International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s, 2025
https://www.theaspd.com/ijes.php

Impact Assessment of Mass Rapid Transit Systems (MRTS) on Land Use: Case Study of Proposed Metro Neo-Corridor in Dehradun, Uttarakhand

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Abstract
Mass Rapid Transit Systems, exemplified by the proposed Metro Neo in Dehradun, represent pivotal urban mobility solutions with considerable effects on land utilization, accessibility, and property values. This research investigates the impact of the 8.52 km ISBT–Gandhi Park corridor through the analysis of spatial data, primary surveys, and comparative case studies from Lucknow and Nagpur. The 698.7-hectare zone of influence surrounding the corridor is assessed for existing land use patterns—dominated by mixed-use and commercial developments—and anticipated changes resulting from enhanced connectivity. The findings suggest that MRTS infrastructure generally leads to increased land values, mixed-use densification, and vertical construction. This study advocates for Transit-Oriented Development strategies, including a graded Floor Space Index of up to 4.0, improved pedestrian infrastructure, and land value capture mechanisms to foster sustainable urban development. The research provides a planning framework to leverage MRTS as a catalyst for compact, inclusive, and ecologically sensitive urban development in medium-sized Himalayan cities.
Keywords: MRTS, Metro Neo, Transit-Oriented Development, Land Value Capture, Urban Ecology, Sustainable Urban Growth`

1. INTRODUCTION

1.1 Urban Transport Challenges in Dehradun

Dehradun, the capital of Uttarakhand, has experienced rapid urban expansion since becoming the state capital in 2000. Between 2001 and 2011, the city's population increased by 32.3%, and in 2023, it was estimated to be 992,000, with projections indicating a rise to 1.4 million by 2041 (Dhankar et al., 2024; Garg et al., 2022; Jain et al., 2021). This demographic surge and increased migration have placed considerable pressure on the city's transport infrastructure. The city, nestled in the Himalayan foothills, faces significant challenges due to rapid growth driven by migration, tourism, and industrial expansion (Farid et al., 2020; Shruti et al., 2021) (Kumar et al., 2024). Existing transport infrastructure, predominantly road-based, is increasingly congested, leading to environmental degradation and reduced quality of life.

A significant challenge is the prevalent use of private vehicles. This unplanned urbanisation exacerbates traffic congestion, strains water resources, complicates waste management, and increases susceptibility to natural disasters such as landslides and flash floods. According to the Comprehensive Mobility Plan of 2018, 78% of trips within Dehradun are made using private transport, predominantly two-wheelers and personal cars (Mahadevia et al., 2023; Malik et al., 2019; Mittal, 2020). This has led to severe traffic congestion, particularly during peak times in areas such as Clock Tower, Saharanpur Road, and Rajpur Road. The absence of robust mass public transport options has exacerbated this issue, rendering the city's road-based transit system ineffective (Kumar et al., 2024).

Another key issue is the condition of Right-of-Way. Many major roads in Dehradun suffer from unmanaged or encroached ROWs, frequently lacking well-defined sidewalks, parking areas, or lane discipline (Agarwal et al., 2021; Kandpal, 2019; Mittal, 2020). The inefficient use of ROW results in congestion, safety risks, and slow vehicular movement. For instance, Saharanpur Road and Haridwar Bypass, two of the city's busiest

routes, regularly experience bottlenecks due to a mix of heavy vehicles, auto-rickshaws, two-wheelers, and non-motorized transport, all without dedicated lanes.

The public transport system is currently underdeveloped and fragmented. While local buses and auto-rickshaws offer limited services, they are unreliable and not integrated into a unified network. CMP 2018 data indicates that buses and shared autos account for only 7% of the modal share, while non-motorized transport, including walking and cycling, makes up 15% (Randall et al., 2022). This is largely due to the lack of motor vehicle access in inner-city areas rather than the presence of supportive infrastructure (Joh et al., 2015; Strömgren et al., 2020; Thombre & Agarwal, 2021).

Air pollution is also an increasing concern. Dehradun is listed among India's top non-attainment cities in terms of air quality. The vehicular sector is a major contributor to PM2.5 and PM10 emissions, further compromising environmental and public health standards (Dhankar et al., 2024; Goyal & Khare, 2012; Kansal et al., 2023). The rise in vehicle ownership—from 372 vehicles per 1,000 population in 2011 to over 500 in 2023—has led to a sharp increase in air and noise pollution levels.

Furthermore, the city's linear structure and geographical constraints, situated between the Shivalik Hills and the Yamuna Valley, limit road expansion and infrastructure development. Many vital urban areas are located in ecologically sensitive zones, such as river floodplains and forested buffers, which further restrict physical road widening. To address these issues, the government of Uttarakhand proposed the Dehradun Metro Neo project in 2019.

In summary, Dehradun's urban transport system is characterized by:

a) High dependence on private modes (78%)
b) Limited and unorganized public transport
c) Encroached and inefficient ROW
d) Rising vehicular pollution
e) Spatial and ecological constraints for infrastructure expansion

These multifaceted challenges demand an urgent, structured intervention. The introduction of the Metro Neo MRTS offers a timely opportunity to create a sustainable, efficient, and inclusive public transport backbone that can address these issues comprehensively (Liu et al., 2024). Integrated planning that links land use and transport, along with policy reforms and infrastructural upgrades, is essential to ensure Dehradun's growth remains livable and environmentally balanced (Dawda et al., 2021; Joshi et al., 2020).

1.2 Metro Neo Initiative

To address the growing mobility challenges of Dehradun, the Government of Uttarakhand approved the Metro Neo system in 2021 as a cost-effective, eco-friendly, and modern public transport solution. Designed specifically for Tier-2 and mid-sized cities, Metro Neo is a rubber-tyred electric transit system that operates on elevated or at-grade corridors (Dhabhai, 2017; Sharma et al., 2013). It serves as an affordable alternative to traditional metro systems like Metrolite or heavy metro, with comparable service quality but significantly reduced capital and operational cost. (Lu et al., 2024).

The Uttarakhand Metro Rail Corporation (UKMRC), under the guidance of the Ministry of Housing and Urban Affairs (MoHUA), prepared the Detailed Project Report (DPR) which outlines the proposed corridors, station locations, ridership forecasts, and implementation strategies. In Phase 1, the DPR proposes the development of two key corridors: North-South Corridor (ISBT – Gandhi Park): This 8.52 km corridor includes 10 elevated stations and connects major urban nodes such as the Inter-State Bus Terminal (ISBT), Railway Station, Court Complex, Patel Nagar, Clock Tower (Ghantaghar), and terminates at Gandhi Park. Figure 1 below indicates the neo corridor for Dehradun with a glance at images.

International Journal of Environmental Sciences
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Vol. 11 No. 16s, 2025
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Figure 1. Visuals of the Proposed Metro Corridor at Dehradun

Figure 2 below indicates the route of the East-West Corridor (FRI – Raipur): Spanning 13.90 km with 15 elevated stations, this corridor connects critical institutions such as the Forest Research Institute (FRI), IMA Blood Bank, Doon School, and residential and administrative areas along Raipur Road.

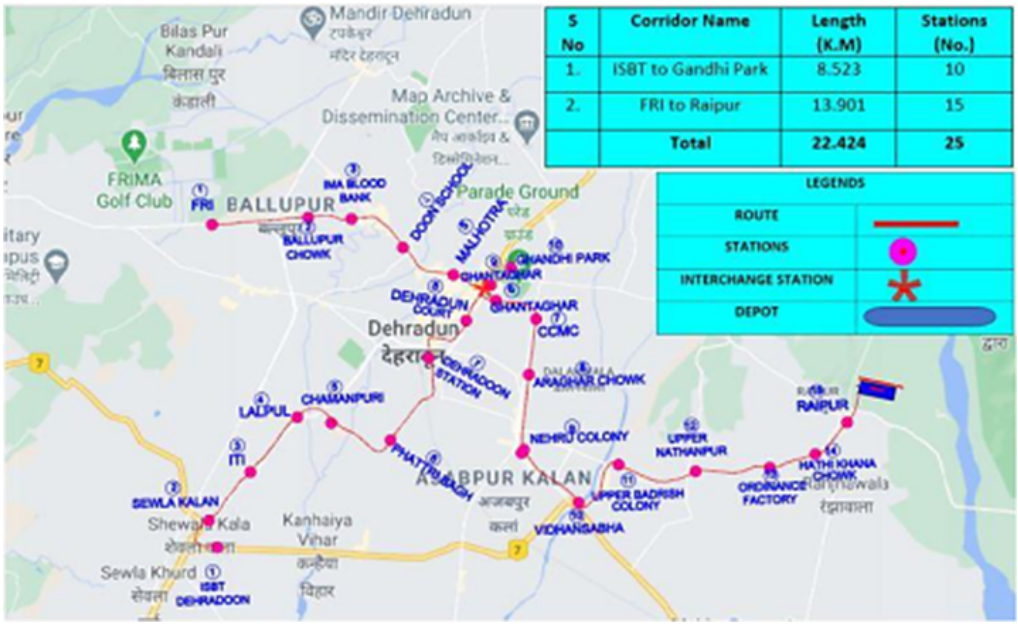

Figure 2. Proposed Metro Neo in Dehradun (Source: Metro Neo DPR UKMRC)

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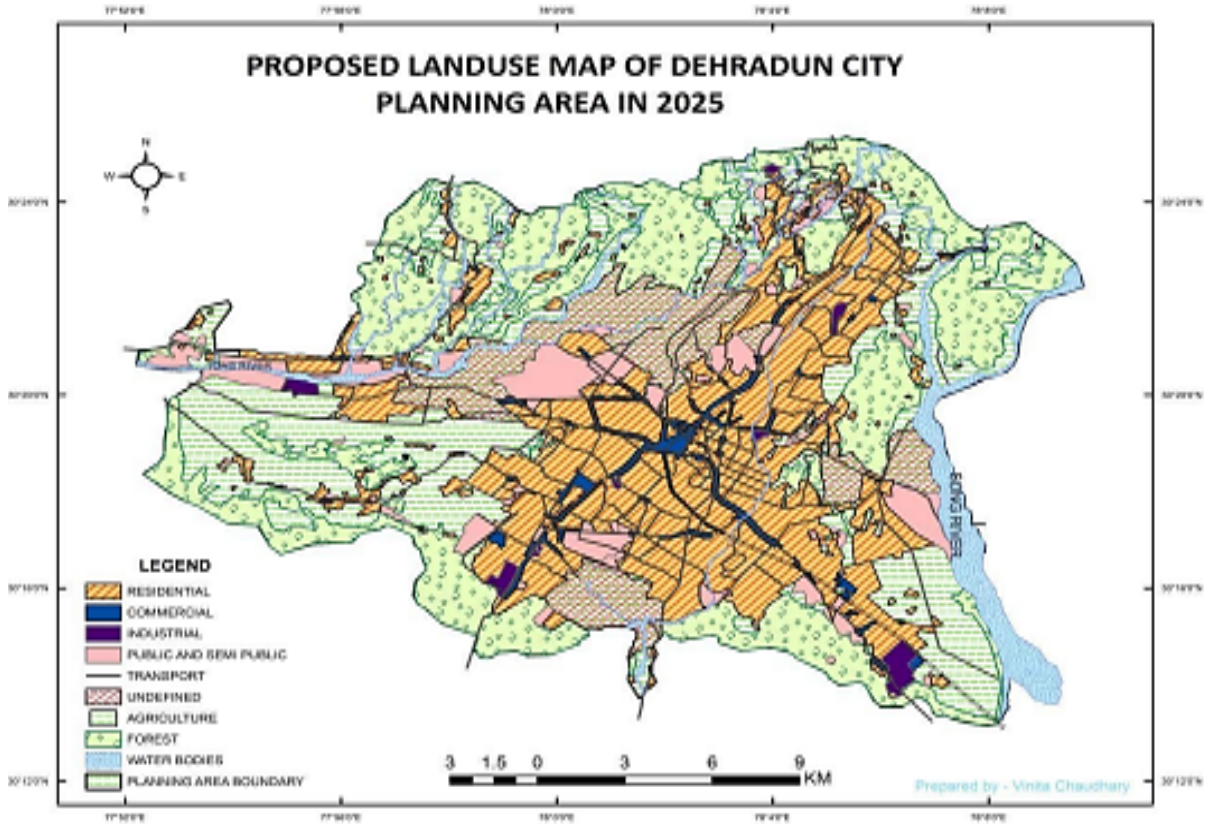

Figure 3. Proposed Land-Use Map of Dehradun Region 2025

The master plan has the provision of expansion of the metro Rail routes, as the capital city of Uttarakhand is facing major challenges with traffic management issues. The proposed Land use in Figure 3 above indicates the major deforested regions for upcoming future, also posing challenges for the environment.

Table 1. Proposed Metro Neo Corridor

Corridor	Length (km)	Stations	Revenue/Fund from the TOD
ISBT – Gandhi Park	8.52	10	200 crores
FRI – Raipur	13.90	15	200 crores
Transport Nagar - Premnagar (suggested/proposed)	22.8	18	Proposed

Table 1 above gives the details related proposed Metro Neo corridor. Together, the corridors total 22.42 km with 25 elevated stations, designed to carry a projected daily ridership of 295,492 passengers by 2051 (Source: DPR, UKMRC). Table 2 below provides the details about Metro Neo trips/daily ridership potential and how vehicles will be equipped with battery-operated rubber tyres, operate on exclusive guideways, and offer last-mile connectivity through integration with e-rickshaws, bicycle-sharing, and pedestrian networks (Liu et al., 2024; Zhang et al., 2025).

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Table 2. Daily Ridership for Dehradun Metro Neo corridors

S. No.	Corridor	Route length (Kms)	Daily Ridership				
			2021	2026	2031	2041	2051
1	ISBT to Gandhi park (N-S)	8.523	79,349	88,215	97,081	120337	147302
2	FRI to Raipur (E-W)	13.901	86076	92679	99283	122190	148190
	Total	**22.424**	**165425**	**180894**	**196364**	**242527**	**295492**

Source: Metro-Neo DPR UKMRC

This initiative reflects a paradigm shift in Dehradun's mobility planning—from fragmented road-based systems to integrated, multimodal, and transit-oriented development. Figure 4 depicts the key influenced area in hectares from 2022 to 2042. Industries are expected to increase substantially shortly.

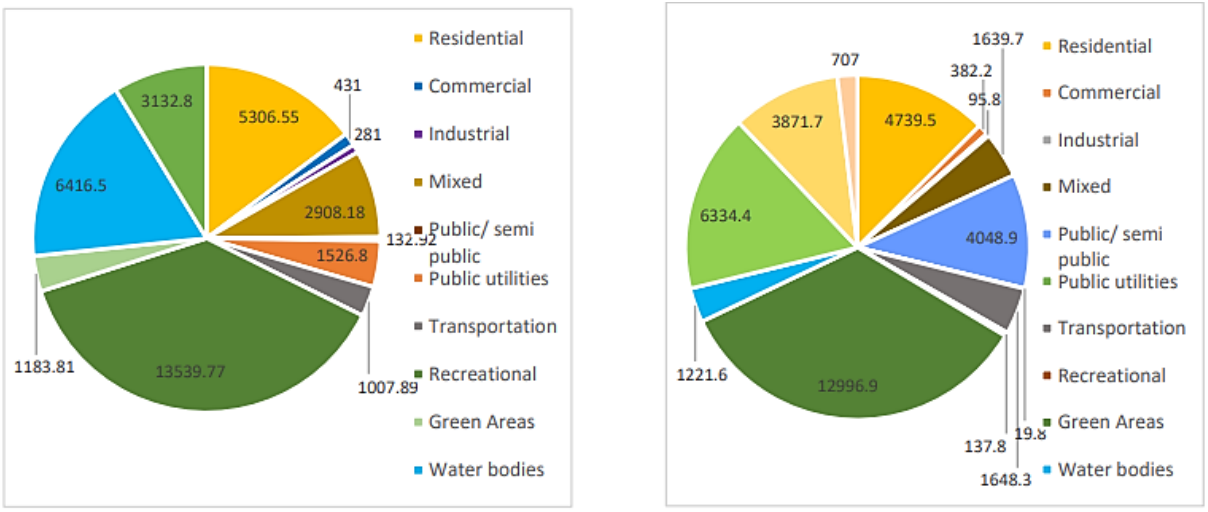

Figure 4. Land use of Dehradun planning area as per ELU 2022 (Source: Master plan 2041)

2. METHODOLOGY

2.1 Study Area & Influence Zone

a) The influence zone is defined as a 400 m buffer, encompassing 698.7 ha.
b) Key zones include ISBT, Patel Nagar, Saharanpur Road, and Clock Tower. Map 1: Influence Zone and Station Locations

2.2 Data Sources

a) Primary data was collected through visual surveys and interviews with real estate agents and commuters.
b) Secondary data sources include the DPR, Master Plans 2025/2041, and case studies from Lucknow and Nagpur

3. LITERATURE REVIEW

3.1 Key concepts include:

a. Bid-Rent Theory: How accessibility affects land value.
b. Land Value Capture: Using tools like betterment levies and TOD premiums to recover public investments.
c. Global Examples:
d. Delhi Metro: Land value increased up to 100%.
e. Nagpur: 25% increase within 500 m.
f. Copenhagen Finger Plan: Integrated land and transport planning for sustainability.

4. CASE STUDIES

Mass Rapid Transit Systems have reshaped urban development across India. To draw relevant lessons for Dehradun's Metro Neo project, this study analyzes three cities—Lucknow, Nagpur, and Kochi—that implemented MRTS projects with varying policy frameworks, land value mechanisms, and transit-oriented development approaches. Examining these diverse cases allows for a comprehensive understanding of best practices and potential pitfalls in implementing similar projects.

Lucknow, the capital of Uttar Pradesh, introduced its metro system in (Sinha, 2021) 2017 to address chronic traffic congestion. The Lucknow Metro Rail Corporation adopted a comprehensive Transit-Oriented Development policy to promote compact, mixed-use development along the metro corridor.

4.1 Lucknow Metro

Lucknow Metro, operational since 2017, covers over 23 km with elevated and underground sections and has demonstrated a tangible impact on land values and urban form (Verma & Tiwari, 2020).

a) **Land value appreciation:** Properties within 500 m of stations experienced a significant 20–25% increase in value, indicating the metro's positive influence on real estate.
b) **Weak TOD policies:** Despite substantial infrastructure investment, last-mile connectivity remains a challenge, particularly in peripheral stations, hindering comprehensive transit-oriented development.
c) **Development Potential Index:** The inconsistent zoning policies have led to mixed results in realising development potential, underscoring the need for integrated urban planning.

Table 3. Development Potential at Select Stations

Station	LPI*	LVI^	Development Potential
Charbagh	0.68	0.64	High
Hazratganj	0.98	0.52	High
Transport Nagar	0.46	0.92	Medium

Note: *LPI: Land Potential Index ^LVI: Land Value Index

Key Challenge: TOD implementation is slow due to rigid master plan boundaries and a lack of integration with feeder systems. Therefore, Dehradun can integrate land use planning with transit nodes to address this challenge. From the case study, Table 3 above shows how development potential is key for land use planning.

4.2 Nagpur Metro

Nagpur Metro emphasizes **green TOD** and financial sustainability through land value capture.

a) **Land value gain**: 25–30% increase within 500 m of stations.
b) **FSI policy**: Base FSI of 2.0; purchasable FSI up to **4.0** near stations.
c) **LVC Tools**: 1% **betterment levy** introduced; generated funding for 15% of project costs.
d) **Green space mandate**: 10% open space compulsory in station-area development.

Key Challenge: Although FSI incentives are generous, low population density in fringe areas limits vertical development potential.

4.3 Kochi Metro

Kochi Metro, operational since 2017, pioneered integrated urban mobility and environmental planning. Its success can be attributed to several key factors:

a) Multi-modal integration: The metro is integrated with buses, boats, and auto services, enhancing connectivity and convenience for commuters (Cui & Zhang, 2024).
b) Land pooling & acquisition: Successful use of land pooling to develop stations with minimal conflict ensured smooth project implementation.
c) Inclusive TOD: There is a focus on affordable housing, heritage-sensitive zones, and walkability, promoting equitable urban development.

Key Features:

a) Integrated ticketing with Water Metro
b) 4–6% annual land value rises in central zones (MG Road, Kaloor)
c) Station redevelopment projects include commercial plazas, green corridors

Key Challenge: High construction costs and soft soil conditions led to delays and cost overruns.

4.4 Comparative Analysis of Metro Case Studies

Here table 4 below showcases the metro rail (MRTS) case study comparison with the respective parameters which may affect the land use development in the city.

Table 4. Comparison of MRTS Case Studies

Parameter	Lucknow	Nagpur	Kochi
Land Value Uplift	20–25%	25–30%	4–6% (avg.)
TOD Implementation	Weak	Moderate	Strong & inclusive
FSI Incentives	Max 2.5	Max 4.0	Variable by zone
LVC Tools	Stamp duty surcharge	Betterment levy	Land pooling, PPP
Integration with NMT	Low	Moderate	High
Heritage/Ecology Sensitivity	Not emphasized	Green TOD policies	Strong focus
Last-Mile Connectivity	Poor	Developing	High (bus, boat, NMT)

4.5 Relevance to Dehradun

a) As a mid-sized capital city with mixed land use and historic cores, Dehradun shares similarities with Lucknow. However, Dehradun must proactively address the shortcomings of Lucknow's metro by strengthening TOD enforcement and ensuring robust feeder services.
b) Dehradun can draw valuable lessons from Nagpur by adopting flexible FSI incentives and implementing betterment levies to finance the project while safeguarding green zones (Metro Neo Project for Uttarakhand, 2021).
c) Given Dehradun's ecological sensitivity and tourism focus, Kochi's approach offers a relevant model. By integrating water-sensitive design principles, promoting inclusive planning practices, and prioritizing last-mile connectivity strategies, Dehradun can guide station-area redevelopment in areas such as Saharanpur Road and Railway Station.

4.6 Challenges in Replication

a) Land constraints in Dehradun’s core make vertical development complex, necessitating innovative design and construction techniques to maximize space utilization.
b) Institutional fragmentation may delay LVC implementation unless a TOD Authority is formed, hindering coordinated planning and revenue generation.
c) Ecological buffers and seismic risk zones limit high-rise development, requiring careful assessment and mitigation strategies to ensure structural integrity and environmental sustainability.

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5. DEHRADUN CORRIDOR: LAND USE & IMPACT ANALYSIS

5.1 Existing Land Use

In the 698.7 ha Influence Zone, the influence zone of the Metro Neo corridor in Dehradun spans a 400-meter buffer on either side of the 8.52 km alignment between ISBT and Gandhi Park, encompassing approximately 698.7 hectares. This area includes several key urban nodes such as ISBT, Patel Nagar, Saharanpur Road, the Railway Station, and Clock Tower, all of which are vital for commercial, administrative, and mobility functions in the city (Begam et al., 2024; Lahoti et al., 2019). The corridor aims to integrate these nodes through an efficient and sustainable transit system. A detailed GIS-based spatial analysis using Master Plan 2041 land use layers reveals the following land use distribution:

Table 5. Land Use Distribution in Influence Zone

Land Use Type	Area (Ha)	% Share
^Mixed Use (Residential + Commercial)	300	43%
Commercial	97	14%
Transportation	94	13%
Vacant Land	46	6%
Green/Open Spaces	33	5%
Others (Institutional, Govt., Utilities)	60	9%
Total	**630**	**100%**

As per the assessment of the Land use Distribution, the most^ influenced will be Mixed Use (Residential + Commercial), consisting of a 300-hectare area with a share of 43% in Dehradun.

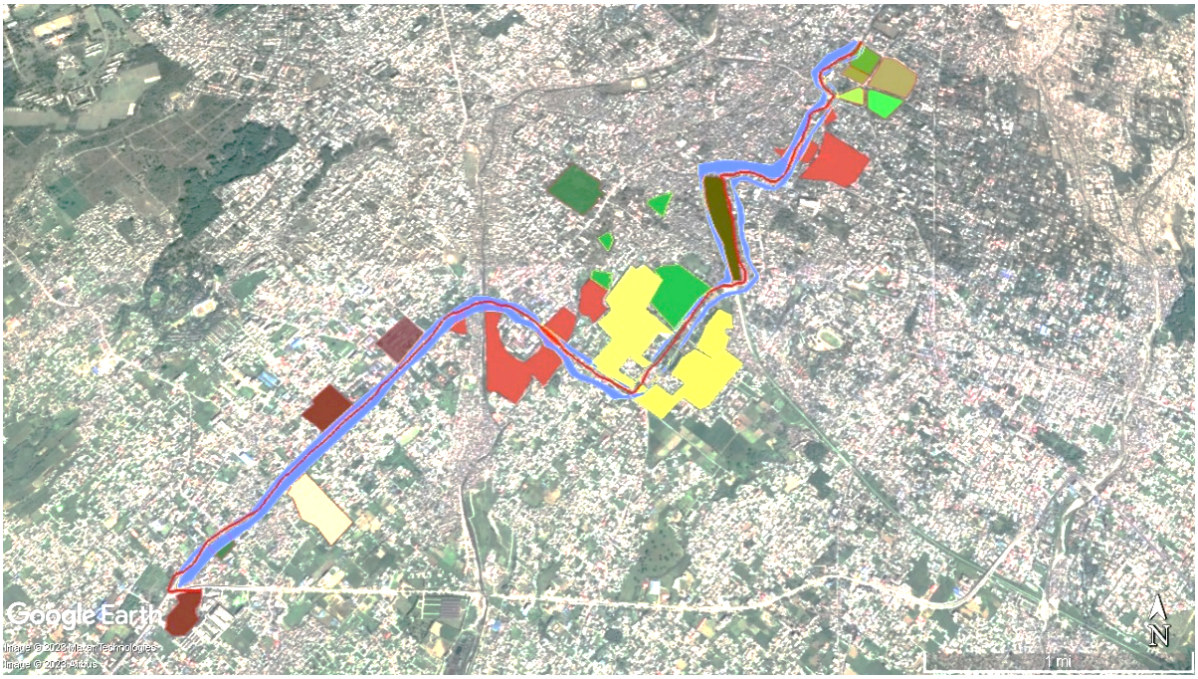

Figure 5. Existing land use in the influence zone of Dehradun. (Source: Author)

Figure 5 above assesses the influence zone of Dehradun. The mixed-use classification, constituting the largest portion at 43% or 300 hectares, underscores the organically developed urban characteristic of the corridor. Zones such as Paltan Bazaar, Saharanpur Road, and Patel Nagar exhibit a detailed integration of residential, retail, and commercial properties, typically within low-rise building structures. Commercial land, covering 97 hectares, is primarily located around Clock Tower, the Railway Station, and near ISBT. These areas function as key commercial centers with substantial pedestrian activity, positioning them as ideal locations for densification strategies under Transit-Oriented Development policies (Purwantiasning & Bahri, 2021;

Widiyastuti et al., 2020). Transportation infrastructure encompasses 13% of the area, including existing roads, terminals, and bus depots. The availability of 46 hectares of vacant land presents notable opportunities for redevelopment or land pooling initiatives, particularly in the vicinity of Saharanpur Road and adjacent residential areas. However, green and open spaces are limited to only 5%, indicating an urgent need to incorporate urban green buffers, green roofs, and compensatory landscaping measures into TOD planning. The current land use distribution presents both opportunities and challenges. While the high density of mixed-use areas supports ridership, unplanned development and prevalent low-rise buildings may restrict vertical expansion unless reinforced by policy reforms and infrastructure enhancements.

5.2 Land Value Trends

The land value along the proposed Metro Neo corridor in Dehradun demonstrates a clear gradient based on proximity to major commercial and transport hubs. In the core areas like Clock Tower, land prices are among the highest in the city, ranging from ₹1.5 to ₹2.5 lakh per square meter, driven by the area's commercial density, pedestrian activity, and institutional presence. This zone includes high-footfall streets such as Paltan Bazaar and Darshan Lal Chowk. These factors collectively enhance the area's attractiveness for businesses and retail, driving up property values. (Uddin et al., 2023). In contrast, areas near the Inter-State Bus Terminal, though significant for transit and logistics, reflect comparatively lower real estate demand. Land prices here currently range from ₹0.8 to ₹1.2 lakh per square meter, largely due to lower commercial activity and the presence of underutilized land parcels. Limited infrastructure and less developed commercial establishments contribute to this price difference (Noorloos et al., 2019)

Based on trend analysis from comparative MRTS projects, the Metro Neo corridor is expected to induce a land value appreciation of 20–30% within 200 meters of station locations. Beyond this, within the 400-meter influence zone, land values are projected to increase by 10–15% over the next 5–10 years. This uplift creates opportunities for land value capture mechanisms such as betterment levies and TOD premiums to fund infrastructure upgrades sustainably (Ahmad et al., 2015; Le et al., 2018; Verma & Tiwari, 2020).

5.3 Forecasted Land Use Change

The introduction of the Metro Neo system is expected to substantially reshape land use patterns within the designated 698.7-hectare impact area. Enhanced accessibility and the potential for increased property values are projected to stimulate vertical densification, particularly in mixed-use districts like Patel Nagar, Saharanpur Road, and Clock Tower. Existing low-rise structures are anticipated to transition into mid-rise buildings to take full advantage of Floor Space Index incentives and opportunities for land value capture. A significant trend involves the conversion of residential and wholesale properties along Saharanpur Road into high-density commercial and hospitality zones, leveraging the increased pedestrian traffic near transit hubs. While this aligns with Transit-Oriented Development principles, it may strain existing road capacities, parking facilities, and municipal services if not carefully managed. Furthermore, spatial simulations suggest a possible 5% decrease in green and open spaces, primarily due to uncontrolled redevelopment and land intensification (Wang et al., 2013; Xu et al., 2020). This poses risks to ecological equilibrium, exacerbates urban heat island effects, and diminishes groundwater recharge in a city already environmentally vulnerable due to its Himalayan setting. It is crucial to consider whether land intensification strategies are adequately balanced with environmental protection measures and social equity considerations. Without proactive zoning regulations, adherence to green building standards, and inclusive redevelopment models, the Metro Neo corridor risks replicating existing patterns of congestion and inequality in a vertical format.

6. STRATEGIC RECOMMENDATIONS

6.1 Transit-Oriented Development (TOD) Zoning

Transit-Oriented Development is a crucial and sustainable urban planning strategy that focuses on creating high-density, mixed-use developments within walking distance of transit stations. This approach aims to reduce reliance on private vehicles, promote the use of public transport, and foster vibrant, pedestrian-friendly neighbourhoods. Table 6 for Proposed FSI Gradients, where the Dehradun MRTS corridor, TOD zoning is

essential for optimising land use, effectively managing urban growth, and mitigating potential environmental impacts (Noorloos et al., 2019).

Table 6. Proposed FSI Gradients

Distance from Station	Commercial FSI	Residential FSI
0–200 m	4.0	3.5
200–500 m	3.0	2.5

6.2 Key Zoning Recommendations

Implementing a gradient-based Floor Space Index system is imperative, with higher FSI values allowed within 200 meters of transit stations to encourage vertical development and optimize land utilization (Xu et al., 2020).

1) Integrate a Mandated 30% Residential Component in Commercial Zones: To foster mixed-use environments, a requirement for a minimum of 30% residential space within commercial zones proximal to transit stations is essential. This strategy aims to promote continuous activity, enhance community safety through increased pedestrian presence, and decrease commuting distances, thereby diminishing vehicular emissions.
2) Implement 15-m Green Buffer Zones Along Drainage Systems: In response to the environmental challenges posed by rapid urbanization, the preservation and enhancement of natural drainage systems are critical. The implementation of a mandatory 15-meter green buffer zone along existing drains and water bodies within the TOD influence zone is recommended to support environmental sustainability.

6.3 Environmental Discussion

Green Buffer Zones: Ecological Role and Advantages

Green buffers are essential ecological components in urban environments, performing several environmental functions:

1) Enhancement of Water Quality: Green buffers act as filters, removing pollutants from stormwater runoff before it enters natural drainage systems. This process enhances water quality and mitigates the risk of contamination to both groundwater and surface water resources. Research indicates that vegetated buffers can effectively reduce pollutants such as nitrates, phosphates, and heavy metals by up to 70%.
2) Mitigation of Flooding and Improved Drainage: In regions like Dehradun, which are prone to flash floods during the monsoon season, green buffers alongside drainage channels enhance water infiltration and reduce the velocity of runoff. This, in turn, decreases peak discharge loads on urban drainage systems, thereby alleviating flood risks (Xu et al., 2020).
3) Regulation of Microclimate: Green buffers contribute to moderating urban heat islands by providing shade and facilitating evapotranspiration cooling effects. This function is particularly relevant for Dehradun, which has experienced increases in average temperatures due to urbanisation and deforestation.
4) Conservation of Biodiversity: These buffer zones foster habitat continuity for local flora and fauna, thereby supporting urban biodiversity and ecological equilibrium (Noorloos et al., 2019).
5) Improvement of Public Health and Recreational Amenities: Green spaces improve air quality by absorbing pollutants and particulate matter, an essential benefit in areas facing increasing traffic-related pollution. Additionally, they offer aesthetic and recreational opportunities, which enhance community well-being.

6.4 Supporting Data and Context from Dehradun

1) Urban Growth and Environmental Stress: Dehradun's rapid expansion toward Selaqui Industrial Area and along transit corridors has led to increased impervious surfaces, reduced green cover, and pressure on drainage systems. Studies indicate a decline in natural vegetation and increasing instances of drainage clogging and water pollution.

2) Drainage System Vulnerability: The existing drainage network in Dehradun is often burdened during monsoons, causing waterlogging and surface runoff contamination. A 15-m green buffer will provide a vegetated zone capable of buffering runoff impacts.
3) Policy Alignment: The proposed buffer aligns with national urban environmental guidelines and Smart City mission objectives that emphasize green infrastructure for sustainable urban water management.

Summary: The TOD zoning strategy for the Dehradun MRTS corridor, featuring tiered FSI values that incentivize high-density construction near stations, along with mandates for mixed-use development and the establishment of green buffer zones, presents a well-rounded approach. This framework effectively promotes urban expansion while simultaneously tackling critical environmental issues like water contamination, flood management, urban heat island effects, and the preservation of biodiversity. Successful execution hinges on rigorous enforcement of zoning regulations, proactive community engagement, and seamless integration with comprehensive city-wide stormwater management strategies. By adopting these measures, Dehradun can accomplish its objectives of fostering sustainable urban development, strengthening urban resilience, and ensuring the long-term environmental health of the region.

6.5 Land Value Capture Mechanisms

To fund infrastructure and transit enhancements within the Dehradun MRTS influence zone, a Betterment Levy of 1% is proposed on the appreciated land value. This levy is designed to capture the incremental increase in land value accruing to landowners as a result of improved accessibility and urban amenities provided by the MRTS project (Xu et al., 2020). With the total land value increase estimated for the influence zone, the Betterment Levy could potentially generate approximately INR 400 crore. These revenues can be strategically reinvested in transit infrastructure, public amenities, and environmental improvements, thereby ensuring sustainable urban growth and a more equitable distribution of development benefits among all stakeholders.

6.6 Supporting Data and Context from Dehradun.

According to research, cities across the globe are leveraging rises in value to support infrastructure development and innovation (Verma & Tiwari, 2020).

1) Land Value Appreciation: Land values near transit corridors in Indian cities typically increase significantly due to enhanced accessibility and infrastructure development. Urban Growth and Environmental Stress: Dehradun's rapid expansion toward Selaqui Industrial Area and along transit corridors has demonstrably increased impervious surfaces, reduced green cover, and strained drainage systems. Empirical studies further validate these observations, indicating a significant decline in natural vegetation cover and a corresponding rise in instances of drainage clogging and aggravated water pollution.
2) Drainage System Vulnerability: The existing drainage network in Dehradun is particularly vulnerable during monsoons, frequently overwhelmed and causing widespread waterlogging and surface runoff contamination. A 15-m green buffer offers a practical, nature-based solution by providing a vegetated zone capable of effectively buffering runoff impacts and mitigating flood risks.
3) Policy Alignment: The proposed buffer aligns seamlessly with national urban environmental guidelines and the Smart City mission objectives, both of which strongly emphasize the integration of green infrastructure for sustainable urban water management and ecological preservation.

6.7 Urban Design Measures

To improve the pedestrian experience and enhance connectivity along the Dehradun MRTS corridor, the implementation of 5 km of shaded footpaths is suggested. These paths will offer protection from adverse weather conditions, encourage pedestrian activity, and reduce reliance on vehicular transport (Noorloos et al., 2019). The shaded walkways are designed to improve the local microclimate by reducing urban heat island effects and encouraging active transportation, thereby diminishing carbon emissions.
To ensure secure and seamless pedestrian movement across heavily trafficked roads and transit centers, the

construction of 10 skywalks is proposed. This will minimize conflicts between pedestrians and vehicles, enhance overall traffic safety, and improve accessibility for individuals with disabilities. The development of integrated multi-modal hubs will provide seamless connections between MRTS stations and various modes of transport, including buses, taxis, and non-motorised options. This will facilitate efficient last-mile connectivity and reduce overall travel times. Such hubs are intended to support a shift toward sustainable transportation methods, alleviating congestion and reducing pollution (Ahmad et al., 2015; Le et al., 2018; Verma & Tiwari, 2020)

To maintain the historical and cultural integrity of the Clock Tower precinct, strict façade controls are crucial. These controls will ensure that new constructions are in harmony with the existing historic context, promoting tourism, community pride, and balanced urban development.

6.8 Discussion Points

a) Environmental Impact: Shaded footpaths and skywalks contribute to urban cooling and improve air quality by encouraging walking and cycling, thereby reducing reliance on motorized transport and associated emissions.
b) Social Inclusion: Multi-modal hubs and pedestrian infrastructure enhance accessibility for all users, including elderly and differently-abled populations, promoting equitable mobility and access to opportunities.
c) Heritage Preservation vs. Modernization: Façade controls balance development pressures with conservation, maintaining the historic fabric while accommodating contemporary urban needs, ensuring that modernization efforts respect the city's cultural identity.
d) Economic Benefits: Improved walkability and connectivity can boost local businesses and property values, generating economic vitality in the corridor by attracting investment and fostering a vibrant public realm.
e) Implementation Challenges: Land acquisition, funding, and stakeholder coordination are critical challenges requiring integrated planning and policy support to ensure project success and minimize disruption.

6.9 Institutional Setup

To facilitate the implementation of Transit-Oriented Development policies along the Dehradun MRTS corridor, the establishment of a dedicated TOD Authority under the Uttarakhand Metro Rail Corporation is recommended. This specialized entity would be responsible for the coordination of planning, zoning, infrastructure development, and the enforcement of TOD guidelines. By centralizing TOD management within UKMRC, the alignment with transit operations is ensured, decision-making processes are streamlined, and integrated urban development is fostered (Farid et al., 2020; Shruti et al., 2021) (Kumar et al., 2024). Furthermore, the institutionalization of ward-level public consultations is essential to incorporate input from local stakeholders, address community concerns, and enhance overall transparency. Public participation is critical for cultivating a sense of ownership, mitigating potential resistance, and tailoring interventions to meet the specific needs of individual neighborhoods. To ensure strict compliance with TOD regulations and quality control in construction projects, establishing an independent regulatory body is crucial. This entity would conduct regular audits, assess environmental impacts, and enforce building standards, thereby promoting sustainable development practices and maintaining the integrity of the TOD vision.

Supporting Data and Context:

a) Global Best Practices: Cities like Singapore and Portland have dedicated TOD agencies that coordinate transit infrastructure with land use, improving project efficiency and community acceptance.
b) Local Context: Dehradun's municipal governance currently lacks a dedicated TOD management framework, leading to fragmented land-use decisions and coordination challenges.
c) Community Engagement: Research indicates that over 70% of urban development projects see improved outcomes when local communities are actively involved in planning phases, reducing

conflict and delays. Such engagement fosters a sense of ownership and ensures that projects are tailored to meet specific community needs.

Critical Discussion:

a) Institutional Challenges: Creating a new authority under UKMRC may face bureaucratic hurdles and require clear jurisdictional mandates to avoid overlap with municipal and state bodies, potentially leading to inefficiencies and conflicts of interest.
b) Resource Allocation: The TOD Authority will need adequate technical, financial, and human resources to be effective; insufficient capacity may undermine its role and limit its ability to implement and enforce TOD policies. (Noorloos et al., 2019)
c) Public Consultation Quality: Ward-level consultations risk becoming tokenistic if not well-structured. Genuine engagement demands transparent processes, feedback mechanisms, and conflict resolution frameworks, ensuring that community input meaningfully shapes project outcomes.
d) Equity Concerns: Without careful oversight, TOD initiatives may prioritize commercial interests over affordable housing, risking displacement of lower-income residents and exacerbating social inequalities.
e) Policy Integration: The authority must coordinate with broader urban policies—environment, transport, heritage—to ensure holistic development, aligning TOD strategies with sustainability goals and preserving cultural assets.

Key Discussion on Emerging Concerns and Planning Implications: While the Metro Neo project presents an unprecedented opportunity for transforming Dehradun's mobility and urban form, certain challenges and additional considerations must be addressed through further research and policy intervention.

6.10 Safety Concerns

The elevated corridor design must be rigorously evaluated for **pedestrian, cyclist, and commuter safety**. Current ROW conditions in areas like Saharanpur Road and Patel Nagar are already constrained and chaotic. Station design must incorporate **universal accessibility**, adequate lighting, clear signage, CCTV surveillance, and **safe pedestrian crossings**. Additionally, overhead infrastructure poses risks during earthquakes and extreme weather—necessitating **seismic resilience audits** as per Dehradun's vulnerability profile (Seismic Zone IV).

6.11 Proposed Extension to Premnagar Institutional Area

Dehradun houses key academic institutions such as the Indian Military Academy, Forest Research Institute, Doon University, and DIT University, many of which are located near Premnagar. Extending Phase II from Gandhi Park or Raipur Road toward Premnagar could connect this major educational hub, relieving pressure on Rajpur Road and improving accessibility for a significant student population. A ridership potential analysis for students and staff commuters can help justify this strategic extension. (Noorloos et al., 2019)

6.11.1 Feasibility: Cost and Environmental Considerations

Although Metro Neo is more affordable than traditional metro systems, a comprehensive cost-benefit feasibility study must weigh capital expenditure against projected ridership, land acquisition, and environmental impact. Dehradun's fragile ecology, including forest belts, water recharge zones, and floodplains, requires a comprehensive Environmental Impact Assessment. Carbon emissions saved through mode shift should be factored into a life-cycle assessment to validate long-term sustainability.

6.11.2 Noise Pollution and Urban Livability

Elevated corridors often introduce noise pollution, especially in dense residential zones. Rubber-tyred coaches, though quieter than steel-wheel metros, still emit operational and structural noise. Enforcing noise attenuation strategies, including sound barriers, green buffers, and acoustic treatment of viaducts, is critical. Residential zones within 100 meters of stations must be assessed for decibel impacts, particularly near schools, hospitals, and religious precincts. This discussion frames actionable research and planning concerns to ensure

the Metro Neo's success is not only infrastructural but also socially and environmentally integrated. It can address the heightened levels of nitrogen dioxide resulting from urbanisation by providing a sustainable transport solution (Dhankar et al., 2024).

7. CONCLUSION

The Metro Neo corridor in Dehradun presents a transformative opportunity to reshape the city's urban land dynamics, offering a chance to foster Transit-Oriented Development that enhances land use efficiency and diminishes dependence on private vehicles. With the potential to escalate land values by 15–25%, the corridor can stimulate compact, high-density development, provided strategic land use policies are in place. Moreover, it represents a crucial revenue stream via Land Value Capture mechanisms, enabling the funding of sustainable infrastructure and public amenities. Drawing lessons from cities like Lucknow and Nagpur underscores the necessity of early integration of land use and transport planning to ensure synchronized urban growth. Conversely, neglecting integrated planning may lead to urban sprawl, traffic congestion, and increased social inequality, thereby diminishing the project's overall advantages. Robust stakeholder engagement, encompassing community consultations and institutional coordination, is vital for crafting inclusive, context-sensitive solutions. To mitigate ecological impacts and preserve heritage values, environmentally conscious zoning practices, such as green buffer zones and façade controls, are essential. Environmental concerns are particularly salient in fragile Himalayan ecosystems such as Dehradun. Insufficient green buffer zones and a lack of environmentally responsive zoning could exacerbate drainage problems, elevate flood risks, and intensify urban heat island effects due to increased construction and impermeable surfaces. Prioritizing the preservation of natural drainage channels and the incorporation of green infrastructure into urban planning is crucial for safeguarding local ecology and bolstering climate resilience. This study serves as a blueprint for harnessing MRTS corridors as catalysts for sustainable urban development in medium-sized Himalayan cities, emphasizing the need for integrated and environmentally sensitive planning approaches.

Way Forward

To facilitate holistic and sustainable urban development, a dedicated Transit-Oriented Development Authority under the Uttarakhand Metro Rail Corporation should coordinate integrated planning and enforce zoning regulations. Public consultations at the ward level will ensure inclusive decision-making processes. Prioritizing green infrastructure, enforcing Land Value Capture policies, and monitoring environmental impacts are crucial for guiding equitable and ecologically sound development. Adaptive management strategies are essential to address evolving urban and climatic challenges.

Declaration of Competing Interest

The authors affirm the absence of any conflicts of interest, whether financial or personal, that could be perceived as influencing the outcomes or interpretations presented in this study.

Funding

This study was conducted without the support of specific grants from public, commercial, or non-profit funding organizations.

REFERENCES

1. Agarwal, M. K., Sehgal, V., & Ogra, A. (2021). A Critical Review of Standards to Examine the Parameters of Child-Friendly Environment (CFE) in Parks and Open Space of Planned Neighborhoods: A Case of Lucknow City, India [Review of A Critical Review of Standards to Examine the Parameters of Child-Friendly Environment (CFE) in Parks and Open Space of Planned Neighborhoods: A Case of Lucknow City, India]. Social Sciences, 10(6), 199. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/socsci10060199
2. Ahmad, S., Avtar, R., Sethi, M., & Surjan, A. (2015). Delhi's land cover change in post transit era. Cities, 50, 111. https://doi.org/10.1016/j.cities.2015.09.003

3. Begam, S., Jha, P., Yadav, P. K., Joy, M. S., Rawat, P., & Bansal, T. (2024). Urban transformation through transit: the case of Delhi metro. Deleted Journal, 1(1). https://doi.org/10.1007/s44327-024-00035-1
4. Cui, C., & Zhang, Y. (2024). Integration of Shared Micromobility into Public Transit: A Systematic Literature Review with Grey Literature. Sustainability, 16(9), 3557. https://doi.org/10.3390/su16093557
5. Dawda, N. H., Joshi, G., & Arkatkar, S. (2021). Synthesizing the Evolution of Multimodal Transportation Planning milestones in Indian Cities. Procedia Computer Science, 184, 484. https://doi.org/10.1016/j.procs.2021.03.061
6. Dhabhai, G. (2017). Excavating the City: Metro Rail Construction and Imagination of Past in Contemporary Jaipur. In Springer eBooks (p. 189). Springer Nature. https://doi.org/10.1007/978-3-319-47623-0_10
7. Dhankar, S., Singh, G., & Kumar, K. (2024). Impact of Urbanization on Air Quality of Dehradun District. Current World Environment, 19(1), 321. https://doi.org/10.12944/cwe.19.1.27
8. Farid, A. M., Alshareef, M., Badhesha, P. S., Boccaletti, C., Cacho, N., Carlier, C.-I., Corriveau, A., Khayal, I. S., Liner, B., Martins, J. S. B., Rahimi, F., Rossett, R., Schoonenberg, W. C. H., Stillwell, A. S., & Wang, Y. (2020). Smart City Drivers and Challenges in Urban-Mobility, Health-Care, and Interdependent Infrastructure Systems. IEEE Potentials, 40(1), 11. https://doi.org/10.1109/mpot.2020.3011399
9. Garg, S., Motagh, M., Indu, J., & Karanam, V. (2022). Tracking hidden crisis in India's capital from space: implications of unsustainable groundwater use. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-021-04193-9
10. Goyal, R., & Khare, M. (2012). Indoor Air Quality: Current Status, Missing Links and Future Road Map for India. Journal of Civil & Environmental Engineering, 2(4). https://doi.org/10.4172/2165-784x.1000118
11. Jain, P., Singh, I. P., & Jain, M. (2021). WITHDRAWN: Urbanization and Land-Use change in the hill town of Nainital. Materials Today Proceedings. https://doi.org/10.1016/j.matpr.2021.01.914
12. Joh, K., Chakrabarti, S., Boarnet, M. G., & Woo, A. (2015). The Walking Renaissance: A Longitudinal Analysis of Walking Travel in the Greater Los Angeles Area, USA. Sustainability, 7(7), 8985. https://doi.org/10.3390/su7078985
13. Joshi, S., Bailey, A., & Datta, A. (2020). On the move? Exploring constraints to accessing urban mobility infrastructures. Transport Policy, 102, 61. https://doi.org/10.1016/j.tranpol.2020.11.005
14. Kandpal, V. (2019). Smart city evolution in India: the cases of Dehradun, Nagpur, and Allahabad. In Elsevier eBooks (p. 243). Elsevier BV. https://doi.org/10.1016/b978-0-12-816169-2.00011-0
15. Kansal, A., Subuddhi, S. P., Pandey, P., Gupta, D., Rawat, T., Gautam, A. S., & Gautam, S. (2023). Investigating the Impression of National Clean Air Programme in Enhancement of Air Quality Characteristics for Non-attainment Cities of Uttarakhand. Aerosol Science and Engineering, 7(3), 415. https://doi.org/10.1007/s41810-023-00181-w
16. Kumar, A., Joshi, A., & Devrani, U. (2024). A Review: Towards Resilient Urban Futures - Analyzing Infrastructure, Health And Community Adaptability In Dehradun Region Under Smart City Initiatives. 53(3), 1376. https://doi.org/10.48047/bdc2hv93
17. Lahoti, S., Lahoti, A., & Saitô, O. (2019). Benchmark assessment of recreational public Urban Green space provisions: A case of typical urbanizing Indian City, Nagpur. Urban Forestry & Urban Greening, 44, 126424. https://doi.org/10.1016/j.ufug.2019.126424
18. Le, H., Lim, W. L., & Leong, W. Y. (2018). Land enhancement and intensification benefits of investing in an urban rail network. Research in Transportation Economics, 69, 512. https://doi.org/10.1016/j.retrec.2018.04.009
19. Liu, Z., Yu, B., Zhang, L., & Sun, Y. (2024). Resilience enhancement of multi-modal public transportation system via electric bus network redesign. Transportation Research Part E Logistics and Transportation Review, 193, 103810. https://doi.org/10.1016/j.tre.2024.103810
20. Lu, K., Zhang, L., Li, S., Huang, Y., Ding, X., Hao, J., Huang, S., Li, X., Lü, F., & Zhang, H. (2024). Urban Rail Transit in China: Progress Report and Analysis (2015–2023). Urban Rail Transit. https://doi.org/10.1007/s40864-024-00231-7
21. Mahadevia, D., Mukhopadhyay, C., Lathia, S., & Gounder, K. (2023). The role of urban transport in delivering Sustainable Development Goal 11: Learning from two Indian cities. Heliyon, 9(9). https://doi.org/10.1016/j.heliyon.2023.e19453

22. Malik, N., Gothi, S., Saini, R., & Aswal, P. (2019). Modelling and Monitoring Urban Landscape Dynamics over Haridwar, India. International Journal of Computer Applications, 181(45), 12. https://doi.org/10.5120/ijca2019918569
23. Metro Neo project for Uttarakhand. (2021). https://urbantransportnews.com/news/ukmrc-submits-dpr-of-rs-1663-crore-metro-neo-project-for-uttarakhand
24. Mittal, G. S. (2020). The state and the production of informalities in urban transport: Vikrams in Dehradun, India. Geoforum, 136, 273. https://doi.org/10.1016/j.geoforum.2020.10.003
25. Noorloos, F. van, Cirolia, L. R., Friendly, A., Jukur, S., Schramm, S., Steel, G., & Valenzuela, L. (2019). Incremental housing as a node for intersecting flows of city-making: rethinking the housing shortage in the global South. Environment and Urbanization, 32(1), 37. https://doi.org/10.1177/0956247819887679
26. Purwantiasning, A. W., & Bahri, S. (2021). Enhancing the quality of historical area by delivering the concept of transit-oriented development within Kota Tua Jakarta. IOP Conference Series Earth and Environmental Science, 878(1), 12007. https://doi.org/10.1088/1755-1315/878/1/012007
27. Randall, L., Brugulat-Panés, A., Woodcock, J., Ware, L. J., Pley, C., Karim, S. A., Micklesfield, L. K., Mukoma, G., Tatah, L., Dambisya, P. M., Matina, S. S., Hambleton, I., Okello, G., Assah, F., Anil, M., Kwan, H., Awinja, A. C., Pujol-Busquets, G., & Foley, L. (2022). Active travel and paratransit use in African cities: Mixed-method systematic review and meta-ethnography. Journal of Transport & Health, 28, 101558. https://doi.org/10.1016/j.jth.2022.101558
28. Sharma, N., Dhyani, R., & Gangopadhyay, S. (2013). Critical Issues Related to Metro Rail Projects in India. Journal of Infrastructure Development, 5(1), 67. https://doi.org/10.1177/0974930613488296
29. Shruti, Singh, P. K., & Ohri, A. (2021). Sensitivity Analysis of the Smart City Environmental Sustainability Index (SCESI). Nature Environment and Pollution Technology, 20(2). https://doi.org/10.46488/nept.2021.v20i02.029
30. Sinha, M. (2021). Harnessing land value capture: Perspectives from India's urban rail corridors. Land Use Policy, 108, 105526. https://doi.org/10.1016/j.landusepol.2021.105526
31. Strömgren, M., Schantz, P., Sommar, J. N., Raza, W., Markstedt, A., & Forsberg, B. (2020). Modeling commuter modal shift from car trips to cycling: Scenario construction and outcomes for Stockholm, Sweden. Journal of Transport Geography, 86, 102740. https://doi.org/10.1016/j.jtrangeo.2020.102740
32. Thombre, A., & Agarwal, A. (2021). A paradigm shift in urban mobility: Policy insights from travel before and after COVID-19 to seize the opportunity. Transport Policy, 110, 335. https://doi.org/10.1016/j.tranpol.2021.06.010
33. Uddin, Md. A., Hoque, Md. S., Tamanna, T., Adiba, S., Muniruzzaman, S., & Parvez, M. S. (2023). A framework to measure transit-oriented development around transit nodes: Case study of a mass rapid transit system in Dhaka, Bangladesh. PLoS ONE, 18(1). https://doi.org/10.1371/journal.pone.0280275
34. Verma, M. C., & Tiwari, R. (2020). Analyzing expectation of landowners from Brownfield TOD project: A case study from MP Nagar, Bhopal. Materials Today Proceedings, 46, 5187. https://doi.org/10.1016/j.matpr.2020.08.482
35. Wang, Y., Zhu, X., Li, L., & Wu, B. (2013). Reasons and Countermeasures of Traffic Congestion under Urban Land Redevelopment. Procedia - Social and Behavioral Sciences, 96, 2164. https://doi.org/10.1016/j.sbspro.2013.08.244
36. Widiyastuti, D., Mudiantoro, B., & Andriyani, L. (2020). Investigating urban space: Potential urban green space in dense city of Yogyakarta. E3S Web of Conferences, 200, 7002. https://doi.org/10.1051/e3sconf/202020007002
37. Xu, S., Song, C., & Deng, Y. (2020). Methodological framework and evaluation for effects of multiple spatial policy derived from urban planning. Habitat International, 98, 102147. https://doi.org/10.1016/j.habitatint.2020.102147
38. Zhang, M., Mohamed, M., Foda, A., & Guo, Y. (2025). Optimal Electric Bus Charging Scheduling with Multiple Vehicle and Charger Types Considering Compatibility. Sustainability, 17(8), 3294. https://doi.org/10.3390/su17083294