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REVIEW ARTICLE

Influence of highway transportation on environment: A state of art

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ABSTRACT

Highway transportation plays a critical role in supporting economic activity, regional connectivity, and social integration. However, its environmental consequences -primarily stemming from fossil fuel consumption- raise significant concerns regarding sustainability. This study provides a comprehensive evaluation of the environmental impacts of highway transportation in Turkey by integrating global literature, national statistical data, and a qualitative SWOT analysis framework. The research focuses on five key environmental dimensions: greenhouse gas (GHG) emissions, air and noise pollution, land-use change, biodiversity loss, and public health effects.

Findings reveal that over 89% of freight and 91% of passenger transport in Turkey occurs via highways, contributing to disproportionate levels of emissions and environmental degradation. According to the European Environment Agency (EEA), road transport accounted for 73.2% of total transport-related GHG emissions in the EU in 2021, a trend mirrored in Turkey. Diesel vehicle prevalence, noise levels exceeding WHO thresholds in urban areas, and fragmentation of ecological habitats are highlighted as critical issues.

The SWOT analysis identified major weaknesses—such as habitat disruption and traffic-induced pollution—alongside opportunities for sustainable transformation via electrified vehicles, green infrastructure, and intelligent transportation systems (ITS). Based on these findings, the study proposes actionable policy recommendations, including emission-based taxation, alternative fuel incentives, investment in low-carbon mobility systems, and ecological conservation in infrastructure planning.

By offering an integrated, data-driven, and region-specific assessment, this study contributes to the global discourse on sustainable transportation and supports evidence-based policymaking in emerging economies.

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INTRODUCTION

With the rapid increase in global population, mobility has become essential to meet the escalating basic needs of society [1]. Numerous transportation systems have been developed to ensure comfortable, efficient, and safe mobility, with technological advancements expected to introduce new transportation modes in the near future. Currently, existing modes include air, water, railways, roads, off-road transportation, pipelines, cable transport, and space transport [2, 3].

Approximately two-thirds of the Earth's surface is covered by water, with the remaining third consisting of interconnected landmasses. For international freight and passenger transport, air and maritime modes are generally preferred due to their speed, safety, and economic advantages [4, 5]. On a national or regional scale, however, highway and railway transportation are predominantly utilized for shorter-distance passenger and freight mobility [6]. Although highway transportation, like other transport modes, has certain disadvantages, it provides considerable benefits such as personalized door-to-door service, cost-effectiveness, accessibility, and operational flexibility. It also reduces reliance on extensive and costly infrastructure such as ports and railway systems. Particularly in residential and urban areas, highways offer superior efficiency and integration capabilities, effectively linking various transportation

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systems [7, 8]. Additionally, highway transportation operations significantly support national economies.

While human-powered and animal-powered transportation also exist, these modes are beyond the scope of this paper. Alternative transportation modes offer distinct advantages in specific contexts. For instance, air transportation, despite its higher costs, is preferred for speed, comfort, and safety [9]. Rail transportation provides efficient freight and passenger services with significant ecological and economic advantages [10]. Maritime transportation, through lower fuel consumption and large-scale cargo capacities, represents an environmentally friendly solution for transporting substantial volumes of commodities compared to road or rail transportation [11]. Furthermore, pipeline transport, recently recognized as a distinct mode, ensures the continuous and secure transfer of liquid commodities such as oil and natural gas to meet growing national and international demands [12].

According to the International Energy Agency (IEA, 2023), road transportation dominates the global mobility sector, accounting for more than 75% of total carbon dioxide (CO_2) emissions across all transportation modes [13]. Although highway transportation provides operational flexibility and economic accessibility, it significantly contributes to environmental externalities, including GHG emissions, noise pollution, deteriorating air quality, and ecological disruptions, especially in rapidly urbanizing regions [14]. These global trends inform and shape the environmental challenges faced by national transport systems. Within this global context, Turkey represents a critical case study for examining the ecological impacts associated with road transportation infrastructure.

In particular, Turkey's rapidly developing highway transportation systems constitute a fundamental element of its national infrastructure, ensuring mobility and accessibility across diverse geographical regions and serving as an integrative component within multimodal transport networks. These systems are vital for socioeconomic integration between urban and rural areas, promoting equitable access to essential services such as education, healthcare, and employment [15]. In developing countries like Turkey, highways facilitate short-distance passenger and freight transport more efficiently than other transportation modes, primarily due to their lower initial investment costs and broader geographic coverage [16–19]. Therefore, this study specifically analyzes Turkey's highway transportation system, drawing comparative insights from global literature.

This study differs from existing literature by comprehensively synthesizing the environmental impacts of highway transportation while simultaneously integrating ecological, socio-cultural, and regional development dimensions into a unified analytical framework. Unlike previous studies, this work provides a holistic evaluation that bridges environmental science and transportation planning, thereby offering a multidimensional understanding of the externalities associated with highway transportation systems.

HIGHWAY TRANSPORTATION SYSTEM

Among the various transportation modes discussed, highway systems warrant particular attention due to their dominant role in national and regional mobility—and their disproportionate environmental footprint [20, 21]. Despite their extensive utility, highway systems increasingly face scrutiny within sustainability discourse due to their ecological implications [22, 23]. The expansion and operation of road networks result in significant environmental disturbances, including habitat fragmentation, deforestation, and land degradation [24]. Additionally, road construction—particularly involving flexible pavements using hot mix asphalt—is highly energy-intensive, requiring substantial material inputs and contributing significantly to various environmental pressures [25].

Flexible pavements constitute the majority of global road networks and typically require bituminous binders combined with specific aggregates [26]. While these pavements offer advantages in terms of lower initial costs and ease of maintenance, they remain vulnerable to environmental stressors, frequently resulting in surface deterioration such as rutting and cracking. Such deterioration negatively impacts ride quality, reduces traffic flow efficiency, and increases fuel consumption due to extended travel times and frequent maintenance requirements [27].

Rigid pavements, by contrast, employ cement-based materials and demonstrate superior durability and load-bearing capacity, particularly under high-traffic and adverse weather conditions [28]. Although their initial construction cost is higher, rigid pavements typically exhibit lower maintenance needs throughout their lifecycle. Several studies indicate that rigid pavements have reduced environmental impacts over their entire lifecycle, primarily due to their extended durability, reduced frequency of major rehabilitation, and lower energy consumption during production compared to hot mix asphalt. Furthermore, cement production facilities can often be located closer to construction sites, minimizing the environmental impacts associated with long-distance material transportation [29–32].

Both pavement types have distinct advantages and limitations, yet recent advancements in sustainable pavement technologies offer promising pathways toward reducing their ecological footprints. Notable innovations include utilizing recycled pavement materials, adopting warm mix asphalt to decrease energy consumption during pavement production, employing pervious concrete to manage stormwater runoff and enhance groundwater recharge, and incorporating comprehensive life-cycle assessment (LCA) methods to optimize resource allocation and reduce overall ecological impacts [33].

Overall, highway transportation embodies a complex interplay between economic utility and environmental costs [34]. Recognizing and addressing these trade-offs through improved design, strategic maintenance, and targeted policy interventions are critical for promoting more sustainable, efficient, and climate-resilient transport infrastructures [35].

In a comparative international context, recent data illustrate that the environmental burdens associated with highway transportation differ significantly among countries. According to data from the IEA and Environmental Protection Agency (EPA), countries highly dependent on highway systems—such as the United States, Turkey, and Brazil—tend to experience disproportionately greater environmental externalities, including higher GHG emissions, urban air pollution, and biodiversity loss. By contrast, nations such as the Netherlands and Japan, which have invested significantly in multimodal, low-emission transportation systems, demonstrate substantially lower ecological impacts [13, 36]. In Turkey, highways currently account for over 89% of freight and 91% of passenger transport, underscoring an urgent need to address the environmental footprint of the sector through sustainable transport policies and innovations [37].

AIM AND SCOPE

The primary aim of this study is to provide a comprehensive analysis of the environmental impacts associated with highway transportation systems [38, 39], specifically focusing on Turkey's national road network. While international studies are referenced for comparative purposes, this review places particular emphasis on evaluating Turkey's highway-related environmental effects, including GHG emissions, noise pollution, biodiversity loss, and their indirect implications for social and regional development [40, 41].

The study seeks to explore how and to what extent highway transportation contributes to environmental degradation, as well as the potential for mitigating adverse effects through sustainable planning and targeted policy-making. Drawing upon recent empirical findings and national statistics, this review provides a detailed assessment of key environmental externalities related to road-based transportation.

Furthermore, the study examines broader implications for public health, social cohesion, and economic growth, emphasizing the interconnectedness between transportation infrastructure and societal well-being. Strategic recommendations, informed by contemporary sustainability frameworks, are presented along with a structured SWOT analysis to illustrate multidimensional trade-offs inherent in highway mobility. By bridging environmental science, civil engineering, and socio-economic planning, this paper contributes novel insights to the interdisciplinary discourse on sustainable transportation.

This paper is structured as a comprehensive review study, synthesizing national statistics and international literature to deliver an integrative perspective on highway transportation's environmental impacts.

THE EFFECT OF HIGHWAY TRANSPORTATION

On the Ecosystem

There is a strong relationship between the transportation sector and economic growth [42, 43]. The transportation sector plays a vital role in driving economic growth by meeting increasing human mobility and product demand in both developed and developing countries. However, this growth also contributes to rising energy consumption and GHG emissions, posing a major global challenge [44, 45].

GHG and air quality

Turkey is used as a case example in this study due to its high road transport dependency, growing vehicle fleet, and rapidly increasing GHG emissions in the transportation sector. Among the environmental consequences of highway transportation, the emission of GHGs—primarily CO_2, methane (CH_4), and nitrous oxide (N_2O)—stands out as the most prominent and well-documented [46, 47]. These emissions are primarily generated through the combustion of fossil fuels such as gasoline, diesel, and liquefied petroleum gas (LPG), which continue to dominate the global transportation energy mix [48].

Since the 18th century, the steady increase in fossil fuel use driven by industrialization has led to a continuous rise in atmospheric CO_2 levels, as illustrated in Figure 1 [49, 50]. Currently, more than 95% of the energy used in the transportation sector is still derived from fossil fuels, and road transportation alone accounts for a substantial portion of global emissions [51].

The mechanism of GHG formation in motor vehicles is multifaceted [52]. In addition to emissions from combustion during engine operation, GHGs are released during cold starts, fuel evaporation from tanks and carburetors, and crankcase leaks [53]. Although modern emission control technologies such as catalytic converters and particulate filters have reduced individual vehicle emissions, the overall increase in the number of vehicles and urban traffic volume offsets these gains [54].

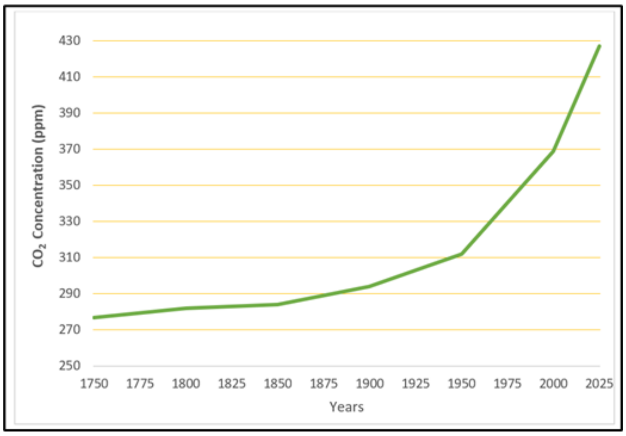

Figure 1. Change of CO_2 concentration over time (1750-2025) [49, 50]

In Turkey, data from TurkStat (TÜİK) indicate a significant rise in CO_2 emissions from road transportation between 1990 and 2022, largely driven by a 192% increase in diesel-powered vehicles over the last decade [55]. Figure 2 (a) shows CO_2 emissions by fuel type, Figure 2 (b) demonstrates the emission distribution across transport modes, emphasizing the predominance of road transport. According to the EEA, road transport accounted for 73.2% of total transport-related GHG emissions in the EU in 2021 [56], whereas in Turkey, this rate reached 94.1%, underlining the country's higher road dependency and emissions intensity [57].

These emissions result in two major environmental consequences: global climate change and local air pollution [58]. First, they exacerbate global warming by intensifying the greenhouse effect, leading to rising average temperatures, extreme weather events, and sea-level rise [59–63]. Second, they significantly deteriorate air quality, especially in dense urban areas. Elevated concentrations of nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM_{10} and $PM_{2.5}$) are frequently recorded in cities like Istanbul and Ankara—often exceeding WHO thresholds [64]. This is primarily due to the dominance of diesel vehicles and chronic traffic congestion [65, 66]. Exposure to these pollutants is strongly associated with respiratory illness, cardiovascular disease, and premature mortality [67–70].

Furthermore, vehicle emissions are closely linked to land-use changes and urban sprawl. As highway networks expand to meet growing demand, forested and agricultural lands are often cleared, reducing carbon sequestration capacity and intensifying atmospheric CO_2 levels [71]. This cyclical relationship between transportation development and environmental degradation highlights the urgency of sustainable mobility planning [72].

Mitigation strategies include promoting modal shifts to public transport [73], enhancing walking and cycling infrastructure [74], expanding the adoption of electric vehicles (EVs) and alternative fuels [75], and implementing congestion pricing or emissions-based taxation [76]. ITS can also improve traffic efficiency and reduce idle emissions [77].

While these measures offer significant potential, their success depends heavily on political will, institutional capacity, and public support. Turkey has recently introduced incentive schemes for EVs, including tax reductions and investments in charging infrastructure. However, EV adoption remains limited compared to European countries [78]. Likewise, the use of alternative fuels such as hydrogen and biofuels is still in its early stages and requires regulatory and financial support [79]. A systems-thinking approach that integrates transportation, energy, land use, and public health into a unified planning framework is essential to ensuring long-term sustainability in the road transport sector [80].

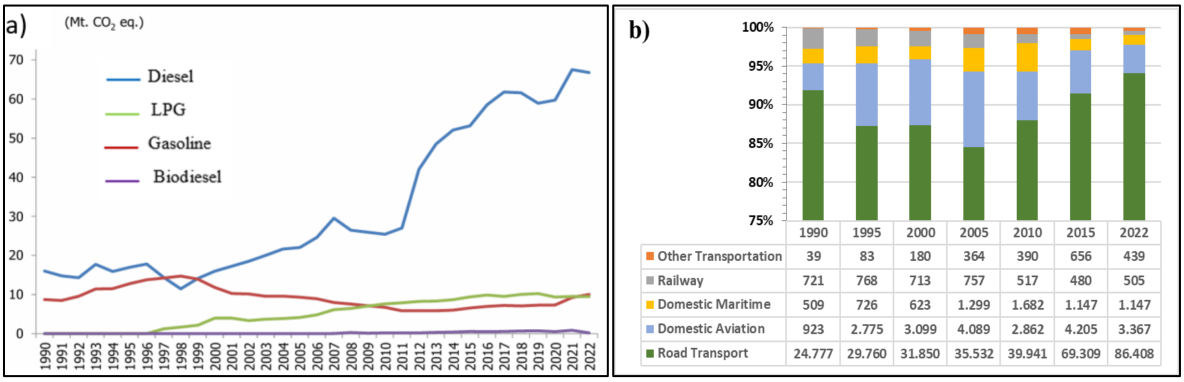

Figure 2. (a) CO_2 emissions by fuel type within road transportation in Turkey (1990-2022) [55] (b) CO_2 emissions by transportation mode in Turkey (1990-2022) (kt CO_2-eq) [57]

Noise

Noise pollution is a major consequence of traffic congestion, primarily arising from vehicle engines, exhaust systems, suspensions, and tire–pavement interaction [81–83]. Additional contributors include aerodynamic resistance and horn usage. Following air pollution, traffic noise is considered the second most significant environmental threat to human health in Europe [84]. It can lead to both physiological and psychological health effects, such as elevated stress levels, anxiety, sleep disturbances, cognitive impairment, and cardiovascular diseases [85–87].

Noise levels exceeding 55 decibels—the World Health Organization's recommended threshold—are associated with a significantly increased risk of cardiovascular disorders, including ischemic heart disease [88]. According to the EEA, over 113 million people across Europe are chronically exposed to traffic noise above this threshold, particularly in densely populated urban areas [89].

Between 2011 and 2020, the proportion of the population in Turkey reporting discomfort due to environmental noise remained over 15% higher than the EU average, indicating a persistent and elevated exposure to noise pollution [90]. The degree of impact varies based on multiple factors including road proximity, vehicle speed and type, road alignment and slope, pavement material, roadside vegetation, and traffic density [91, 92].

In response to these adverse effects, several mitigation strategies have been proposed. First, maintaining a minimum buffer zone of 30–40 meters between residential areas and highways can significantly reduce noise exposure [92]. Second, low-noise pavement materials—such as rubberized asphalt—should be prioritized over noisier options like traditional concrete [93]. Third, the promotion of quieter vehicle technologies and retrofitting existing fleets with noise-suppression systems can further alleviate the problem [94, 95]. Additional measures include enhancing building insulation, constructing acoustic barriers along roadways, and designing road surfaces with noise-absorbing textures and materials [96–98].

Biodiversity and land use

Highway transportation systems significantly impact biodiversity and land use during both construction and operation phases [99]. These effects can be either positive or negative, depending on the characteristics and design of the infrastructure [100].

Negative impacts include deforestation, reduction of agricultural land, destruction of water resources, and soil contamination during construction and maintenance activities [101]. Additionally, the extraction of raw materials for road building alters the natural structure of land surfaces.

Highway networks also fragment ecosystems by dividing natural habitats, thereby restricting wildlife movement and reducing interspecies interactions [102]. This can lead to a decline in genetic diversity, population losses, and in extreme cases, species extinction [103]. Furthermore, road-related wildlife collisions and the lack of ecological corridors in high-biodiversity areas pose additional threats to vulnerable species, exacerbating biodiversity loss [104, 105].

On the other hand, roads often serve as development catalysts in rural areas by improving accessibility [106]. They enhance the growth of agricultural and livestock sectors and support the marketing and transport of goods [107]. While roads promote tourism by improving access to natural and cultural heritage sites, they simultaneously disrupt ecological habitats and threaten biodiversity [108].

On the Social and Cultural Developments

Highway transportation systems play a pivotal role in enhancing social interactions by facilitating participation in cultural, educational, and artistic activities [109]. They enable individuals to explore diverse geographies and cultures, promoting mutual understanding and cultural integration despite existing social differences [110].

These systems also significantly contribute to the education sector by improving students' access to schools and training institutions. Enhanced transportation infrastructure broadens educational reach and enables more equitable access to learning opportunities [111]. Moreover, it improves the quality and efficiency of education by ensuring the mobility of teachers, staff, and educational resources [112].

Importantly, highway systems also influence patterns of social inequality. Access to reliable transportation directly impacts employment, education, and healthcare opportunities. Urban transport policies illustrate this dynamic: well-developed, affordable public transportation in low-income neighborhoods helps reduce mobility disparities and promote social inclusion [113]. In contrast, car-centered infrastructure that neglects underserved areas may deepen social exclusion. Inclusive policies—such as subsidized fares and Bus Rapid Transit services—demonstrate how transport planning can promote social equity [114].

Highway infrastructure also facilitates tourism development by improving accessibility to cultural heritage sites, natural attractions, and local events. This not only strengthens rural economies but also encourages intercultural dialogue and the preservation of heritage areas [115]. By increasing tourist numbers and fostering local-global connections, such infrastructure positively affects the lifestyle and worldview of local communities [116].

Despite these benefits, highway transportation has negative social consequences. Increased vehicle use is associated with sedentary lifestyles and higher rates of obesity and related health conditions such as hypertension and diabetes [117, 118]. Encouraging walking, cycling, and public transport—especially those requiring pedestrian activity—may help counteract these health risks [119]. Furthermore, road transport is inherently linked to traffic accidents, which jeopardize both life and property. Globally, approximately 1.3 million people die in road accidents annually, with two deaths and 95 serious injuries occurring every minute [120, 121]. In Turkey, approximately 6,500 people lost their lives and 350,000 were injured in road traffic accidents in 2023 [122].

On the Economic and Regional Development

Transportation plays a pivotal role in national economies by supporting agricultural and industrial sectors through the facilitation of logistics and distribution operations [123, 124]. Well-developed transportation networks enhance regional attractiveness for commercial, touristic, and industrial investment. Improved access to transport infrastructure fosters job creation, expands educational and economic services, and enriches social opportunities [125].

Moreover, efficient transportation enables the effective distribution of goods and services through door-to-door delivery, reducing time and operational costs [126]. Many settlements have developed along highway corridors due to improved connectivity. Enhanced access to domestic and international markets strengthens local economies and supports broader regional prosperity [127]. It also facilitates the rapid and safe marketing of agricultural and livestock products in rural areas [128].

Improved transportation systems allow farmers and local businesses to reach broader domestic and international markets [129]. Tourism also thrives through enhanced accessibility to cultural and natural heritage destinations provided by road infrastructure [130, 131].

While road infrastructure contributes significantly to regional development, it also entails substantial economic and environmental costs. The construction, maintenance, and expansion of highways require high capital investments and often lead to increased vehicle dependency, traffic congestion, and land consumption [132, 133]. In contrast, alternative transportation investments—such as public transit systems, cycling networks, and other sustainable mobility options—tend to be more cost-effective in the long term, particularly in urban areas [134]. These modes reduce environmental externalities and promote equitable access to economic opportunities. Therefore, evaluating the long-term financial trade-offs and societal benefits of these alternatives is essential for guiding sustainable transportation investment decisions [135].

Furthermore, transportation networks enhance quality of life by increasing mobility and social integration [136]. Investment in transport systems is thus crucial for sustainable regional development [137]. Cultural, artistic, and sporting events—such as festivals—are increasingly hosted in regions with strong transport infrastructure, generating substantial economic and social returns [138, 139]. For instance, the Rio Carnival in Brazil attracted 1.1 million foreign visitors in 2017 and generated over $3 billion in revenue. In 2019, the number of international tourists exceeded 1.5 million [140]. Such events not only promote cultural heritage but also contribute meaningfully to local economies [141].

STATUS (SWOT) ANALYSIS

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is employed to systematically evaluate the environmental implications of highway transportation systems. This approach allows for a structured synthesis of the multifaceted impacts highlighted in the preceding sections and provides actionable insights for evidence-based policy development and long-term transport planning. Table 1 summarizes the environmental strengths and limitations of highway transport, along with potential opportunities for improvement and the threats it poses to sustainability.

Table 1. Status (SWOT) analysis of highway transportation

Strengths	Weaknesses
• Facilitates economic integration and access to services across urban and rural areas. • Offers flexibility and door-to-door connectivity unmatched by other transportation modes. • Supports emergency response, logistics, and national security operations. • Serves as a platform for technological innovation, including electrification and ITS.	• High dependency on fossil fuels with limited incentives for adopting cleaner alternatives. • Fragmented policies between regional and national levels hinder integrated environmental planning. • Inadequate infrastructure for non-motorized and public transport systems. • Limited enforcement of vehicle emission standards in certain regions.
Opportunities	**Threats**
• Rapid development of low-emission vehicle technologies (e.g., EVs, hydrogen fuel cells). • Expansion of smart transportation systems for traffic flow optimization and emissions reduction. • Global policy frameworks (e.g., Paris Agreement) encouraging sustainable transport investments. • Increasing public awareness and demand for green infrastructure and low-carbon mobility.	• Climate change-induced risks to transport infrastructure (e.g., flooding, heat damage). • Urban sprawl and car dependency exacerbating emissions and land-use pressures. • Socioeconomic disparities in access to clean transport solutions. • Delay in policy harmonization could result in regulatory inconsistencies and underperformance in sustainability goals.

CONCLUSION

This study provides a comprehensive assessment of the environmental impacts of highway transportation, particularly within the context of Turkey. While highways facilitate socio-economic development by improving access to markets, education, and services, they also pose significant environmental challenges. Key findings indicate that GHG emissions from fossil fuel-based vehicles, habitat fragmentation, noise pollution, and degraded air quality are among the most critical concerns.

The analysis reveals that Turkey's high dependence on road transport -accounting for over 89% of freight and 91% of passenger mobility- intensifies environmental externalities, especially in urban and ecologically sensitive regions. The study emphasizes that innovations such as EVs, ITS, and green infrastructure offer substantial potential for mitigation, but their effectiveness depends on integrated planning and strong regulatory frameworks.

Ultimately, addressing the environmental footprint of highway transportation requires a multidimensional strategy that aligns technological innovation, environmental justice, and long-term sustainability principles. These findings provide a robust, evidence-based foundation for shaping future transportation policies and advancing integrated sustainability planning.

RECOMMENDATIONS

To translate the findings of this study into actionable solutions, the following evidence-based and policy-relevant recommendations are proposed:

1. **Alternative Fuel Policies:** Accelerate the deployment of low-emission and zero-emission vehicles by implementing financial incentives (e.g., subsidies, tax exemptions) and expanding infrastructure for electric charging and hydrogen fueling.
2. **Smart Transportation Strategies:** Invest in ITS to optimize traffic flow, reduce idle time, and enhance fuel efficiency through digital technologies such as AI-based traffic monitoring, adaptive signaling, and route optimization.
3. **Urban Mobility Planning:** Encourage modal shift from private cars to public transport, cycling, and walking through integrated urban transport plans, prioritizing transit-oriented development and non-motorized infrastructure.
4. **Green Infrastructure Expansion:** Establish urban green corridors and expand forests to enhance carbon sequestration, reduce urban heat island effects, and improve air quality.
5. **Emissions Regulation and Carbon Pricing:** Enforce strict emissions standards for new vehicles, and implement carbon pricing mechanisms (e.g., emissions trading or fuel-based carbon taxes) to internalize the environmental costs of transportation.
6. **Noise and Air Pollution Control:** Promote research and development of noise-reducing pavements and low-emission road materials. Encourage the use of barriers and buffers in urban design to minimize noise pollution.
7. **Public Engagement and Education:** Enhance public awareness on sustainable mobility through education campaigns, participatory planning, and behavioral nudges encouraging eco-friendly transport habits.
8. **Data-Driven Decision Making:** Establish national and local transportation-related emissions inventories and integrate environmental performance indicators into transportation planning and budgeting.

Collectively, these recommendations aim to guide policymakers, urban planners, and stakeholders in implementing coherent, long-term transportation strategies that align with climate targets, public health priorities, and sustainable urban development frameworks.

LIMITATIONS AND FUTURE STUDIES

This review provides a broad evaluation of the environmental, economic, and public health implications of highway transportation systems based on existing literature and national statistics. However, due to the scope of the study, several limitations should be acknowledged. First, the analysis is primarily based on qualitative synthesis and lacks empirical modeling or spatially resolved environmental simulation, which would enhance the robustness of findings. Additionally, the focus is limited to Turkey's national highway system and does not include comparative assessment across different transportation modes.

Future research could expand on this work by conducting quantitative, data-driven analyses for specific environmental indicators—such as localized air quality, traffic noise exposure, and biodiversity impact. Region-specific case studies using Geographic Information Systems (GIS)-based modeling or LCA would also strengthen understanding of transport-related externalities. Moreover, interdisciplinary investigations integrating climate science, urban planning, and transportation engineering could provide a deeper perspective on sustainability trade-offs. Finally, comparative studies involving other transport systems—such as rail, maritime, and pipeline networks—are encouraged to place highway transportation within a broader mobility and environmental policy context.

DATA AVAILABILITY STATEMENT

No datasets were generated or analyzed during the current study.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest with any individual, institution, or organization in the preparation, evaluation, or publication of this study.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1]. M. Canbulat, and İ. Alkara, "Which one is greener for the consumer? Product emission comparison between diesel and battery electric vehicles," Environmental Research and Technology, Vol. 8(1) pp. 44-56, 2025.

[2]. R. Soni, A. Dvivedi, and P. Kumar, "Carbon neutrality in transportation: In the context of renewable sources," International Journal of Sustainable Transportation, Vol. 19(1), pp. 1-15, 2025.

[3]. B. Royo, Y. Zhang, A. Lewis, and P. Dehdari, "CO2 emissions in urban freight transport: Developing and testing the EcoLogistics tool," Case Studies on Transport Policy, Vol. 20, 101415, 2025.

[4]. M. Christiansen, E. Hellsten, D. Pisinger, D. Sacramento, and C. Vilhelmsen, "Liner Shipping Network Design," European Journal of Operational Research, Vol. 286(1), pp. 1–20, 2020.

[5]. F. Zhang, and D. J. Graham, "Air Transport and Economic Growth: A Review of the Impact Mechanism and Causal Relationships," Transport Reviews, Vol. 40(4), pp.506–528, 2020.

[6]. W. Fu, (2025, February 21). Public Transportation Commuting: Inequity and Polycentric Urban Structure [Paper presentation]. In E3S Web of Conferences Vol. 617, 02017.

[7]. M. Bagamanova, M. Mujica Mota, and V. Di Vito, "Exploring The Efficiency of Future Multimodal Networks: A Door-To-Door Case in Europe," Sustainability, Vol. 14(20), pp. 13621, 2022.

[8]. B. Özoğlu, and S. B. Demirci, "Türkiye'de Karayolu Taşımacılığının Değerlendirilmesi: Bir Literatür Taraması," Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 14(2), 670–687, 2021.

[9]. B. Şahin, and N. Tektaş, "Havacılıkta SWOT analizi: Türkiye için durum değerlendirmesi," Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi, Vol. 4(1), pp. 87–98, 2021.

[10]. E. Isik, A. Ozyilmaz, Y. Bayraktar, M. Toprak, M. F. Olgun, and N. K. Senturk, "Assessing the Impact of Multimodal Transportation on Economic Growth: A Machine Learning and Cointegration Approach in 28 Countries: Assessing the Impact of Multimodal Transportation on Economic Growth," European Journal of Transport and Infrastructure Research, Vol. 25(1), pp. 178-207, 2025.

[11]. E. İ. Develi, "Lojistik türlerinden denizyolu taşımacılığı ve Türkiye pazarı özelinde bir durum (GZFT) analizi," İstanbul Ticaret Üniversitesi Sosyal Bilimler Dergisi, Vol. 20(42), pp. 1640–1661, 2021.

[12]. M. Dedík, M. Kendra, M. Senci, D. Pribula, and M. Vojtek, "Progressive Methods of the Harmfulness Evaluation of Transport in Terms of Emission Production," Sustainability, Vol. 16(23), pp. 10290, 2024.

[13]. IEA. (2023). Global CO2 emissions from transport by sub-sector in the Net Zero Scenario, 2000-2030. Available: Global CO2 emissions from transport by sub-sector in the Net Zero Scenario, 2000-2030 – Charts – Data & Statistics - IEA., (accessed 5 April 2025)

[14]. S. Gürçam, and E. Konuralp, "Küreselden Yerele Çevresel Politika Yapimi: Iğdir Il Özel Idaresi Üzerine Bir Memorandum," Iğdır Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, Vol. 6, pp. 65-84, 2021

[15]. Ü. Taş, "Future Forecast and Economic Perspective of the Distribution of Greenhouse Gas Emissions by Sectors, "Uluslararası Sosyal Bilimler Akademik Araştırmalar Dergisi," Vol. 8(1), pp. 80–87, 2024.

[16]. R. G. Ö. Karlı, and H. S. Çelikyay, "Akıllı Ulaşım Sistemleri (AUS) Üzerine Türkiye'deki Politikaların Araştırılması," Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi, Vol. 5(2), pp. 1–14, 2022.

[17]. A. Kranioti, D. Tsiotas, and S. Polyzos, "The Topology of Cultural Destinations' Accessibility: The Case of Attica, Greece," Sustainability, Vol. 14(3), pp. 1860, 2022.

[18]. J. Zhang, S. Li, and Y. Wang, "Shaping A Smart Transportation System for Sustainable Value Co-Creation," Information Systems Frontiers, Vol. 25(1), pp. 365–380, 2023.

[19]. B. K. Sovacool, and S. Griffiths, "Culture and Low-Carbon Energy Transitions," Nature Sustainability, Vol. 3(9), pp. 685–693, 2020.

[20]. D. Hopkins, "Sustainable Mobility at The Interface of Transport and Tourism: Introduction to The Special Issue on 'Innovative Approaches to The Study and Practice of Sustainable Transport, Mobility and Tourism'," Journal of Sustainable Tourism, 28(2), 129–143, 2020.

[21]. A. Gómez-Lobo, and D. Oviedo, D. "Spatial inequality and income disparities in Latin America: a multiscale analysis," Oxford Open Economics, Vol. 4, pp. 307-333, 2025.

[22]. C. Kouridis, and C. Vlachokostas, "Towards Decarbonizing Road Transport: Environmental and Social Benefit of Vehicle Fleet Electrification in Urban Areas of Greece," Renewable and Sustainable Energy Reviews, Vol. 153, pp. 111775, 2022.

[23]. Ü. Taş, "Case Study of Intralogistics in the Framework of Logistics 4.0," International Journal of Automotive Science and Technology, Vol. 7(1), pp. 18–24, 2023.

[24]. O. Kunytska, L. Persia, N. Gruenwald, D. Datsenko, and M. Zakrzewska, (2019, November 29). The sustainable and smart mobility strategy: Country comparative overview [Paper presentation]. International Conference on Smart Technologies in Urban Engineering, pp. 656–668.

[25]. F. Jalaei, J. Zhang, N. Mcneil-Ayuk, and C. McLeod, "Environmental life cycle assessment (LCA) for design of climate-resilient bridges–a comprehensive review and a case study," International Journal of Construction Management, Vol 25(1), pp. 99-114, 2025.

[26]. D. Kılıç, A. Öz, A. Benli, A. Tortum, G. Kaplan, and A.C. Aydın, "Integration of reclaimed asphalt aggregates into glass fiber-reinforced alkali-activated composites: Mechanical performance and durability," Construction and Building Materials, Vol 458, 139645, 2025.

[27]. J. He, F. Wang, Y. Duan, Z. Yang, and J. Yang, "Energy-efficient train timetable optimization for tram system under multi-signal priority strategies," Scientific Reports, Vol 15(1), 8123, 2025.

[28]. R. Al-Nawasir, B. Al-Humeidawi, M. I. Khan, R. M. Choudhry, R. M. Malik, and M. A. Dhaheer, "Innovative use of ceramic waste in cement grout for sustainable semi-flexible pavement solutions," Innovative Infrastructure Solutions, 10(2), 64, 2025.

[29]. L. F. Walubita, G. Martinez-Arguelles, R. Polo-Mendoza, S. Ick-Lee, and L. Fuentes, "Comparative environmental assessment of rigid, flexible, and perpetual pavements: A case study of Texas," Sustainability, Vol. 14(16), 9983, 2022.

[30]. A. R. Haris, W. Oetomo, and R. Marleno, "Comparison of Concrete and Asphalt Pavements: Cost and Time Analysis on The Bendung-Bantengan Road Section in Mojokerto District," Asian Journal of Social and Humanities, Vol. 3(6), pp. 1151-1162, 2025.

[31]. M. A. Azadgoleh, M. M. Mohammadi, H. AzariJafari, J. Santos, A. Ahmadi, M. Z. Alavi, and P. Ayar, "A comparative life cycle assessment (LCA), life cycle cost analysis (LCCA), mechanical and long-term leaching evaluation of road pavement structures containing multiple secondary materials," Journal of Cleaner Production, Vol. 458, 1424848, 2024.

[32]. W. Zhao, and Q. Yang, "Life-cycle assessment of sustainable pavement based on the coordinated application of recycled asphalt pavement and solid waste: Environment and economy," Journal of Cleaner Production, Vol 434, 140203, 2024.

[33]. C. Oreto, F. Russo, G. Dell'Acqua, and R. Veropalumbo, "A comparative environmental life cycle assessment of road asphalt pavement solutions made up of artificial aggregates," Science of the Total Environment, Vol 927, 171716, 2024.

[34]. Z. Zhijie, "Characterization of spatiotemporal relationship of cross-region transfer of carbon emissions from transportation system in pearl river delta," Systems Science & Control Engineering, Vol 13(1), 2474455, 2025.

[35]. A. Sharifi, M. Amirzadeh, and A. R. Khavarian-Garmsir, "The metaverse as a future form of smart cities: A systematic literature review of co-benefits and trade-offs for sustainable development goals," Cities, Vol 161, 105879, 2025.

[36]. EPA. (2024). Fast Facts on Transportation Greenhouse Gas Emissions. Available: https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions., (accessed 5 April 2025)

[37]. CSB. (2022). 10.2 Ulaştırma Türlerine Göre Taşınan Yolcu ve Yük Miktarı. Available: https://cevreselgostergeler.csb.gov.tr/ulastirma-turlerine-gore-tasinan-yolcu-ve-yuk-miktari-i-85789., (accessed 5 April 2025)

[38]. S. Gössling, J. Nicolosi, and T. Litman, "The Health Cost Of Transport In Cities," Current Environmental Health Reports, Vol. 8, pp. 196–201, 2021.

[39]. R. Fisa, M. Musukuma, M. Sampa, P. Musonda, and T. Young, "Effects Of Interventions For Preventing Road Traffic Crashes: An Overview of Systematic Reviews," BMC Public Health, Vol. 22(1), pp. 513, 2022.

[40]. A. Glazener, and H. Khreis, "Transforming Our Cities: Best Practices Towards Clean Air and Active Transportation," Current Environmental Health Reports, Vol. 6, pp. 22–37, 2019.

[41]. T. Münzel, S. Kröller-Schön, M. Oelze, T. Gori, F. P. Schmidt, S. Steven, O. Hahad, M. Röösli, J. M. Wunderli, A. Daiber, and M. Sørensen, "Adverse Cardiovascular Effects Of Traffic Noise with A Focus on Nighttime Noise and The New WHO Noise Guidelines," Annual Review Of Public Health, Vol. 41, pp. 309–328, 2020.

[42]. S. Gürçam, "Global commercial aviation policies in the context of the climate crisis and an analysis of these approaches from the perspective of Türkiye," Environmental Research and Technology, Vol. 5(3), pp. 227-240, 2022.

[43]. Ü. Taş, and H. Bolakar Tosun, "Assessment of the highway logistics on carbon footprint," Environmental Research and Technology, Vol. 5(3), pp. 241–248, 2022.

[44]. M. Deveci, I. Gokasar, Y. Chen, W. Wang, A. E. Karaismailoğlu, and J. Antucheviciene, "Analysis of Green Energy in Sustainable Transportation in Developing Nations through a Decision Support Model," Renewable Energy, Vol. 244, 122643, 2025.

[45]. S. Gürçam, "Analysing the Global Fight Against Climate Change and the Turkish Context," Lectio Socialis, Vol. 6(1), pp. 39–54, 2022.

[46]. A. N. Mistry, U. Ganta, J. Chakrabarty, and S. Dutta, "A Review on Biological Systems for CO_2 Sequestration: Organisms and Their Pathways," Environmental Progress & Sustainable Energy, Vol. 38(1), pp. 127–136, 2019.

[47]. O. J. Oladunni, K. Mpofu, and O. A. Olanrewaju, "Greenhouse gas emissions and its driving forces in the transport sector of South Africa," Energy Reports, Vol. 8, pp. 2052-2061, 2022.

[48]. R. Li, Y. Wei, W. Cai, Y. Liu, K. You, and Y. Yu, "Tracking cement transportation carbon emissions in China: Historical assessment and future simulation," Environmental Impact Assessment Review, Vol. 110, 107696, 2025.

[49]. H. Ritchie, M. Roser, and P. Rosado, (2025). "CO_2 and Greenhouse Gas Emissions," Available: https://ourworldindata.org/co2-and-greenhouse-gas-emissions., (accessed 5 April 2025)

[50]. Noaa. (2025). "Trends in Atmospheric Carbon Dioxide (CO_2)". Available: https://gml.noaa.gov/ccgg/trends/., (accessed 5 April 2025)

[51]. S. Berdysheva, and S. Ikonnikova, "The energy transition and shifts in fossil fuel use: the study of international energy trade and energy security dynamics," Energies, Vol 14(17), 5396, 2021.

[52]. V. Vasan, N. V. Sridharan, M. Feroskhan, S. Vaithiyanathan, B. Subramanian, P. C. Tsai, Y. C. Lin, C. H. Lay, C. T. Wang, and V. K. Ponnusamy, "Biogas production and its utilization in internal combustion engines-A review," Process Safety and Environmental Protection, Vol. 186, pp. 518-539, 2024.

[53]. A. Cernat, C. Pana, and N. Negurescu, "Solutions for Polluting Emissions Reduction in Internal Combustion Engines," G. Lazaroiu, and L. Mihaescu (Ed.), Innovative Renewable Waste Conversion Technologies. Springer, pp. 237-279, 2021.

[54]. Y. Zhang, J. Du, Y. Shan, F. Wang, J. Liu, M. Wang, Z. Liu, Y. Yan, G. Xu, G. He, X. Shi, Z. Lian, Y. Yu, W. Shan, and H. He, "Toward synergetic reduction of pollutant and greenhouse gas emissions from vehicles: a catalysis perspective," Chemical Society Reviews, Vol 54, 1151-1215, 2025.

[55]. UNFCCC. (2024). TURKISH GREENHOUSE GAS INVENTORY 1990–2022. Available: TUR NID 2024.pdf., (accessed 5 April 2025)

[56]. EEA. (2024). Greenhouse gas emissions from transport in Europe. Available: Greenhouse gas emissions from transport in Europe | European Environment Agency's home page., (accessed 5 April 2025)

[57]. CSB. (2023). 10.3 Ulaştırma Türüne Göre Seragazı Emisyonu 2022. Available: cevreselgostergeler.csb.gov.tr/ulastirma-turune-gore-seragazi-emisyonu-i-85790., (accessed 5 April 2025)

[58]. S. Gürçam, "Paving the way for climate resilience through sustainable urbanization: A comparative study," Lectio Socialis, Vol. 8(1), pp. 17-34, 2024.

[59]. F. D. Albuquerque, M. A. Maraqa, R. Chowdhury, T. Mauga, and M. Alzard, "Greenhouse Gas Emissions Associated with Road Transport Projects: Current Status, Benchmarking, And Assessment Tools," Transportation Research Procedia, Vol. 48, pp. 2018–2030, 2020.

[60]. G. H. Safari, A. Asl Hashemi, and F. Y. Roodposhti, "Eco-Driving Technology: An Effective and Economical Approach to Reduce Fuel Consumption and Greenhouse Gas," Journal of Environmental Science Studies, Vol. 8(1), pp. 5960–5976, 2023.

[61]. D. L. Bleviss, "Transportation is Critical to Reducing Greenhouse Gas Emissions in The United States," Wiley Interdisciplinary Reviews: Energy and Environment, Vol. 10(2), pp. 390, 2021.

[62]. A. O. Dündar, and A. Kolay, "Karayolu Yük ve Yolcu Taşımacılığının Çevresel Sürdürülebilirlik Bakımından Değerlendirilmesi ve Konya İli Sera Gazı Emisyonunun Hesaplanması," Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, Vol. 14(1), pp. 317–334, 2021.

[63]. İ. Kırbaş, and T. Kocakulak, "Burdur ili karbon ayak izinin belirlenmesi," Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi, Vol. 24(70), pp. 317–327, 2022.

[64]. WHO. (2021). "What are the WHO Air quality guidelines?," Available: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines., (accessed 5 April 2025)

[65]. E. Koçak, and İ. Balcılar, "Spatio-temporal variation of particulate matter with health impact assessment and long-range transport-case study: Ankara, Türkiye," Science of the Total Environment, Vol. 938, 173650 2024.

[66]. Ü. A. Şahin, C. Ayvaz, S. Hama, B. Onat, B. Uzun, M. Dogan, G. Bediroglu, and R. M. Harrison, "Assessment of ambient particulate matter and trace gases in Istanbul: Insights from long-term and multi-monitoring stations," Atmospheric Pollution Research, Vol. 15(5), 102089, 2024.

[67]. J. Lelieveld, K. Klingmüller, A. Pozzer, R. T. Burnett, A. Haines, and V. Ramanathan, "Effects of Fossil Fuel and Total Anthropogenic Emission Removal on Public Health and Climate," Proceedings of the National Academy of Sciences, Vol. 116(15), pp. 7192–7197, 2019.

[68]. T. Litman, "Transportation and Public Health," Annual Review of Public Health, Vol. 34, pp. 217–233, 2013.

[69]. D. Sofia, F. Gioiella, N. Lotrecchiano, and A. Giuliano, "Mitigation Strategies for Reducing Air Pollution," Environmental Science and Pollution Research, Vol. 27(16), pp. 19226–19235, 2020.

[70]. O. Uğur, (2021). "Nevşehir ili karayolu ulaşımından kaynaklanan sera gazı emisyonunun değerlendirilmesi (Master's thesis, Nevşehir Hacı Bektaş Veli Üniversitesi)." Available from Ulusal Tez Merkezi Global database.

[71]. J. Lohwasser, T. Bolognesi, and A. Schaffer, "Impacts of population, affluence and urbanization on local air pollution and land transformation–A regional STIRPAT analysis for German districts," Ecological Economics, Vol 227, 108416, 2025.

[72]. W. A. Abujder Ochoa, A. Iarozinski Neto, P. C. Vitorio Junior, O. P. Calabokis, and V. Ballesteros-Ballesteros, The Theory of complexity and sustainable urban development: A systematic literature review. Sustainability, Vol 17(1), 3, 2025

[73]. H. Thomas, and A. C. Serrenho, "Using different transport modes: An opportunity to reduce UK passenger transport emissions?," Transportation Research Part D: Transport and Environment, Vol 126, 103989, 2024.

[74]. L. Klos, J. Fiedler, C. Nigg, C. Niessner, H. Wäsche, and A. Woll, "Walking and non-motorized vehicle use in adolescents: the role of neighborhood environment perceptions across urbanization levels," German journal of exercise and sport research, Vol 54(1), pp. 145-155, 2024.

[75]. G. H. Broadbent, G. Metternicht, T. Wiedmann, and C. Allen, "Transforming Australia's road fleet with electric vehicles: Strategies and impediments affecting net-zero emissions targets for 2050," Case Studies on Transport Policy, Vol 16, 101191, 2024.

[76]. H. Peng, Y. Sun, J. Hao, C. An, and L. Lyu, "Carbon emissions trading in ground transportation: Status quo, policy analysis, and outlook," Transportation Research Part D: Transport and Environment, Vol 131, 104225, 2024.

[77]. M. Elassy, M. Al-Hattab, M. Takruri, and S. Badawi, "Intelligent transportation systems for sustainable smart cities," Transportation Engineering, Vol 16, 100252, 2024.

[78]. M. Bildirici, and O. Kaplan, (2024, May 27-29). Electric Vehicle Projection and Incentive Recommendations in Türkiye [Paper presentation]. In 2024 12th International Conference on Smart Grid (icSmartGrid), pp. 835-839.

[79]. G. Cevheribucak, "Energy transition and sustainable road transportation in Turkey: Multiple policy challenges for inclusive change," Frontiers in Sustainable Cities, Vol. 3, 631337, 2021.

[80]. U. Okonta, A. Hosseinian-Far, and D. Sarwar, "A systemic approach to sustainable railway infrastructure planning: The case study of Milton Keynes," Smart and sustainable built environment, Vol 14(2), pp. 407-428, 2025.

[81]. L. Pecić, and P. Pravdić, "Road Traffic as A Source of Noise Pollution (Case Study: Trstenik Municipality)," Bizinfo (Blace), Vol. 10(1), pp. 69–83, 2019.

[82]. S. Ling, F. Yu, D. Sun, G. Sun, and L. Xu, "A Comprehensive Review of Tire-Pavement Noise: Generation Mechanism, Measurement Methods, and Quiet Asphalt Pavement," Journal of Cleaner Production, Vol. 287, pp. 125056, 2021.

[83]. Ü. Taş, E. Pak, B. Uğur, "Recent engineering applications for noise reduction in an automotive industry," Journal of Advanced Research in Natural and Applied Sciences, Vol. 10(1), pp. 207–217, 2024.

[84]. P. Mikhailenko, Z. Piao, M. R. Kakar, M. Bueno, S. Athari, R. Pieren, K. Heutschi, and L. Poulikakos, "Low-Noise Pavement Technologies and Evaluation Techniques: A Literature Review," International Journal of Pavement Engineering, Vol. 23(6), pp. 1911–1934, 2022.

[85]. A. Dülgeroğlu, "Trafik ve Çevre Etkisi," Uluslararası Trafik ve Yol Güvenliği Kongresi, Ankara, 2002.

[86]. L. Jiang, and J. Nellthorp, "Valuing Transport Noise Impacts in Public Urban Spaces in The UK: Gaps, Opportunities and Challenges," Applied Acoustics, Vol. 166, pp. 107376, 2020.

[87]. T. Münzel, M. Sørensen, and A. Daiber, "Transportation Noise Pollution and Cardiovascular Disease," Nature Reviews Cardiology, Vol. 18(9), pp. 619–636, 2021.

[88]. Y. Lan, H. Roberts, M. P. Kwan, and M. Helbich, "Transportation Noise Exposure and Anxiety: A Systematic Review and Meta-Analysis," Environmental Research, Vol. 191, pp. 110118, 2020.

[89]. EEA. (2020). 11. Environmental noise. Available: https://www.eea.europa.eu/en/analysis/publications/soer-2020/chapter-11_soer2020-environmental-noise/@@download/file#page=5.81., (accessed 5 April 2025)

[90]. A. Kasap, "Evaluation of Sustainable City Performances from the Perspective of Sustainable Development: A Comparison Between the EU and Turkey," Tokat Gaziosmanpaşa Üniversitesi Turhal Uygulamalı Bilimler Fakültesi Dergisi, Vol 1(2), pp. 13-30, 2024.

[91]. M. Manohare, E. Rajasekar, M. Parida, and S. Vij, "Bibliometric Analysis and Review of Auditory and Non-Auditory Health Impact due to Road Traffic Noise Exposure," Noise Mapping, Vol. 9(1), pp. 67–88, 2022.

[92]. S. Savaş, (2019). "İstanbul Kavacık mevkiinde tem otoyolundan kaynaklanan gürültünün haritalanması ve gürültü perdesi modelinin uygulanması (Master's thesis, Namık Kemal Üniversitesi)." Available from Ulusal Tez Merkezi Global database.

[93]. A. Awwal, N. Mashros, S. A. Hasan, N. A. Hassan, N. Darus, and R. Rahman, (2020 December 1-2). Road traffic noise for asphalt and concrete pavement [Paper presentation]. IOP Conference Series: Materials Science and Engineering, 1144(1), 012082.

[94]. T. Capuder, D. M. Sprčić, D. Zoričić, and H. Pandžić, "Review of Challenges and Assessment of Electric Vehicles Integration Policy Goals: Integrated Risk Analysis Approach," International Journal of Electrical Power & Energy Systems, Vol. 119, pp. 105894, 2020.

[95]. Y. Tao, M. Ren, H. Zhang, and T. Peijs, "Recent Progress in Acoustic Materials and Noise Control Strategies–A Review," Applied Materials Today, Vol. 24, pp. 101141, 2021.

[96]. W. Yang, and J. Y. Jeon, "Design Strategies and Elements of Building Envelope for Urban Acoustic Environment," Building and Environment, Vol. 182, pp. 107121, 2020.

[97]. P. Kopelias, E. Demiridi, K. Vogiatzis, A. Skabardonis, and V. Zafiropoulou, "Connected & Autonomous Vehicles–Environmental Impacts–A Review," Science of The Total Environment, Vol. 712, pp. 135237, 2020.

[98]. S. Kumari, A. Sharma, and A. K. Ghosh, "A comprehensive review of noise pollution monitoring studies at bus transit terminals," Noise Mapping, Vol. 11(1), 20220180, 2024.

[99]. E. Wachs, and B. Engel, "Land Use for United States Power Generation: A Critical Review of Existing Metrics with Suggestions for Going Forward," Renewable and Sustainable Energy Reviews, Vol. 143, pp. 110911, 2021.

[100]. I. Khan, D. Shah, and S. S. Shah, "COVID-19 Pandemic and Its Positive Impacts on Environment: An Updated Review," International Journal of Environmental Science and Technology, Vol. 18, pp. 521–530, 2021.

[101]. M. Altomare, H. L. Vasconcelos, V. S. do Vale, and I. O. Menor, "The conservation potential of road verges in the savannas of Brazil: Challenges and opportunities," Perspectives in Ecology and Conservation, Vol. 23, pp. 19-25, 2025.

[102]. F. A. Pinto, A. P. Clevenger, and C. Grilo, "Effects of Roads on Terrestrial Vertebrate Species in Latin America," Environmental Impact Assessment Review, Vol. 81, pp. 106337, 2020.

[103]. K. Allberry, J. J. Rovie-Ryan, N. A. N. G. Ali, N. A. Elias, M. R. Darmaraj, C. C. T. Wong, L. C. Fong, O. Smith, K. A. B. Mohamed, M. I. B. A. Mukri, M. H. B. M. Yazid, M. J. Struebig, R. Ogden and J. J. Groombridge, "Emerging patterns of genetic diversity in the critically endangered Malayan tiger (Panthera tigris jacksoni)," Biodiversity and Conservation, Vol. 33(4), pp. 1325-1349, 2024.

[104]. U. Tuttu, E. Ulaş, D. Gülçin, J. Velázquez, K. Çiçek, and A. U. Özcan, "Assessment of Ecological Bridges at Wildlife Crossings in Türkiye: A Case Study of Wild Boar Crossings on the Izmir-Çeşme Motorway," Animals, Vol. 14(1), 30, 2023.

[105]. C. Grilo, T. Neves, J. Bates, A. le Roux, P. Medrano-Vizcaíno, M. Quaranta, I. Silva, K. Soanes, and Y. Wang, "Global Roadkill Data: a dataset on terrestrial vertebrate mortality caused by collision with vehicles," Scientific Data, Vol. 12(1), 505, 2025.

[106]. L. Ali, A. Nawaz, S. Iqbal, M. Aamir Basheer, J. Hameed, G. Albasher, S.A.R. Shah, and Y. Bai, "Dynamics of transit oriented development, role of greenhouse gases and urban environment: a study for management and policy," Sustainability, Vol. 13(5), pp. 2536, 2021.

[107]. J. Hine, M. Sasidharan, M. Eskandari Torbaghan, M. Burrow, and K. Usman, (2019). "Evidence on impact of rural roads on poverty and economic development," Available: https://opendocs.ids.ac.uk/articles/report/Evidence_of_the_Impact_of_Rural_Road_Investment_on_Poverty_Reduction_and_Economic_Development/26435254?file=48084628., (accessed 5 April 2025)

[108]. P. Y. Tan, and H. N. Ismail, (2019 November 6-7). Reviews on Interrelationship Between Transportation and Tourism: Perspective on Sustainability of Urban Tourism Development [Paper presentation]. IOP Conference Series: Earth and Environmental Science, Vol. 447(1), pp. 012065.

[109]. K. Mouratidis, "Urban Planning and Quality of Life: A Review of Pathways Linking the Built Environment to Subjective Well-Being," Cities, Vol. 115, pp. 103229, 2021.

[110]. C. Jones, K. Borkin, and D. Smith, "Roads and Wildlife: The Need for Evidence-Based Decisions; New Zealand Bats As A Case Study," New Zealand Journal of Ecology, Vol. 43(2), pp. 3376, 2019.

[111]. A. H. Bierbaum, A. Karner, and J. M. Barajas, "Toward Mobility Justice: Linking Transportation and Education Equity in the Context of School Choice," Journal of The American Planning Association, Vol. 87(2), pp. 197–210, 2021.

[112]. P. Acheampong, and J. F. Gyasi, "Teacher Retention: A Review of Policies for Motivating Rural Basic School Teachers in Ghana," Asian Journal of Education and Training, Vol. 5(1), pp. 86–92, 2019.

[113]. G. T. Tucho, "A review on the socio-economic impacts of informal transportation and its complementarity to address equity and achieve sustainable development goals," Journal of Engineering and Applied Science, Vol. 69(1), 28, 2022.

[114]. A. M. Liezenga, T. Verma, J. R. Mayaud, D. Y. Aydin, and B. Van Wee, "The first mile towards access equity: Is on-demand microtransit a valuable addition to the transportation mix in suburban communities?," Transportation research interdisciplinary perspectives, Vol. 24, 101071, 2024.

[115]. K. Wiweka, T. Indrajaya, S. S. Wachyuni, P. P. Adnyana, and A. E. Hanorsian, "Opportunities and Challenges for the Development of Sustainable Tourism Attraction at Batu Kapal Beach, Central Maluku Lilibooi Village," Advances in Research, Vol. 19(3), pp. 1–14, 2019.

[116]. A. Hussain, A. Mandić, and F. Fusté-Forné, "Transforming communities: Analyzing the effects of infrastructure and tourism development on social capital, livelihoods, and resilience in Gilgit-Baltistan, Pakistan," Journal of Hospitality and Tourism Management, Vol. 59, pp. 276-295, 2024.

[117]. K. J. Hansmann, M. Grabow, and C. McAndrews, "Health Equity and Active Transportation: A Scoping Review of Active Transportation Interventions and Their Impacts on Health Equity," Journal of Transport & Health, Vol. 25, pp. 101346, 2022.

[118]. M. A. Erçetin, and İ. Gökalp, (2023, October 18-20). Karayolu Ulaşımının Çevresel Etkileri Üzerine Bilimsel Çalışmalar Işığında Bir İnceleme [Paper presentation]. 14. Ulaştırma Kongresi, Vol. 1 pp. 211-223.

[119]. M. A. Saif, M. M. Zefreh, and A. Torok, "Public Transport Accessibility: A Literature Review," Periodica Polytechnica Transportation Engineering, Vol. 47(1), pp. 36–43, 2019.

[120]. H. M. Hammad, M. Ashraf, F. Abbas, H. F. Bakhat, S. A. Qaisrani, M. Mubeen, S. Fahad, and M. Awais, "Environmental Factors Affecting the Frequency of Road Traffic Accidents: A Case Study of Sub-Urban Area of Pakistan," Environmental Science and Pollution Research, Vol. 26, pp. 11674–11685, 2019.

[121]. A. Singh, R. Kaur, N. Deka, M. Singh, and S. Marwaha, "Road Traffic Accidents: An Overview," European Journal of Molecular and Clinical Medicine, Vol. 9(8), pp. 2463–2467, 2022.

[122]. TUIK. (2024). Road Traffic Accident Statistics, 2023 (Corrected). Available: TURKSTAT Corporate

[123]. H. T. Erdoğan, "Ulaşım Hizmetlerinin Ekonomik Kalkınma Üzerine Etkisi," İstanbul Gelişim Üniversitesi Sosyal Bilimler Dergisi, Vol. 3(1), pp. 187–215, 2016.

[124]. O. J. Oladunni, O. A. Olanrewaju, and C. K. Lee, "The Environmental Kuznets Curve (EKC) Hypothesis on GHG emissions: analyses for transportation industry of South Africa," Discover Sustainability, Vol. 5(1), 302, 2024.

[125]. M. Asif, M. Ali, A. M'Begniga, Z. Guoqing, L. Yang, and M. Hashim, "China-Pakistan Economic Corridor: Analytical Overview on Socio-Cultural Romance Between China and Pakistan," Randwick International of Social Science Journal, Vol. 2(4), pp. 492–508, 2021.

[126]. L. J. R. Nunes, T. P. Causer, and D. Ciolkosz, "Biomass for Energy: A Review on Supply Chain Management Models," Renewable and Sustainable Energy Reviews, Vol. 120, pp. 109658, 2020.

[127]. L. Zou, J. H. Shen, J. Zhang, and C. C. Lee, "What is The Rationale Behind China's Infrastructure Investment under The Belt and Road Initiative," Journal of Economic Surveys, Vol. 36(3), pp. 605–633, 2022.

[128]. A. J. Stein, and F. Santini, "The Sustainability of "Local" Food: A Review for Policy-Makers," Review of Agricultural, Food and Environmental Studies, Vol. 103(1), pp. 77–89, 2022.

[129]. N. Kaiser, and C. K. Barstow, "Rural transportation infrastructure in low-and middle-income countries: a review of impacts, implications, and interventions," Sustainability, Vol. 14(4), 2149, 2022.

[130]. M. E. Apriyanti, "The importance of tourism infrastructure in increasing domestic and international tourism," International Journal of Research in Vocational Studies (IJRVOCAS), Vol. 3(4), pp. 113-122, 2024.

[131]. S. Gurcam, "Determination of personal carbon footprint in aviation and tourism axis: Cappadocia Airport case," Environmental Research and Technology, Vol. 6(1), pp. 60–67, 2023.

[132]. C. Magazzino, and M. Mele, "On the relationship between transportation infrastructure and economic development in China," Research in Transportation Economics, Vol. 88, 100947, 2021.

[133]. O. J. Oladunni, and O. A. Olanrewaju, "Effects of the impact factors on transportation sector's CO2-eq emissions: panel evaluation on South Africa's major economies," Atmosphere, Vol. 13(10), 1705, 2022.

[134]. A. K. Srivastava, I. A. Srivastava, and P. S. Rana, "Advancing Sustainable Urban Mobility by Exploring Trends and Reimagining Cost-Benefit Analysis for Active Travel," Transport Policy, Vol. 167, pp. 91-100, 2025.

[135]. A. M. Bassi, G. Pallaske, N. Niño, and L. Casier, "Does sustainable transport deliver societal value? Exploring concepts, methods, and impacts with case studies," Future Transportation, Vol. 2(1), pp. 115-134, 2022.

[136]. M. Crane, S. Lloyd, A. Haines, D. Ding, E. Hutchinson, K. Belesova, M. Davies, D. Osrin, N. Zimmermann, A. Capon, P. Wilkinson, and C. Turcu, "Transforming Cities for Sustainability: A Health Perspective," Environment international, Vol. 147, pp. 106366, 2021.

[137]. G. T. Tucho, "A Review on The Socio-Economic Impacts of Informal Transportation and Its Complementarity to Address Equity and Achieve Sustainable Development Goals," Journal of Engineering and Applied Science, Vol. 69(1), pp. 28, 2022.

[138]. A. Vaishar, M. Šťastná, and J. Zapletalová, "From industry to cultural tourism: Structural transformation of

the second-order city. Case Brno," Cities, Vol. 158, 105685, 2025.

[139]. S. Yiamjanya, K. Kankaкvy, B. Sitikarn, P. Siriwongs, and C. G. Proches, "Indigenous Tourism: The Challenges and Opportunities on Local Residents, Pha Mi Village, Chiang Rai, Thailand," Geo Journal of Tourism and Geosites, Vol. 45, pp. 1594–1601, 2022.

[140]. H. Kendir, E. Arslan, and F. Türkmen, "Türk Dünyası'nda Nevruz (Yengi-Kün) Kutlamalarının Festival Turizmi Açısından Değerlendirilmesi: Çimkent-Van Karşılaştırması," Journal of Tourism & Gastronomy Studies, Vol. 7(4), pp. 2668–2684, 2019.

[141]. S. H. Mteti, C. J. Mpambije, and D. J. Manyerere, "Unlocking cultural tourism: Local community awareness and perceptions of cultural heritage resources in Katavi Region in southern circuit of Tanzania," Social Sciences & Humanities Open, Vol. 11, 101295, 2025.