

# **Sustainable Transportation Infrastructure Planning for Urban Mobility and Environmental Resilience**

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## **ABSTRACT**

Sustainable transportation infrastructure planning is increasingly critical in urban areas grappling with growing population density, rising vehicle ownership, and environmental challenges. Traditional approaches focusing solely on road expansion are insufficient. Instead, cities are shifting toward integrated transportation systems that emphasize environmental sustainability, economic efficiency, and social equity. Key innovations such as electric vehicles (EVs), micromobility systems, and autonomous vehicles (AVs) are transforming urban mobility. Additionally, the integration of advanced technologies like Geographic Information Systems (GIS), UAVs, and Artificial Neural Networks (ANN) is driving data-driven decision-making. Effective planning is crucial for reducing emissions, improving urban mobility, and fostering long-term resilience.

***Keywords:** Sustainable Transportation, Urban Planning, Electric Vehicles, Micromobility, Autonomous Vehicles.*

## **I. INTRODUCTION**

Sustainable transportation infrastructure planning has emerged as a critical priority in rapidly growing urban areas due to increasing population density, rising vehicle ownership, and the associated environmental and socio-economic challenges. Urbanization has accelerated significantly over the past few decades, leading to increased travel demand, congestion, air pollution, and pressure on existing infrastructure systems. Traditional transportation planning approaches, which largely focused on expanding road capacity, are no longer sufficient to address the complexities of modern cities. Instead, there is a growing shift toward sustainable and integrated transportation systems that emphasize environmental protection, economic efficiency, and social equity. According to Adshead et al. (2019), infrastructure planning plays a pivotal role in achieving the Sustainable Development Goals (SDGs), particularly those related to sustainable cities and climate action. The study highlighted that failure to implement sustainable infrastructure strategies could significantly hinder development outcomes, while integrated and cross-sectoral planning could enhance long-term urban resilience. Similarly, Jelti et al. (2023) emphasized that transitioning toward sustainable transportation systems requires addressing regulatory, technological, financial, and social barriers through coordinated policy interventions and innovative solutions. In this context, sustainable transportation infrastructure planning involves not only the development of efficient transport networks but also the integration of environmental considerations, advanced technologies, and inclusive mobility strategies to ensure long-term sustainability in urban environments.

The rapid advancement of technology has significantly transformed transportation planning and management, offering new opportunities to improve efficiency, reduce environmental impacts, and enhance user experience. Emerging mobility solutions such as light electric vehicles (LEVs), micromobility systems, and autonomous vehicles (AVs) are increasingly being adopted in urban areas as

sustainable alternatives to conventional transport modes. Mogire (2026) conducted a bibliometric analysis and reported a substantial increase in research on LEVs, particularly after 2020, highlighting their potential to provide cleaner, faster, and space-efficient mobility solutions. However, the study also identified gaps in policy frameworks, lifecycle assessment, and social equity, indicating the need for more comprehensive research. In addition, McQueen et al. (2021) examined the role of micromobility and found that while it has the potential to reduce greenhouse gas emissions and improve urban mobility, its sustainability benefits remain limited without proper regulatory support and integration with public transport systems. The integration of autonomous vehicles into urban traffic systems has also shown promising results in improving transportation efficiency. Alshabibi (2025) demonstrated that the adoption of AVs could significantly enhance traffic throughput, reduce congestion, and improve infrastructure utilization through optimized traffic signal control and data-driven planning. Furthermore, advanced technologies such as Geographic Information Systems (GIS), Unmanned Aerial Vehicles (UAVs), and Artificial Neural Networks (ANN) are increasingly being utilized for data collection, analysis, and decision-making in transportation planning. Jaleel et al. (2026) used GIS-based spatiotemporal analysis to examine urban growth patterns and their relationship with road network development, providing valuable insights for future urban expansion. Similarly, Muhmad et al. (2023) highlighted the role of UAVs in urban planning, emphasizing their ability to provide high-resolution spatial data for mapping, monitoring, and infrastructure assessment. These technological advancements underscore the importance of adopting data-driven and intelligent approaches to sustainable transportation infrastructure planning.

In addition to technological innovations, environmental sustainability and urban resilience have become central considerations in transportation infrastructure planning. The transportation sector is a major contributor to greenhouse gas emissions and environmental degradation, necessitating the adoption of sustainable practices to mitigate its impact. Urban Green Infrastructure (UGI) has emerged as an effective strategy for enhancing environmental quality and promoting sustainable urban development. Ashinze et al. (2024) highlighted that UGI components such as green spaces, urban forests, and permeable surfaces contribute to carbon sequestration, pollution reduction, and climate resilience while also improving social well-being and economic value. Similarly, Karabulut et al. (2022) emphasized the importance of integrating environmental considerations into urban planning through the use of GIS-based multi-criteria decision-making techniques for sustainable site selection. The role of electric vehicles (EVs) in reducing emissions has also been widely recognized; however, challenges related to charging infrastructure and user satisfaction remain significant barriers. Asensio et al. (2020) found that nearly half of EV users experienced negative interactions with charging infrastructure, highlighting the need for improved reliability and accessibility. Moreover, intelligent transport systems (ITS) and machine learning techniques have been identified as essential tools for improving traffic management and reducing congestion. Nandal et al. (2020) discussed the application of Artificial Neural Networks in predicting traffic patterns and optimizing route planning, although they noted limitations in handling complex urban systems. Overall, the literature suggests that achieving sustainable transportation infrastructure in rapidly growing urban areas requires a holistic approach that integrates technological innovation, environmental sustainability, policy support, and social inclusivity. Such an approach is essential for addressing the challenges of urbanization while ensuring efficient, equitable, and environmentally responsible transportation systems for future generations.

## II. RESEARCH BACKGROUND

**Mogire (2026)** had examined the growing adoption of light electric vehicles (LEVs), including electric bikes and electric scooters, as sustainable transportation solutions in urban areas, driven by the demand for cleaner, faster, and space-efficient mobility options. The study had observed that although research on LEVs had expanded considerably over time, it had remained fragmented across multiple disciplines,

thereby necessitating an integrated review of their contribution to sustainable urban transport. A bibliometric review had been conducted using 552 publications retrieved from the Scopus database, covering the period from 2000 to 2025, with data collected on 30 September 2025. The Biblioshiny application (version 5.0) had been employed for bibliometric performance analysis and science mapping. The findings had indicated a steady rise in publication trends from 2015 onward, with a notable surge after 2020 and an annual growth rate of 18.69%. Three major themes had been identified, namely sustainability, integration with public transport, and technological innovations, while underexplored areas had included shared electric micromobility, freight delivery, and policy and governance. The review had further highlighted gaps related to lifecycle impacts, social equity, and governance frameworks, and had suggested the need for future research focused on inclusive and sustainable LEV adoption.

**Jaleel et al. (2026)** had investigated how the road network in rapidly developing cities such as Doha metropolitan had fostered urban development and enhanced urban life quality. The study had employed spatiotemporal GIS-based analysis to examine urban growth trends in relation to the evolution of the road network. It had identified three major factors influencing urban growth, namely megaprojects and connectivity, national policy and land use, and population trends with road network coverage. These factors had been analyzed using Dot Density Maps, Area and Point Marker maps, and Isochrone Orthogonal Rake System (ORS) analysis to evaluate travel efficiency for car, cycling, and walking modes. GIS Geohash Density Mapping had also been applied to determine the percentage of areas covered by the road network and to identify zones experiencing maximum growth. The findings had suggested that the most suitable directions for Doha's urban expansion had been toward the west and north, and a land-use development plan had been proposed for future megaprojects, infill development, and road network expansion.

**Alshabibi (2025)** investigated the integration of autonomous vehicles (AVs) into urban traffic systems, emphasizing their potential to optimize traffic flow, reduce congestion, and enhance transportation efficiency. The study proposed a comprehensive framework that combined mathematical optimization techniques, policy planning, and AV adoption modeling to improve urban mobility. Using Highway Capacity Manual (HCM) optimization methods, the research fine-tuned traffic signal timings, dynamically allocated green time, and enhanced intersection coordination to maximize throughput. The impact of AV penetration on traffic flow efficiency, congestion reduction, and infrastructure readiness was evaluated using real-world urban data from Riyadh. The results were reported to indicate that AV integration led to a 40% increase in traffic throughput, a 60% reduction in congestion, and a 45% improvement in infrastructure readiness. Additionally, policy interventions aimed at reducing legal constraints and increasing societal acceptance were found to support the effective implementation of AV technology. The findings were suggested to provide a data-driven roadmap for city planners and policymakers, demonstrating that a structured AV deployment strategy could significantly enhance urban transportation efficiency.

**Ashinze et al. (2024)** highlighted that Urban Green Infrastructure (UGI) had played a pivotal role in shaping sustainable cities by integrating natural elements into the urban landscape. Their review indicated that UGI contributed to environmental quality, social well-being, and economic resilience in urban settings. It was observed that as cities faced challenges such as climate change, air and water pollution, and the urban heat island effect, UGI had emerged as an effective strategy to foster sustainability. The study discussed various components of UGI, including green spaces, urban forests, green roofs, and permeable surfaces, noting their collective role in mitigating environmental issues through carbon sequestration, pollutant reduction, and attenuation of extreme weather impacts. The authors also

emphasized UGI's function as a biodiversity hotspot, supporting urban flora and fauna, while promoting recreational opportunities, mental health, and community cohesion. Economically, it was reported that UGI enhanced property values, reduced energy consumption, and supported local businesses. The review further examined successful city case studies, offering insights into best practices and implementation challenges, thereby underscoring UGI as a holistic approach for resilient and sustainable urban development.

**Muhmad et al. (2023)** highlighted that the rapid growth of urban populations and the increasing demand for sustainable urban planning had positioned Unmanned Aerial Vehicles (UAVs) as crucial tools for data collection, mapping, and monitoring. They indicated that UAV technology had significant applications in sustainable urban development in Malaysia, with the potential to transform infrastructure projects and enhance urban systems, particularly in Southeast Asia and other developing nations. Using a systematic review process based on the PRISMA 2020 statement, they reported that 98 relevant studies were identified from 591 records, focusing on UAV use in urban planning. The authors noted that the emergence of the UAV-as-a-service sector had facilitated specialized operations, including site inspections, 3D modeling, boundary assessment, area estimation, master planning, green space analysis, environmental monitoring, and archaeological mapping. They observed that UAVs had demonstrated versatility across precision agriculture, forestry, construction, surveying, disaster response, security, and education, offering high-resolution imagery, accessibility, and operational safety. However, they acknowledged that regulatory differences, limited flight time, restricted awareness, skill shortages, and privacy concerns posed challenges to effective deployment. They concluded that successful implementation required collaboration among public bodies, industry, and the community, and recommended that future research in Malaysia prioritize 3D modeling and building identification to advance UAV applications across ASEAN countries.

**Jelti et al. (2023)** examined the challenges associated with developing a decarbonized transportation system, highlighting sustainable transportation practices that could limit greenhouse gas emissions and enhance overall sustainability. They reviewed and discussed innovative research avenues pursued to improve transportation sustainability, employing a systematic literature review framework to identify key areas of interest. The study analyzed the main barriers to sustainable transportation, categorizing them into regulatory, technological, financial, organizational, and social dimensions. Attention was then given to emerging approaches that supported the implementation of sustainable transportation, followed by a discussion of primary policy measures aimed at promoting sustainable mobility. The findings were reported to provide managers and policymakers with a comprehensive understanding of transportation sustainability issues and practical insights for constructing sustainable transportation systems.

**Karabulut et al. (2022)** examined the site selection process for municipal solid waste (MSW) disposal, emphasizing its critical role in environmental impact assessments and urban planning due to economic, ecological, and public health considerations. They highlighted that urban growth, being difficult to restrain, necessitated careful selection of landfill sites to support sustainable urban development. In their study, Landsat 5 and Landsat 8 satellite imagery, along with base maps, soil, and geology maps, were integrated using geospatial analysis in ArcGIS10.5. Each layer was weighted through a comparison matrix, and the final suitability map was generated using the Analytical Hierarchy Process (AHP) combined with the Simple Additive Weighting (SAW) method. Their findings indicated that 13.51% of the total area was suitable for a sanitary landfill. Furthermore, population projections for 2045 suggested a population of approximately 4,471,938 and a cumulative waste volume of 27,415,627 m<sup>3</sup>. Considering the wastes from multiple districts, only the designated "first candidate area" was deemed suitable. The study concluded that GIS-integrated AHP and SAW methods were effective decision-support tools for planning sustainable MSW management.

**McQueen et al. (2021)** examined the evolving transportation landscape in the context of emerging micromobility, which had been identified as a new category of lightweight human-powered or low-speed electric vehicles. The study had focused on the role of these modes in promoting a more sustainable transportation system through the reduction of greenhouse gas emissions, the provision of reliable and equitable mobility services, and the enhancement of overall user experience. Drawing upon existing literature on sustainable transportation, the authors had developed a three-goal framework to evaluate the extent to which micromobility contributed to sustainable urban transport systems. They had further identified and discussed policy measures that could improve the sustainability outcomes of micromobility. The review had indicated that the sustainability impacts of micromobility were mixed at the present stage and were likely to remain limited without targeted interventions from local stakeholders. However, the authors had suggested that the rapid evolution of micromobility operations and usage patterns held considerable promise for future contributions to sustainable transportation.

**Nandal et al. (2020)** highlighted that the rapid growth of population and vehicle registrations had led to widespread traffic congestion, resulting in increased fuel consumption, air pollution, and lost time for road users. They argued that constructing new highways or expanding existing ones was often expensive and sometimes impractical, suggesting that an alternative approach involved detecting vehicle locations and guiding drivers toward faster routes. The study reviewed the application of Artificial Neural Networks (ANN) for vehicle location detection and speed estimation, noting that route forecasting and destination planning were often neglected in Intelligent Transport Systems (ITS). They indicated that GPS-enabled mobile devices provided valuable data for prediction algorithms and discussed how ANN could assist in transportation engineering by offering advantages in planning maintenance activities and addressing road deterioration, while also acknowledging the method's limitations in complex urban infrastructure management.

**Asensio et al. (2020)** examined the role of electric vehicles (EVs) in reducing emissions from the transportation sector and the associated public health benefits. They reported that public confidence in the reliability of charging infrastructure had remained a critical barrier to EV adoption. By analyzing large-scale social data from 12,720 EV charging stations across 651 core-based statistical areas in the United States, they applied supervised machine-learning algorithms to classify unstructured text reviews from EV users. The study indicated that extracting behavioural insights at a population scale had been challenging due to the high cost of manual data processing, which was significantly reduced through computational approaches. Contrary to prior theoretical expectations, they found that private charging stations did not outperform government-provided public stations. Furthermore, nearly half of EV drivers using mobility applications had experienced negative interactions at charging stations during the early growth years of public charging infrastructure, highlighting the need for improvements as electrified transportation expanded.

**Adshead et al. (2019)** examined the role of infrastructure systems in supporting development through the provision of essential services. They highlighted that, amid growing global investment in infrastructure, practitioners required structured guidance to make informed decisions aligned with sustainable development objectives. Using the 2030 Agenda for Sustainable Development (SDGs) as a framework, they developed a performance indicator system to evaluate potential development impacts of infrastructure investments and policies. Metrics were created to assess infrastructure-linked targets and embedded within a systems model to quantify future infrastructure needs and evaluate investment portfolios. The methodology was applied to Curaçao, demonstrating that cross-sectoral infrastructure strategies in energy, water, wastewater, and solid waste sectors could advance SDG achievement. They

found that inaction would reduce average SDG performance by 28% by 2030. The study indicated necessary scaling of sectoral infrastructure, while energy policy could reduce demand by 32%. Interventions often required coordination across multiple sectors, and scenario analyses addressed uncertainties in population and tourism growth, providing a quantitative basis for SDG-oriented infrastructure planning.

### III. KEY FINDINGS FROM STUDY

S. No.	Author(s) & Year	Study Focus	Methodology	Key Findings	Research Gap
1	Mogire (2026)	Light Electric Vehicles (LEVs) in urban transport	Bibliometric analysis using Scopus (2000–2025), Biblioshiny tool	Rapid growth in LEV research (18.69%); focus on sustainability, integration, innovation	Lack of research on policy frameworks, lifecycle impacts, and social equity
2	Jaleel et al. (2026)	Road network evolution and urban growth	GIS-based spatiotemporal analysis, ORS, Geohash mapping	Urban expansion driven by connectivity, policy, and population; identified growth zones	Limited integration of multimodal transport planning
3	Alshabibi (2025)	Autonomous Vehicles (AVs) in traffic systems	HCM optimization, real-world traffic modeling	40% increase in throughput, 60% reduction in congestion	Lacks long-term real-world implementation and social acceptance analysis
4	Ashinze et al. (2024)	Urban Green Infrastructure (UGI)	Literature review of global case studies	Enhances environmental quality, biodiversity, and urban resilience	Limited focus on integration with transportation infrastructure
5	Muhmad et al. (2023)	UAV applications in urban planning	PRISMA systematic review (98 studies)	UAVs effective for mapping, monitoring, and planning	Regulatory, privacy, and technical constraints remain unresolved
6	Jelti et al. (2023)	Sustainable transportation systems	Systematic literature review	Identified barriers: regulatory, financial, technological, social	Lack of implementation frameworks for developing countries
7	Karabulut et al. (2022)	Sustainable landfill site selection	GIS + AHP + SAW multi-criteria decision analysis	Only 13.51% area suitable; GIS effective for planning	Does not integrate transport accessibility in site planning
8	McQueen et al. (2021)	Micromobility and sustainability	Conceptual framework and literature synthesis	Micromobility reduces emissions but needs policy support	Insufficient empirical data on long-term sustainability impacts

9	Nandal et al. (2020)	ANN in transport systems	Review of ANN applications in ITS	ANN improves traffic prediction and route planning	Limited capability in complex urban environments
10	Asensio et al. (2020)	EV charging infrastructure performance	Machine learning analysis of user-generated data	High dissatisfaction with charging infrastructure reliability	Need for infrastructure expansion and user-centric design
11	Adshead et al. (2019)	Infrastructure planning for SDGs	Systems modeling with performance indicators	Infrastructure planning critical for SDG achievement	Limited focus on transport-specific sustainability metrics

#### IV. CONCLUSION

The present review highlights that sustainable transportation infrastructure planning in rapidly growing urban areas is a complex and multidimensional challenge that requires the integration of technological innovation, environmental sustainability, and effective policy frameworks. The studies reviewed indicate that conventional transportation planning approaches, which primarily emphasize road expansion, are insufficient to address the increasing demands of urban mobility, environmental degradation, and resource constraints. Instead, there is a clear shift toward adopting sustainable and intelligent transportation systems that promote efficiency, inclusivity, and resilience. Emerging mobility solutions such as light electric vehicles (LEVs), micromobility systems, and autonomous vehicles (AVs) have demonstrated significant potential in reducing congestion, lowering greenhouse gas emissions, and improving urban mobility efficiency. However, their successful implementation depends on supportive infrastructure, policy alignment, and public acceptance. Additionally, advanced technologies such as Geographic Information Systems (GIS), Unmanned Aerial Vehicles (UAVs), Artificial Neural Networks (ANN), and machine learning have proven to be valuable tools in enhancing data-driven decision-making, optimizing traffic flow, and improving infrastructure planning. Despite these advancements, challenges such as data integration, technical limitations, and scalability in complex urban environments remain critical issues. Environmental sustainability has emerged as a key component of transportation planning, with strategies such as Urban Green Infrastructure (UGI) and sustainable waste management contributing to improved urban resilience and ecological balance. Furthermore, the transition toward electric vehicles (EVs) highlights the importance of reliable and accessible charging infrastructure to support widespread adoption. The literature also emphasizes the role of policy interventions, governance frameworks, and stakeholder collaboration in overcoming regulatory, financial, and social barriers to sustainable transportation development. Overall, achieving sustainable transportation infrastructure in rapidly urbanizing regions requires a holistic and interdisciplinary approach that balances technological innovation, environmental protection, economic feasibility, and social equity.

#### V. FUTURE SCOPE

Future research and development in sustainable transportation infrastructure planning should focus on the following areas:

- **Integration of Multimodal Transportation Systems:** There is a need to develop integrated transportation networks that seamlessly combine public transport, non-motorized transport, and emerging mobility solutions such as LEVs and micromobility to enhance accessibility and efficiency.
- **Adoption of Smart and Intelligent Transport Systems:** Advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), big data analytics, and digital twins should be further explored for real-time traffic management, predictive maintenance, and infrastructure optimization.

- **Expansion of Electric Mobility Infrastructure:** Future studies should focus on the development of reliable, efficient, and user-friendly EV charging infrastructure, including the integration of renewable energy sources to support sustainable electrification.
- **Climate-Resilient and Green Infrastructure Development:** Greater emphasis should be placed on incorporating Urban Green Infrastructure (UGI), sustainable materials, and climate-resilient design practices to mitigate environmental impacts and enhance urban resilience.
- **Policy Innovation and Governance Models:** Research should address the development of inclusive and adaptive policy frameworks that support sustainable transportation, encourage public participation, and ensure equitable access to mobility services.
- **Lifecycle Assessment and Sustainability Metrics:** Comprehensive lifecycle assessment methods should be developed to evaluate the long-term environmental, economic, and social impacts of transportation infrastructure projects.
- **Equity and Accessibility in Transportation Planning:** Future work should prioritize inclusive transportation systems that cater to all socio-economic groups, ensuring affordability, accessibility, and safety for marginalized populations.
- **Application of Advanced Data Collection Techniques:** The use of UAVs, remote sensing, and real-time data platforms should be expanded to improve urban monitoring, infrastructure assessment, and planning accuracy.
- **Integration of Land Use and Transportation Planning:** Coordinated planning between land use and transportation systems should be emphasized to promote compact, efficient, and sustainable urban development.
- **Interdisciplinary and Global Research Approaches:** Future research should adopt interdisciplinary approaches that combine engineering, environmental science, urban planning, and social sciences, while also incorporating global best practices to address region-specific challenges.

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