan, Balakati, and Kantapada additionally contribute important

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semi-urban and rural population clusters supporting regional socio-economic interaction and mobility demand.

The South-East BDPA region therefore represents an important case for examining integrated transport planning within rapidly urbanizing metropolitan fringe territories. The coexistence of highway-oriented development, dispersed settlement growth, mixed land use transition, and fragmented mobility systems provides a suitable context for evaluating sustainable mobility strategies, multimodal accessibility frameworks, and transport-linked spatial planning approaches within peri-urban environments.

The assessment of non-motorized transport infrastructure reveals severe deficiencies in pedestrian and cycling facilities. Continuous footpaths are absent across several corridors, pedestrian crossings remain unsafe, and encroachments significantly restrict walkability within market and activity zones. Cycling infrastructure is nearly non-existent despite substantial short-distance travel demand and relatively suitable mobility conditions within semi-urban stretches.

Public transport accessibility remains corridor-dependent with limited penetration into peripheral settlements. Several residential clusters require users to travel long distances to access formal transit services. The absence of organized feeder systems and weak integration between public transport and informal mobility systems further reduce accessibility efficiency.

The study also identifies strong land use–transport conflicts resulting from ribbon development patterns and unregulated roadside expansion. Commercial activities concentrated along major corridors generate roadside parking pressure, traffic conflict, and reduced carriageway efficiency.

IV. METHODOLOGY

The study adopts an integrated transport planning methodology combining field-based mobility assessment, spatial interpretation, accessibility analysis, infrastructure evaluation, and transport–land use assessment to examine the mobility structure and transport conditions within the South-East Bhubaneswar Development Plan Area (BDPA). The methodological framework was designed to evaluate multimodal accessibility, transport hierarchy efficiency, non-motorized transport infrastructure, commuter dependency patterns, and transport-linked spatial growth dynamics within rapidly urbanizing peri-urban settlements.

The research methodology was structured into four major phases comprising literature review and problem identification, primary and secondary data collection, analytical assessment, and proposal formulation. The initial phase involved an extensive review of literature related to sustainable urban mobility, peri-urban transport systems, Transit-Oriented Development (TOD), Complete Streets, accessibility theory, non-motorized transport planning, and transport–land use integration. This phase assisted in identifying major analytical indicators associated with multimodal accessibility, connectivity structure, mobility efficiency, transport hierarchy, travel behavior, and last-mile accessibility.

The second phase focused on primary and secondary data collection across the South-East BDPA region. Primary data collection included commuter surveys, bus user surveys, local resident surveys, intermediate public transport (IPT) driver interviews, key informant interviews, field observation studies, and infrastructure assessment surveys. Commuter surveys were conducted across Balianta, Balipatna, Pratapsasan, Balakati, and Kantapada to evaluate travel behavior, mode choice, destination patterns, travel time, daily transport expenditure, and accessibility conditions. Bus user surveys focused on service frequency, waiting time, route accessibility, interchange dependency, and last-mile connectivity challenges associated with formal public transport systems.

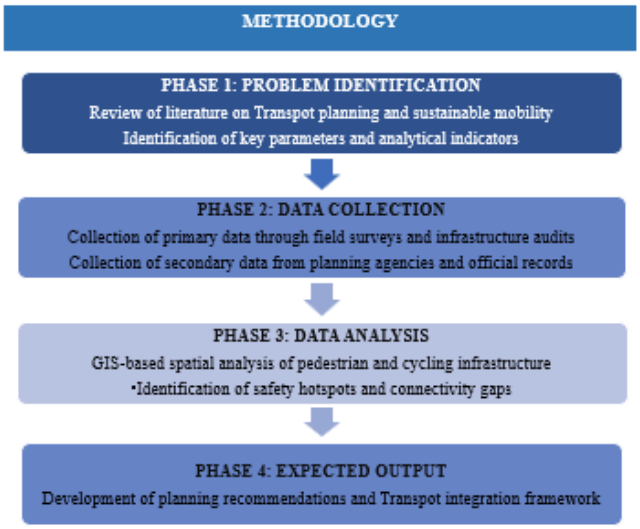

Fig. 2. Methodology

Local resident surveys were undertaken to assess household-level accessibility conditions, dependency on private vehicles, distance from transport corridors, and local mobility challenges. Intermediate public transport (IPT) driver interviews provided insights into operational routes, peak-hour demand, connectivity gaps, service deficiencies, and the role of informal mobility systems within the regional transport structure. Key informant interviews with officials from planning agencies, transport authorities, and infrastructure departments further supported understanding regarding existing mobility challenges, policy limitations, future mobility proposals, and institutional constraints affecting transport integration within the peri-urban region.

Field observation studies and infrastructure audits were conducted across major corridors and transport nodes to evaluate carriageway conditions, pedestrian infrastructure continuity, cycling facilities, roadside encroachment, traffic conflicts, parking pressure, and multimodal accessibility conditions. Particular emphasis was placed on assessing Complete Streets potential, transport hierarchy structure, and operational deficiencies within major mobility corridors such as NH-316, SH-13, Balianta Bazar Road, Balipatna corridors, and Pratapsasan transport nodes.

Secondary data were collected from Bhubaneswar Development Authority (BDA) plans, Census of India 2011 datasets, Comprehensive Development Plan (CDP) documents, transport policy reports, CRUT and Mo Bus route information, Public Works Department (PWD) records, satellite imagery,

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and regional planning documents. These datasets were utilized to evaluate settlement growth patterns, road hierarchy distribution, transport network structure, population concentration, land use transformation, and regional accessibility dynamics.

The analytical phase integrated both spatial and non-spatial assessment techniques to evaluate mobility structure and transport efficiency across the study area. Spatial interpretation focused on transport hierarchy mapping, corridor influence assessment, accessibility distribution, multimodal integration potential, and transport-linked land use transition. Survey findings were analyzed to evaluate modal dependency, travel time distribution, transport affordability, public transport accessibility, and last-mile connectivity conditions. The analytical framework additionally examined mobility inefficiencies associated with corridor dependency, fragmented east–west connectivity, mixed traffic conditions, and inadequate non-motorized transport infrastructure.

The final phase involved the formulation of an integrated transport planning framework for the South-East BDPA region. The proposed framework was developed through synthesis of accessibility analysis, mobility assessment, transport hierarchy evaluation, and spatial growth interpretation. The framework emphasizes sustainable mobility systems, multimodal accessibility enhancement, climate-responsive infrastructure, Transit-Oriented Development (TOD), Complete Streets, feeder mobility systems, and transport-linked land use planning in order to support resilient and inclusive peri-urban mobility development.

V. PERI-URBAN MOBILITY, ACCESSIBILITY, AND TRANSPORT STRUCTURE ANALYSIS

This section examines the existing mobility structure, accessibility conditions, transport hierarchy, and transport–land use interaction within the South-East BDPA region. The analysis integrates commuter surveys, infrastructure assessment, corridor evaluation, field observations, and spatial interpretation to understand the functioning of the peri-urban transport system and identify major mobility inefficiencies affecting regional accessibility. Particular emphasis is placed on multimodal accessibility, last-mile connectivity, non-motorized transport infrastructure, public transport efficiency, corridor dependency, and transport-linked spatial growth patterns in order to evaluate the broader mobility dynamics of the rapidly urbanizing fringe settlements.

A. Existing Mobility Structure and Commuter Dependency

The mobility structure of the South-East BDPA region demonstrates a predominantly mono-centric commuting pattern strongly oriented toward Bhubaneswar city. Approximately 70% of surveyed commuters travel daily toward Bhubaneswar for employment, education, commercial activity, and service access, indicating high dependency on the metropolitan core. In contrast, only nearly 20% of movement remains localized within individual settlements, while the remaining proportion is directed toward other surrounding regional destinations. This directional concentration of movement generates substantial peak-hour pressure along NH-316 and associated radial corridors connecting peri-urban settlements with the urban core.

The regional mobility structure therefore functions through a corridor-oriented transport system where major arterial routes dominate movement patterns while internal inter-settlement connectivity remains relatively fragmented. The findings indicate that fringe settlements are increasingly integrated into the metropolitan economic structure but remain inadequately supported through balanced transport infrastructure and decentralized accessibility systems. Consequently, excessive dependence on a limited number of regional corridors has intensified congestion pressure, travel inefficiency, and operational imbalance across the transport network.

Travel purpose analysis further reveals that work-related trips constitute nearly 50% of total daily movement, followed by educational trips accounting for approximately 30% of mobility demand. Shopping and other social trips collectively form a smaller proportion of movement patterns. The dominance of work-oriented commuting indicates a commuter-driven mobility structure characterized by strong directional flow during peak periods. Such mobility concentration increases transport stress along radial corridors and reflects the growing functional dependency of peri-urban settlements on Bhubaneswar's employment and institutional systems.

B. Modal Dependency and Public Transport Accessibility

The modal structure of the South-East BDPA region demonstrates increasing dependence on private and intermediate transport systems due to weak integration and limited penetration of formal public transport infrastructure. The transport system presently operates through a semi-integrated mobility structure where intermediate public transport systems such as shared autos and e-rickshaws function as important accessibility components complementing formal bus services. However, inadequate coordination between transport modes continues to reduce overall mobility efficiency.

Public transport accessibility remains highly corridor-dependent, with most formal services concentrated along major arterial routes and highway corridors. Approximately 75% of respondents reported moderate-to-low bus service frequency, indicating inconsistent service reliability and weak operational efficiency across the regional public transport system. Limited route coverage and insufficient feeder integration further constrain accessibility within peripheral settlements located away from major corridors.

The analysis additionally reveals significant last-mile accessibility deficiencies within the region. Approximately 63% of users travel more than 500 meters to access formal public transport facilities, while nearly one-fifth travel beyond one kilometer to reach bus stops and mobility nodes. Such accessibility gaps disproportionately affect low-income users, elderly populations, students, and individuals dependent on walking and shared mobility systems. The findings therefore indicate that the current transport structure inadequately supports equitable and inclusive accessibility within the peri-urban fringe environment.

The weak penetration of formal public transport systems has simultaneously intensified dependency on private two-wheelers and intermediate public transport modes. The mobility structure therefore reflects an emerging transition toward increasing motorization accompanied by declining multimodal balance. Such modal imbalance contributes toward

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rising congestion pressure, roadside conflicts, parking inefficiencies, and growing environmental stress within major corridors.

C. Travel Time, Cost, and Mobility Efficiency

Travel time analysis indicates moderate spatial separation between residential settlements and major activity centers within the metropolitan region. Approximately 60% of surveyed commuters experience travel durations ranging between 30 and 60 minutes, while nearly 20% require more than one hour for daily travel. Although the overall travel durations remain functionally manageable at present, increasing urban expansion and corridor dependency may significantly intensify travel inefficiencies in the future if integrated transport interventions are not implemented.

Daily transport expenditure patterns reveal that nearly 60% of users spend between ₹50 and ₹100 per day on mobility. The findings indicate a relatively cost-sensitive commuter structure where transport affordability plays an important role in mode choice decisions. Consequently, inadequate public transport efficiency and weak feeder integration may disproportionately affect economically vulnerable users dependent on affordable mobility systems.

The combined interpretation of travel time and travel cost indicates that the existing mobility system demonstrates moderate operational functionality but limited efficiency optimization. Although users currently maintain manageable travel durations and expenditure levels, increasing motorization pressure, congestion intensity, and transport fragmentation may progressively reduce mobility efficiency across the peri-urban transport network.

D. Transport Hierarchy and Corridor Dependency

The transport structure of the South-East BDPA region demonstrates a highly imbalanced hierarchy dominated by NH-316 and associated radial corridors. NH-316 functions as the principal regional mobility spine organizing north–south movement and connecting peri-urban settlements with Bhubaneswar city. Secondary mobility corridors such as SH-13 and internal arterial roads support local accessibility; however, internal east–west connectivity remains weak and fragmented across several portions of the study area.

The absence of strong collector road systems and lateral connectors has intensified dependency on primary arterial corridors even for short-distance inter-settlement movement. Consequently, substantial mobility demand becomes concentrated along a limited number of transport corridors, increasing congestion pressure and operational inefficiency. Settlements such as Balianta and Balipatna demonstrate particularly strong dependence on NH-316, while peripheral regions such as Kantapada experience comparatively weaker accessibility and partial transport isolation.

The transport hierarchy additionally reflects emerging peri-urban transition dynamics characterized by corridor-oriented urbanization, ribbon development, and transport-induced spatial growth. Several fringe corridors currently experience increasing roadside commercialization, mixed land use transition, and uncontrolled edge development, thereby intensifying traffic conflicts, parking pressure, and carriageway inefficiency. The findings therefore indicate the urgent requirement for a structured three-tier mobility hierarchy integrating primary corridors, secondary connectors, and local accessibility streets within the broader peri-urban transport framework.

E. Non-Motorized Transport (NMT) Infrastructure Analysis

The assessment of non-motorized transport infrastructure reveals severe deficiencies in pedestrian and cycling facilities across the South-East BDPA region despite substantial local demand for walking and cycling-based movement. Continuous footpaths remain absent across several major corridors, while pedestrian crossings are poorly designed and unsafe under mixed traffic conditions. Encroachments, informal parking, discontinuous walking edges, and inadequate street design further reduce pedestrian safety and accessibility within market zones and high-activity corridors.

Cycling infrastructure remains almost entirely absent despite relatively favorable conditions for short-distance non-motorized movement within semi-urban and peri-urban stretches. The absence of dedicated cycle tracks, bicycle parking systems, and protected mobility corridors significantly discourages active mobility and increases dependence on motorized modes even for short-distance trips.

The analysis further indicates that several corridors possess substantial potential for Complete Streets restructuring without requiring extensive right-of-way expansion. Corridors such as Balianta Bazar Road, Balipatna stretches, and Balakati market areas can significantly improve operational efficiency and safety through pedestrian prioritization, organized parking systems, traffic calming measures, carriageway discipline, and dedicated non-motorized transport infrastructure. Such interventions can improve mobility performance while simultaneously strengthening environmental sustainability and inclusive accessibility.

F. Transport–Land Use Interaction and Spatial Growth Dynamics

The study reveals a strong relationship between transport infrastructure and emerging spatial growth patterns within the South-East BDPA region. Major transport corridors currently function as dominant urbanization axes influencing residential growth, commercial concentration, and land use transformation across fringe settlements. Ribbon development along NH-316 and associated arterial routes has intensified roadside commercialization, mixed traffic conditions, parking encroachment, and transport conflict within several growth corridors.

Balianta and Balipatna demonstrate particularly strong corridor-based expansion patterns influenced by regional accessibility and proximity to Bhubaneswar. Pratapsasan exhibits strategic potential as a future multimodal interchange node due to its central spatial location and accessibility linkage structure. Balakati demonstrates relatively compact settlement morphology favorable for walkable neighborhood development, while Kantapada retains predominantly rural characteristics but demonstrates increasing integration with regional mobility systems.

The findings collectively indicate that transport infrastructure is functioning as a major driver of peri-urban transformation within the study area. However, the absence of coordinated transport–land use planning frameworks has intensified fragmented urbanization patterns, accessibility

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imbalance, and corridor congestion. The study therefore emphasizes the necessity of integrating mobility systems with land use planning, corridor management, and transit-oriented growth strategies in order to support sustainable peri-urban development.

VI. INTEGRATED TRANSPORT PLANNING FRAMEWORK

The analysis demonstrates that the South-East BDPA region is undergoing a rapid transition from fragmented peri-urban settlements toward an increasingly integrated metropolitan fringe corridor. However, the existing transport structure remains highly corridor-dependent, spatially imbalanced, and weakly integrated with emerging land use transformation patterns. The proposed integrated transport planning framework therefore aims to establish a sustainable, multimodal, climate-responsive, and accessibility-oriented mobility structure capable of supporting balanced peri-urban growth and resilient metropolitan expansion.

The framework emphasizes coordinated integration of transport infrastructure, land use systems, public transport networks, non-motorized mobility infrastructure, and regional accessibility systems. The proposed interventions are structured according to transport hierarchy deficiencies, accessibility gaps, corridor pressure, mobility behavior, and spatial growth dynamics identified during the analytical phase of the study. The framework additionally recognizes transport infrastructure not merely as a movement system, but as a major structuring element influencing urban expansion, accessibility equity, environmental sustainability, and regional socio-economic integration.

A major component of the framework involves restructuring the existing transport hierarchy into an integrated three-tier mobility system comprising primary regional corridors, secondary inter-settlement connectors, and tertiary local accessibility streets. NH-316 is proposed as the principal regional mobility spine supporting high-capacity public transport integration, corridor-based transit systems, and Transit-Oriented Development (TOD) strategies. Secondary connector systems linking Balianta, Balipatna, and Kantapada are proposed to strengthen east–west accessibility and reduce excessive dependence on radial movement corridors. Local streets and tertiary mobility networks are further proposed to support neighborhood accessibility, walkability, and low-speed local movement systems.

The framework places significant emphasis on multimodal accessibility enhancement through integrated feeder systems and public transport restructuring. Peripheral settlements presently demonstrate weak connectivity to formal public transport infrastructure, thereby intensifying dependence on private vehicles and intermediate public transport systems. Consequently, feeder mobility loops involving e-rickshaws, mini-buses, shared mobility systems, and bicycle-sharing infrastructure are proposed to strengthen last-mile connectivity between residential clusters, activity centers, and major transit corridors.

Strategic multimodal mobility hubs are proposed at Pratapsasan, Balipatna, and major corridor intersections to facilitate seamless interchange between buses, feeder systems, intermediate public transport, and non-motorized mobility systems. These mobility hubs are envisioned as integrated accessibility nodes incorporating transit plazas, passenger facilities, feeder integration systems, parking management infrastructure, and smart mobility services. Pratapsasan, due to its central location and corridor connectivity, demonstrates particularly strong potential for functioning as a future regional interchange node within the South-East BDPA mobility structure.

The framework additionally proposes adoption of Complete Streets principles across major peri-urban corridors in order to improve pedestrian accessibility, cycling infrastructure, and inclusive mobility conditions. Corridors such as Balianta Bazar Road, Balipatna stretches, Balakati market corridors, and SH-13 demonstrate substantial potential for street restructuring without extensive right-of-way expansion. Proposed interventions include continuous pedestrian pathways, segregated cycle tracks, traffic calming systems, universal accessibility features, drainage integration, organized parking zones, vending management systems, and shaded mobility corridors.

Particular emphasis is placed on strengthening non-motorized transport (NMT) systems due to the significant prevalence of short-distance movement within the region. Dedicated cycling corridors are proposed along canal roads, semi-urban connectors, and local market corridors in order to promote low-carbon mobility and reduce dependence on motorized systems. Pedestrian-priority environments are additionally proposed around schools, local markets, bus stops, and activity centers to improve commuter safety and neighborhood accessibility.

The framework also introduces Transit-Oriented Development (TOD) principles within emerging growth corridors influenced by NH-316 and associated mobility spines. Corridor-based mixed land use development, compact growth patterns, walk-to-transit zones, and transport-linked zoning systems are proposed to reduce travel demand and strengthen accessibility efficiency. The TOD strategy further aims to control ribbon development and transport-induced sprawl by promoting structured urban growth around accessible transit corridors and mobility nodes.

Climate-responsive mobility infrastructure constitutes another major component of the framework. Green mobility corridors, shaded pedestrian systems, solar-lit streets, low-carbon feeder mobility, and environmentally responsive street design interventions are proposed to improve thermal comfort, environmental sustainability, and resilience within peri-urban mobility systems. Such interventions become increasingly important within rapidly urbanizing fringe territories experiencing rising vehicular emissions, heat stress, and declining environmental quality.

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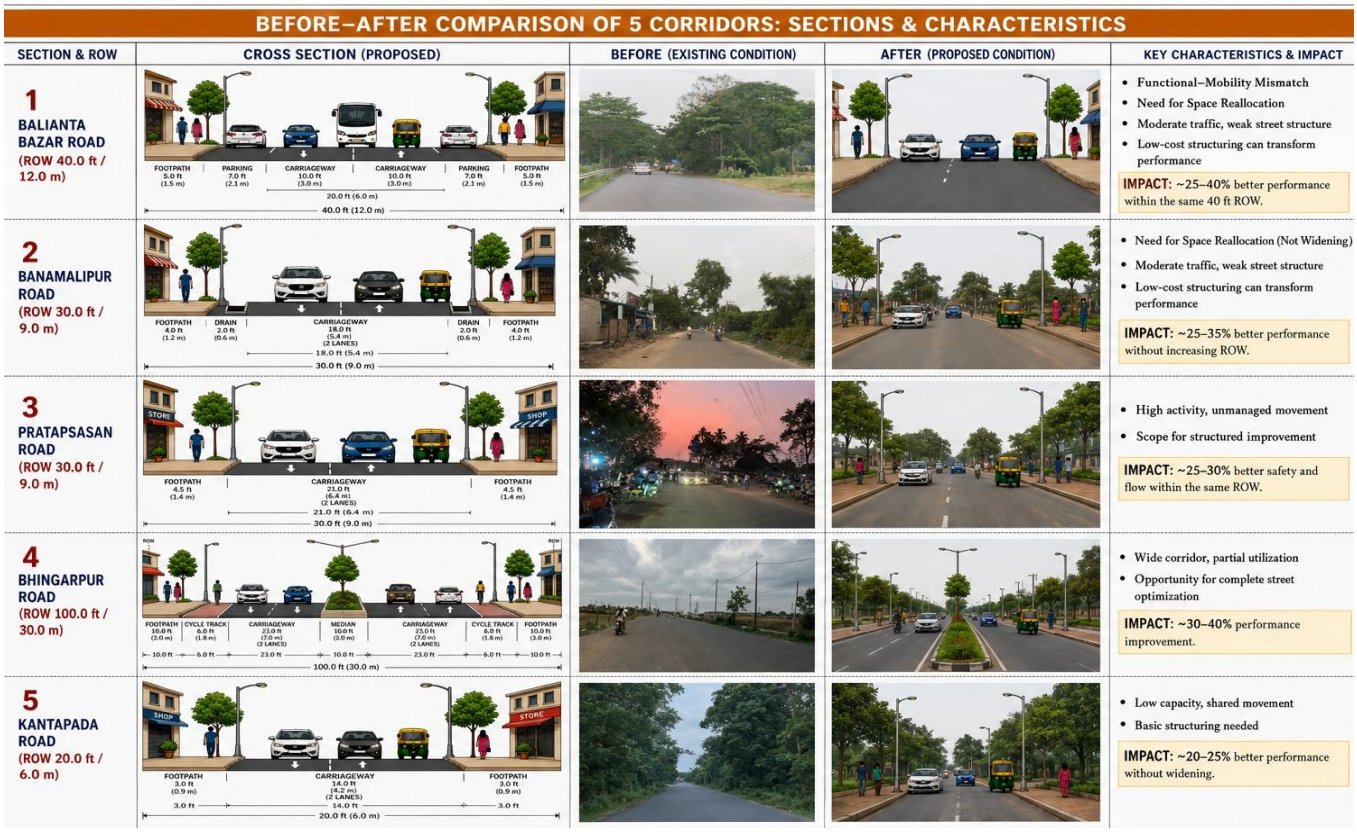

Fig 4. Integrated Proposals

The framework additionally recognizes the importance of rural–urban accessibility integration within peripheral regions such as Kantapada and adjoining rural settlements. Rural feeder transit systems, village footpaths, shared mobility corridors, agro-market accessibility routes, and universal accessibility infrastructure are proposed to strengthen socio-economic integration and inclusive regional mobility. Such interventions aim to improve access to educational institutions, healthcare services, markets, and urban employment opportunities for peripheral rural populations.

At the policy level, the framework recommends integrating transport planning with future land use regulation, zoning controls, corridor management systems, and metropolitan development strategies. Transport-linked zoning regulations, grid-based road planning, mobility-sensitive development controls, parking management systems, and corridor-specific planning guidelines should be systematically incorporated within future regional planning frameworks in order to support balanced and sustainable peri-urban growth.

Overall, the proposed integrated transport planning framework positions mobility infrastructure as a central component of sustainable metropolitan development capable of improving accessibility equity, strengthening multimodal integration, reducing transport fragmentation, and supporting climate-responsive peri-urban transformation. The framework demonstrates that coordinated transport–land use planning, multimodal accessibility enhancement, and complete street restructuring are essential for developing resilient and inclusive mobility systems within rapidly urbanizing metropolitan fringe regions.

urbanizing metropolitan regions.

The analysis additionally highlights strong accessibility inequities within the regional mobility system. Despite increasing commuter dependency, formal public transport infrastructure demonstrates weak penetration into peripheral settlements and remains largely concentrated along major corridors. Significant proportions of users currently travel beyond acceptable walking distances to access public transport facilities, reflecting severe last-mile accessibility deficiencies. Such conditions disproportionately affect economically vulnerable populations, students, elderly users, and individuals dependent on walking and intermediate public transport systems. The findings therefore indicate that mobility inequality within peri-urban regions is not merely a transportation issue but also a broader socio-spatial accessibility challenge associated with uneven infrastructure distribution and fragmented regional planning.

The dominance of private two-wheelers and informal mobility systems further reflects the inability of existing transport structures to provide efficient, reliable, and accessible multimodal mobility alternatives. Although the regional transport system demonstrates moderate operational functionality at present, increasing motorization pressure may significantly intensify congestion, environmental degradation, and transport inefficiency if sustainable mobility interventions are not introduced at an early stage of peri-urban expansion. The study therefore emphasizes the urgent need to shift from road-oriented mobility planning toward accessibility-oriented and multimodal transport frameworks capable of strengthening

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public transport systems, feeder integration, and non-motorized mobility infrastructure.

The findings additionally demonstrate that non-motorized transport (NMT) systems possess substantial untapped potential within peri-urban regions. Several settlements within the study area exhibit favorable conditions for walking and cycling due to relatively compact morphology, short-distance travel patterns, and moderate traffic intensity. However, the near absence of dedicated pedestrian and cycling infrastructure significantly discourages active mobility and increases dependence on motorized movement systems even for local trips. This reflects a broader planning deficiency frequently observed across rapidly urbanizing Indian fringe regions where transport planning frameworks prioritize vehicular throughput while inadequately addressing inclusive mobility and pedestrian accessibility.

The transport hierarchy assessment further indicates that the regional mobility system remains structurally imbalanced due to excessive dependence on NH-316 and weak east–west connector systems. Such corridor dependency creates directional peak-hour pressure and reduces network resilience by concentrating movement along a limited number of arterial routes. The study therefore supports the need for integrated transport hierarchy restructuring involving primary regional corridors, secondary collector systems, and tertiary neighborhood accessibility networks capable of distributing mobility demand more efficiently across the peri-urban landscape.

Another important implication emerging from the study concerns the relationship between transport infrastructure and land use transformation within peri-urban territories. The findings clearly demonstrate that transportation corridors are functioning as major structuring elements influencing settlement expansion, commercial concentration, and peri-urban spatial transformation. However, the absence of coordinated transport–land use planning has intensified fragmented urbanization patterns and transport-induced sprawl across several corridors. Consequently, integrating Transit-Oriented Development (TOD), transport-linked zoning systems, and corridor-based growth management strategies becomes essential for controlling dispersed expansion and improving long-term accessibility efficiency within emerging metropolitan fringe regions.

The study additionally contributes toward contemporary discourse concerning sustainable and climate-responsive mobility systems within Global South metropolitan regions. The proposed framework demonstrates that integrated transport planning within peri-urban territories must extend beyond highway expansion and traffic engineering approaches to incorporate multimodal accessibility, Complete Streets, non-motorized transport systems, climate-sensitive mobility infrastructure, and inclusive regional accessibility strategies. Such integrated approaches become increasingly critical within rapidly urbanizing cities facing growing mobility demand, environmental stress, and spatial fragmentation.

Overall, the findings indicate that peri-urban mobility systems represent one of the most critical yet under-addressed dimensions of metropolitan planning within Indian cities. The South-East BDPA region illustrates how rapid fringe urbanization without integrated transport planning can intensify accessibility imbalance, corridor dependency, and mobility fragmentation. Simultaneously, the study demonstrates that strategic multimodal integration, transport hierarchy restructuring, and transport-linked spatial planning possess substantial potential for developing resilient, inclusive, and sustainable peri-urban mobility systems.

VIII. CONCLUSION

The study examined the existing mobility structure, accessibility conditions, transport hierarchy, and transport–land use interaction within the rapidly urbanizing fringe settlements of the South-East Bhubaneswar Development Plan Area (BDPA). The findings demonstrate that the region is experiencing a significant transition from dispersed peri-urban settlements toward increasingly integrated metropolitan growth corridors characterized by rising commuter dependency, corridor-oriented urbanization, and growing mobility demand. However, transport infrastructure integration has not progressed proportionately with spatial expansion, resulting in fragmented accessibility systems, multimodal inefficiencies, and increasing corridor pressure across the regional transport network.

The analysis reveals that the existing mobility structure is predominantly mono-centric and heavily dependent on NH-316 and associated arterial corridors linking peri-urban settlements with Bhubaneswar city. Although regional accessibility toward the metropolitan core remains functionally adequate, internal connectivity, feeder mobility systems, and multimodal integration remain comparatively weak. Significant last-mile accessibility deficiencies, moderate-to-low public transport frequency, inadequate non-motorized infrastructure, and increasing dependence on private two-wheelers collectively indicate the emergence of structurally imbalanced mobility systems within the fringe region.

The study further demonstrates that transport infrastructure is functioning as a major driver of peri-urban spatial transformation within the South-East BDPA region. Corridor-oriented development, ribbon urbanization, and unregulated roadside expansion have intensified congestion pressure, roadside conflicts, parking inefficiencies, and operational safety concerns along several major corridors. Simultaneously, weak coordination between transport systems and land use planning has contributed toward fragmented accessibility structures and transport-induced spatial inefficiencies.

The proposed integrated transport planning framework emphasizes multimodal accessibility enhancement, transport hierarchy restructuring, Complete Streets, non-motorized mobility systems, Transit-Oriented Development (TOD), feeder connectivity, and climate-responsive mobility infrastructure as essential components of sustainable peri-urban development. Strategic interventions including mobility hubs, east–west connector systems, pedestrian-priority corridors, dedicated cycling infrastructure, rural feeder transit systems, and transport-linked zoning mechanisms collectively aim to improve accessibility equity, reduce congestion, strengthen public transport integration, and support resilient metropolitan expansion.

The study contributes toward emerging planning discourse concerning peri-urban mobility systems, sustainable transport planning, multimodal accessibility, and transport–land use integration within rapidly urbanizing metropolitan fringe territories of the Global South. The findings highlight that peri-

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urban regions require integrated and accessibility-oriented transport planning approaches capable of balancing mobility demand, spatial growth, environmental sustainability, and inclusive regional development. The study therefore emphasizes that future metropolitan planning frameworks must systematically integrate transport systems with land use regulation, multimodal infrastructure, and regional accessibility strategies in order to support resilient, sustainable, and people-centered peri-urban transformation.

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