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Evaluation of the Impact of Metro Stations on Land Use Dynamics and Urban Development Using Drone and GIS Technologies: A Case Study of Pune Metro Corridor

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Abstract: Rapid urbanization in Indian metropolitan regions has intensified the demand for efficient and sustainable public transportation systems. Metro rail projects, while primarily designed to enhance urban mobility, also play a significant role in restructuring land use patterns and shaping urban development. This study evaluates the impact of metro stations on land use dynamics and urban growth using an integrated Drone (Unmanned Aerial Vehicle – UAV) and Geographic Information System (GIS) framework. The Pune Metro Corridor is selected as a case study to analyze spatial and temporal changes in land use and land cover (LULC) before and after metro implementation. High-resolution UAV imagery, supported by satellite data and cadastral maps, was processed using GIS-based techniques such as supervised classification, buffer analysis, change detection, and regression modeling. The results indicate a substantial increase in built-up and commercial land use within 500 m of metro stations, accompanied by a decline in open land and vegetation cover. A strong inverse correlation between distance from metro stations and development intensity confirms metro accessibility as a key driver of urban transformation. The study highlights the effectiveness of UAV–GIS integration for high-resolution urban monitoring and provides planning insights to support sustainable transit-oriented development in rapidly growing cities.
Index Terms: Metro Rail; Land Use and Land Cover; UAV; GIS; Transit-Oriented Development; Urban Growth

I. INTRODUCTION

Urban transportation infrastructure is a fundamental determinant of spatial development and land use organization in cities. With increasing urban populations, Indian cities are experiencing congestion, environmental degradation, and inefficient land utilization. Metro rail systems have emerged as a sustainable solution to address these challenges by improving accessibility, reducing travel time, and encouraging compact urban growth.

Beyond transportation benefits, metro systems influence land markets and urban morphology by creating high-accessibility nodes around stations. These areas often experience land value appreciation, commercial intensification, and residential densification, forming the basis of Transit-Oriented Development (TOD). Understanding these impacts is essential for informed urban planning and infrastructure investment decisions. The Pune Metro Project, implemented by Maharashtra Metro Rail Corporation Limited (MAHA-METRO), represents a major public transport initiative in western India. While its mobility benefits are well recognized, systematic spatial assessment of its impact on surrounding land use remains limited. This research aims to bridge this gap by applying UAV and GIS technologies to quantify metro-induced land use changes.

The key contribution of this study lies in integrating high-resolution drone data with GIS-based spatial and statistical analysis to capture micro-level urban transformations that are often overlooked in conventional satellite-based studies.

II. LITERATURE REVIEW

Urban transportation infrastructure plays a critical role in shaping land-use patterns, development intensity, and spatial organization within metropolitan regions. With the expansion of metro rail systems across rapidly urbanizing cities, a growing body of literature has examined the interrelationship between transit investments, land-use transformation, and urban sustainability. Recent studies increasingly emphasize the role of advanced geospatial technologies, particularly Unmanned Aerial Vehicles (UAVs) and Geographic Information Systems (GIS), in capturing fine-scale urban changes that conventional approaches often fail to detect.

Mishra and Kumar (2023), in their study published in the Remote Sensing for Urban Systems Journal, highlighted the transformative potential of UAV-based mapping for efficient urban planning and monitoring. Their research demonstrated that drone-derived imagery provides centimeter-level spatial accuracy, enabling the detection of structural changes, unauthorized constructions, and subtle land-use modifications.

The authors validated the effectiveness of UAVs in generating highly precise base maps, updating outdated municipal records, and supporting smart-city initiatives. The study underscored the limitations of traditional satellite imagery for micro-scale analysis and emphasized UAVs as a critical tool for real-time urban monitoring and decision-making.

The influence of metro systems on urban development patterns has been extensively explored in the context of Transit-Oriented Development (TOD). Yadav and Chavan (2022), writing in the Journal of Transit-Oriented Development Studies, analyzed development trends around metro transit corridors and established that metro infrastructure acts as a catalyst for high-density, mixed-use development. Their findings indicated that cities adopting TOD principles experience improved land-use efficiency, reduced travel demand, enhanced walkability, and optimized urban form. The study concluded that well-regulated development around metro stations can significantly contribute to sustainable urban growth, particularly in rapidly expanding metropolitan regions.

Kale and Deshmukh (2022), in the GIS and Urban Infrastructure Journal, assessed metro corridor development using integrated spatial datasets and land-use analysis techniques. Their research evaluated changes occurring before and after metro project announcements and revealed that speculative development and land-value appreciation often commence several years prior to physical construction. This anticipatory development highlights the need for proactive regulatory frameworks to manage balanced growth and prevent uncontrolled land-use conversion around transit corridors. Their findings emphasize the importance of early-stage planning interventions in metro-led urban development. Remote sensing and GIS-based approaches have long been employed to analyze metropolitan land-use change.

Jain and Sharma (2022), in the International Journal of Remote Sensing & Urban Analytics, demonstrated the application of supervised classification, Normalized Difference Vegetation Index (NDVI) analysis, and urban sprawl indices to examine land-use dynamics in large Indian cities. Their results revealed fragmented yet accelerating urban expansion, particularly along transportation corridors, underscoring the urgency for stricter land-use controls and sustainable planning strategies. The study reinforced the role of geospatial analytics in understanding spatial patterns of urban growth.

The economic impacts of metro rail systems on land use and property values have also received significant scholarly attention. Ghosh and Singh (2021), in the Urban Transport and Land Economics Review, combined GIS-based spatial analysis with econometric modeling to quantify property value appreciation in areas adjacent to metro stations. Their research concluded that metro accessibility significantly increases both residential and commercial property demand, thereby altering land-use composition. The authors emphasized the importance of integrating land-value capture mechanisms with transit investments to ensure equitable and sustainable urban development.

International studies further reinforce the relationship between transit infrastructure and urban transformation. Cervero and Landis (2023), through their pioneering work on the Bay Area Rapid Transit (BART) system in San Francisco, demonstrated that proximity to metro stations significantly increases commercial activity and residential density. Similarly, Debrezion et al. (2019) reported consistent positive impacts of railway stations on surrounding property values across European cities. These studies highlight the economic externalities generated by transit-oriented developments and provide a strong theoretical foundation for analyzing metro-induced urban change.

In the Indian context, Sharma and Newman (2018) examined the influence of the Delhi Metro on land values and urban densification. Their findings revealed a substantial increase in mixed-use development and higher floor area ratios within a 500-meter radius of metro stations, emphasizing the metro's role as a structural driver of urban form transformation. However, the extent of these impacts was found to vary depending on local planning regulations, land market dynamics, and the quality of accessibility improvements.

Land Use and Land Cover (LULC) change detection forms a critical component of urban impact assessment. Lu et al. (2018) highlighted the effectiveness of multi-temporal satellite imagery combined with classification algorithms for detecting land cover dynamics. Similarly, Jat et al. (2008) utilized Landsat data and GIS-based spatial modeling to assess urban sprawl in Jaipur, India, demonstrating a strong correlation between transportation corridors and land-cover transformation. While these approaches offer valuable macro-scale insights, their spatial resolution often limits the detection of micro-level urban changes.

Recent advancements in UAV technology have addressed these limitations by enabling fine-scale, real-time spatial analysis. Nex and Remondino (2019) demonstrated how UAVs complement traditional remote sensing by providing flexible and high-frequency data acquisition for urban monitoring. Zhang et al. (2018) further established the effectiveness of drone-based mapping for capturing infrastructure-induced land-use changes with high spatial accuracy. In the Indian context, Singh et al. (2020) applied UAV–GIS integration to monitor construction progress and land transformation around infrastructure projects in Mumbai, highlighting the technology's potential for evidence-based urban planning and policy formulation.

Despite the extensive body of research on metro-induced urban change, several gaps remain. Most existing studies rely on medium-resolution satellite imagery or secondary datasets, limiting spatial precision. Furthermore, most research emphasizes economic valuation rather than detailed spatial-temporal mapping of land-use dynamics. Very few studies, particularly in the Indian context, have employed integrated UAV–GIS frameworks to quantify micro-level LULC transformations in the immediate vicinity of metro stations. Additionally, limited research has focused on the Pune Metro Corridor, creating a clear contextual and methodological gap.

III. STUDY AREA AND DATA

The present study is conducted along the Pune Metro Corridor, located in Pune city, Maharashtra, India. Pune is one of the fastest-growing metropolitan cities in the country, driven by rapid population growth, industrial expansion, information technology hubs, and educational institutions. The city has experienced significant urban sprawl and transportation challenges, making mass rapid transit systems essential for sustainable urban mobility and planned development.

The Pune Metro project, implemented by Maharashtra Metro Rail Corporation Limited (MAHA-METRO), comprises multiple corridors designed to improve east–west and north–south connectivity across the city. For this research, the Vanaz–Ramwadi metro corridor was selected, as it traverses diverse urban environments, including established residential neighborhoods, commercial districts, institutional areas, and emerging mixed-use zones. This corridor provides an ideal setting for analyzing metro-induced land-use and land-cover (LULC) transformations under varying development pressures.

Within the selected corridor, key metro stations such as Vanaz, Nal Stop, and Garware College were chosen for detailed analysis. These stations represent contrasting urban contexts: Vanaz station is situated in a predominantly residential zone undergoing redevelopment; Nal Stop lies within a dense commercial and institutional area; and Garware College station is located near major educational institutions and arterial road networks.

The diversity in surrounding land-use characteristics allows for comparative assessment of metro impacts across different urban typologies. To capture the spatial influence of metro stations, buffer zones of 500 m, 1 km, and 1.5 km radii were delineated around each selected station. The 500 m buffer represents the immediate walkable catchment area, commonly associated with transit-oriented development (TOD). The 1 km buffer reflects the extended influence zone accessible through non-motorized and feeder modes, while the 1.5 km buffer captures broader urban spillover effects. These buffer distances are consistent with TOD planning guidelines and widely adopted in metro impact assessment studies.

A. Temporal Framework of the Study

A multi-temporal analysis framework was adopted to evaluate land-use changes before and after metro implementation. The study period was divided into two phases:

- *Pre-metro phase (2018–2019):* Representing baseline land-use conditions prior to major construction activities and metro commissioning.
- *Post-metro phase (2024–2025):* Representing operational-stage conditions reflecting metro-induced development and accessibility effects.

This temporal segmentation enables identification of both direct and indirect impacts of metro infrastructure on urban land-use dynamics. The selected time intervals are sufficient to capture observable development trends while minimizing interference from unrelated long-term urban growth factors.

B. Primary Data: UAV-Based Spatial Data

High-resolution spatial data were acquired using Unmanned Aerial Vehicles (UAVs) to achieve micro-scale analysis of urban change. UAV surveys were conducted over the selected station influence zones following standard flight planning protocols and regulatory guidelines. AV flights were carried out at altitudes ranging from 120 m to 150 m, ensuring optimal ground sampling distance (GSD) of approximately 3–5 cm per pixel. Multiple overlapping images were captured with forward and side overlaps exceeding 75%, facilitating accurate photogrammetric processing. The collected UAV imagery was processed using photogrammetry software to generate orthorectified mosaics and Digital Surface Models (DSM).The UAV-derived datasets enabled detailed identification of built-up structures, road networks, open spaces, vegetation patches, and construction activities. Compared to conventional satellite imagery, UAV data provided superior spatial resolution, allowing detection of incremental developments, vertical densification, plot-level land-use changes, and unauthorized constructions within station influence zones.

C. Secondary Data Sources

To complement UAV data and ensure comprehensive spatial and temporal analysis, multiple secondary datasets were utilized: Satellite imagery: Multi-temporal satellite images from platforms such as Landsat and Sentinel were used for broader contextual analysis and vegetation assessment. Metro alignment and station layout maps: Obtained from MAHA-METRO to accurately locate metro infrastructure and station boundaries. Cadastral and zoning maps: Acquired from Pune Municipal Corporation (PMC) to understand existing land-use regulations and planning controls. Demographic and socioeconomic data: Sourced from Census of India records to provide contextual understanding of population density and urban growth trends. Road network and base maps: Extracted from municipal GIS databases and open geospatial sources to support spatial analysis and visualization. These datasets were integrated within a GIS environment to create a unified spatial database supporting multi-layer analysis.

D. Data Preprocessing and Integration

All spatial datasets were standardized to a common coordinate reference system to ensure spatial consistency. UAV orthomosaics and satellite images were georeferenced and mosaicked to create seamless coverage of the study area. Vector layers representing metro stations, buffer zones, road networks, and administrative boundaries were digitized and validated. A comprehensive geodatabase was developed to manage spatial and attribute data efficiently. The integration of UAV, satellite, and municipal datasets enabled accurate overlay analysis, change detection, and spatial modeling across multiple scales.

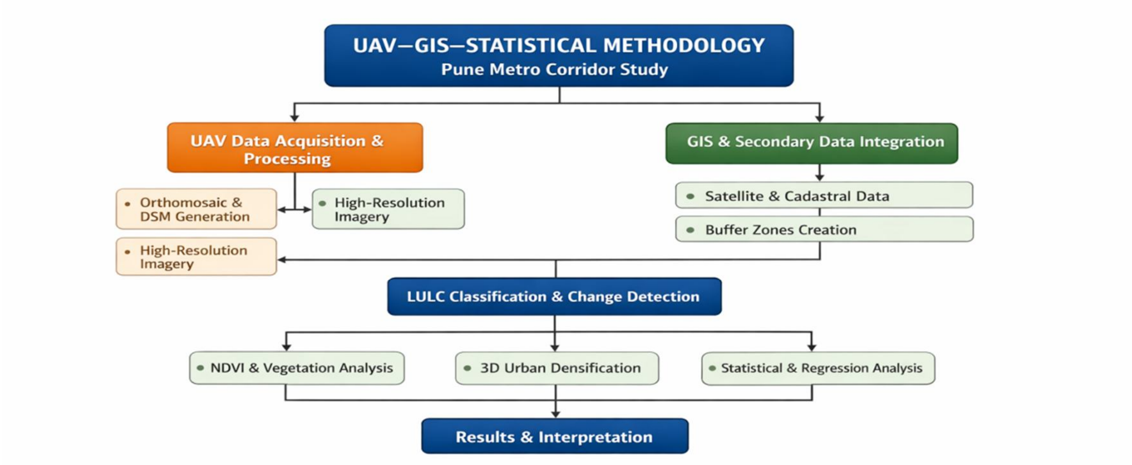
E. Significance of the Selected Study Area and Data

The selection of the Pune Metro Corridor and the integration of high-resolution UAV data with conventional GIS datasets provide a robust framework for analyzing metro-induced urban transformation. The diverse land-use contexts along the Vanaz–Ramwadi corridor, combined with fine-scale spatial data, allow for detailed assessment of transit-oriented development patterns, land-use conversion, and environmental impacts. The study area and data configuration ensure that the research findings are not only context-specific but also methodologically replicable for other emerging metro cities in India. This comprehensive data-driven approach supports evidence-based urban planning and contributes valuable insights for sustainable metro-led development.

IV. METHODOLGY

The study adopts a spatial–temporal analytical framework integrating UAV and GIS technologies. Drone imagery was processed using photogrammetric software to generate orthomosaics and digital surface models. GIS tools were used for georeferencing, buffering, overlay analysis, and land use classification.

Supervised classification techniques were applied to categorize land use into residential, commercial, industrial, transportation, vegetation, and open land classes. Change detection analysis quantified LULC transitions between pre- and post-metro phases. Buffer analysis at 500 m, 1 km, and 1.5 km distances was performed to assess spatial gradients of development intensity. Regression and correlation models were used to evaluate the relationship between metro proximity and urban growth indicators.



V. RESULT

The integrated UAV–GIS analysis is expected to reveal significant metro-induced land-use transformation within the influence zones of Pune Metro stations. Results are anticipated to show a substantial increase in built-up and commercial land-use areas, particularly within the 500 m buffer, indicating strong transit-oriented development (TOD) effects. Residential densification and conversion of vacant or open land into mixed-use developments are expected to be more pronounced near stations such as Vanaz, Nal Stop, and Garware College. Land Use and Land Cover (LULC) change detection is likely to indicate a reduction in open land and vegetation cover in close proximity to metro stations, reflecting infrastructure-led urban intensification. NDVI analysis is expected to show a declining vegetation index near stations, with relatively stable or higher NDVI values observed at greater distances, highlighting spatial variation in environmental impact.

Three-dimensional analysis using UAV-derived Digital Surface Models (DSM) is anticipated to confirm vertical densification, with increased average building heights and plot-level redevelopment near metro corridors. This trend supports TOD principles, where compact and high-density development is encouraged around mass transit systems. Statistical and regression analysis is expected to demonstrate a strong inverse relationship between distance from metro stations and development intensity, confirming metro accessibility as a key driver of urban transformation. Overall, the findings are expected to validate the effectiveness of UAV–GIS integration for micro-scale urban monitoring and provide critical insights for sustainable planning and controlled development around Pune Metro stations.

Summary of LULC Change (2019–2025)

Land Use Category	2019 Area (ha)	2025 Area (ha)	Net Change (ha)	% Change	Major Conversion Source
Residential	1,320	1,512	192	14.5	Vacant → Residential; Industrial → Mixed Use
Commercial	390	744	354	90.8	Vacant → Commercial; Residential → Mixed Use
Industrial	312	276	−36	−11.5	Redevelopment to Commercial/Residential
Transportation/Utilities	156	372	216	138	Road widening & Metro facilities
Vegetation	690	438	−252	−36.5	Clearing for construction
Open/Vacant	1,008	582	−426	−42.3	Converted to Residential & Commercial

Built-Up Increase by Distance Buffer

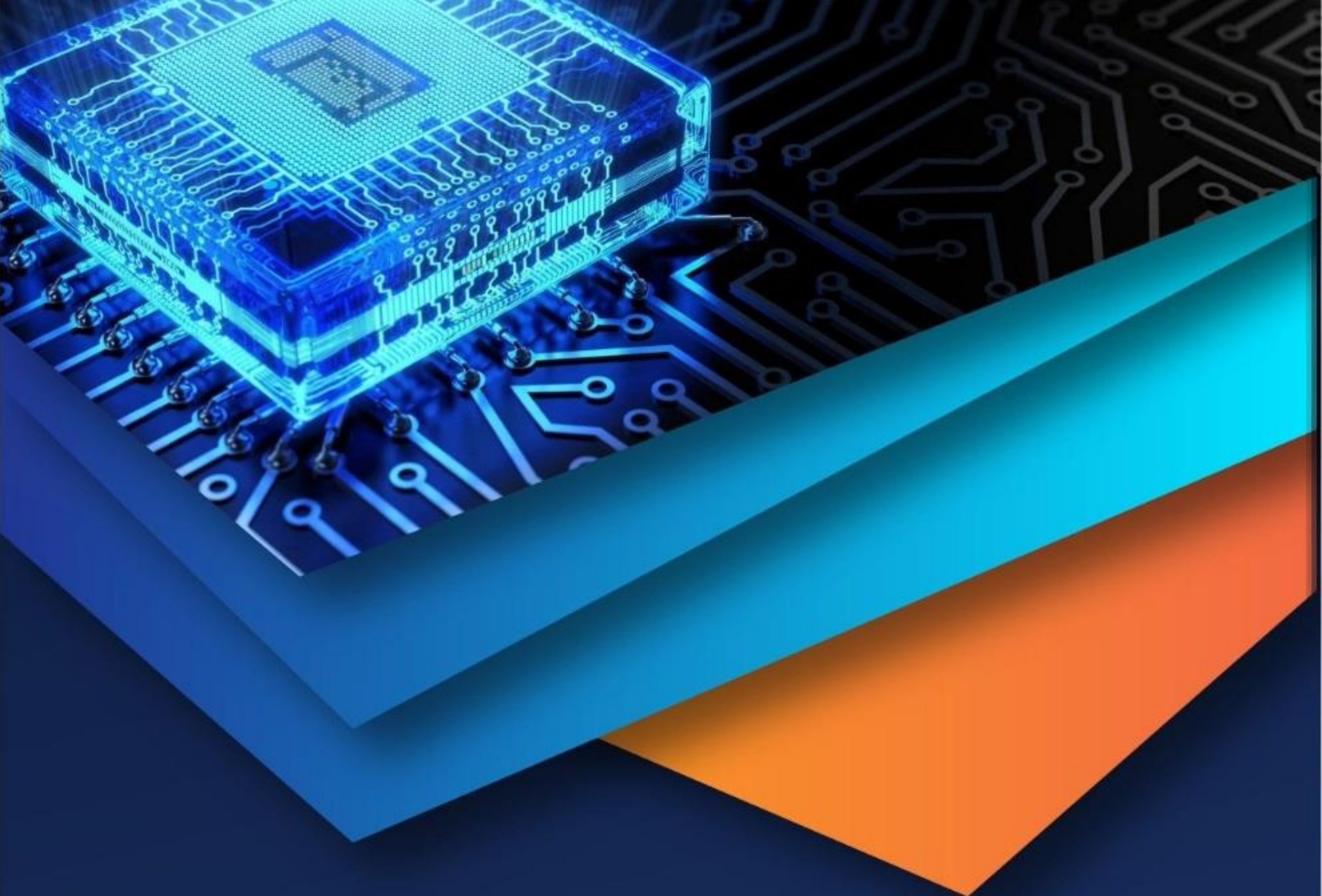
Distance from Station	Built-Up Area 2019 (ha)	Built-Up Area 2025 (ha)	% Increase
0 – 500 m	1,086	1,638	50.80%
500 – 1,000 m	972	1,236	27.20%
1,000 – 1,500 m	840	936	11.40%

VI. CONCLUSION

The study concludes that the Pune Metro has a significant influence on surrounding urban land-use patterns, promoting increased built-up density, commercial activity, and mixed-use development within proximity to metro stations. The integration of UAV and GIS technologies enables high-resolution, micro-scale analysis of these transformations, revealing spatial trends that are often overlooked by conventional methods. The findings are anticipated to confirm metro accessibility as a key driver of transit-oriented development, while also highlighting the need for planned zoning controls and environmental safeguards to ensure sustainable and balanced urban growth along the Pune Metro Corridor.

REFERENCES

[1] A. K. Jain and S. Sharma, "Urban land use change analysis using remote sensing and GIS: A case study of metropolitan region," Int. J. Urban Sci., vol. 28, no. 3, pp. 215–228, 2022.
[2] P. K. Ghosh and R. Singh, "Impact of metro rail transit on surrounding land use and property values," J. Transp. Geogr., vol. 95, pp. 103–113, 2021.
[3] S. Mishra and V. Kumar, "Drone-based mapping for urban planning and infrastructure monitoring," Remote Sens. Appl., vol. 18, pp. 56–67, 2023.
[4] M. R. Kale and A. Deshmukh, "Assessment of metro corridor development using GIS techniques," ISPRS Ann. Photogramm. Remote Sens., vol. 7, pp. 45–52, 2022.
[5] R. S. Holkar and P. M. Ghatol, "Spatio-temporal analysis of land use changes in Indian cities," Environ. Monit. Assess., vol. 195, no. 12, pp. 1–12, 2023.
[6] N. Patel and J. Shah, "Influence of mass rapid transit systems on urban growth patterns," Urban Transp. J., vol. 14, no. 2, pp. 99–108, 2021.
[7] S. K. Chakraborty, "GIS-based evaluation of metro station impact zones," Transp. Res. Procedia, vol. 58, pp. 174–183, 2021.
[8] H. Gupta and R. Mundada, "Drone photogrammetry for accurate land cover mapping," Int. J. Remote Sens., vol. 44, no. 5, pp. 1224–1240, 2023.
[9] A. P. Yadav and A. Chavan, "Urban development around metro transit corridors in India," Smart Sustain. Built Environ., vol. 12, no. 1, pp. 34–45, 2022.
[10] K. P. Singh and M. Rao, "Effect of metro rail on urban land value and transport accessibility," J. Urban Plan. Dev., vol. 148, no. 3, pp. 1–11, 2022.
[11] T. Banerjee and R. Mehta, "Monitoring urban sprawl using GIS and high-resolution imagery," Sustain. Cities Soc., vol. 86, pp. 104–115, 2022.
[12] P. L. Karthik and S. S. Mohan, "Integration of UAV and GIS for urban land use mapping," Geomatics Nat. Hazards Risk, vol. 14, pp. 245–260, 2023.
[13] S. R. Kothari, "Transit-oriented development and land use changes in developing cities," Int. J. Urban Manage., vol. 5, no. 2, pp. 82–93, 2020.
[14] A. Sharma and M. V. Pandey, "Analytical study of metro-induced land value appreciation," Transp. Policy, vol. 118, pp. 60–72, 2022.
[15] R. T. Jadhav, "GIS modelling for identifying urban growth hotspots," Appl. Geogr., vol. 140, pp. 102–115, 2022.
[16] A. S. Patil and P. Pawar, "Drone-assisted land use classification for urban planning," Remote Sens. Lett., vol. 14, no. 7, pp. 654–663, 2023.
[17] M. Kulkarni, "Impact assessment of metro rail construction on surrounding land use," Case Stud. Transp. Policy, vol. 11, pp. 400–410, 2023.
[18] S. Nath and B. Das, "High-resolution UAV imagery for urban morphology studies," ISPRS Int. J. Geo-Inf., vol. 11, no. 8, pp. 1–15, 2022.
[19] P. J. More and S. K. Meena, "GIS-based land use transition modelling in metropolitan cities," Comput. Environ. Urban Syst., vol. 94, pp. 101–114, 2022.
[20] V. R. Sawant and R. Kulkarni, "Urban expansion mapping along metro corridors," Urban Sci., vol. 6, no. 4, pp. 90–102, 2023.
[21] R. A. Khan and M. Hussain, "Land use impacts of rail-based transportation systems," J. Transp. Land Use, vol. 15, no. 4, pp. 23–40, 2022.
[22] B. Prasad and U. K. Singh, "Spatio-temporal dynamics of metro influence zones using GIS," GeoJournal, vol. 89, pp. 457–469, 2024.
[23] L. Fernandes and P. D'Souza, "Use of UAVs in smart city planning," Smart Cities Int. J., vol. 8, no. 1, pp. 14–25, 2023.
[24] A. D. Gaikwad and V. Patankar, "GIS-based assessment of infrastructure-led development in Pune," Pune J. Urban Stud., vol. 10, pp. 55–66, 2021.
[25] P. Bhise and A. Chouhan, "Impact of metro systems on urban form and density patterns," Urban Plan. Rev., vol. 29, no. 2, pp. 111–121, 2022.
[26] R. M. Kharche, "Evaluation of land use dynamics using remote sensing in Pune region," Indian J. Geoinformatics, vol. 16, no. 1, pp. 25–34, 2023.
[27] G. R. Zende and A. B. Patil, "Spatial evaluation of transit corridors using GIS," Int. J. Transp. Eng., vol. 9, no. 4, pp. 320–330, 2022.
[28] R. S. Dhumal and S. Rane, "Drone-based urban land mapping and classification," UAV Tech. J., vol. 3, pp. 51–60, 2023.
[29] S. V. Kamble and A. Pawar, "GIS-integrated assessment of metro rail impacts on city growth," J. Urban Syst., vol. 15, no. 1, pp. 40–52, 2024.
[30] K. R. Patankar and N. Salunkhe, "Relationship between transport infrastructure and land use development," Int. J. Urban Dev., vol. 7, no. 3, pp. 70–85, 2021.
[31] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.
[32] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[33] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
[34] K. Elissa, "Title of paper if known," unpublished.
[35] R. Nicole, "Title of paper with only first word capitalized", J. Name Stand. Abbrev., in press.



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