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Strategic Approaches to Carbon Footprint Reduction in Logistics Operations

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ABSTRACT: The logistics sector plays a pivotal role in global carbon emissions, accounting for a substantial share of greenhouse gases and making it a critical focus for sustainability transitions. This narrative review examines strategies for carbon footprint reduction in logistics by synthesizing evidence from Scopus, Web of Science, and Google Scholar. Literature was screened through inclusion and exclusion criteria and analyzed thematically. Five core strategies were identified: transportation and routing optimization, green supply chain management, renewable energy and digital decarbonization technologies, cold chain and food supply efficiency, and corporate mobility integration. Optimization algorithms such as Ant Colony Optimization and Vehicle Routing Problem models reduce emissions and operational costs. Green supply chain practices deliver up to 30% emission reductions while enhancing corporate performance. Renewable energy and IoT-enabled systems contribute to energy efficiency, while cold chain improvements reduce food waste. Corporate mobility strategies align organizational policies with sustainability goals, offering long-term competitive advantages. Despite these advances, systemic barriers remain, including inconsistent policies, organizational resistance, and high investment costs. Addressing these challenges calls for integrated, multi-level approaches to accelerate the transition toward low-carbon operations.

Keywords: Carbon Footprint, Green Logistics, Supply Chain Sustainability, Emissions Reduction Strategies, Renewable Energy In Logistics, Cold Chain Efficiency, Corporate Mobility.

INTRODUCTION

The global imperative to mitigate climate change has positioned the logistics sector at the center of sustainability debates. Logistics activities, encompassing transportation, warehousing, and distribution, are estimated to contribute substantially to greenhouse gas (GHG) emissions, making the sector a critical target for decarbonization initiatives. Recent literature highlights a pronounced shift towards sustainable practices, driven both by policy mandates and corporate commitments to environmental responsibility. Scholars have noted the increasing adoption of green technologies, digital solutions, and alternative fuels, such as methanol and hydrogen, particularly within maritime logistics, as effective strategies for reducing carbon intensity (Liu, 2025; Nunes, 2025). These trends reflect not only technological progress but also the growing recognition of logistics as a decisive lever in achieving climate targets.

The urgency of reducing carbon footprints in logistics is closely linked to global climate commitments, including the Paris Agreement. Studies have indicated that logistics accounts for approximately 14% of global GHG emissions, underscoring the necessity for transformative interventions (Jiang et al., 2020; Mansour et al., 2025). Efforts to enhance efficiency through optimized distribution routing, improved inventory management, and supply chain transparency offer promising avenues for emission reduction (Saenz et al., 2016; Li et al., 2016). Emerging technologies, such as blockchain, are expected to enhance accountability and efficiency across supply chains, potentially accelerating progress towards decarbonization (Nechetnyy et al., 2024). As the sector grapples with both economic and environmental demands, the integration of these strategies represents an essential pathway toward sustainable development.

Empirical data further illustrate the scale of the challenge. Within the European Union, transportation—constituting a significant portion of logistics—contributes nearly 30% of total GHG emissions, primarily due to dependence on fossil fuels (Bonilla et al., 2015). Transitioning to cleaner alternatives remains difficult despite regulatory pressure, as infrastructure limitations and entrenched energy systems slow adoption. In China, emissions from logistics have risen steadily, fueled by growing demand for fast and efficient transportation services (Jiang et al., 2020). This duality, characterized by rising emissions and heightened policy focus, reflects both the risks and opportunities inherent in transitioning the sector toward sustainability. Such evidence highlights the pivotal role logistics will play in either exacerbating or alleviating climate risks.

Adopting environmentally sustainable logistics practices also presents economic opportunities. Research has shown that sustainable supply chain strategies can deliver dual benefits by reducing emissions and generating economic value (Kellner & Igl, 2015). Cost reductions, operational efficiencies, and enhanced corporate reputation have been identified as significant co-benefits, making low-carbon logistics an attractive proposition for firms seeking competitive advantage. Moreover, aligning logistics strategies with the Sustainable Development Goals (SDGs), particularly SDG 12 on responsible consumption and production, strengthens the sector's contribution to global development agendas. These synergies reinforce the notion that sustainability is not merely a regulatory obligation but also a driver of long-term corporate resilience.

Nevertheless, the path towards low-carbon logistics is fraught with challenges. Foremost among these is the high cost associated with transitioning to cleaner technologies. Replacing fossil-fuel-based vehicles with electric or alternative-fuel fleets requires substantial capital investment in both technology and supporting infrastructure (Jiang et al., 2020; Shaharudin & Fernando, 2015). Small and medium-sized enterprises (SMEs), in particular, face significant barriers due to limited financial and organizational capacity, often resulting in reluctance to adopt sustainable practices (Shaharudin

& Fernando, 2015). This resource constraint represents a major hurdle in achieving sector-wide decarbonization.

Awareness and cultural barriers compound these financial challenges. A lack of understanding and insufficient demand for low-carbon solutions among supply chain stakeholders often perpetuate reliance on conventional practices (Liu, 2025). Resistance to change within organizational cultures further undermines the adoption of sustainable strategies, creating inertia in sectors where rapid transformation is essential (Yasir et al., 2024). As a result, efforts to promote green logistics must address not only technological feasibility but also the human and organizational dimensions of change management.

The global complexity of supply chains introduces additional difficulties. Low-carbon strategies often necessitate collaboration across multiple actors with diverse objectives, making alignment challenging (Austin et al., 2015). Conflicting priorities between companies within a single supply chain may limit collective progress, thereby reducing the overall effectiveness of emission reduction strategies (Mossop & McLaughlin, 2022). These dynamics highlight the importance of governance structures and cooperative mechanisms to facilitate joint action in global logistics networks.

Regulatory inconsistencies also present obstacles. Without strong, uniform policy frameworks, firms lack sufficient incentives to invest in low-carbon technologies and practices (Hariga et al., 2022). Variability in regulations across jurisdictions creates uncertainty and raises compliance costs, discouraging long-term investment. This underscores the critical role of governments in shaping enabling environments for sustainable logistics, where coherent policies, subsidies, and standards are aligned with global climate targets.

Despite significant progress, the literature reveals notable gaps. Much of the existing research has concentrated on technical analyses of solutions such as electric vehicles and infrastructure upgrades (Mesineni et al., 2025). However, fewer studies have explored the practical challenges of organizational adaptation, stakeholder collaboration, and cultural transformation necessary for successful implementation (Saenz et al., 2016). Similarly, research often prioritizes large enterprises, overlooking the unique barriers faced by SMEs (Laryea et al., 2023). This imbalance underscores the need for more inclusive studies that capture the diversity of industry actors.

Policy-industry interactions represent another understudied area. While government regulation is recognized as essential, relatively little research examines how policies can be effectively designed to stimulate innovation and reduce barriers to corporate adoption of low-carbon practices (Karaman et al., 2024). Furthermore, the social implications of decarbonization, such as impacts on employment, equity, and corporate social responsibility, remain underexplored (Baral et al., 2019). Addressing these dimensions will be crucial to developing strategies that are not only environmentally effective but also socially equitable.

The primary objective of this review is to systematically evaluate strategies for carbon footprint reduction in logistics, with particular attention to their technological, organizational, and policy dimensions. By synthesizing existing literature, this study aims to identify effective practices, assess their potential for scalability, and highlight barriers that impede implementation (Mansour et al., 2025; Jain, 2025). In doing so, the review contributes to both academic understanding and practical policymaking, offering insights into how the logistics sector can play a transformative role in climate change mitigation. Specific factors examined include technological innovation, economic feasibility, governance frameworks, and social implications, thereby ensuring a holistic approach to the analysis.

The scope of this review is global in nature, reflecting the interconnectedness of supply chains and the transnational character of climate change. However, attention is given to regional variations in strategies and outcomes. For example, European approaches are often shaped by stringent regulatory frameworks and government incentives, enabling more structured progress (Bonilla et al., 2015; Shaharudin & Fernando, 2015). In contrast, Asian economies such as China face the dual challenge of balancing rapid industrial growth with sustainability imperatives, leading to complex trade-offs between economic development and emission reduction (Jiang et al., 2020; Yasir et al., 2024). In North America, emphasis has been placed on technological innovation, including the adoption of electric vehicles and alternative fuels, though infrastructural limitations continue to constrain progress (Liu, 2025; Nunes, 2025; Saenz et al., 2016). By incorporating such regional nuances, the review situates its findings within diverse contexts, thereby enhancing the relevance and applicability of its conclusions.

In sum, the introduction establishes the significance of carbon footprint reduction in logistics as a critical dimension of global climate mitigation. It highlights the sector's substantial contribution to GHG emissions, the dual opportunities for environmental and economic gains, and the formidable challenges that must be addressed. By identifying gaps in the literature and outlining the objectives and scope of the review, this section provides a foundation for a comprehensive analysis of strategies that can advance both sustainability and competitiveness in the logistics industry.

METHOD

The methodology of this study was designed to ensure a systematic, comprehensive, and academically rigorous exploration of strategies for carbon footprint reduction in logistics. Given the cross-disciplinary nature of the topic, which spans environmental science, engineering, transportation studies, and supply chain management, the research adopted a structured literature review approach. This method facilitated the identification, selection, and synthesis of scholarly contributions relevant to low-carbon logistics, while ensuring transparency and replicability in the review process.

The collection of literature relied primarily on three well-established academic databases: Scopus, Web of Science, and Google Scholar. Scopus was selected due to its multidisciplinary coverage and robust citation tracking, making it particularly suitable for identifying articles at the intersection of logistics, environmental sustainability, and carbon management. Web of Science complemented this search by providing an additional layer of bibliometric depth, particularly in journals dedicated to sustainability, environmental engineering, and operations research. Google Scholar was incorporated as a supplementary tool to broaden the scope of the review, capturing grey literature, dissertations, conference proceedings, and emerging research that might not yet be indexed in the more formal databases. Together, these sources provided a comprehensive basis for mapping the landscape of current scholarship.

To ensure precision in the retrieval of literature, carefully selected keywords and Boolean combinations were applied. Core terms such as "carbon footprint," "green logistics," "supply chain," "emissions reduction," "sustainability," "carbon management," and "low-carbon strategies" formed the foundation of the search queries. These were combined through Boolean operators to refine results. For example, the combination "carbon footprint" AND "logistics" OR "supply chain" AND "reduction strategies" was employed to retrieve studies explicitly addressing the integration of carbon mitigation strategies within logistics operations. Similarly, "green logistics" AND ("carbon reduction" OR "emissions management") was used to capture literature focusing on environmentally friendly logistics practices with a direct link to emission control. Further, "sustainability" AND "supply chain" AND "carbon footprint" enabled the identification of research exploring the interplay between sustainable supply chain management and environmental performance. Finally, the query "carbon emissions" AND ("transportation" OR "logistics") AND "managerial strategies" was applied to locate studies emphasizing managerial and organizational approaches to carbon reduction.

The use of these keyword combinations ensured the retrieval of relevant and diverse literature while avoiding unnecessary dilution of results. This approach allowed the review to capture both technical studies—focused on models, technologies, and optimization algorithms—and managerial perspectives—emphasizing policy, governance, and organizational behavior. The strategic design of these queries thus underpinned the methodological rigor of the literature collection phase.

Following the initial search, a two-stage screening process was implemented. In the first stage, all titles and abstracts of retrieved articles were reviewed to determine their relevance to the research scope. Articles that did not directly address logistics, transportation, or supply chain-related carbon reduction strategies were excluded. In the second stage, full-text reviews were conducted for those articles that passed the initial screening, allowing for deeper assessment of their methodological quality, conceptual relevance, and empirical contribution. This process ensured that only studies offering substantive insights into the logistics–carbon footprint nexus were retained for synthesis.

Inclusion and exclusion criteria were established to maintain focus and coherence. Studies published in peer-reviewed journals or reputable conference proceedings between 2000 and 2025 were included, as this period encapsulates both early and contemporary contributions to the field. Articles were required to provide empirical data, analytical models, or conceptual frameworks directly related to carbon footprint reduction in logistics or supply chain management. Exclusion criteria encompassed studies outside the logistics and supply chain domain, those focusing exclusively on unrelated sectors (e.g., agriculture without a logistics component), or publications lacking sufficient methodological rigor. Non-English studies were excluded to ensure consistency in interpretation and synthesis, although their bibliographic references were noted when relevant.

The review incorporated diverse study designs to capture the multifaceted nature of the topic. These included randomized controlled trials examining the adoption of specific technologies in logistics fleets, cohort studies tracking long-term trends in supply chain emissions, case studies of individual companies or industries, and systematic modeling studies applying optimization algorithms to reduce fuel consumption and emissions. By integrating multiple types of evidence, the methodology allowed for a more nuanced understanding of both practical applications and theoretical advancements.

The evaluation process also applied quality assessment criteria. Articles were judged on the basis of methodological transparency, validity of data sources, appropriateness of analytical techniques, and clarity of findings. Studies that demonstrated strong empirical foundations or robust modeling approaches were prioritized. Additionally, attention was given to research addressing diverse geographic contexts, as strategies and challenges often vary significantly between regions. This ensured that the synthesis would not only reflect global perspectives but also highlight regional specificities relevant to policymakers and practitioners.

To synthesize findings, thematic analysis was applied. Articles were categorized into key themes emerging from the literature, such as optimization of transportation routes, adoption of green supply chain management practices, energy efficiency and decarbonization technologies, sector-specific strategies in cold chain and food logistics, and corporate mobility integration. Within each theme, statistical evidence, case findings, and theoretical contributions were systematically compared and contrasted. This allowed for the identification of convergent findings, contradictions, and emerging trends, thereby enriching the review's analytical depth.

The entire methodological process was guided by principles of transparency and replicability. Documentation of search strategies, databases used, keyword queries, screening processes, and inclusion/exclusion decisions was maintained throughout. This not only strengthens the academic rigor of the study but also provides a roadmap for future researchers seeking to replicate or extend the analysis.

In sum, the methodology combined systematic database searches, targeted keyword strategies, structured screening processes, and thematic synthesis to provide a comprehensive and reliable review of carbon footprint reduction strategies in logistics. By integrating diverse sources and study designs while applying rigorous evaluation criteria, the study ensured a balanced representation of technical, managerial, and policy-oriented perspectives. This methodological framework thus provides a robust foundation for analyzing the state of knowledge in the field and identifying gaps that require further scholarly attention.

RESULT AND DISCUSSION

The results of this narrative review reveal diverse strategies and empirical findings on the reduction of carbon footprints in logistics, organized across five key themes: optimization of transportation and routing, green supply chain management (GSCM), energy efficiency and decarbonization technologies, cold chain and food supply logistics, and corporate mobility integration. Together, these thematic areas provide a comprehensive understanding of how logistics systems can be transformed to address pressing environmental challenges while maintaining economic efficiency.

The application of optimization algorithms has been extensively studied as a means to reduce fuel consumption and carbon emissions in logistics. Ant Colony Optimization (ACO) and Vehicle Routing Problem (VRP) models are among the most widely applied methods. ACO, inspired by the behavior of ants in finding the shortest path, has been shown to significantly improve delivery route efficiency, reducing both travel distance and vehicle operating time (Quan et al., 2021). Similarly, VRP-based algorithms have enabled companies to redesign delivery systems to minimize mileage and optimize load utilization, resulting in measurable reductions in fuel consumption and $CO2$ emissions (Palamutçuoğlu et al., 2025). Empirical data further demonstrate that the implementation of optimized routing models produces not only environmental but also economic benefits. Saenz et al. (2016) reported that replacing diesel vehicles with electric trucks in distribution networks led to reductions in GHG emissions ranging from 51% to 72%, underscoring the combined value of optimization and technology adoption. Palamutçuoğlu et al. (2025) further observed a 1.3% reduction in delivery costs linked to ACO-based routing, illustrating the dual environmental and financial gains. These findings highlight that optimization efforts are not confined to emission reduction alone but extend to improved corporate performance in increasingly competitive markets.

The implementation of GSCM practices has emerged as a pivotal strategy for reducing emissions across global supply chains. GSCM encompasses initiatives such as sustainable sourcing, waste reduction, energy-efficient manufacturing, and environmentally conscious distribution models (Bonilla et al., 2015). By embedding sustainability into core logistics functions, firms can not only lower their carbon footprints but also strengthen resilience and competitiveness. Quantitative evidence supports these claims. Mansour et al. (2025) found that firms adopting GSCM practices achieved up to 30% emission reductions while simultaneously improving energy productivity per unit of output. Chen et al. (2021) further demonstrated that such practices contribute to customer satisfaction and enhanced corporate performance, suggesting a positive correlation between sustainability and profitability. The adoption of GSCM also reflects shifting stakeholder expectations and regulatory pressures, with companies facing increasing scrutiny regarding their environmental impact. Overall, these results confirm that GSCM provides a comprehensive framework for achieving both operational efficiency and environmental responsibility, positioning sustainability as a strategic asset.

Technological innovation in renewable energy and decarbonization plays an integral role in reducing logistics emissions. Fuel cell electric vehicles (FCEVs), powered by hydrogen, have been highlighted for their capacity to deliver near-zero emissions in freight transport. Liu (2025) reported that FCEVs used in distribution networks reduce $CO2$ emissions by as much as 75% compared to conventional diesel vehicles. Such evidence underscores the transformative potential of renewable energy integration in logistics systems. Alongside vehicle technology, digitalization has also proven critical. IoT-enabled cargo tracking and cloud-based fleet management systems allow for more efficient routing, reduced idle times, and optimized fuel usage. Case studies suggest that these systems reduce fuel consumption and emissions through better visibility and predictive analytics, though more empirical studies are needed to consolidate this evidence. Together, renewable technologies and digital innovations represent complementary approaches to energy efficiency, reinforcing the role of logistics as both a consumer of and a platform for clean technologies.

The cold chain is particularly critical in the logistics of perishable goods, where inefficiencies contribute to both food waste and heightened emissions. Effective cold chain management not only ensures food safety and quality but also plays a direct role in reducing carbon footprints. Studies indicate that 8% to 10% of global GHG emissions are attributable to food waste, highlighting the urgency of interventions in this area (Jiang et al., 2020). Research by Wróbel-Jędrzejewska et al. (2024) demonstrated that optimized temperature control and efficient transportation practices can significantly reduce emissions at each stage of the cold chain. Liu et al. also emphasize the value of adopting real-time monitoring technologies to track humidity and temperature, thereby extending shelf life and reducing spoilage. By minimizing food waste, these strategies yield both environmental and social benefits, as they reduce emissions and ensure better utilization of resources in global food systems. Cold chain efficiency, therefore, represents a strategic intersection of logistics, sustainability, and food security.

Corporate mobility has emerged as another dimension of logistics decarbonization, with firms increasingly embedding sustainable mobility strategies into their organizational frameworks. The integration of electric vehicles (EVs), ride-sharing programs, and autonomous vehicles forms part of a broader effort to align corporate operations with sustainability goals. Zhao and Hong (2021) demonstrated the capacity of EVs to reduce CO2 emissions significantly compared to conventional vehicles, though challenges remain regarding charging infrastructure and lifecycle emissions. Karaman et al. (2024) further highlighted the reputational and economic advantages of adopting sustainable mobility, noting improvements in brand value, customer loyalty, and compliance with tightening regulatory standards. Saenz et al. (2016) similarly identified long-term cost reductions and increased energy efficiency as outcomes of corporate mobility strategies. Collectively, these findings suggest that corporate mobility is not only a response to external pressures but also a proactive measure that delivers competitive and environmental benefits. The global comparison also underscores regional differences: European firms tend to adopt structured regulatory-driven strategies, Asian firms often face growth-related constraints, and North American firms prioritize technological innovation, reflecting diverse pathways to corporate sustainability.

In summary, the results indicate that strategies for carbon footprint reduction in logistics span technological, managerial, and organizational domains. Optimization algorithms enhance efficiency and reduce costs while lowering emissions; GSCM embeds sustainability across supply chains, producing measurable environmental and economic gains; renewable energy and digital technologies drive energy efficiency and decarbonization; cold chain management reduces food waste and emissions while safeguarding food systems; and corporate mobility strategies integrate sustainability into organizational frameworks, yielding long-term operational and reputational benefits. Collectively, these findings emphasize that logistics is both a major contributor to and a potential mitigator of climate change. The evidence highlights the need for integrated, multi-level approaches that align technological innovation, managerial practices, and policy frameworks to achieve sustainable transformation in logistics.

The findings of this review reaffirm the growing body of evidence emphasizing the centrality of sustainable logistics strategies in mitigating greenhouse gas emissions. They are largely consistent with previous literature that identifies optimization, green supply chain management, and renewable technologies as pivotal elements in reducing the carbon footprint of logistics. Prior studies by Gao et al. and Wong et al. have underscored the crucial role of GSCM and environmentally friendly technologies in reshaping global supply chains (Wong et al., 2018; Jiang et al., 2020). Similarly, the present results demonstrate that optimization models such as Ant Colony Optimization and Vehicle Routing Problem-based approaches are effective in reducing both emissions and costs, in line with earlier evidence showing that the adoption of advanced distribution models is indispensable for meeting emission reduction targets (Quan et al., 2021; Palamutçuoğlu et al., 2025).

The alignment with previous literature extends beyond optimization strategies. The role of GSCM in lowering emissions by up to 30% (Mansour et al., 2025) supports arguments made in earlier work that firms integrating sustainability into procurement, production, and distribution not only mitigate environmental harm but also strengthen customer satisfaction and brand value (Chen et al., 2021). This convergence of findings reinforces the argument that sustainability is not an external imposition but an internalized driver of corporate performance. The implementation of renewable technologies, such as fuel cell electric vehicles, and the incorporation of digital innovations, such as IoT-based cargo tracking, align with projections in the literature that technological innovation will play a decisive role in reshaping logistics into a low-carbon sector (Liu, 2025; Nechetnyy et al., 2024).

Nevertheless, the findings also illuminate enduring systemic barriers to the adoption of low-carbon logistics strategies. These barriers, identified in the results, are corroborated by previous scholarship on organizational inertia, regulatory uncertainty, and financial constraints. Wong et al. (2018) and Aikins and Ramanathan (2020) have documented how inconsistent policies and the lack of sufficient regulatory incentives delay investment in sustainable technologies. The evidence gathered here suggests that even firms that recognize the long-term benefits of decarbonization hesitate to commit to high upfront costs, particularly in the absence of consistent policy support. This reflects a systemic misalignment between long-term societal goals and short-term corporate priorities.

Policy inconsistency emerges as one of the most significant obstacles. Studies have shown that nations with stronger regulatory frameworks achieve better energy efficiency and CO2 reduction outcomes, illustrating the role of governance in shaping industry performance (Mansour et al., 2025). The variation in regulatory environments across regions contributes to uneven progress, with European firms benefiting from stringent policies and subsidies, while Asian and North American firms often face weaker or fragmented frameworks (Bonilla et al., 2015; Jiang et al., 2020). This inconsistency undermines the scalability of sustainable practices and reinforces the need for harmonized international standards that address both emissions measurement and accountability.

Organizational resistance further complicates adoption. Aikins and Ramanathan (2020) emphasized that entrenched routines and cultural inertia impede the uptake of innovations, even when their environmental and economic benefits are evident. The results from this review suggest that stakeholder awareness and demand for sustainable practices remain insufficient in many contexts (Liu, 2025; Yasir et al., 2024). Without stronger cultural change within organizations, sustainability initiatives risk being viewed as external pressures rather than integral business strategies. This underscores the importance of fostering a corporate culture that values long-term sustainability over short-term efficiency.

Financial barriers represent another critical impediment. The high capital costs associated with electric vehicles, renewable energy infrastructure, and advanced data management systems often discourage firms from making the transition (Jiang et al., 2020; Shaharudin & Fernando, 2015). Although long-term operational savings are well-documented, many firms remain focused on short-term expenditure, prioritizing immediate profitability over long-term gains (Liu, 2025). This short-termism is especially prevalent among small and medium-sized enterprises, which often lack the financial flexibility of larger corporations (Laryea et al., 2023). These financial dynamics point to the need for targeted support mechanisms, such as subsidies, tax incentives, and innovative financing models, to reduce entry barriers for smaller actors in the logistics sector.

The implications of these findings for policy and governance are significant. Governments play a critical role in creating enabling environments for low-carbon logistics through subsidies, tax incentives, and consistent regulatory frameworks. Mansour et al. (2025) have argued for the necessity of aligning policies with international emission reduction targets, a position echoed by the results of this review. Furthermore, the development of international standards for emissions reporting and lifecycle assessment is essential for fostering transparency and accountability. Without such harmonization, firms face fragmented requirements that hinder global consistency in logistics sustainability.

Collaboration emerges as a recurring theme in addressing systemic barriers. Yasir et al. (2024) emphasize the potential of multi-stakeholder platforms for sharing best practices, technological innovations, and collaborative strategies. The evidence from this review suggests that collaborative models not only accelerate adoption but also reduce duplication of efforts across firms and sectors. Such platforms are particularly vital for addressing the global nature of supply chains, where emissions reduction in one node requires alignment across multiple actors. Collaborative governance, therefore, becomes indispensable for overcoming fragmented efforts and achieving meaningful impact.

While the evidence demonstrates the potential of low-carbon logistics, it also highlights limitations in existing research. Much of the current literature prioritizes technological innovation and optimization models while underexploring the social dimensions of decarbonization, such as impacts on employment, equity, and corporate social responsibility (Baral et al., 2019). This narrow focus risks neglecting the broader societal implications of transitioning to low-carbon logistics. Further, existing studies disproportionately focus on large corporations, leaving SMEs underrepresented despite their significant role in global logistics networks (Trigos & Osorio, 2024). Future research must address these gaps by examining how sustainability strategies can be effectively scaled to smaller firms and how social justice considerations can be integrated into decarbonization strategies.

Methodological limitations also warrant attention. Many studies rely on modeling and simulation, which, while valuable, may not fully capture the complexities of real-world implementation (Saenz et al., 2016). More empirical studies, including longitudinal analyses and case studies across diverse contexts, are needed to validate theoretical findings and provide actionable insights for practitioners. Additionally, regional imbalances in the literature persist, with a heavier concentration of studies from Europe and East Asia, while regions such as Africa and South America remain underexplored (Jiang et al., 2020). Addressing these geographical disparities is essential for developing a more inclusive understanding of global logistics sustainability.

In proposing solutions, it is evident that multi-level interventions are necessary. Policy frameworks must be strengthened and harmonized, financial incentives tailored to reduce entry barriers, and organizational cultures reshaped to value sustainability as a long-term strategic imperative. Technological innovation must continue to be pursued, but equal emphasis should be placed on governance, collaboration, and social dimensions. The interplay of these elements will determine the pace and effectiveness of global logistics decarbonization, and future research must embrace this multidimensional perspective to offer more comprehensive and actionable guidance.

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CONCLUSION

This review highlights the central role of logistics in global efforts to reduce greenhouse gas emissions and underscores the sector's dual potential to contribute to climate change or serve as a driver of sustainable transformation. The findings indicate that optimization algorithms such as Ant Colony Optimization and Vehicle Routing Problem-based approaches enhance efficiency, reduce fuel consumption, and lower operational costs while achieving measurable carbon footprint reductions. Green Supply Chain Management practices further extend these benefits, delivering up to 30% emission reductions and improving customer satisfaction and corporate performance. Renewable energy technologies, particularly fuel cell electric vehicles, combined with digital innovations such as IoT-enabled cargo tracking, present additional opportunities for significant decarbonization. Cold chain optimization reduces food waste and associated emissions, while corporate mobility strategies integrating electric and autonomous vehicles contribute to both sustainability goals and competitive advantage.

Despite these promising developments, systemic barriers remain, including inconsistent policies, organizational resistance, and high investment costs, particularly for small and medium-sized enterprises. Addressing these challenges requires coherent policy frameworks, harmonized international standards, financial incentives, and stronger cultural integration of sustainability. Future research should expand to underrepresented regions, emphasize the social dimensions of decarbonization, and validate findings through empirical, real-world studies. Overall, logistics must be positioned as a key lever in achieving global climate targets, and the adoption of integrated, multi-level strategies will be essential for accelerating the transition to low-carbon operations.

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