International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 09 | Sep 2026 www.irjet.net p-ISSN: 2395-0072

Transit-Oriented Development and Sustainable Urbanism: A Review of Principles, Case Studies and Planning Implications for Indian Cities

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Abstract - *Rapid urbanization, increasing travel demand and growing dependence on private vehicles have created significant challenges for sustainable urban development. Transit-Oriented Development (TOD) has emerged as an approach that integrates public transportation with compact development, mixed land uses, pedestrian accessibility and improved connectivity. However, the presence of mass transit infrastructure alone does not guarantee a sustainable urban environment. The quality of development around transit stations depends on the integration of density, land-use diversity, pedestrian connectivity, public spaces, non-motorized transport and appropriate urban design. This paper reviews the principles of TOD and examines selected Indian and international metro case studies to understand their implications for sustainable urban development. The review considers accessibility, land-use mix, density, walkability, connectivity, public-realm quality and multimodal integration. Bengaluru and Chennai are examined as Indian examples, while a California metro case is reviewed as an international reference. The comparative assessment indicates that metro infrastructure can influence land-use transformation and development intensity, but the resulting urban form depends on existing land-use patterns, accessibility, development opportunities and planning conditions. The study concludes that Indian cities should move beyond transit-adjacent development towards integrated TOD in which transportation, land use, urban form, pedestrian mobility, public spaces and environmental considerations are planned together.*

Key Words: Transit-Oriented Development, Sustainable Urbanism, Public Transport, Walkability, Mixed-Use Development

1. INTRODUCTION

Urbanisation has significantly transformed the spatial structure and mobility patterns of cities. Rapid population growth, expansion of urban areas and increasing travel demand have placed considerable pressure on land, infrastructure, transportation systems and environmental resources. In many cities, urban expansion has occurred alongside increasing dependence on private vehicles, resulting in congestion, air pollution, longer travel distances and inefficient use of urban land.

Transportation and land use are closely interconnected components of urban development. Improvements in transportation accessibility can influence the location and intensity of residential, commercial and institutional activities, while the distribution of activities influences travel demand and transportation requirements. Therefore, transportation planning and land-use planning cannot be considered as completely separate processes.

Mass Rapid Transit Systems (MRTS) can improve urban accessibility and provide an alternative to private vehicle-based mobility. However, the benefits of transit infrastructure depend considerably on the characteristics of the surrounding urban environment. A station may provide excellent regional connectivity while the immediate neighbourhood continues to have poor pedestrian facilities, fragmented streets, inadequate public spaces or limited integration with other modes of transport.

Transit-Oriented Development (TOD) emerged from this relationship between transportation and urban form. TOD promotes compact and mixed-use development around public transportation nodes while encouraging walking, cycling and public transportation. Calthorpe's work established an important foundation for the concept by emphasising pedestrian-oriented development around transit stations [1]. Dittmar and Ohland subsequently positioned TOD within the broader movement towards sustainable urban development [2].

The relationship between built environment characteristics and travel behaviour has also been widely discussed in planning research. Ewing and Cervero identified density, diversity, design, destination accessibility and distance to transit as important built-environment characteristics influencing travel behaviour [3]. These relationships demonstrate that transit infrastructure needs to be supported by an appropriate urban structure if sustainable mobility objectives are to be achieved.

The relevance of TOD is particularly significant for Indian cities. Rapid urbanisation and increasing mobility demand have resulted in major investments in metro rail systems across cities such as Delhi, Bengaluru, Chennai, Mumbai, Hyderabad and Ahmedabad. The National Transit Oriented Development Policy introduced by the Government of India promotes high-density and mixed-use development around mass transit stations, together with pedestrian and non-motorised transport and integration of land use with transportation [4].

However, the implementation of TOD within existing Indian urban areas presents several challenges. These include inadequate pedestrian infrastructure, parking pressure, fragmented street networks, unplanned commercial development and limited public and green spaces. Consequently, simply increasing development intensity around a metro station may not necessarily produce a sustainable built environment.

This paper therefore reviews TOD from the perspective of sustainable urbanism and examines selected case studies to identify planning lessons that can support more integrated transit-oriented development in Indian cities.

2. AIM AND OBJECTIVES

2.1 Aim

The study aims to examine Transit-Oriented Development as an approach to sustainable urban development and identify planning implications for Indian cities.

2.2 Objectives

The objectives of the study are:

- To review the key principles and spatial dimensions of Transit-Oriented Development.
- To comparatively examine selected Indian and international transit-oriented case studies.
- To identify transferable planning lessons for sustainable metro station-area development in Indian cities.

3. RESEARCH METHODOLOGY

The study adopts a **qualitative review and comparative case-study methodology**.

Relevant literature, planning policies, institutional guidelines and published case studies related to TOD, MRTS, land-use integration, accessibility, urban form and sustainable mobility were reviewed.

The review was organised around the following major dimensions:

- Land-use integration
- Development density
- Accessibility and connectivity
- Walkability and non-motorised transport
- Public realm and urban design
- Multimodal integration
- Environmental sustainability

Three major case-study contexts examined in the research were subsequently reviewed:

1. Bengaluru Metro
2. Chennai Metro
3. California Metro Rail

The case studies were compared in terms of land-use characteristics, development patterns, accessibility-related considerations and planning implications.

The study is based on secondary literature and published case-study material. It does not include the detailed primary GIS and survey analysis of the selected Delhi Metro stations; that analysis is reserved for a separate empirical study.

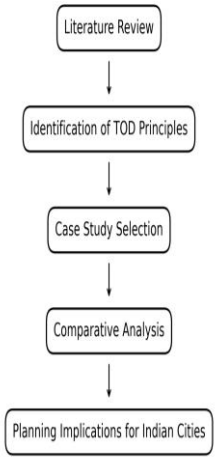

Figure 1. Review and Comparative Case-Study Methodology

4. CONCEPTUAL UNDERSTANDING OF TRANSIT-ORIENTED DEVELOPMENT

4.1 Evolution of the TOD Concept

The relationship between transportation and urban development existed before the emergence of the term TOD. Traditional settlements were often compact and supported walking and public transportation. The expansion of automobile-oriented development subsequently encouraged the separation of residential areas, employment centres and services.

This spatial separation increased travel distances and contributed to private vehicle dependence. TOD emerged as an approach to reconnect transportation infrastructure with compact, mixed-use and pedestrian-oriented urban development.

Calthorpe [1] proposed a pedestrian-oriented development model in which transit stations form the centre of compact

neighbourhoods containing residential, commercial and institutional uses. Dittmar and Ohland [2] further developed the concept by relating TOD to sustainable urban development and accessibility.

TOD has consequently evolved from a primarily transportation-focused concept into a broader planning approach involving:

Transit + Land Use + Urban Form + Mobility + Public Realm + Sustainability

5. PRINCIPLES OF SUSTAINABLE TOD

5.1 Walkability

Walkability is a fundamental component of TOD. A transit station cannot function effectively as the centre of a sustainable neighbourhood if pedestrians encounter discontinuous footpaths, unsafe crossings, encroachments or uncomfortable walking conditions.

Station areas should provide continuous pedestrian routes, safe crossings, universal accessibility, appropriate lighting, shade and direct connections between the station and surrounding destinations.

5.2 Cycling and Non-Motorised Transport

Cycling can provide an effective first- and last-mile connection to public transportation. Safe cycle routes, bicycle parking and integration with transit can encourage non-motorised mobility.

5.3 Mixed Land Use

Mixed land use allows residential, commercial, institutional and recreational activities to occur within relatively short distances. This can reduce travel distances and support active neighbourhoods.

However, simply placing different uses within the same area does not automatically create successful TOD. The relationship between land uses, pedestrian movement, accessibility and public space is equally important.

5.4 Appropriate Density

Density is important for supporting public transportation and efficient infrastructure utilisation. TOD commonly promotes higher development intensity around transit stations.

However, density should not be treated as the sole measure of TOD success. Higher intensity must be supported by pedestrian infrastructure, public spaces, green areas, drainage, social infrastructure and adequate transportation capacity.

5.5 Connectivity

A connected street network reduces walking distances and provides multiple route choices. Fine-grained streets, interconnected blocks and continuous pedestrian paths are therefore important components of station-area planning.

5.6 Public Realm and Open Spaces

Transit stations often become important public spaces within their surrounding neighbourhoods. Station plazas, sidewalks, streets and green spaces influence the environmental and social quality of station areas.

A sustainable TOD approach should therefore consider the station precinct as an integrated public realm rather than treating the station as an isolated transportation facility.

6. TOD AND SUSTAINABLE URBAN DEVELOPMENT

TOD contributes to sustainable urban development through several interconnected mechanisms.

Table 1. Relationship Between TOD Principles and Sustainability Outcomes

TOD Dimension	Planning Intervention	Sustainability Outcome
Walkability	Continuous pedestrian network	Reduced short-distance vehicle dependence
Cycling	Connected cycle infrastructure	Increased non-motorised mobility
Mixed land use	Residential-commercial integration	Reduced travel distances
Density	Compact development	Efficient use of infrastructure
Connectivity	Fine-grained street network	Improved accessibility
Public transport	Integrated transit system	Reduced private vehicle dependence
Green infrastructure	Trees, parks and green corridors	Improved environmental quality
Public realm	Pedestrian-oriented streets and plazas	Improved social and spatial quality

The sustainability benefits of TOD therefore emerge from the **interaction of multiple urban characteristics**, rather than from proximity to a transit station alone.

7. CASE STUDY: BENGALURU METRO

Bengaluru provides an important Indian example of the relationship between metro infrastructure and surrounding urban development.

The case study examined three stations on the Purple Line:

- Mahatma Gandhi Road (MG Road)
- Halasuru
- Swami Vivekanand Road

The station influence areas were divided into four zones extending from 0–150 m, 150–250 m, 250–500 m and 500–1000 m from the stations.

The study examined changes in land use between 2001 and 2021 and considered parameters such as land value, accessibility, population density, transport network, vacant land and social infrastructure.

The results indicate a general reduction in residential land use accompanied by increases in commercial and mixed-use development.

Table 2. Land-use Change around Selected Bengaluru Metro Stations

Station	Residential Change	Mixed-use Change	Commercial Change	Public/Semi-public Change
MG Road	−5.85%	+2.20 %	+6.45%	−0.10%
Halasuru	−7.10%	+2.00 %	+5.00%	+4.60%
Swami Vivekanand Road	−6.80%	+2.00 %	+5.10%	+5.10%

The observed pattern suggests that increased accessibility and demand for commercial and office activities contributed to the transformation of residential areas towards commercial and mixed-use development.

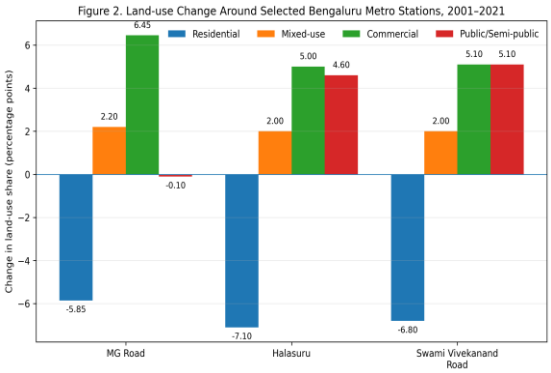

Figure 2. Comparative Land-use Change around Selected Bengaluru Metro Stations

The case demonstrates that metro investment can influence land-use transformation around station areas. At the same time, development outcomes are influenced by existing land ownership, urban structure, land availability and other local conditions.

Planning lesson: Metro accessibility can encourage mixed-use and commercial intensification, but such transformation should be supported by pedestrian infrastructure, public spaces, parking management and appropriate development controls.

8. CASE STUDY: CHENNAI METRO

The Chennai case examined development patterns around Ashok Nagar and Guindy Metro stations. Land-use conditions were compared within an 800 m influence zone for 2006 and 2018, representing conditions before and after metro implementation.

8.1 Ashok Nagar

Ashok Nagar is predominantly a residential neighbourhood. Within the 0–800 m influence zone, residential land use decreased from 80.49% in 2006 to 71.24% in 2018, representing a reduction of 9.25 percentage points. Commercial land use increased from 1.76% in 2006 to 4.27% in 2018, an increase of 2.51 percentage points.
The results indicate a gradual shift from residential land use towards commercial activity within the station influence area.

8.2 Guindy

Guindy has strong regional connectivity and is located along an important activity corridor. Within the 0–800 m influence zone, residential land use decreased from 17.96% in 2006 to 12.93% in 2018, a reduction of 5.03 percentage points. Commercial land use increased from 1.76% in 2006 to 3.78% in 2018, an increase of 2.02 percentage points.

The results indicate that the relationship between transit accessibility and land-use change is influenced not only by the metro station but also by the existing economic and spatial characteristics of the surrounding area.

Table 2. Land-use Change Around Selected Chennai Metro Stations, 2006–2018

Station	Residential 2006	Residential 2018	Change	Commercial 2006	Commercial 2018	Change
Ashok Nagar	80.49 %	71.24 %	−9.25 pp	1.76%	4.27%	+2.51 pp
Guindy	17.96 %	12.93 %	−5.03 pp	1.76%	3.78%	+2.02 pp

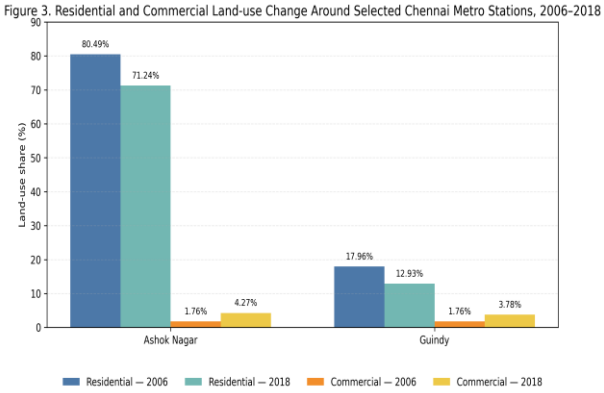

Figure 3. Residential and Commercial Land-use Change in Selected Chennai Metro Station Areas, 2006–2018

Planning lesson: Metro accessibility can support commercial and mixed-use intensification, but such transformation should be accompanied by pedestrian infrastructure, public-space provision, parking management and appropriate development controls.

9. CASE STUDY: CALIFORNIA TRANSIT NODES

The California case examines the land-use composition surrounding two transit nodes: St. Rose of Lima Park in Sacramento and Emeryville Amtrak Station in Emeryville, California. Rather than representing a before-and-after land-use change analysis, the available case data describe the composition of surrounding land uses and therefore provide a comparative indication of the types of activities associated with transit-oriented locations.

Table 3. Land-use Composition of Selected California Transit Nodes

Land Use	St. Rose of Lima Park	Emeryville Amtrak
Residential	9%	10%
Commercial	13%	19%
Public/Semi-public	67%	30%
Industrial	5%	38%
Open/Green	6%	3%

The data indicate different development contexts around the two transit nodes. St. Rose of Lima Park has a substantial public/semi-public land-use component, while Emeryville Amtrak has a relatively high proportion of industrial and commercial land. This suggests that transit-oriented development does not produce a uniform land-use pattern; rather, outcomes depend on the existing economic, spatial and land-use context of the station area.

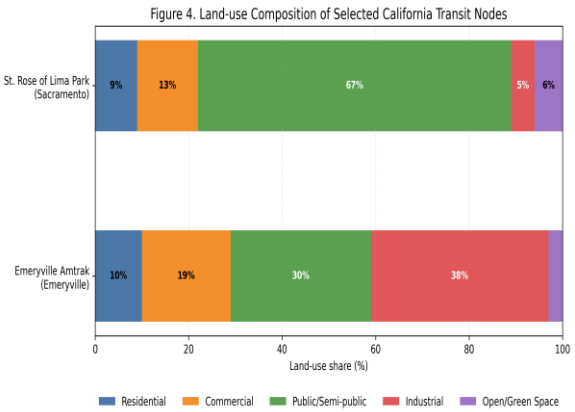

Figure 4. Land-use Composition of Selected California Transit Nodes

Planning lesson: Transit investment should be integrated with the existing development context rather than treated as a standalone mechanism for creating TOD.

10. COMPARATIVE ANALYSIS

The case studies demonstrate that metro investment can influence land-use transformation and development intensity around transit nodes, but the nature of this transformation varies according to the existing urban context.

In **Bengaluru**, residential land use declined while commercial and mixed-use land increased around the selected metro stations between 2001 and 2021. A similar pattern was observed in **Chennai**, where residential land use declined and commercial land use increased between 2006 and 2018.

The **California** cases demonstrate that transit nodes can have substantially different land-use compositions, indicating that transit accessibility alone does not produce a uniform TOD pattern.

Overall, the cases suggest that metro accessibility is an enabling condition rather than a sufficient condition for TOD. Effective TOD requires the integration of land use, urban form, pedestrian/NMT connectivity, public realm and development management.

Table 4. Comparative Findings from the Case Studies

Aspect	Bengaluru	Chennai	California	Overall Finding
Land-use change	Residential ↓; commercial & mixed-use ↑	Residential ↓; commercial ↑	Different land-use composition	Transit can influence surrounding land use
Commercial activity	Increased	Increased	Higher share at Emeryville	Accessibility can support commercial intensification
Urban context	Influences outcomes	Influences outcomes	Strong variation	TOD outcomes are context-specific
Pedestrian/ NMT	Important	Important	Important	Transit access requires local connectivity
TOD implication	Integrate land use and transit	Manage commercial intensification	Adapt to existing land-use structure	Transit proximity alone does not constitute TOD

The cases show that transit-oriented development cannot be understood simply as development occurring within a certain radius of a station.

The outcomes are influenced by:

- existing land-use structure;
- accessibility;
- development potential;
- land availability;
- population and employment;
- economic conditions;
- planning regulations; and
- Quality of public infrastructure.

11. FROM TRANSIT-ADJACENT DEVELOPMENT TO TOD

A major distinction emerging from the review is between transit-adjacent development and genuine Transit-Oriented Development.
Transit-adjacent development occurs when development takes place close to a transit station but does not necessarily integrate:

- walking;
- cycling;
- mixed land uses;
- public spaces;
- multimodal transportation; or
- environmental considerations.

In contrast, TOD seeks to create an integrated urban environment in which:

Transit + Land Use + Urban Form + Walking + Cycling + Public Realm
function together.

Therefore, a high-density commercial area around a metro station cannot automatically be considered successful TOD if pedestrians face unsafe streets, parking dominates the public realm and green infrastructure is inadequate.

Transit proximity should therefore not be treated as a sufficient indicator of TOD success.

12. SUSTAINABLE TOD FRAMEWORK FOR INDIAN CITIES

Based on the literature and reviewed case studies, sustainable TOD in Indian cities can be organised around five interconnected components.

1. Transit Integration

- Mass rapid transit
- Feeder services
- Multimodal interchange
- Efficient last-mile connections

2. Sustainable Urban Form

- Appropriate density
- Mixed land use
- Compact development
- Fine-grained blocks

3. Pedestrian and NMT Infrastructure

- Continuous footpaths
- Safe crossings
- Cycling facilities
- Universal accessibility
- Traffic calming

4. Public Realm and Environment

- Green spaces
- Street trees
- Shaded pedestrian routes
- Public plazas
- Climate-responsive streets
- Stormwater-sensitive surfaces

5. Social Sustainability

- Affordable housing
- Inclusive public spaces
- Equitable access
- Integration of informal activities
- Protection of vulnerable communities

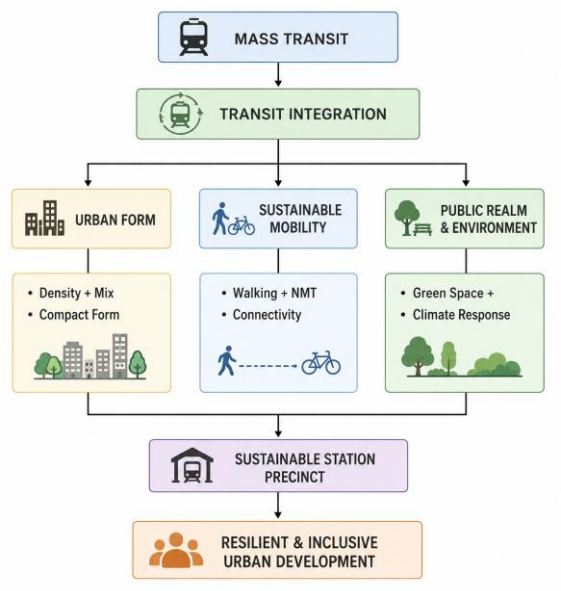

Figure 5. Sustainable TOD Framework for Indian Cities

13. PLANNING IMPLICATIONS FOR INDIAN CITIES

13.1 Plan the Station Precinct, Not Only the Station

TOD planning should extend beyond the physical metro station and consider the surrounding neighbourhood as an integrated urban precinct.

13.2 Prioritise Pedestrians

Pedestrian movement should receive greater priority in the design of station areas through continuous footpaths, safe crossings, shade and universal accessibility.

13.3 Balance Density with Environmental Capacity

Higher development intensity should be supported by adequate infrastructure, public spaces, green areas and pedestrian facilities.

13.4 Integrate Land Use and Transport

Land-use regulations and transportation planning should be coordinated from the early stages of transit development.

13.5 Strengthen Last-Mile Connectivity

Walking, cycling, feeder buses and intermediate public transport should provide convenient connections between stations and surrounding neighbourhoods.

13.6 Protect Public and Green Spaces

Transit-oriented intensification should not result in the unnecessary loss of ecological and recreational resources.

13.7 Incorporate Climate Responsiveness

Future station-area planning should consider shade, vegetation, permeability, stormwater management, thermal comfort and outdoor environmental quality.

14. CONCLUSION

Transit-Oriented Development provides an important opportunity to align transportation investment with sustainable urban development. However, the review demonstrates that the presence of a metro station alone does not guarantee a sustainable built environment.

The Bengaluru and Chennai cases demonstrate that metro infrastructure can be associated with changes in residential, commercial and mixed-use development around station areas. The California case demonstrates that transit nodes can have substantially different land-use compositions depending on their surrounding urban and economic context. At the same time, the cases show that development outcomes vary according to existing urban form, land availability, accessibility, economic conditions and planning regulations. Therefore, TOD strategies cannot simply be transferred from one city to another without considering local conditions.

For Indian cities, the emphasis should move from transit-adjacent development towards integrated station-area planning. Compact and mixed-use development should be

combined with pedestrian and cycling infrastructure, multimodal connectivity, public spaces, green infrastructure and appropriate development controls.

The study concludes that TOD should be understood not merely as a strategy for increasing density around transit stations, but as an integrated approach to sustainable urbanism. When transportation, land use, urban form, mobility, public realm and environmental considerations are addressed together, metro investments can contribute to more accessible, compact, inclusive and environmentally responsive urban development.

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BIOGRAPHIES

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