ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26mar1874

Green Logistics: Reducing Carbon Footprint in Transportation

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Publication Date: 2026/04/06

Abstract: Transportation plays a critical role in global economic development; however, it is also a major contributor to greenhouse gas emissions and environmental degradation. With the expansion of global supply chains and increasing demand for rapid deliveries, the environmental impact of logistics operations has become a significant concern. In this context, green logistics has emerged as a strategic approach to minimize the carbon footprint associated with transportation while maintaining operational efficiency and competitiveness. This paper examines the environmental impact of transportation activities, particularly in terms of carbon emissions and energy consumption. It explores key strategies for reducing the carbon footprint, including route optimization, adoption of eco-friendly vehicles, use of alternative fuels, and intermodal transportation systems. Furthermore, the study analyzes the benefits of green logistics practices, such as environmental protection, cost reduction, improved regulatory compliance, and enhanced corporate reputation. Despite its advantages, the implementation of green logistics presents challenges, including high initial investment costs and infrastructural limitations. The paper also highlights best practices and emphasizes the importance of technological innovation and stakeholder collaboration in achieving sustainable logistics. By adopting green logistics, businesses can contribute to environmental sustainability while improving operational performance. Ultimately, integrating the principles of "reduce, reuse, and recycle" into logistics operations can pave the way for a greener and more sustainable future.

Keywords: *Green Logistics, Carbon Footprint, Eco-Friendly Vehicles, Sustainable Logistics.*

How to Cite: Anagha Sunil; Nikhina Reji; Shari Sadasivan (2026) Green Logistics: Reducing Carbon Footprint in Transportation. *International Journal of Innovative Science and Research Technology*, 11(3), 3323-3328. https://doi.org/10.38124/ijisrt/26mar1874

I. INTRODUCTION

Transportation plays a critical role in global economic development; however, it is also one of the largest contributors to greenhouse gas emissions and environmental degradation. With the rapid expansion of global supply chains and increasing demand for faster deliveries, the environmental impact of logistics operations has become a growing concern. Consequently, there is an urgent need to adopt sustainable practices that reduce emissions while maintaining operational efficiency.

Green logistics has emerged as a strategic approach to addressing these challenges. It refers to the integration of environmentally sustainable practices into supply chain management and transportation systems, with the objective of minimizing the carbon footprint generated by activities such as freight transport, warehousing, packaging, and distribution. This approach aligns closely with global sustainability frameworks, including the United Nations Sustainable Development Goals, particularly Goal 9 (Industry, Innovation and Infrastructure) and Goal 13 (Climate Action), as well as international agreements such as the Paris Agreement.

Green logistics encompasses a range of practices aimed at improving environmental performance. These include the adoption of fuel-efficient and alternative-energy vehicles, route optimization, modal shifts to lower-emission transport options such as rail and sea, and the use of advanced digital technologies for monitoring and reducing emissions. Additionally, energy-efficient warehousing and sustainable packaging solutions contribute to reducing overall environmental impact.

Beyond environmental benefits, green logistics offers significant economic and strategic advantages. By reducing energy consumption and improving operational efficiency,

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organizations can achieve cost savings, enhance regulatory compliance, and strengthen their corporate reputation in an increasingly sustainability-driven market. However, the transition to green logistics is not without challenges, including high initial investment costs, infrastructural limitations, and technological barriers.

This paper explores the concept of green logistics in transportation, examining its key drivers and challenges, and analysing innovative strategies and technologies that enable sustainable freight systems. By understanding the environmental, economic, and technological dimensions of green logistics, this study identifies practical pathways toward building a low-carbon and resilient transportation future.

➢ *Statement of the Study*

The transportation and logistics sector is a critical driver of global economic development, facilitating trade, industrial expansion, and market accessibility. However, it is also a significant contributor to greenhouse gas emissions, posing serious environmental challenges. Despite international commitments such as the Paris Agreement and sustainability initiatives aligned with the Sustainable Development Goals, the logistics industry continues to face persistent barriers in reducing its carbon footprint.

These challenges include a heavy reliance on fossil fuels, inefficient route planning, fragmented supply chain structures, limited adoption of alternative fuel technologies, and inadequate infrastructure to support green logistics practices. Additionally, the increasing demand for rapid delivery, driven by the growth of e-commerce, has intensified last-mile emissions and urban congestion. Small and medium-sized enterprises (SMEs) are particularly constrained by limited financial resources, technological capabilities, and access to sustainable logistics solutions.

While existing studies have explored various aspects of sustainable transportation, there remains a gap in integrating operational efficiency with environmental sustainability in a manner that is both scalable and economically viable across diverse logistics networks. The core problem lies in reconciling cost efficiency, service performance, and environmental responsibility within transportation systems.

This study aims to bridge this gap by critically examining practical strategies, emerging technologies, and policy interventions that can effectively reduce carbon emissions in logistics operations. It seeks to provide an integrated framework that supports the transition toward low-carbon transportation while maintaining competitiveness and operational efficiency in the logistics sector.

➢ *Objectives of the Study*

- To critically analyse the environmental impact of transportation activities within logistics operations, with specific reference to greenhouse gas emissions and the overall Carbon Footprint
- To examine and categorize the primary sources of carbon emissions across different transportation modes, including road, rail, air, and maritime logistics
- To evaluate the effectiveness and feasibility of sustainable transportation strategies in reducing emissions while maintaining operational efficiency
- To assess the role of emerging technologies—such as Artificial Intelligence, electric vehicles, and alternative fuels—in enabling green logistics practices

II. RESEARCH METHODOLOGY

This study adopts a descriptive and analytical research design to examine green logistics practices and their effectiveness in reducing carbon emissions in transportation systems. The research integrates both primary and secondary data to ensure a comprehensive analysis.

Primary data are collected through structured questionnaires and semi-structured interviews administered to logistics managers, transport operators, and supply chain professionals. These instruments are designed to capture insights on current sustainability practices, challenges in implementation, and the adoption of green logistics strategies aimed at reducing the Carbon Footprint.

Secondary data are sourced from peer-reviewed journals, industry reports, government publications, and corporate sustainability reports to provide a theoretical and empirical foundation for the study.

A purposive sampling technique is employed to select respondents with relevant expertise and experience in logistics and transportation. The sample is chosen to ensure representation of key stakeholders involved in logistics operations.

For data analysis, both descriptive and comparative statistical techniques are used. Percentage analysis is applied to interpret response patterns, while comparative analysis is used to evaluate the environmental and economic impacts of different green logistics strategies. The findings are further interpreted to assess the role of technological innovations, including Artificial Intelligence, in enhancing sustainability in transportation.

III. REVIEW OF LITERATURE

Existing research on green logistics highlights the growing importance of integrating environmental considerations into transportation systems, particularly in reducing the Carbon Footprint.

Early work by **Behdani et al. (2017)** emphasized the role of sustainable supply chain strategies, demonstrating that the incorporation of environmental performance metrics into logistics decision-making can significantly reduce emissions. Their findings suggest that optimization-based transport planning is essential for balancing environmental and operational objectives.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26mar1874

Building on this, **Yadav, Gaur, and Jain (2019)** provided a comprehensive review of green logistics practices, identifying key barriers such as high implementation costs, lack of awareness, and limited technological adoption. Their study highlighted that while eco-friendly transportation strategies—such as fuel-efficient vehicles and route optimization—offer substantial environmental benefits, their adoption remains limited, particularly among small and medium-sized enterprises (SMEs).

Further expanding the technological perspective, **Rauf and Sari (2020)** explored the role of digital innovations, including Artificial Intelligence, Internet of Things (IoT), and blockchain, in enhancing transportation sustainability. Their findings indicate that although these technologies improve efficiency and transparency, their practical implementation is constrained by infrastructural and financial limitations. Similarly, Jahagirdar et al. (2022) demonstrated that AI-driven routing, machine learning-based forecasting, and predictive maintenance can significantly reduce fuel consumption and emissions, though high initial investment remains a critical barrier.

From a collaborative perspective, **Mendy Bilek et al. (2020)** argued that effective carbon reduction in logistics requires coordinated efforts among stakeholders, including logistics providers, manufacturers, and customers. Their study showed that shared sustainability goals and integrated planning can enhance environmental performance across supply chains.

In terms of analytical approaches, **Wu et al. (2021)** highlighted the importance of operations research techniques, such as optimization models, simulation, and network design, in minimizing both costs and emissions. Their findings reinforce the role of data-driven decision-making in achieving sustainable logistics outcomes.

Additionally, **D'Adamo et al. (2022)** examined low-carbon freight systems, particularly multimodal transport solutions integrating rail and road networks. Their research demonstrated that modal shifts from road to rail or sea can significantly reduce emissions, although the effectiveness of such strategies depends heavily on infrastructure availability and supportive policy frameworks.

Despite extensive research on green logistics strategies, several gaps remain. Most studies focus either on technological innovations, operational optimization, or policy frameworks in isolation. There is limited research that integrates these dimensions into a unified framework that simultaneously addresses environmental sustainability, economic feasibility, and operational efficiency. Furthermore, empirical studies focusing on the practical challenges faced by logistics stakeholders—particularly in emerging economies—remain insufficient. This study aims to bridge this gap by providing a comprehensive analysis of green logistics practices and proposing actionable strategies that align sustainability goals with real-world operational constraints.

IV. FINDINGS

The analysis of primary and secondary data reveals several important insights regarding green logistics practices and their role in reducing the Carbon Footprint in transportation systems.

- *Significant Environmental Impact of Transportation*

The study confirms that transportation is a major contributor to environmental degradation within logistics operations. Road freight, in particular, remains the dominant source of emissions due to its heavy reliance on diesel-powered vehicles. Furthermore, the rapid expansion of e-commerce has intensified last-mile delivery activities, leading to increased urban emissions and congestion.

- *Major Sources of Carbon Emissions*

The findings identify several key sources of emissions in logistics systems, including fossil fuel-based road transport, inefficient route planning, empty backhauls, energy-intensive warehousing, air freight usage, and urban congestion. Among these, road transport and air cargo emerge as the most carbon-intensive modes due to high fuel consumption and operational inefficiencies.

Table 1: Key Sources of Carbon Emissions in Transportation

Emission Source	Description	Contribution / Impact
Fossil fuel-based road transport	Diesel trucks and vans for long-haul and last-mile deliveries	High
Inefficient route planning & empty trips	Poor logistics planning, underutilized vehicle capacity	Medium-High
Air freight	Time-sensitive goods transported by air	High
Energy-intensive warehousing	Lighting, heating, and cooling in warehouses	Medium
Urban congestion	Increased idling and stop-start driving in cities	Medium

- *Effectiveness of Green Logistics Strategies*

The study finds that multiple green logistics strategies contribute significantly to emission reduction. Route optimization and load consolidation help minimize fuel consumption, while modal shifts from road to rail or sea reduce emissions per ton-kilometre. Additionally, fleet electrification and the adoption of alternative fuels lower direct emissions. Organizations implementing these strategies reported not only environmental benefits but also long-term cost savings, indicating a positive relationship between sustainability and operational efficiency.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26mar1874

Table 2: Preferred Green Logistics Strategies

Strategy	Percentage of Respondents
Fleet electrification / alternative fuels	29%
AI-based route optimization	21%
Modal shift (road → rail/sea)	17%
Government incentives	13%
Others (training, infrastructure)	20%

➢ *Role of Technological Innovations*

Technological advancements play a critical role in enabling green logistics practices. Innovations such as electric and hybrid vehicles, real-time tracking systems, and smart transportation management tools enhance operational efficiency and reduce fuel consumption. In particular, applications of Artificial Intelligence in route optimization and demand forecasting significantly improve logistics performance while lowering emissions. Energy-efficient warehousing further supports sustainability goals.

➢ *Preferred Strategies for Emission Reduction*

The study reveals that fleet electrification and the use of alternative fuels are the most preferred strategies, accounting for 29% of responses. This is followed by route optimization using AI and digital systems (21%), modal shift strategies (17%), and the need for stronger government incentives (13%). These findings indicate a growing emphasis on both technological and policy-driven solutions.

➢ *Managerial and Organizational Insights*

Respondents highlighted managerial commitment (25%) as a critical factor for successful implementation of green logistics initiatives. Financial constraints (21%) were identified as a major barrier, particularly for smaller firms. However, a positive outlook toward sustainability (19%) suggests increasing awareness and willingness to adopt green practices. Additionally, infrastructure development and employee training were emphasized as essential for long-term success.

The findings suggest that while green logistics strategies and technologies are effective in reducing emissions, their adoption is influenced by economic, infrastructural, and organizational factors. A coordinated approach involving technological innovation, policy support, and managerial commitment is essential to achieve sustainable logistics operations.

V. DISCUSSION

The findings of this study reinforce the growing consensus that transportation activities are a major contributor to environmental degradation, particularly in terms of increasing the Carbon Footprint. The dominance of road freight as the primary source of emissions aligns with the observations of Behdani et al. (2017), who emphasized the environmental impact of transport-intensive logistics systems and the need for optimized planning. Similarly, the present study confirms that the rapid growth of e-commerce has intensified last-mile delivery emissions, further exacerbating urban congestion and environmental stress.

The identification of key emission sources—such as fossil fuel-based transport, inefficient routing, and air freight—corroborates the findings of Yadav, Gaur, and Jain (2019), who categorized these factors as major barriers to sustainable logistics. The current study extends this understanding by empirically highlighting the continued dominance of road and air transport as the most carbon-intensive modes, suggesting that despite awareness, structural dependence on these modes persists.

In terms of sustainable strategies, the study's findings support the work of D'Adamo et al. (2022), who demonstrated that modal shifts from road to rail or sea significantly reduce emissions. Likewise, the effectiveness of route optimization and load consolidation observed in this study is consistent with Wu et al. (2021), who emphasized the role of optimization models in minimizing both costs and environmental impact. Importantly, the present study adds practical insight by showing that firms adopting such strategies not only achieve environmental benefits but also realize long-term cost efficiencies, reinforcing the business case for sustainability.

The role of technology in enabling green logistics is strongly validated by the findings. The adoption of tools based on Artificial Intelligence, real-time tracking systems, and smart transportation management aligns with Rauf and Sari (2020), who highlighted the transformative potential of digital technologies in improving logistics efficiency and sustainability. Furthermore, the results are consistent with Jahagirdar et al. (2022), who noted that AI-driven routing and predictive analytics can significantly reduce fuel consumption and emissions. However, this study also confirms that high implementation costs and technological complexity remain critical barriers, limiting widespread adoption.

From an organizational perspective, the importance of managerial commitment identified in this study supports the arguments of Mendy Bilek et al. (2020), who emphasized stakeholder collaboration and aligned sustainability goals as essential for effective carbon reduction. The finding that financial constraints and lack of awareness hinder adoption—particularly among SMEs—further strengthens the conclusions of earlier studies, highlighting persistent gaps between sustainability intentions and actual implementation.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26mar1874

Additionally, the study contributes new insights by quantifying stakeholder preferences, revealing that fleet electrification and alternative fuels are the most favored strategies, followed by AI-based route optimization and modal shifts. This indicates a shift toward technology-driven and policy-supported solutions. However, the relatively lower emphasis on policy incentives suggests a need for stronger regulatory frameworks to accelerate adoption.

The discussion highlights that although green logistics strategies are well-established in theory, their practical implementation remains uneven due to economic and infrastructural constraints. Achieving sustainable transportation requires a balanced approach that combines technological innovation, efficient logistics planning, and supportive policy measures aligned with global frameworks such as the Paris Agreement.

VI. CONCLUSION

The present study examined the role of green logistics in reducing emissions within transportation systems and highlighted the urgent need to address the environmental impact of logistics operations. The findings confirm that transportation—particularly road freight—remains a major contributor to greenhouse gas emissions, significantly increasing the overall Carbon Footprint.

The study demonstrates that sustainable logistics strategies, such as route optimization, modal shifts, fleet electrification, and the adoption of alternative fuels, are effective in reducing emissions while also improving long-term operational efficiency. Technological innovations, especially those driven by Artificial Intelligence and digital systems, play a crucial role in enhancing transparency, efficiency, and sustainability in logistics operations.

However, despite the availability of these solutions, their adoption remains uneven due to several challenges, including high initial investment costs, inadequate infrastructure, limited awareness among small and medium enterprises, and inconsistent policy support. The study also highlights the importance of managerial commitment and stakeholder collaboration in successfully implementing green logistics practices.

Overall, the research concludes that achieving sustainable transportation requires an integrated approach that balances environmental responsibility with economic efficiency. Without coordinated efforts from industry stakeholders and policymakers, the logistics sector may struggle to meet global sustainability targets such as those outlined in the Paris Agreement.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are proposed:

- Logistics companies should accelerate the transition toward electric and hybrid vehicles, as well as alternative fuels such as biofuels and hydrogen, to reduce dependence on fossil fuels.
- Organizations should invest in digital tools and intelligent systems, including Artificial Intelligence, for route optimization, demand forecasting, and fleet management to improve efficiency and minimize emissions.
- Greater emphasis should be placed on shifting freight from road transport to more sustainable modes such as rail and sea, which offer lower emissions per ton-kilometre.
- Governments should introduce supportive policies, subsidies, and tax incentives to encourage the adoption of green logistics practices. Investment in infrastructure, such as EV charging stations and multimodal transport networks, is also essential.
- Awareness programs and training initiatives should be conducted to educate logistics professionals—especially in SMEs—about the benefits and implementation of sustainable practices.
- Collaboration among logistics providers, manufacturers, policymakers, and customers should be strengthened to ensure coordinated efforts toward sustainability goals.
- Special attention should be given to last-mile delivery by promoting urban consolidation centers, electric delivery vehicles, and optimized delivery routes to reduce congestion and emissions in cities.

REFERENCES

[1]. Behdani, B., van der Laan, E., & van der Heijden, M. (2017). Sustainable supply chain strategies: A carbon footprint perspective. *Journal of Cleaner Production, 142*, 2347–2360. https://doi.org/10.1016/j.jclepro.2016.11.022

[2]. Yadav, R., Gaur, J., & Jain, A. (2019). Green logistics: Practices, challenges, and future directions. *The International Journal of Logistics Management, 30*(2), 450–472. https://doi.org/10.1108/IJLM-01-2018-0012

[3]. Rauf, M. I. A., & Sari, I. T. P. (2020). From emissions to efficiency: A narrative review on sustainable transportation and logistics. *Sinergi International Journal of Logistics, 2*(1), 62–75. https://journal.sinergi.or.id/index.php/ijl/article/view/620

[4]. Mendy Bilek, A., Acar, H., & Yildiz, H. (2020). Collaboration and sustainability in logistics: Stakeholder perspectives on green transport. *Logistics, 8*(3), 68. https://www.mdpi.com/2305-6290/8/3/68

[5]. Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., & Chen, Z. (2020). A systematic literature review of green and sustainable logistics: Bibliometric analysis and research trends. *International Journal of Environmental Research and Public Health, 17*(1), 261. https://www.mdpi.com/1660-4601/17/1/261

[6]. Wu, Y., Li, X., & Zhang, J. (2021). Operations research approaches to green logistics and sustainable transportation. *Frontiers in Engineering Management, 8*(2), 101–115. https://doi.org/10.1007/s42524-023-0265-1

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26mar1874

[7]. Jahagirdar, S., Jahagirdar, S., & Apandkar, A. (2022). Green logistics and sustainable transportation: AI-based route optimization and eco-friendly supply chains. *Journal of Informatics Education and Research, 5*(1), 47–56. https://jier.org/index.php/journal/article/view/2323

[8]. Lu, Y., & Li, S. (2023). *Green transportation model in logistics considering the carbon emissions costs based on improved Grey Wolf Algorithm*. **Sustainability, 15**(14), 11090. https://doi.org/10.3390/su151411090

[9]. Toktaş, D., Ülkü, M. A., & Habib, M. A. (2024). *Toward greener supply chains by decarbonizing city logistics: A systematic literature review and research pathways*. **Sustainability, 16**(17), 7516. https://doi.org/10.3390/su16177516

[10]. Agarwal, N., & Goel, P. (2025). *Sustainable supply chain networks: Integrating green transportation and logistics solutions*. **Journal of Quantum Science and Technology, 2**(1), 189. https://doi.org/10.63345/jqst.v2i1.189

[11]. Jefimovaite, L., & Vienazindiene, M. (2025). *Green logistics concept and the impact of its implementation in the organisation: A systematic literature review and meta-analysis*. **Engineering Management in Production and Services, 17**(1), 39–51. https://doi.org/10.2478/emj-2025-0004

[12]. Shee Weng, L. (2025). *Green logistics in 2025: Integrating sustainability, technology, and business strategy* (SSRN Working Paper). SSRN. https://doi.org/10.2139/ssrn.5168169

[13]. Shee Weng, L. (2025). *Green logistics innovations: Sustainable supply chain strategies in emerging markets* (SSRN Working Paper). SSRN. https://doi.org/10.2139/ssrn.5166641

[14]. Singh, P., Antonyraj, M. A., & Shrivastav, R. (2024). *Green logistics sustainable and eco-friendly transportation practices. International Journal of Multidisciplinary Research in Science Engineering and Technology, 7*(05), 10226–10233. https://doi.org/10.15680/IJMRSET.2024.0705104

[15]. Jahagirdar, S., Jahagirdar, S., & Apandkar, A. (2025). *Green logistics and sustainable transportation: AI-based route optimization, carbon footprint reduction, and the future of eco-friendly supply chains*. *Journal of Informatics Education and Research, 5*(1), 2323. https://doi.org/10.52783/jier.v5i1.2323

[16]. Khan, I., Ali, W., Tayyab, M., et al. (2025). *The role of green supply chain management in achieving the United Nations Sustainable Development Goals: A meta-analysis approach*. *Discover Sustainability, 6*, 920. https://doi.org/10.1007/s43621-025-01882-7

[17]. Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., & Chen, Z. (2020). *A systematic literature review of green and sustainable logistics: Bibliometric analysis and research trends*. *International Journal of Environmental Research and Public Health, 17*(1), 261. https://doi.org/10.3390/1660-4601/17/1/261