GIS-Based Transportation Infrastructure Analysis for Improving Regional Accessibility and Sustainable Mobility

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ABSTRACT

Geographic Information Systems (GIS) play a vital role in transportation infrastructure analysis and regional accessibility improvement. GIS supports spatial data integration, network analysis, route optimization, accident hotspot identification, and infrastructure performance evaluation. It helps planners and policymakers understand transport connectivity, accessibility patterns, and regional development needs more effectively. By combining GIS with modern technologies such as remote sensing, GPS, AI, IoT, and big data analytics, transportation planning becomes more accurate, sustainable, and data-driven. Therefore, GIS-based spatial analysis is an essential tool for improving mobility, safety, infrastructure management, and balanced regional growth.

Keywords: *GIS, Transportation Infrastructure, Regional Accessibility, Spatial Analysis.*

I. INTRODUCTION

Geographic Information Systems (GIS) have emerged as one of the most transformative technologies in the field of transportation engineering and regional planning. The integration of GIS with transportation infrastructure analysis has significantly enhanced the capability of planners, engineers, and policymakers to understand spatial relationships, optimize transport networks, and improve regional accessibility. Transportation infrastructure, including roads, railways, bridges, ports, and transit systems, plays a critical role in economic development, social integration, and urban expansion. Traditional methods of transportation planning often relied on static maps and manual surveys, which limited the efficiency of spatial analysis and decision-making. However, the advancement of GIS technologies has enabled dynamic visualization, data integration, real-time monitoring, and sophisticated network analysis for transportation systems. According to Transportation Engineering and ArcGIS based studies, GIS has become an essential tool for identifying transportation bottlenecks, evaluating infrastructure performance, and enhancing accessibility in urban and rural regions. Trung Hieu and Le (2026) observed that GIS applications had evolved from simple mapping tools into integrated digital platforms capable of supporting the entire lifecycle of transportation infrastructure, including planning, construction, maintenance, and management. Their bibliometric review of 3091 publications highlighted major research themes such as transportation planning, mobility behavior, environmental management, and digital integration with emerging technologies like artificial intelligence (AI), Building Information Modeling (BIM), and the Internet of Things (IoT). Similarly, Zaroujtaghi et al. (2025) emphasized that GIS had become indispensable for sustainable transportation planning by supporting equity analysis, land use integration, accessibility assessment, and stakeholder participation. These advancements demonstrate that GIS-based spatial analysis has become increasingly relevant in addressing complex transportation challenges associated with rapid urbanization, population growth, and regional disparities.

The significance of GIS-based transportation infrastructure analysis has further increased due to the growing demand for sustainable and accessible transportation systems. Accessibility refers to the ease with which people can reach desired services, employment centers, educational institutions, healthcare facilities, and economic opportunities through transportation networks. Efficient regional accessibility contributes to balanced regional development, reduced travel time, improved economic productivity, and enhanced quality of life. GIS enables planners to evaluate accessibility through spatial modeling, network analysis, hotspot analysis, and connectivity assessment. Daniel et al. (2019) demonstrated that GIS combined with graph theory could effectively measure road network connectivity using indices such as alpha, beta, gamma, cyclomatic number, and network density. Their study highlighted that higher transportation connectivity improved accessibility and mobility across urban regions. Likewise, Kim et al. (2020) applied GIS-based network analysis to evaluate transportation routes connecting mineral resource locations to ports and railway junctions in North Korea, revealing the strategic role of integrated transport systems in enhancing economic accessibility. GIS has also proven valuable in safety analysis and accident management. Mohammed et al. (2023) utilized advanced GIS techniques such as Time-Space Cube analysis, Geographically Weighted Regression (GWR), and Emerging Hot Spot analysis to identify road traffic crash clusters in Qatar. The findings suggested that spatial clustering of accidents was strongly influenced by driver behavior and urban traffic conditions, thereby assisting policymakers in implementing targeted safety interventions. Similarly, Bilașco and Man (2024) developed a GIS-based Analytic Hierarchy Process (AHP) model to assess cumulative accident risks in Romania, successfully identifying high-risk accident zones through geospatial databases and network analysis. These studies indicate that GIS not only improves infrastructure planning but also enhances transportation safety, operational efficiency, and regional connectivity.

In recent years, GIS-based spatial analysis has increasingly been integrated with modern technologies and sustainable urban development strategies to address emerging transportation challenges. Rapid urbanization and urban sprawl have created immense pressure on transportation infrastructure, requiring advanced planning methods capable of analyzing spatial growth patterns and infrastructure adequacy. Ammapa et al. (2022) reported that GIS overlay techniques effectively identified patterns of urban expansion along transportation corridors in Thailand, revealing that infrastructure investment density closely followed socio-economic development trends. Furthermore, GIS has been widely applied in infrastructure maintenance and decision support systems. Ayeni et al. (2026) developed a GIS-based Spatial Decision Support System for road maintenance management, demonstrating how spatial databases and GPS-integrated analysis could support efficient allocation of maintenance resources under budget constraints. In freight transportation, Asborno et al. (2021) proposed a GIS-based methodology for identifying multimodal freight transportation catchment areas using GPS and AIS data, which significantly improved the estimation of transportation influence zones compared to traditional fixed-radius methods. Moreover, the COVID-19 pandemic highlighted the importance of GIS in spatiotemporal transportation analysis. Feizizadeh et al. (2022) used GIS-based kernel density estimation and network analysis to examine urban traffic accident hotspots during lockdown periods, revealing a substantial reduction in accidents due to mobility restrictions. The integration of GIS with artificial intelligence, machine learning, remote sensing, IoT, and big data analytics is expected to further revolutionize transportation infrastructure management and accessibility analysis in the future. Therefore, GIS-based spatial analysis has become an indispensable approach for evaluating transportation infrastructure development, enhancing regional accessibility, improving safety, supporting sustainable mobility, and enabling data-driven transportation planning in modern societies (Trung Hieu & Le, 2026; Zaroujtaghi et al., 2025).

II. RESEARCH BACKGROUND

Trung Hieu and Le (2026) examined the evolution of Geographic Information Systems (GIS) from static mapping tools to integrated platforms supporting the entire lifecycle of transportation infrastructure. It was reported that, despite significant advancements, systematic comparative analyses of GIS applications across different transportation modes and technological paradigms had remained limited. The study conducted a systematic review and bibliometric analysis of 3091 Scopus-indexed publications published between 2000 and April 2025. Using co-authorship, co-word, and thematic evolution analyses through VOSviewer and Bibliometrix, five major research clusters were identified, including transportation planning, environmental impacts, resource management, mobility behaviour, and soil pollution assessment. The findings indicated that road transportation dominated the literature, followed by bridges and railways. Furthermore, a growing trend toward integrating GIS with emerging technologies such as BIM, IoT, and artificial intelligence was observed. The United States and China were identified as leading contributors, and key research gaps in multimodal integration and interoperability were highlighted.

Ayeni et al. (2026) reported that a user-friendly and simplified Spatial Decision Support System had been developed using Geographic Information System (GIS) techniques to assist road managers in making informed maintenance decisions. It was indicated that the system enabled the application of appropriate treatments at optimal times based on budget constraints. The study had utilized a Global Positioning System (GPS) device to collect coordinate data for selected routes within Akure metropolis, where twenty roads had been examined. Data relating to road characteristics were gathered through surveys and processed using Microsoft Excel, while GIS-based database creation and spatial analysis had been performed in the ArcGIS environment. The findings revealed that most roads lacked essential facilities such as traffic lights and pedestrian bridges. It was concluded that the developed system could effectively support administrative decision-making and improve road maintenance planning.

Zaroujtaghi et al. (2025) reviewed prior studies and noted that earlier reviews had focused on specific aspects of Geographic Information Systems (GIS) in transportation planning, including transit-oriented applications and open-source geospatial tools. They reported that their study had presented the first systematic, PRISMA-guided longitudinal evaluation of GIS integration in transportation planning from 2004 to 2024. It was indicated that a mixed-methods analysis of 241 peer-reviewed articles had been conducted to identify key trends such as sustainability, equity, stakeholder participation, and the integration of advanced technologies. The authors highlighted major domains, including land use–transportation integration, accessibility, artificial intelligence, and real-time monitoring. They further observed that despite advancements in data sources and modeling techniques, challenges related to data availability, ethics, and expertise had persisted, particularly in developing regions. It was concluded that GIS had evolved into a critical tool for sustainable and equitable transportation planning.

Bilașco and Man (2024) examined the global significance of traffic incidents as a major cause of mortality and material loss, highlighting that Romania had recorded the highest rate of road traffic fatalities within the European Union and globally. The study adopted a comprehensive approach by utilizing a spatial analysis model grounded in the Analytic Hierarchy Process (AHP). It was reported that multiple spatial databases were employed to map the geographical distribution and characteristics of road accidents, enabling an assessment of their cumulative national impact and the identification of high-risk zones. Furthermore, the spatial database was developed using geolocation techniques and integrated with network analysis to evaluate distance-related impacts. The AHP framework was applied across dimensions such as accident severity, occurrence mode, weather conditions, traffic restrictions, and road markings. The findings indicated that the model effectively identified accident hotspots and validated the robustness of the spatial analytical approach.

Mohammed et al. (2023) examined the growing global concern of road traffic crashes and emphasized the need for effective strategies to reduce their occurrence and support sustainable transport systems. The study aimed to investigate the spatiotemporal distribution of road traffic crashes in the State of Qatar by identifying crash hotspots and assessing whether these incidents were primarily influenced by driver behaviour or the geometrical design of roads and intersections. It was reported that advanced analytical techniques, including Time-Space Cube analysis, Geographically Weighted Regression (GWR), Emerging Hot Spot analysis, and Spatial Autocorrelation, were applied to historical crash data from 2015 and 2019. The findings indicated that crashes were predominantly concentrated in the central-eastern region and were largely associated with behavioural factors. It was further observed that weekday crashes in 2019 showed stronger clustering compared to 2015, suggesting a systematic underlying cause. The study provided valuable insights for policymakers to design targeted interventions and improve road safety.

Ammapa et al. (2022) examined the relationship between urban expansion and transportation infrastructure development within the context of rapid urbanization. It was reported that transportation had played a crucial role as a key infrastructure supporting urban growth. The study had raised concerns regarding the compatibility between infrastructure development and urban expansion, particularly in suburban regions. Pathum Thani province was selected as a representative area within the Bangkok Metropolitan Region, which had experienced significant urban sprawl due to population migration from the city center. It was observed that transport infrastructure investment in suburban areas had remained insufficient. The researchers had utilized Geographic Information System (GIS) data and applied overlay techniques to analyze spatial patterns of urban growth. The findings had indicated that urban expansion had predominantly occurred along transportation corridors, especially Phaholyothin Road. Furthermore, it was revealed that infrastructure investment density had increased notably in Mueang Pathum Thani and Khlong Luang districts, aligning with socio-economic and environmental growth trends.

Feizizadeh et al. (2022) investigated the spatiotemporal trends of urban traffic accident hotspots during the COVID-19 pandemic. It was reported that a severity index had been employed to determine high-risk areas, while the kernel density estimation method had been applied to identify accident hotspots. Accident data from April 2018 to November 2020 had been collected from the traffic police of Tabriz, Iran, and were analyzed using GIS-based spatial and network analysis techniques. The impacts of COVID-19 were assessed by examining seasonal variations in accident occurrences. Furthermore, the sustainability of urban transport had been evaluated using demographic and land-use data. The findings indicated that lockdown measures had significantly reduced road traffic accidents. It was also observed that areas with higher populations of elderly individuals and children had been more affected. The study concluded that the results could support urban planning and decision-making to minimize future accidents.

Asborno et al. (2021) examined the necessity of identifying the area of influence of transportation infrastructure projects to support impact estimation, cost–benefit analysis, and project prioritization. The authors noted that conventional approaches for freight-related projects, particularly ports, tended to overlook complex interactions within multimodal supply chains. It was reported that although travel demand models could estimate multimodal trips, they often lacked accurate representations of water and rail transport and did not provide direct observational data. The study highlighted that project-specific data collection methods, such as traffic counts and surveys, were often costly and subjective. Therefore, a systematic and objective methodology was developed to delineate multimodal freight-shed areas using vehicle tracking data. The approach involved preprocessing GPS and AIS data, including noise reduction, clustering, and map-matching. Application across 43 port terminals demonstrated that traditional fixed-radius methods significantly underestimated actual freight-shed areas, leading to inaccurate project benefit assessments.

Kim et al. (2020) investigated the potential for future mineral resource trade with North Korea by analyzing the spatial distribution of mines and transportation infrastructure and evaluating their interrelationships. It was reported that a Geographic Information System (GIS) database integrating data on mines and transport networks was developed to support the analysis. Connectivity analysis focusing on minerals with high domestic demand was conducted to assess transportation efficiency. The study examined optimal routes linking mines to the nearest ports and railway junctions, revealing that mineral resources could be transported effectively by first accessing railway systems via road networks. Furthermore, the accessibility of railway junctions and ports was evaluated. The findings indicated that western mines exhibited strong connectivity to Songlim Port, while eastern mines were found to be well connected to Dancheon, Wonsan, and Chongjin ports, highlighting the strategic importance of integrated transport networks.

Daniel et al. (2019) examined the significance of the topological structure of road networks in shaping urban form and emphasized that evaluating such networks was a crucial component of urban transportation planning. The study explained that connectivity referred to the density of links within a transport network, and it was observed that higher connectivity generally enhanced accessibility and mobility. It was reported that recent advancements in Geographic Information Systems (GIS) had improved the understanding of topographical characteristics of road networks. The authors aimed to analyze the connectivity of road networks across 36 wards of Thiruvananthapuram district, Kerala, using graph theory. Connectivity indices such as cyclomatic number, alpha, beta, gamma, and eta indices, along with network and intersection densities, were computed using ArcGIS Network Analyst. Statistical relationships among these parameters were examined, and variations at different spatial levels, as well as accessibility using the Shimbel index, were evaluated.

III. KEY FINDINGS FROM STUDY

Author & Year	Objective of Study	Methodology Used	Major Findings
Trung Hieu and Le K. G. (2026)	To examine the evolution of GIS applications in transportation infrastructure	Systematic review and bibliometric analysis of 3091 Scopus-indexed publications using VOSviewer and Bibliometrix	Identified five major research clusters and highlighted integration of GIS with AI, BIM, and IoT
Ayeni T. S. et al. (2026)	To develop a GIS-based decision support system for road maintenance management	GPS data collection, GIS database development, ArcGIS spatial analysis	Found that GIS effectively supported maintenance planning and administrative decision-making
Zaroujtaghi A. et al. (2025)	To evaluate GIS evolution in transportation planning	PRISMA-guided systematic review of 241 articles	GIS evolved into a critical tool for sustainable and equitable transportation planning
Bilașco Ș. and Man T. C. (2024)	To assess cumulative road accident risks using GIS	GIS-based AHP spatial analysis and network analysis	Successfully identified high-risk accident zones in Romania
Mohammed S. et al. (2023)	To analyze spatiotemporal road crash patterns in Qatar	Time-Space Cube analysis, GWR, hotspot analysis	Crashes were concentrated in central-eastern Qatar and linked to behavioral factors
Ammapa J. et al. (2022)	To compare urbanization patterns and transportation infrastructure	GIS overlay analysis of spatial urban growth patterns	Urban expansion predominantly occurred along transport corridors

Feizizadeh B. et al. (2022)	To model urban traffic accident hotspots during COVID-19	Kernel density estimation and GIS network analysis	Lockdowns significantly reduced accident occurrences
Asborno M. I. et al. (2021)	To identify multimodal freight transportation catchment areas	GPS and AIS-based GIS spatial analysis	Traditional methods underestimated freight-shed areas
Kim S. M. et al. (2020)	To evaluate transportation infrastructure for mineral trade	GIS-based network connectivity analysis	Identified efficient transport connectivity between mines, ports, and railways
Daniel C. B. et al. (2019)	To evaluate road connectivity using graph theory	GIS Network Analyst and connectivity indices	Higher road network connectivity improved accessibility and mobility

IV. CONCLUSION

GIS-based spatial analysis has emerged as a highly effective and innovative approach for evaluating transportation infrastructure development and regional accessibility. The reviewed studies collectively demonstrated that GIS technologies significantly improve transportation planning, network analysis, maintenance management, accident assessment, and accessibility evaluation through advanced spatial modeling and visualization techniques. Researchers have shown that GIS enables transportation engineers and planners to analyze spatial relationships, identify transportation corridors, assess connectivity patterns, and evaluate infrastructure efficiency with greater accuracy than conventional approaches. Studies focusing on road safety and accident hotspot analysis revealed that GIS-based methods such as kernel density estimation, hotspot analysis, and network analysis effectively support traffic safety management and policy interventions. Furthermore, the integration of GIS with technologies such as artificial intelligence, IoT, GPS, BIM, and big data analytics has expanded the capabilities of transportation systems toward intelligent and sustainable infrastructure management. The literature also highlighted the importance of GIS in understanding urban expansion, multimodal transportation systems, and freight movement patterns, which are essential for regional economic growth and sustainable urban development. Additionally, GIS-based accessibility analysis was found to support equitable infrastructure distribution and efficient connectivity between rural and urban regions. Despite these advancements, several challenges such as limited data availability, interoperability issues, technical expertise requirements, and unequal technological adoption in developing regions continue to affect implementation effectiveness. Nevertheless, GIS remains a powerful decision-support tool capable of enhancing transportation efficiency, reducing travel risks, improving regional accessibility, and supporting sustainable transportation planning. Therefore, GIS-based transportation infrastructure analysis is expected to play an increasingly important role in future smart city development, regional planning, and integrated transportation management systems.

V. FUTURE SCOPE

The future scope of GIS-based spatial analysis in transportation infrastructure development and regional accessibility is highly promising due to continuous technological advancements and the increasing demand for sustainable transportation systems. Future research can focus on integrating GIS with advanced artificial intelligence and machine learning algorithms to develop predictive transportation models capable of real-time traffic forecasting, accident prediction, and intelligent route optimization. The incorporation of Internet of Things (IoT) sensors, remote sensing technologies, drones, and satellite imagery can further enhance real-time transportation monitoring and infrastructure condition assessment. Researchers may also explore the development of digital twins for transportation infrastructure using GIS and BIM integration to support smart infrastructure management and lifecycle analysis. Another important future direction involves improving multimodal transportation accessibility by integrating road, rail, air, and water transport systems into unified GIS-based platforms for comprehensive regional connectivity analysis. Future studies can also emphasize climate-resilient transportation planning by assessing the impacts of floods, extreme weather events, and environmental degradation on transportation networks using spatial risk assessment models. In developing countries, efforts should be directed toward creating cost-effective and user-friendly GIS platforms to support infrastructure planning in resource-constrained regions. Additionally, greater attention can be given to social equity and accessibility studies by analyzing transportation access for vulnerable populations, rural communities, and economically disadvantaged groups. The integration of big data analytics, cloud computing, and real-time geospatial databases can further improve transportation decision-making processes and urban mobility management. Consequently, future GIS-based transportation research is expected to contribute significantly toward smart cities, sustainable infrastructure development, intelligent transportation systems, and improved regional accessibility worldwide.

REFERENCES

1. Trung Hieu, H., & Le, K. G. (2026). GIS in transportation infrastructure: a systematic review and bibliometric analysis of construction, management, and digital integration. *All Earth*, *38*(1), 2637588.
2. Ayeni, T. S., Aderinola, O. S., Akande, S. O., & Akinwonmi, F. C. (2026). Development of Gis-Based Decision Support System for the Maintenance Management of Road Infrastructure. *Engineering Headway*, *33*, 327-338.
3. Zaroujtaghi, A., Mansourihanis, O., Tayarani, M., Mansouri, F., Hemmati, M., & Soltani, A. (2025). A Systematic Review of GIS Evolution in Transportation Planning: Towards AI Integration. *Future Transportation*, *5*(3), 97.
4. Bilașco, Ș., & Man, T. C. (2024). GIS-Based Spatial analysis model for assessing impact and cumulative risk in road traffic accidents via analytic hierarchy process (AHP)—Case study: Romania. *Applied Sciences*, *14*(6), 2643.
5. Mohammed, S., Alkhereibi, A. H., Abulibdeh, A., Jawarneh, R. N., & Balakrishnan, P. (2023). GIS-based spatiotemporal analysis for road traffic crashes; in support of sustainable transportation Planning. *Transportation research interdisciplinary perspectives*, *20*, 100836.
6. Ammapa, J., Visuttiporn, P., Klaylee, J., Chayphong, S., & Iamtrakul, P. (2022, August). Using GIS-based spatial analysis: comparing pattern of urbanization and transportation networks. In *2022 10th International Conference on Traffic and Logistic Engineering (ICTLE)* (pp. 17-21). IEEE.
7. Feizizadeh, B., Omarzadeh, D., Sharifi, A., Rahmani, A., Lakes, T., & Blaschke, T. (2022). A GIS-based spatiotemporal modelling of urban traffic accidents in Tabriz City during the COVID-19 pandemic. *Sustainability*, *14*(12), 7468.
8. Asborno, M. I., Hernandez, S., & Yves, M. (2021). GIS-based identification and visualization of multimodal freight transportation catchment areas. *Transportation*, *48*(6), 2939-2968.
9. Kim, S. M., Suh, J., Oh, M., Yang, A., Song, J., & Park, H. D. (2020). GIS-based network analysis of North Korea’s transportation infrastructure for the trade of mineral resources in North Korea. *Journal of the Korean Society of Mineral and Energy Resources Engineers*, *57*(2), 159-167.
10. Daniel, C. B., Saravanan, S., & Mathew, S. (2019). Gis based road connectivity evaluation using graph theory. In *Transportation Research: Proceedings of CTRG 2017* (pp. 213-226). Singapore: Springer Singapore.