Reconfiguring Urban Form through Transit-Oriented Development: A case of Banergaon metro station, Pune

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***Abstract*—Pune is experiencing rapid urban transformation, driven by the expansion of its metro network, which is significantly influencing mobility patterns, land use, and the built environment. As a radial city, the metro enhances urban connectivity while simultaneously disrupting existing spatial dynamics, calling for strategic planning interventions. This research focuses on the Banergaon Metro Station precinct to examine the implications of Transit-Oriented Development (TOD) regulations on land use, density distribution, and spatial planning. The study evaluates the effects of current and proposed policies and explores alternative urban models aligned with TOD principles. Employing field observations, spatial analysis, and stakeholder interviews, it identifies prevailing development trends and planning challenges. On-site assessments examined the precinct's physical infrastructure, accessibility, connectivity, land use patterns, and transportation networks. Based on the analysis, the study proposes development guidelines aimed at enhancing multimodal integration, promoting pedestrian-friendly design, and encouraging sustainable urban form. The proposed framework seeks to alleviate traffic congestion, improve air quality, and foster livable, accessible urban spaces. These insights contribute to the broader discourse on embedding transit infrastructure within sustainable urban growth strategies and also contribute to the social & economic dimensions in rapidly developing metropolitan contexts.**

***Index Terms*—Transit-Oriented Development (TOD), Urban Form, Sustainable Mobility, Pune Metro**

I. INTRODUCTION

Pune is undergoing rapid urban transformation driven by the development of metro corridors, which are significantly influencing mobility patterns and urban form. As a radial city, the metro network enhances connectivity while altering spatial dynamics around station precincts.

In response, the Pune Metro Project incorporates Transit-Oriented Development (TOD) regulations through increased Floor Space Index (FSI) under the 2017 Development Control Regulations (DCR), allowing intensification up to 4.0 FSI within a 500 m influence zone, subject to road width conditions. While this policy aims to promote compact urban growth and enhance ridership, its implications on land use, density distribution, and spatial structure require critical evaluation.

This study examines these impacts through the Banergaon metro precinct and proposes planning strategies that align density with accessibility, mobility integration, and sustainable urban development.

Methodology

This study adopts a case-based approach focusing on the Banergaon Metro Station precinct along Pune's Red Line. Field observations, spatial mapping, and stakeholder inputs were used to analyze land use, connectivity, and mobility systems.

Comparative evaluation of DCR and TOD frameworks was undertaken to assess development patterns. The findings informed the formulation of planning and design guidelines aimed at improving multimodal integration, walkability, and ecological resilience.

Research Aim and Objectives

Aim:

To examine the impact of Transit-Oriented Development (TOD) regulations, particularly increased FSI, on urban form and land use along the Pune Metro corridor, using the Banergaon precinct to propose context-specific planning and design guidelines for sustainable, multimodal development.

Objectives:

- To assess TOD-based FSI impacts on density and built form.
- To study land use, infrastructure, and spatial patterns.
- To evaluate connectivity and multimodal integration.
- To examine TOD effectiveness in shaping walkable environments.
- To identify integration challenges.
- To propose context-responsive planning and design guidelines.

Scope And Limitations of The Study

Scope:

The study focuses on the Banergaon metro station precinct along the Pune Metro Red Line, within a 500–800 m TOD influence zone. It examines the impact of TOD regulations on land use, density, and spatial structure through field observations and spatial analysis. The study also evaluates accessibility, connectivity, and multimodal networks, and proposes planning and design strategies for pedestrian-friendly and sustainable urban development.

Limitations:

- The study is confined to a single precinct and is not representative of the entire Pune Metro corridor or other TOD zones.
- The analysis relies primarily on qualitative methods, with limited quantitative validation.
- Findings reflect current policies and development trends, which may change over time.
- Data limitations and restricted stakeholder access may affect analytical depth.
- Proposed guidelines are conceptual and require further detailed planning and policy validation.

Background On Pune's Urban Transformation and Metro Expansion

Pune has rapidly transformed into a major metropolitan center, driven by its education and IT sectors, leading to challenges such as congestion, land pressure, and infrastructure deficits. The Pune Metro Rail Project addresses these issues by acting as both a transit system and a catalyst for urban development. TOD policies along metro corridors promote higher FSI, mixed-use development, and walkability, resulting in visible land use intensification. This study examines these impacts through the Banergaon metro precinct, evaluating how TOD influences urban form, density, and spatial structure, and assessing its effectiveness in achieving sustainable and integrated urban development.

Figure 1: Pune Metro Route Map

Importance Of Transit-Oriented Development (Tod) In Shaping Urban Form

Transit-Oriented Development (TOD) in Pune is implemented through Development Control Regulations (DCR), primarily by permitting higher FSI within metro influence zones to promote densification and increase transit ridership. However, the spatial distribution of this additional FSI significantly shapes urban form and morphology. The effectiveness of TOD depends not only on increased density but also on the integration of land use, mobility networks, and public realm design. Without adequate pedestrian infrastructure, last-mile connectivity, and multimodal integration, high-density development may result in congestion and inefficiency. Therefore, TOD must be evaluated as an integrated planning approach aligning regulations with on-ground infrastructure and spatial development.

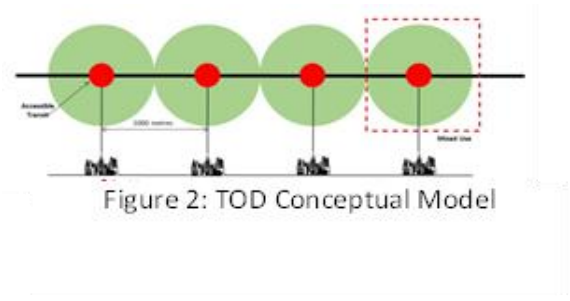

Figure 2: TOD Conceptual Model

II. LITERATURE REVIEW

Theoretical Foundation of Tod Principles

Transit-Oriented Development (TOD) integrates land use and transport to create compact, accessible, and sustainable urban environments. Guided by the 3D/5D framework, it has been institutionalized in India through national policies and DCR-based FSI incentives. However, implementation often prioritizes density over integrated urban design and mobility, necessitating a more balanced, design-led approach.

Review Of Tod Policy Frameworks

International TOD models demonstrate integrated transit, land use, and urban design through strong institutional coordination. In contrast, India's TOD approach, including Pune's FSI-driven framework, focuses on regulatory densification with limited integration of urban design and mobility, resulting in fragmented development patterns.

Case Studies of Tod Implementation in Similar Metropolitan Contexts

To contextualize TOD outcomes in rapidly urbanizing environments, comparable case studies were selected based on their relevance to transit-led development and policy frameworks. Delhi Metro and Ahmedabad BRTS represent Indian contexts with regulatory-driven TOD, highlighting challenges of inadequate pedestrian infrastructure and last-mile connectivity. In contrast, Hong Kong was selected as a global benchmark for its integrated Rail + Property model. These cases demonstrate that TOD effectiveness depends not only on density incentives but on coordinated planning, design integration, and robust implementation mechanisms.

Table 1 Comparative Analysis of TOD Implementation in Selected Case Studies

Parameter	Delhi Metro TOD (India)	Ahmedabad BRTS (India)	Hong Kong R+P Model
Planning Approach	Policy-driven TOD with FAR incentives	Corridor-based TOD along BRTS	Integrated transit + real estate model
Planning Approach	High-density through FAR increase	Linear densification along corridors	High-density vertical mixed-use development
Land Use Integration	Mixed-use promoted but uneven	Partial mixed-use integration	Strong mixed-use integration at all levels
Urban Form Outcome	Fragmented and uneven	Linear but inconsistent	Compact, cohesive, and integrated
Pedestrian Infrastructure	Inadequate, discontinuous	Limited and inconsistent	Highly developed, multi-level connectivity
Last-Mile Connectivity	Weak and unorganized	Limited and inconsistent	Strong, seamless multimodal integration
Institutional Coordination	Moderate, varies by precinct	Limited coordination	Strong institutional integration
Implementation Effectiveness	Moderate, varies by precinct	Partial and inconsistent	Highly effective and efficient
Key Challenges	Poor walkability, weak last-mile connectivity	Weak enforcement, limited integration	High cost, complex governance
Key Strengths	Strong policy framework	Corridor-based growth structuring	Fully integrated TOD model
Overall TOD Performance	Moderate	Moderate–Low	High

The comparative analysis highlights that while Indian TOD models primarily rely on regulatory incentives such as increased FAR/FSI, their effectiveness is limited by weak implementation and inadequate integration of design and mobility systems. In contrast, the Hong Kong model demonstrates the benefits of coordinated, design-led, and institutionally integrated TOD development.

Gaps in Existing Research

Existing studies predominantly focus on density and regulatory frameworks, with limited emphasis on precinct-level spatial impacts, urban design quality, and ecological integration. Additionally, the gap between TOD policy intent and its implementation remains underexplored. This study addresses these gaps through a precinct-level analysis of the Banergaon metro station area, linking TOD regulations with urban form and proposing context-responsive, design-oriented strategies.

III. STUDY AREA AND PRECINCT ANALYSIS

Baner, a rapidly urbanizing suburb of Pune, is strategically located between the city's second and third ring corridors and as shown in figure 3 the area serves as a key connector between the metropolitan core and the Hinjewadi IT hub. Its location along a major arterial route linking to NH-4 enhances its accessibility and development potential, making it a significant node within Pune's radial urban structure.

Figure 3: Influence area of Banergaon and its overall location in Pune city. Source: Author

The study focuses on the Banergaon Metro Station precinct, situated within a peri-urban interface undergoing transit-led transformation. The area reflects a shift from low-density, organic settlement patterns to higher-density development influenced by emerging Transit-Oriented Development (TOD) policies. Baner is also characterized by a sensitive ecological framework defined by Baner Hill to the south and the Mula River to the north. The natural slope from hill to river governs drainage patterns and has historically shaped settlement morphology and land-use distribution. Refer Fig. 4

The hydrological framework of the study area as shown in figure 5 consists of a network of interconnected water systems, including the Dev Nadi and Ram Nadi, which originate from Baner Hill and surrounding regions and converge into the Mula River. The Mula River, originating in the Sahyadri ranges and regulated by the Mulshi Dam, forms the primary drainage spine, supported by several secondary streams (nalas). This interconnected ecological system highlights the environmental sensitivity of the Banergaon precinct and establishes it as a relevant case for examining the spatial implications of TOD, particularly in relation to land-use transformation, density intensification, and integration of ecological systems within urban development.

The ecological character of the study area as shown in figure 5 is defined by the Mula River, its network of water channels, and Baner Hill, indicating a high degree of environmental sensitivity. However, rapid urbanization and transit-led development have led to encroachment and degradation of these systems, disrupting natural drainage patterns. Low-lying and vacant plots, which function as seasonal wetlands, act as important hydrological buffers during monsoons. Their decline, along with inadequate stormwater management, has resulted in recurring flooding and waterlogging.

This highlights a key challenge for Transit-Oriented Development (TOD): balancing density with environmental resilience. The study therefore emphasizes the integration of blue-green infrastructure to restore natural systems, mitigate flood risks, and support sustainable urban development.

Figure 4: Banergaon Location Map. (Source: Academic research)

Figure 5: Ecology Map (Source: Academic research)

The land-use pattern of the study area as shown in figure 6 is predominantly characterized by gated residential developments, reflecting rapid urbanization. However, significant pockets of open and agricultural land remain, particularly along the Mula River corridor. These areas have the potential to function as natural "sponge" zones, supporting stormwater absorption and reducing runoff during monsoons. Their conservation and integration into planning frameworks can strengthen blue-green infrastructure and mitigate flooding.

Despite TOD policies promoting higher density and compact growth, the existing spatial structure reflects fragmented and uneven development. Gated residential enclaves dominate the precinct, exhibiting inward-oriented layouts that reduce permeability and limit street-level interaction. The lack of mixed-use development further weakens the relationship between land use and mobility, sustaining dependence on private vehicles.

Density distribution across the precinct remains inconsistent. While some parcels have undergone vertical intensification, several low-lying and river-edge plots remain underutilized. This uneven consumption of FSI highlights the absence of strategic planning mechanisms to guide TOD implementation.

Accessibility and connectivity also remain inadequate. Discontinuous pedestrian infrastructure, encroachments, and poor street design hinder walkability within the 500–800 m influence zone. Additionally, the lack of organized last-mile connectivity and non-motorized transport (NMT) systems limits the effective catchment of the metro, reducing its impact on travel behavior.

The mobility structure of the area as shown in figures 7 and 8 continues to be dominated by vehicular movement, with arterial roads experiencing congestion, particularly during peak hours. The integration between different modes of transport—

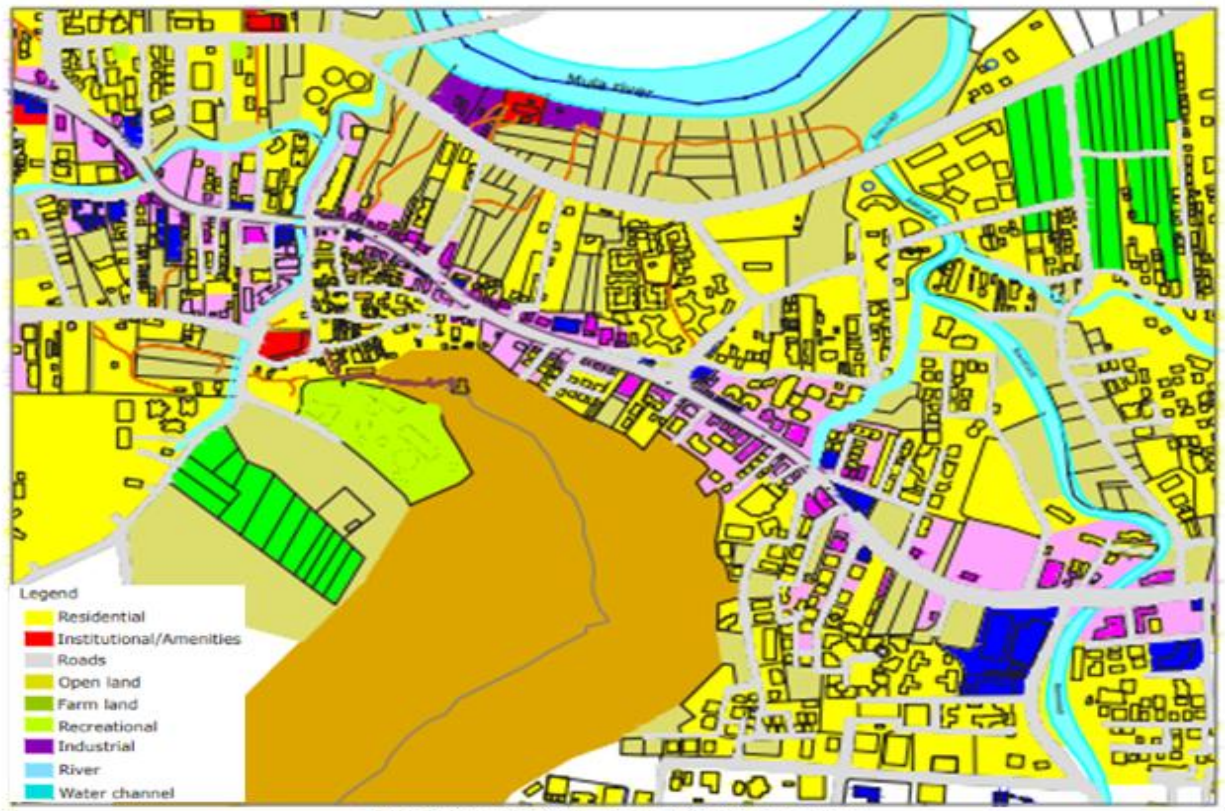

Figure 6: Land Use Map. (Source: Academic research)

metro, buses, intermediate public transport, and pedestrian systems—remains weak and uncoordinated.

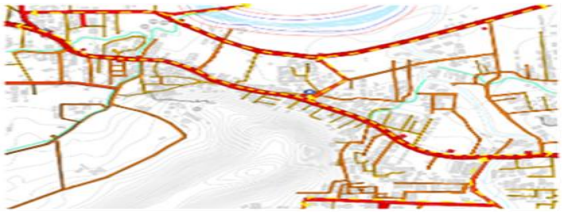

Figure 7: Transport + Road Hierarchy (Source: Academic research)

The lack of multimodal integration undermines the core objective of Transit-Oriented Development (TOD), which aims to reduce dependence on private vehicles and promote efficient public transport systems. This challenge is further intensified by the disconnect between ecological systems and urban development. Encroachment on natural drainage channels and the reduction of permeable surfaces have disrupted the hydrological balance, leading to increased surface runoff and recurring flooding during monsoon periods.

These conditions indicate that while TOD regulations in Pune promote density and compact growth, their translation into a cohesive and sustainable urban form remains limited. The Banergaon precinct reflects a transitional stage, where policy intentions are not fully aligned with spatial planning, urban design, and infrastructure provision. This highlights a broader disconnect between TOD principles and their on-ground implementation, particularly in the context of DCR-based regulatory frameworks.

Under base DCR provisions, development in the precinct follows an incremental pattern with moderate density. However, TOD introduces additional FSI incentives, significantly increasing development intensity. Although TOD policies promote plot amalgamation and cluster-based development to achieve coordinated high-density urban form, this approach is only partially realized in Banergaon.

Development remains largely regulation-driven, with FSI consumed at the individual plot level rather than through integrated planning. This results in fragmented urban morphology and limited spatial cohesion. The applicability of TOD is further constrained by local conditions, as the 500 m radial influence model does not align with the linear settlement pattern and undulating terrain. Additionally, regulatory thresholds such as minimum road width (9 m) and plot size (1000 sq.m) restrict TOD implementation across large parts of the precinct. This leads to a dual development pattern, where high-rise TOD-compliant structures coexist with low-rise, incremental growth under DCR. The resulting urban form is discontinuous and lacks integration. The absence of urban design guidelines further limits improvements in public realm, pedestrian infrastructure, and last-mile connectivity, while gated typologies continue to reduce permeability. These observations indicate that a uniform, regulation-driven TOD approach, without contextual adaptation, results in fragmented and inconsistent urban outcomes.

Figure 9: Existing Urban Form (Source: Academic research)

Figure 10: TOD FSI Footprint (Source: Academic research)

Figure 11: FSI as per TOD and DCR, new building added on open plots. (Source: Academic research)

Table 2: Summary of Precinct-Level Observations – Banergaon Metro Station Area

Parameter	Observation
Land Use Pattern	Predominantly gated residential developments with limited mixed-use integration
Density Distribution	Uneven density with localized vertical intensification and underutilized plots
FSI Utilization	Fragmented, plot-level consumption of FSI without coordinated cluster development
Connectivity	Inadequate pedestrian infrastructure with discontinuous footpaths and encroachments
Mobility Structure	Weak multimodal integration and limited last-mile connectivity systems
Ecological Condition	Flood-prone areas with disrupted drainage and reduced permeable surfaces

The table summarizes key spatial, mobility, and ecological characteristics of the precinct, highlighting critical gaps in TOD implementation.

IV. KEY FINDINGS AND DISCUSSION

The study identifies that TOD implementation in the Banergaon precinct is largely regulation-driven rather than design-oriented. Increased FSI has led to vertical intensification without corresponding improvements in spatial integration, resulting in a fragmented urban structure. Development potential is unevenly utilized due to constraints such as road width and plot size, leading to a dual pattern of high-rise and low-rise growth. This disparity disrupts morphological continuity and limits the effectiveness of TOD. The persistence of gated residential typologies further weakens the public realm and reduces permeability, contradicting TOD principles of active and accessible urban environments. Connectivity remains inadequate despite the presence of a metro station. Discontinuous pedestrian infrastructure, weak last-mile connectivity, and poor multimodal integration reduce the effective catchment of the transit system. Ecological systems are insufficiently integrated into development practices. Encroachments on drainage channels and loss of permeable surfaces contribute to flooding and waterlogging, highlighting environmental vulnerabilities.

Overall, the findings suggest that while TOD policies enable density, they fail to achieve integrated outcomes across land use, mobility, public realm, and ecological systems.

V. TOD-BASED PLANNING AND DESIGN GUIDELINES

The following guidelines are derived from the specific spatial, ecological, and regulatory conditions observed in the Banergaon metro station precinct and aim to address the key gaps identified in TOD implementation.

1. Strategic Land Use and Density Structuring Density intensification should be strategically aligned with transit accessibility. Higher FSI utilization must be concentrated within the immediate 500 m influence zone, particularly along major transit corridors. To avoid fragmented development, cluster-based planning and plot amalgamation should be actively incentivized, enabling cohesive and integrated urban form.

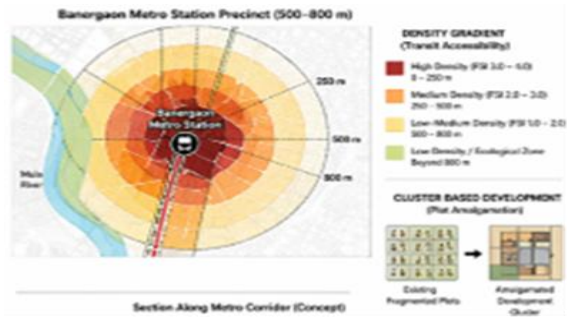

Figure 12: Strategic land use & Density structuring. Source: author

2. Integrated Mobility and Accessibility Framework A multimodal and pedestrian-oriented mobility system is essential for effective TOD. Continuous, universally accessible, and shaded pedestrian pathways should be developed across the precinct. Dedicated cycling infrastructure and efficient last-mile connectivity—such as feeder buses, e-rickshaws, and shared mobility systems—must be integrated to enhance metro accessibility and reduce private vehicle dependence.

Figure 13: Last mile connectivity. Source: author

3. Public Realm and Urban Design Enhancement The quality of the public realm should be strengthened through active street frontages, mixed-use development, and human-scale design interventions. Streets must function as social and interactive spaces, encourage walkability and improve urban vitality. Reducing inward-looking gated developments and enhancing street permeability should be prioritized.

Figure 14: Creation of public realm. Source: Author

4. Blue-Green Infrastructure and Ecological Integration Ecologically sensitive zones, including river edges, natural drainage channels, and low-lying areas, should be protected and integrated into a continuous blue-green network. These areas can function as urban "sponge systems" to manage stormwater, mitigate flooding, and enhance environmental resilience, while also contributing to public open spaces.

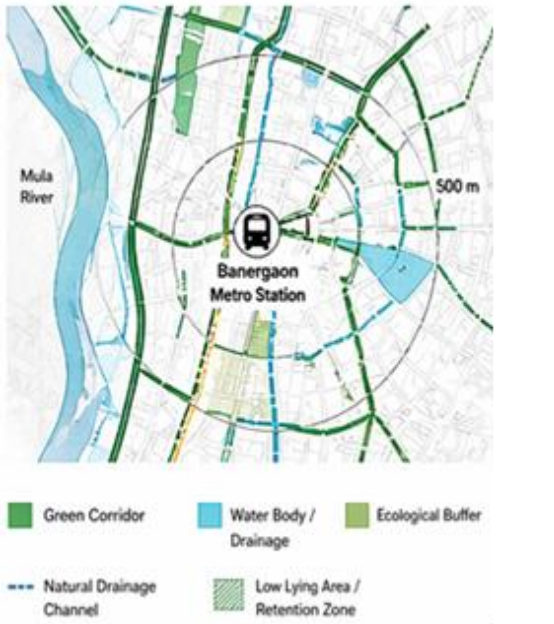

Figure 14: Blue & Green network diagram. Source: author

5. Implementation Mechanisms and Governance Framework TOD implementation must move beyond regulatory provisions to a coordinated, design-led approach. This requires detailed urban design guidelines, phased development strategies, and strong institutional coordination among stakeholders. Infrastructure provision should be synchronized with land development to ensure holistic and sustainable outcomes.

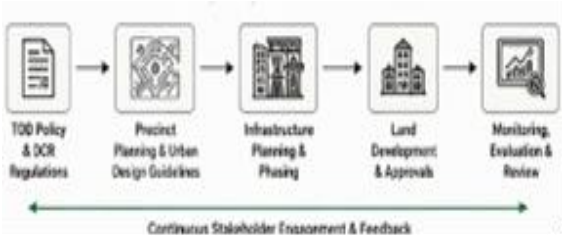

Figure 15: Policy to implementation flow

These strategies emphasize a shift from plot-level densification towards a coordinated, precinct-scale and design-led approach to TOD implementation.

VI. CONCLUSION

This study critically examined the spatial implications of Transit-Oriented Development (TOD) within the Banergaon metro station precinct in Pune, focusing on the relationship between regulatory frameworks and on-ground urban transformation. While TOD policies in Pune promote density through increased FSI, the findings indicate that their implementation remains predominantly regulation-driven, resulting in fragmented and inconsistent urban development.

The research highlights a significant disconnect between TOD policy intent and its spatial outcomes. Increased density has not translated into improved walkability, accessibility, or multimodal integration. Instead, the persistence of gated typologies, inadequate pedestrian infrastructure, and weak last-mile connectivity continue to reinforce private vehicle dependency. Additionally, the neglect of ecological systems has intensified environmental vulnerabilities such as flooding and waterlogging.

These findings underscore the limitations of a uniform, FSI-based TOD approach when applied without contextual adaptation. The study emphasizes the need for a shift towards a design-led, precinct-scale planning framework that integrates land use, mobility systems, public realm design, and ecological infrastructure.

By proposing context-responsive planning and design strategies, the research contributes to bridging the gap between TOD policy and implementation. The recommendations advocate for a more holistic and integrated approach to urban development, aligning density with accessibility, livability, and environmental resilience.

The framework developed through this study has broader applicability and can inform TOD implementation in other emerging metro precincts in Pune and similar rapidly urbanizing Indian cities, supporting the transition towards more sustainable and transit-supportive urban environments.

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