Malaysian Journal of Sustainable Environment
Vol.13.No.1 (2026) 349-367
doi: 10.24191/aq7tvb75

GREEN TRANSPORTATION FOR A SUSTAINABLE FUTURE: A CONCEPTUAL INSIGHT ON KEY INFLUENCING FACTORS AND ENVIRONMENTAL IMPACT

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Received: 14 May 2025
Accepted: 30 July 2025
Published: 31 March 2026

ABSTRACT

Green transportation is becoming a key component in addressing climate change and promoting urban sustainability. This paper examines the essential factors for the successful implementation of green transport systems, including electric vehicles, hydrogen technology, and smart mobility. A Systematic Literature Review (SLR) was conducted using the PRISMA framework. Articles were retrieved from Scopus and Web of Science, focusing on publications from 2020 to 2025. Out of an initial retrieval of 115 articles, 29 were ultimately selected through a systematic, multi-phase screening process, which included the removal of duplicates and a thorough review of titles, abstracts, and full texts based on clearly defined inclusion criteria. Content analysis revealed four key factors influencing the effectiveness and acceptance of green transport: technological and infrastructure support, government policies and incentives, and social awareness and behaviour. Additionally, the study identified three main impacts of green transportation: reduction in carbon emissions, decreased air pollution, and improved energy efficiency. Future research in green transportation could explore how variables such as weather patterns and

socio-acoustic manufacturing attitudes influence individuals' choice of travel mode, as well as the long-term benefits experienced by different age groups who adopt green practices such as walking and cycling.

Keywords: *Green transportation, Electric vehicle, Sustainable transport, Eco- innovations, Ecological stewardship*

INTRODUCTION

With rapid global urbanization over the past several decades alongside improvements in living standards and rising incomes, there has been an increasing dependence on transportation. This trend is further exacerbated by the dual threats of climate change and environmental degradation. As a result, the transition to greener modes of transportation has become more critical than ever. Conventional fossil fuel-powered transportation is one of the major contributors to greenhouse gas (GHG) emissions, air pollution, and resource depletion.

Green transportation, which includes electric vehicles (EVs), hydrogen technologies, intelligent mobility solutions, and sustainable public transport systems, has emerged as one of the most promising solutions to mitigate environmental harm while supporting economic and social sustainability (Chawla et al., 2023). According to Zahedi (2012), green transportation refers to eco-friendly modes of travel that minimize negative impacts on both human health and the environment.

Transportation is among the largest contributors to climate change, accounting for approximately 25% of global CO_2 emissions, most of which originate from road transport (Xia et al., 2022). In 2023, global CO_2 emissions from transportation were estimated at 8,239 tons, a dramatic rise from 4,618.5 tons in 1990 (World Bank, 2025). In the European Union, the transportation sector contributes to 25% of total GHG emissions, with urban mobility alone responsible for 40% of CO_2 emissions (Cortez-Ordoñez & Tulcanaza-Prieto, 2023). These statistics underscore the urgency of developing low-carbon transport systems, as emphasized by international climate commitments such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

Despite growing awareness, the transition toward greener transport systems still faces significant challenges, including high implementation costs, inadequate charging infrastructure, and limited user engagement. There is a pressing need for further research to better understand the factors influencing the adoption and effectiveness of green transportation, as well as its environmental impacts.

Technology trends continue to be an underdeveloped yet essential element in advancing green transportation. Key innovations such as hydrogen fuel cell vehicles (HFCVs), intelligent charging systems, and AI-driven mobility solutions offer promising benefits including reduced carbon emissions, enhanced energy efficiency, and improved urban mobility (Adlakha et al., 2022).

Developing green transport infrastructure is increasingly vital for sustainable urban development, particularly with the integration of renewable energy sources (Deng et al., 2024). However, challenges remain, such as high technology costs, limited infrastructure support, and the need to assess the long-term environmental impacts of these systems.

Existing research has often focused on isolated aspects of green transportation such as evaluating specific technologies or assessing environmental outcomes without adequately exploring the interconnections among technology, infrastructure, environmental sustainability, and overall system performance. Furthermore, there is a notable gap in comprehensive analytical frameworks for evaluating the sustainability of green transport technologies (Dutta & Hwang, 2021). This lack of integrated research complicates efforts to develop evidence-based policies and investment strategies.

Although many studies have addressed green transportation, few have simultaneously examined the factors driving its adoption and its environmental impacts. To address this research gap, the present study conducts a systematic literature review (SLR) to: (1) identify the key drivers of efficiency and acceptance in green transportation, and (2) assess its impacts on carbon emissions, air pollution, and energy consumption.

The structure of this paper is as follows: Section 2 outlines the research

methodology, including data selection and analysis procedures. Section 3 presents the results and discusses key sustainability variables, environmental impacts, and technological innovations, along with the identified research gaps. Section 4 offers conclusions and future research directions. This study aims to provide a comprehensive and systematic understanding of green transportation for academics, policymakers, and industry stakeholders, with the goal of supporting a transition to more sustainable transport systems.

METHODOLOGY

The selection and analysis of articles in this study were conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. The supplementary material, including the study selection diagram and identification process, serves to enhance the reproducibility and transparency of the systematic review. The five phases of the PRISMA framework followed in this study are: (1) identifying the research question, (2) developing a search strategy, (3) screening the literature, (4) extracting data, and (5) analyzing the results.

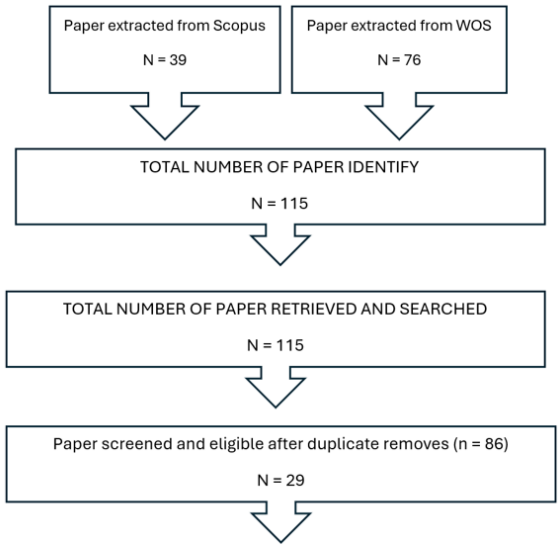

Figure 1. PRISMA Flow Diagram of Study Identification, Retrieval, and Screening Process

Source: Author

The search strategy employed the following search string in both Scopus and Web of Science (WOS) databases: ("green transportation" OR "electric vehicle" OR "sustainable transport" OR "eco-innovations" OR "ecological stewardship" OR "climate") AND ("characteristic" OR "different" OR "comparison"). This combination was designed to retrieve all relevant documents while filtering for the most pertinent results, yielding a total of 115 articles.

Study Selection

Duplicates were subsequently removed to ensure clarity and precision in the selection process. As highlighted by Danraka et al. (2024), eliminating duplicates helps streamline the review and avoids unnecessary redundancy. After this step, titles and abstracts were screened against predefined inclusion and exclusion criteria, as outlined in Table 1. Of the 115 articles initially identified, 86 were excluded based on the criteria, resulting in 29 articles being selected for in-depth review.

Table 1. The Criteria For Including and Excluding Studies

Inclusion	Exclusion
English written articles only.	Studies focused only on green transportation.
Studies published between 2020 - 2025.	Redundant or duplicate articles.
This includes articles on sustainable transportation, urban mobility, and tourism	This does not meet the quality standards papers.

Source: Author

The review process involved detailed analysis and coding of each study, focusing on transportation-related attributes and their contextual relevance (including links to tourism and urban mobility, where applicable). Each article was organized in a tabular format that captured key variables such as thematic focus, geographic scope, methodology, and reported outcomes.

The researcher adhered strictly to the PRISMA guidelines throughout the process to ensure consistency and replicability. Final conclusions from this review contribute to the growing body of knowledge on the implementation and impact of green transportation projects. Data such as frequency of study themes, number of authors, and recurring project types

were also recorded to support trend analysis within the field.

Peer Review Articles

Table 2 summarizes 29 peer-reviewed studies, including information on the authors, year of publication, country of focus, and key research themes. The first main theme focuses on factors influencing the effectiveness and acceptance of green transportation. The second theme explores the environmental impacts of green transportation, specifically in terms of carbon emissions, air pollution, and energy efficiency.

Notably, 88.9% of the selected papers were published between 2020 and 2024, reflecting a growing global interest in sustainable and green mobility solutions (Dutta & Hwang, 2021; Park et al., 2022; Zhang & Yan, 2023; Zhao et al., 2024; Vilarinho et al., 2024). The reviewed studies span diverse geographical regions, including Asia (China, Korea, India, and Vietnam), Europe (UK, Poland, and Romania), the Middle East (Saudi Arabia), and Latin America (Brazil), highlighting the widespread relevance of this topic.

Approximately 62% of the papers (18 out of 29) emphasized technology and infrastructure support. Additionally, more than half of the studies examined the role of social behavior (15 out of 29) and public awareness (13 out of 29) in promoting green transport adoption. Policy-related aspects were discussed in about 45% of the reviewed literature.

Regarding environmental impacts, the most commonly addressed issues were carbon emissions (55.2%), air pollution (48.3%), and energy efficiency (41.4%). However, only around 17% of the studies adopted an integrated approach that addressed all three main themes, suggesting that future research would benefit from more comprehensive and interdisciplinary perspectives.

Table 2. Peer Review Articles

No	Authors/ Year	Study Areas	First main theme				Second main theme		
			TIS	PIG	SAB	EEC	CE	AP	EE
1	Dutta & Hwang (2021)	Taiwan		x		x	x		

2	Khayyat et al. (2024)	Saudi Arabia				x			
3	Machedon-Pisu & Borza (2020)	Romania				x			
4	Schiavo et al. (2021)	Brazil				x			
5	Park et al. (2022)	Seoul, Korea	x	x	x	x	x	x	
6	Xiao & Wang (2020)	China				x			
7	Zhang & Yan (2023)	Shanghai, China		x		x			
8	Zhang et al. (2021)	Beijing, China	x	x	x	x		x	x
9	Zhao et al. (2024)	Nanjing, Chaina				x	x	x	x
10	Chawla et al. (2023)	India	x						
11	Cortez-Ordoñez & Tulcanaza-Prieto (2023)	Spain	x					x	
12	Han (2021)	Taiwan	x	x				x	
13	Krzykowska-Piotrowska et al. (2022)	European Union (Adriatic, Ionian, Baltic regions)	x					x	
14	Vilarinho et al. (2024)	Brazil	x	x			x		x
15	Xia et al. (2022)	Beijing, China	x						
16	Soomro et al. (2022)	Karachi, Pakistan	x						
17	Yuan et al. (2022)	China	x				x		x
18	Adlakha et al. (2022)	UK (Belfast)		x					x
19	Jou (2024)	Philippines		x					
20	Skupień (2024)	Poland		x					
21	Wang & Tian (2023)	China		x	x		x	x	x
22	Fan & Chen (2020)	Beijing, China			x				
23	Yu (2024)	Orlando,UK			x				
24	Ko (2022)	Gyeonggi, South Korea			x				
25	Li (2022)	China			x		x		
26	Huu & Ngoc (2021)	Vietnam					x		
27	Deng et al. (2024)	Harbin, China							x
28	Ibnoulouafi et al. (2022)	Global							x
29	Ou (2023)	China							x

Note: TIS- Technological and Infrastructure Support; PIG - Policies and Incentives from the Government; SAB - Social Awareness and Behavior; EEC - Economic and Environmental Costs; CE - Carbon Emissions; AP - Air Pollution; EE - Energy Efficiency

RESULT & DISCUSSION

Key Elements on the Effectiveness and Public Acceptance of Green Transportation

Support for Technology and Infrastructure

The success of green transportation heavily depends on adequate infrastructure and the adoption of next-generation technologies. Essential components such as well-distributed charging stations, dedicated bike lanes, and intelligent public transport systems are necessary to support the widespread use of electric vehicles (EVs) and bike-sharing initiatives. The availability of charging infrastructure is a critical factor in making EVs a viable alternative to internal combustion engine vehicles. However, the limited number of charging stations remains a key barrier to EV adoption (Chawla et al., 2023).

Efficient bike-sharing systems, such as BiciLog in Logroño, Spain, depend on strategically placed docking stations and integration with broader transport networks (Cortez-Ordoñez & Tulcanaza-Prieto, 2023). Similarly, the success of EVs is closely linked to the expansion of charging networks and the integration of renewable energy into power grids (Han, 2021). Despite progress, infrastructure inadequacy continues to hinder green transport, particularly outside major urban centres and in developing regions. For example, Seoul has implemented bicycle-sharing systems to support green transport initiatives (Krzykowska-Piotrowska et al., 2022; Park et al., 2022).

Substantial investments are still required to expand the use of electric and shared vehicles. Technological innovation must enhance the economic feasibility of green transportation by improving charging infrastructure and integrating renewable sources. The Bus Rapid Transit (BRT) system in Karachi is one example of a public transport improvement that encourages

shifts away from private vehicle use (Soomro et al., 2022).

Urban demand for sustainable options necessitates investments in EV charging stations, bike-sharing kiosks, and public transport linkages. These systems require effective demand–supply balancing to prevent usage imbalances during peak hours (Yuan et al., 2022; Zhang et al., 2021). Ultimately, widespread adoption of green transport depends on long-term infrastructure investment, including maintenance, to make green modes the default choice.

Government Policies and Incentives

Government policies play a central role in determining the success and scale of green transportation adoption. Financial incentives and regulatory frameworks, such as EV subsidies and charging station development in countries like Taiwan and China, have significantly accelerated EV adoption, reducing fossil fuel reliance and carbon emissions (Adlakha et al., 2021; Dutta & Hwang, 2021).

Strict emissions standards and phased-out policies for internal combustion engine vehicles are pushing both manufacturers and consumers toward greener alternatives. Additional incentives such as reduced registration fees and road tax exemptions further promote EV use (Han, 2021). The effectiveness of these policies, however, depends on their enforcement and integration into broader sustainable mobility strategies.

Conversely, Brazil's adoption of EVs has been slow due to high costs, limited infrastructure, and a lack of government prioritization (Schiavo et al., 2021). Successful implementation of green transport also requires the transition to renewable energy, integration of EVs into national grids, and incentives that improve affordability and accessibility (Park et al., 2022).

Intermodal mobility linking waterways, railways, and public transit can support shifts away from road-based transport (Vilarinho et al., 2024). Countries such as China have demonstrated success through tax rebates, subsidies, and public investment in sustainable modes (Skupień, 2024; Wang & Tian, 2023).

Cities like Beijing have addressed congestion through integrated

mobility solutions, connecting bicycle-sharing systems with metro networks (Zhang & Yan, 2023). Effective green transportation policies must balance economic constraints with innovation to ensure a sustainable and resilient transport ecosystem.

Social Behaviour and Awareness

Raising public awareness and shifting social behaviour remain critical yet challenging components of green transport adoption. Many urban populations continue to prefer private vehicles due to convenience or habit. However, studies in Beijing show that increased public transit accessibility has led to a rise in green transport usage (Fan & Chen, 2020). These changes are evident in cities like Nanjing, where public acceptance has grown (Yu, 2024). Additionally, shared mobility solutions such as Mobility as a Service (MaaS) reflect growing social trends favouring sustainability (Ko et al., 2022). In contrast, high air pollution has discouraged cycling in cities like Seoul, highlighting the complex relationship between environmental conditions and behaviour (Park et al., 2022). Behavioural shifts are closely linked to public education and awareness campaigns. Efforts to promote sustainable transport must include outreach initiatives that highlight the health and environmental benefits of green mobility (Li, 2022; Park et al., 2022).

Interplay Between Technology and Policy

Wang & Tian (2023) observed a generally positive public attitude towards green transport in Europe, where cycling and EV usage are culturally ingrained. However, in places like Karachi, adoption remains low, requiring cultural transformation and policy support (Soomro et al., 2022). To promote sustainable mobility, governments and urban planners must address social norms and emphasize the environmental benefits of green transport. Legislative outreach programs should inform citizens of the long-term advantages of eco-friendly mobility solutions and support the creation of a publicly accepted, efficient, and resilient transport ecosystem (Zhang et al., 2021).

Financial and Environmental Costs

The high initial costs of green transportation technologies discourage both individuals and businesses, despite long-term savings on fuel and maintenance (Dutta & Hwang, 2021). Although operating costs are lower,

the high upfront investment in EVs continues to be a barrier (Khayyat et al., 2024). Nevertheless, combining alternative fuels with energy-efficient technologies can reduce long-term costs and enhance the viability of green transportation. Infrastructure development including charging stations and bike-sharing facilities requires heavy investment. Limited infrastructure and high initial costs result in lower uptake (Machedon-Pisu & Borza, 2020; Schiavo et al., 2021).

Raising awareness about energy conservation and urban air quality can help build resilience in cities (Park et al., 2022). EVs and fuel-efficient buses offer both economic and environmental benefits over their lifespans (Xiao & Wang, 2020), though their uptake often depends on supportive financial policies. In Chinese cities, commercial partnerships can ease the economic burden on citizens and municipalities, improving the financial sustainability of green technologies (Zhang & Yan, 2023; Zhang et al., 2021). As Zhao et al. (2024) argue, long-term viability hinges on financial support mechanisms that reduce operating costs and fund infrastructure development. If these challenges are addressed, green transportation could become an attractive and practical option for a broader population.

The Effect of Green Transportation on Carbon Emissions, Air Pollution and Energy Efficiency

Carbon Emissions

Electric vehicles (EVs) have a considerably smaller carbon footprint compared to traditional internal combustion engine vehicles (ICEVs), and this gap widens further when EVs are powered by renewable energy sources (Ou & He, 2023). EVs consume significantly less energy than ICEVs, and their widespread adoption could lead to substantial reductions in CO_2 emissions especially within the transportation sector, one of the largest contributors to global greenhouse gas (GHG) emissions (Dutta & Hwang, 2021; Jou et al., 2024). In Vietnam, for instance, transitioning from petrol-powered motorcycles to electric scooters and e-bikes has proven effective in reducing emissions, particularly when the electricity grid includes renewable energy sources such as hydropower (Huu & Ngoc, 2021). Similarly, Mobility as a Service (MaaS) systems reduce the need for private vehicle ownership and optimize travel routes, thus limiting emissions.

Di Gebn (2022) highlights that coupling EVs with public transportation and renewable energy sources as demonstrated in cities like Seoul, can significantly lower GHG emissions (Li, 2022). On a national level, Park et al. (2022) argue that transitioning from fossil fuel-based transportation systems to electric mobility is vital for mitigating climate change. Low-carbon transport systems such as renewable-powered public transit and inland waterway transport (IWT) are proving effective in countries like Brazil, where road transport still dominates (Vilarinho et al., 2024; Wang & Tian, 2023). In rapidly urbanizing cities such as Shanghai and Beijing, the transition to EVs has already demonstrated significant environmental benefits. Integrated solutions such as shared bicycle programs and EV infrastructure can further reduce urban transportation emissions (Yuan et al., 2022; Zhang et al., 2021). The electrification of mobility is therefore pivotal, offering substantial potential to reduce emissions from the transportation sector. If cities expand and integrate renewable-powered transport networks, they can achieve widespread reductions in carbon emissions and accelerate the transition to sustainable mobility.

Air Pollution

Bicycles and e-bikes not only produce minimal emissions but also promote active mobility and enhance public health (Cortez-Ordoñez & Tulcanaza-Prieto, 2023). Replacing high-emission public transit with electric buses and trains has significantly improved air quality in many major cities worldwide. Green transport technologies including EVs and bike-sharing systems reduce the reliance on traditional vehicles, thereby improving urban air quality. For instance, Logroño's bike-sharing program has successfully lowered pollution levels while fostering a healthier city environment (Han, 2021). In Seoul, increased bicycle use and EV adoption have contributed to reduced air pollution and lower risks of respiratory and cardiovascular diseases (Krzykowska-Piotrowska et al., 2022; Park et al., 2022).

Wang & Tian (2023) further demonstrate that a transition to electric and shared mobility systems can produce significant reductions in CO_2 emissions, leading to improved air quality. ICEVs are a major source of urban air pollution, emitting large quantities of pollutants such as CO_2 and particulate matter. In contrast, EVs produce zero tailpipe emissions (Zhang et al., 2021). Urban initiatives like Nanjing's adaptive reuse of underground

spaces for public transport infrastructure help mitigate the externalities of traffic emissions while enhancing the urban tourism experience (Zhao et al., 2024). Bicycle-sharing systems continue to play a vital role in reducing air pollution by offering sustainable alternatives to motorized transport (Zhang et al., 2021). As electric vehicles, shared mobility, and sustainable infrastructure gain momentum, it becomes increasingly important to implement long-term policies that ensure both improved air quality and public health.

Energy Efficiency

Electric vehicles offer significantly higher energy conversion efficiency compared to traditional gasoline-powered vehicles. EVs convert a greater proportion of stored electrical energy into motion, thereby reducing energy waste. Public transport systems powered by renewable energy sources such as solar and wind further reduce dependence on fossil fuels and contribute to energy conservation (Adlakha et al., 2022; Deng et al., 2024). The use of kinetic energy regeneration systems in EVs further enhances their efficiency and reduces emissions. Integrated transportation systems that combine EVs with rail networks offer low-energy, high-capacity solutions for long-distance mobility at minimal fuel usage (Ibnoulouafi et al., 2022). Improving energy efficiency in urban transport may also require hybrid systems, such as those combining supercapacitors with batteries (Machedon-Pisu & Borza, 2020).

Significant energy savings can be achieved through green public transportation options like electric buses and hybrid trains, which optimize network performance and enable transitions toward energy-efficient transport systems (Vilarinho et al., 2024; Wang & Tian, 2023). Additionally, underground transit systems contribute to energy efficiency by minimizing land use, reducing the need for above-ground infrastructure, and enhancing overall mobility (Zhao et al., 2024). Effective and renewable-powered transport networks allow cities to lower energy consumption while promoting global sustainability (Yuan et al., 2022; Zhang et al., 2021). Increased availability of green public transport such as Light Rail Transit (LRT) systems allows commuters access to workplaces, healthcare, and recreational destinations in a more sustainable manner. Railways, in particular, provide reliable mobility throughout the day, offering energy-efficient alternatives for urban travel (Ibrahim et al., 2024).

CONCLUSION

The adoption of greener transportation technologies such as electric vehicles (EVs), smart bike-sharing systems, and improved public transport infrastructure has the potential to significantly reduce harmful emissions and enhance the overall quality of life. As climate change and pollution continue to pose urgent global threats, the transition to sustainable mobility solutions offers a critical pathway toward building more resilient and inclusive urban economies. Beyond addressing environmental concerns, green transportation also contributes to cleaner public spaces, reduced public health risks, and improved air quality.

Future research on green transportation should explore how factors such as weather conditions and socio-environmental attitudes influence individuals' travel mode choices. Long-term studies could also examine the sustained benefits of active mobility such as walking and cycling across different age groups and communities. It is essential to prioritize the development of EV infrastructure even in resource-constrained cities and to leverage real-time spatial data to validate and enhance sustainability-oriented transport models.

In addition, a deeper understanding of consumer behaviour is needed to assess how it influences the adoption of sustainable travel options, including Mobility as a Service (MaaS) and shared mobility systems. While autonomous vehicles continue to gain research attention, further investigation is warranted into the effectiveness of financial subsidies, the role of infrastructure, and the unique challenges faced by developing markets in adopting EVs and MaaS solutions across diverse contexts.

ACKNOWLEDGEMENT

The authors would like to express their sincere appreciation to Universiti Teknologi MARA (UiTM) for providing the academic environment and research facilities necessary for this study. Special thanks are extended to all participants and individuals who contributed directly or indirectly to the completion of this research.

DECLARATION OF AI-GENERATED CONTENT

AI tools (e.g, ChatGPT, Grammarly) were used for drafting, assistance, paraphrasing and grammar checking. All content was critically reviewed and edited by researcher.

FUNDING

There is no funding for this research.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception, design, data analysis, and manuscript preparation. All authors reviewed and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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