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Overcoming Barriers to Electric Freight Vehicle Adoption: A Narrative Review of Global Evidence

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ABSTRACT: The rapid growth of urban logistics has intensified concerns about sustainability, making Electric Freight Vehicles (EFVs) a critical innovation for reducing greenhouse gas emissions and improving urban air quality. This study aims to provide a narrative review of the factors influencing EFV adoption, with a focus on technological, economic, infrastructural, and policy dimensions. Literature was systematically retrieved from major databases, including Scopus, Web of Science, IEEE Xplore, and Google Scholar, using targeted keywords related to EFVs, sustainable logistics, charging infrastructure, and adoption policies. Inclusion criteria emphasized empirical studies, case analyses, and decision-making frameworks relevant to urban freight logistics. Findings reveal that technological barriers, particularly limited battery range and insufficient charging networks, remain significant impediments to EFV adoption. Economic considerations, such as high initial investment and retrofitting costs, continue to deter smaller logistics firms, although long-term savings in energy and maintenance strengthen the economic rationale. Policy measures, including subsidies, tax incentives, and Low Emission Zones, have proven effective in accelerating adoption, particularly when aligned with infrastructure development. Cross-country comparisons demonstrate uneven progress, with Norway, the Netherlands, and China leading, while many developing regions lag due to systemic and financial constraints. The discussion emphasizes the need for holistic strategies that integrate policy, infrastructure, and technological innovations. Future research should explore longitudinal policy impacts, innovative charging solutions, and behavioral aspects of adoption to inform more effective pathways toward sustainable urban logistics.

Keywords: Electric Freight Vehicles, Sustainable Urban Logistics, Charging Infrastructure, Policy Incentives, Global Adoption Strategies, Low Emission Zones.

INTRODUCTION

Electric Freight Vehicles (EFVs) have emerged as a transformative solution in urban logistics, addressing the growing demand for sustainable transportation systems. Rapid urbanization and

the concentration of populations in metropolitan areas have intensified the need for freight systems that are both efficient and environmentally friendly. Conventional freight vehicles powered by internal combustion engines (ICEs) are major contributors to greenhouse gas emissions and air pollution, thereby exacerbating health risks and environmental degradation (Torbatian et al., 2024; Hu et al., 2021). In contrast, EFVs offer a promising pathway toward decarbonizing logistics operations while improving urban livability, as demonstrated by measurable emission reductions in cities such as Shanghai.

The global momentum for EFVs is driven by advances in battery technology, renewable energy integration, and government regulations. Policy frameworks—such as subsidies, tax incentives, and Low Emission Zones (LEZs)—have accelerated adoption in regions like Europe and China (Saxena & Yadav, 2023; Qiao & Raufer, 2022). Nevertheless, adoption remains uneven across countries. While developed economies benefit from strong policy support and robust infrastructure, developing regions face financial and institutional constraints that limit large-scale implementation (Paddeu et al., 2018).

Despite clear environmental benefits, EFV deployment still encounters substantial challenges. Limited vehicle range, high upfront investment, and inadequate charging infrastructure have been consistently cited as barriers, particularly for small and medium-sized logistics companies (Pelletier et al., 2018; Winkler et al., 2022). Furthermore, fragmented governance and weak stakeholder coordination hinder integrated strategies for large-scale adoption (Golińska-Dawson & Sethanan, 2023).

While existing studies have largely focused on the environmental advantages and technological feasibility of EFVs, less attention has been paid to their economic viability, long-term operational implications, and the systemic conditions that shape adoption. Empirical evidence on real-world logistics operations, especially in developing contexts, also remains limited. This review contributes by synthesizing technological, economic, policy, and social perspectives on EFV adoption across diverse regions. By highlighting both common barriers and context-specific opportunities, it seeks to advance scholarly understanding and provide actionable insights for policymakers and industry stakeholders aiming to accelerate the transition to sustainable freight systems.

METHOD

This study adopted a structured methodological approach to synthesize existing literature on the adoption of Electric Freight Vehicles (EFVs) in urban logistics and the readiness of supporting infrastructure. The methodology was designed to ensure both breadth and depth in capturing the multifaceted dimensions of technological, economic, social, and policy-related factors influencing EFV integration. In order to achieve this, the research relied on a systematic search of reputable academic databases, the application of carefully chosen keywords, and the establishment of clear

inclusion and exclusion criteria. The process was guided by the standards of systematic reviews in transport and sustainability research to ensure methodological rigor and transparency.

The literature collection process began with the selection of relevant academic databases. Scopus was identified as a primary source due to its extensive coverage of peer-reviewed journals across diverse fields, including transportation, engineering, and environmental studies. Web of Science was similarly employed to broaden the scope of high-quality sources and to capture studies at the intersection of innovation, technological adoption, and policy evaluation. Google Scholar was used as a supplementary tool to ensure inclusivity by identifying gray literature and additional academic contributions that may not be indexed in traditional repositories. IEEE Xplore was also consulted, given its emphasis on engineering and technological innovations directly relevant to electric vehicle development and application. Although PubMed is primarily health-oriented, it was included in the initial search strategy to trace interdisciplinary works addressing the health implications of urban air quality improvements through EFV adoption. Collectively, these databases offered a comprehensive foundation for capturing scholarly discussions surrounding EFVs in urban freight systems.

The keyword selection process was critical to ensuring that the scope of retrieved literature aligned with the objectives of this study. Keywords and phrases such as "Electric Freight Vehicles," "Electric Vehicles," "Sustainable Urban Logistics," "Charging Infrastructure for Electric Vehicles," "Adoption of Electric Vehicles," and "Urban Air Quality and Electric Vehicles" were employed to capture the technical and environmental aspects of the research. In addition, terms like "Green Transportation," "Last-Mile Delivery Solutions," and "Policies for Electric Vehicle Adoption" were integrated to broaden the scope toward operational, managerial, and regulatory considerations. Keywords such as "Multi-Criteria Decision Analysis (MCDA) for Electrification," "Impact of E-Commerce on Urban Logistics," "Infrastructure Readiness for Electric Freight," and "Environmental Impacts of Electric Vehicles" were included to capture methodological frameworks and cross-cutting themes that highlight the systemic implications of EFV adoption. The combination of these terms was tested in Boolean structures to maximize retrieval precision and minimize irrelevant results.

The search strategy was complemented by strict inclusion and exclusion criteria designed to ensure that only relevant and high-quality studies were considered. Studies were included if they (1) were peer-reviewed journal articles, book chapters, or reputable conference proceedings, (2) addressed the adoption, infrastructure readiness, or policy environment of EFVs, and (3) provided empirical data, theoretical models, or decision-making frameworks relevant to urban freight contexts. Articles published in English within the past fifteen years were prioritized to ensure contemporary relevance, though seminal earlier works were also considered if they held significant foundational value. Studies focusing exclusively on passenger electric vehicles without any link to freight logistics were excluded, as were publications lacking empirical or methodological grounding, such as opinion pieces or non-academic reports. By enforcing these criteria, the study maintained a focus on literature capable of advancing scholarly understanding and supporting evidence-based policy recommendations.

The types of research included in this review were diverse, reflecting the interdisciplinary nature of EFV studies. Experimental and engineering-focused studies were incorporated to capture advances in vehicle design, charging technologies, and battery innovations (Pietrzak et al., 2021; Qiao & Raufer, 2022). Case studies provided insights into localized adoption patterns, highlighting the role of regulatory environments, financial incentives, and operational contexts in shaping adoption trajectories (Saxena & Yadav, 2023; Paddeu et al., 2018). Cohort-based and longitudinal analyses were included where available to explore changes over time in adoption rates and infrastructure development. Decision-analytic studies employing methods such as Multi-Criteria Decision Analysis (MCDA) offered valuable frameworks for evaluating trade-offs between cost, performance, policy, and environmental impacts (Ahani et al., 2023). Collectively, the diversity of research designs enabled a comprehensive synthesis of technological, economic, social, and institutional dimensions.

The process of literature selection was carried out in multiple stages to maintain rigor and consistency. The initial search yielded a broad pool of results, which were then screened based on titles and abstracts to filter out irrelevant studies. Articles that appeared relevant were retrieved in full and assessed against the inclusion criteria. During this process, duplicate studies across databases were removed, and particular attention was paid to ensuring that diverse geographic contexts were represented. To evaluate the quality and relevance of studies, each article was assessed in terms of methodological clarity, data robustness, and the extent to which findings addressed the core themes of EFV adoption and infrastructure readiness. Disagreements during the selection process were resolved through iterative re-evaluation of the inclusion criteria, ensuring consistency across the review.

In synthesizing the selected literature, emphasis was placed on capturing recurring themes and identifying areas of divergence. For instance, studies such as those by Saxena and Yadav (2023) underscored technological and operational barriers such as range anxiety and charging time constraints, while works like Gruber et al. (2024) highlighted broader urban mobility trends, including the preference for smaller freight vehicles in densely populated areas. Settey et al. (2021) contributed insights into the intersection of EFVs with the rapid growth of e-commerce and its implications for last-mile delivery systems. Other studies, including those by Pietrzak et al. (2021) and Qiao and Raufer (2022), emphasized the importance of charging infrastructure readiness as a determinant of adoption feasibility. The inclusion of such varied perspectives allowed the synthesis to present a multidimensional view of EFV integration into urban freight.

Through this methodological framework, the study ensured that the resulting synthesis was both comprehensive and analytically robust. By systematically integrating sources across databases, applying well-defined keywords, and enforcing strict inclusion and exclusion criteria, the methodology not only identified a wide range of relevant studies but also filtered them to emphasize empirical and conceptual rigor. The final body of literature thus provided a reliable foundation for the subsequent analysis of adoption drivers, barriers, and infrastructure readiness in urban EFV deployment. In doing so, the methodological approach positioned the review to generate insights of both academic and practical relevance, capable of informing ongoing debates and guiding policy and industry strategies for sustainable urban logistics.

RESULT AND DISCUSSION

The results of this narrative review are organized around four central themes that emerged consistently across the literature: technological and infrastructural factors, economic and operational factors, policy and regulatory frameworks, and global comparative perspectives. Each theme captures specific challenges, opportunities, and empirical findings that illuminate the complex dynamics of Electric Freight Vehicle (EFV) adoption in urban logistics.

Technological and Infrastructure Factors

Technological limitations have consistently been identified as one of the primary barriers to EFV adoption. The most critical issues are associated with battery capacity and vehicle range. Saxena and Yadav (2023) emphasized that "range anxiety," or the persistent fear among operators that EFVs cannot complete long-haul or multi-stop urban delivery routes on a single charge, remains a significant impediment. This concern is particularly acute in dense urban environments where delivery schedules are rigid, and delays caused by recharging could have cascading impacts on operational efficiency. Similar findings were reported by Pelletier et al. (2018), who highlighted how limited battery autonomy continues to reduce confidence among fleet managers, despite incremental improvements in battery technology.

Infrastructure readiness further shapes adoption trajectories. Pietrzak et al. (2021) demonstrated that insufficient charging networks exacerbate range anxiety and discourage logistics companies from investing in EFVs. The presence of widely accessible and strategically located charging stations has been shown to positively influence operator confidence and adoption rates. In regions where infrastructure is underdeveloped, operators tend to postpone or reject investment in EFVs, highlighting the importance of policy-driven infrastructure expansion. Qiao and Raufer (2022) added that robust policy support combined with developed charging networks in cities such as Shenzhen and Beijing significantly accelerated adoption, compared to areas with fragmented or underfunded infrastructure. European countries like Norway and the Netherlands provide further empirical support, where rapid infrastructure development coincided with high EFV penetration rates (Settey et al., 2021).

The evidence suggests that technological and infrastructural readiness are mutually reinforcing. Without reliable charging infrastructure, technological advancements in battery capacity have limited impact on adoption, while underdeveloped technology undermines the benefits of even well-established infrastructure systems. These findings underscore the need for holistic approaches that integrate advancements in battery technology with coordinated infrastructure planning.

Economic and Operational Factors

Economic considerations form another crucial dimension of EFV adoption. Initial investment costs remain substantially higher for EFVs compared to conventional internal combustion engine (ICE) vehicles. Macharis et al. (2013) observed that while upfront purchase prices are significantly elevated, long-term operational savings in energy and maintenance provide compelling incentives for adoption. Nevertheless, high capital requirements deter small and medium-sized enterprises with limited financial flexibility from transitioning to EFVs.

Total Cost of Ownership (TCO) analyses have been widely used to contextualize these dynamics. Sendek-Matysiak et al. (2022) illustrated that TCO comparisons between EFVs and ICE vehicles must account for reduced energy consumption, lower maintenance costs, and potential subsidies, all of which can offset the initial investment over time. Accardo et al. (2021) provided empirical evidence showing that despite costly infrastructure deployment, the energy efficiency of EFVs resulted in significant long-term savings. The reduced maintenance burden, largely due to fewer moving parts compared to diesel engines, further reinforces the economic rationale for EFV adoption (Iwan et al., 2021).

Operational efficiency also influences adoption decisions. EFVs present unique logistical challenges, including the need for strategic planning around charging cycles, fleet management adjustments, and workforce training (Sayarshad et al., 2021). However, when these challenges are effectively managed, operators benefit from lower energy costs and predictable fuel pricing relative to the volatility of fossil fuel markets (Winkler et al., 2022). These operational advantages create long-term competitiveness, but the transition demands careful management of short-term economic barriers.

Policy and Regulatory Factors

Policy and regulatory frameworks emerge as critical enablers of EFV adoption. Incentives such as purchase subsidies, tax exemptions, and reduced tolls have proven effective in accelerating uptake among logistics companies. Goulianou et al. (2024) demonstrated that adoption rates are strongly correlated with the availability of financial incentives, particularly when combined with rising fossil fuel prices. Qiao and Raufer (2022) further confirmed this by showing that Chinese cities offering comprehensive incentive packages experienced faster and more extensive EFV adoption than those relying solely on regulatory mandates.

Environmental regulations also exert significant influence. Low Emission Zones (LEZs) in cities such as London and Paris restrict access to conventional diesel freight vehicles, creating direct incentives for operators to adopt EFVs. Iwan et al. (2021) noted that such regulations not only improved air quality but also reshaped the competitive landscape by making compliance through EFVs more attractive than facing penalties or restricted access. Ahani et al. (2023) highlighted that LEZs, when combined with infrastructure investment and public-private collaboration, yield particularly strong results. However, Bastida-Molina et al. (2022) pointed out that the alignment between national and local policies often determines the overall success of regulatory interventions, as fragmented governance can dilute the effectiveness of incentives and regulations.

Overall, the literature suggests that financial incentives and regulatory mechanisms are most effective when implemented in tandem, supported by infrastructure development and institutional alignment.

Global Perspectives and Cross-Country Comparisons

Comparative evidence reveals stark differences in EFV adoption rates across countries. Norway exemplifies a high-adoption environment, where over 54% of all new vehicles sold are electric, driven by strong governmental support and extensive infrastructure networks (Pilati et al., 2020). Similarly, the Netherlands has achieved notable penetration due to a combination of supportive

policies and investments in charging infrastructure (Settey et al., 2021). In contrast, developing economies in Asia and Latin America continue to face substantial barriers, including insufficient financial incentives, weak infrastructure development, and limited stakeholder collaboration (Chakravarthy et al., 2025; Paddeu et al., 2018).

Best practices from specific countries illustrate replicable strategies. For instance, Berlin's adoption of urban consolidation centers has reduced emissions and improved efficiency by centralizing freight distribution, enabling EFVs to handle last-mile delivery more effectively (Amodeo et al., 2015). Szczecin in Poland has experimented with strategically placed charging hubs near delivery destinations, which has improved route planning and reduced downtime for EFVs (Iwan et al., 2021). These innovations demonstrate how context-specific policies and infrastructural interventions can address operational barriers and facilitate widespread adoption.

The global comparison highlights both opportunities and inequities in EFV adoption. While wealthier countries with robust governance systems and financial capacity have moved ahead, developing regions lag behind, reinforcing the need for international collaboration and knowledge transfer. Lessons from successful cases can inform strategies in less advanced contexts, provided that interventions are adapted to local socio-economic realities.

Synthesis of Findings

Taken together, the results suggest that the adoption of EFVs in urban logistics is influenced by an interdependent set of factors spanning technology, economics, policy, and governance. Technological limitations, particularly range anxiety and battery capacity, continue to constrain adoption despite incremental progress. Infrastructure readiness remains uneven globally, reinforcing disparities in adoption rates. Economic considerations, especially high initial costs, represent a major barrier, although long-term savings in energy and maintenance provide strong counterweights. Policy interventions, ranging from financial incentives to environmental regulations, have proven indispensable in creating enabling environments. Finally, comparative global perspectives underscore that while some countries demonstrate rapid adoption through coordinated strategies, others struggle due to infrastructural, financial, or institutional constraints.

This review thus illustrates that EFV adoption is not solely a technological challenge but a systemic one, requiring alignment across economic incentives, infrastructural investments, and policy frameworks. Moreover, it highlights the importance of global knowledge exchange to replicate best practices and adapt strategies to diverse urban contexts. By synthesizing these findings, this study lays the groundwork for a more nuanced understanding of EFV integration into urban freight logistics and identifies pathways for future research and policy design aimed at accelerating the transition to sustainable urban transportation.

The findings of this review underscore the interdependence of systemic, technological, and economic factors in shaping the adoption trajectory of Electric Freight Vehicles (EFVs) in urban logistics. The literature highlights that EFV adoption cannot be understood solely through the lens of vehicle performance or operational efficiency, but rather must be examined within the broader systemic environment that includes energy production, regulatory frameworks, economic incentives, and societal perceptions. This discussion analyzes the key results in relation to existing

literature, examines how systemic factors exacerbate or alleviate adoption challenges, and considers potential solutions while identifying limitations in the current body of research.

A critical observation emerging from the literature is the significant role of systemic conditions, particularly the energy mix used in electricity generation, in determining the environmental benefits of EFVs. Torbatian et al. (2024) argued that in contexts where electricity is still predominantly generated from fossil fuels, the reductions in greenhouse gas emissions achieved through EFV adoption are marginal at best. This challenges the widespread assumption that electrification universally translates to decarbonization. Instead, it suggests that EFVs can only realize their full environmental potential when integrated with broader systemic efforts to transition to renewable energy. The implication is that electrification strategies must be paired with energy policy reforms to achieve sustainability goals, as noted in earlier studies on urban air quality improvements linked to EFV deployment in Shanghai (Hu et al., 2021).

Economic factors further complicate EFV adoption, with range anxiety representing both a technological and perceptual barrier. Saxena and Yadav (2023) demonstrated that operator concerns about limited range reflect not only technological limitations but also broader issues of trust and perceived reliability. These perceptions are reinforced by the lack of sufficient charging infrastructure, which increases operational uncertainty. In this sense, range anxiety is not merely an engineering challenge but also a systemic problem rooted in infrastructural inadequacies and economic constraints. The cost implications are significant, as logistics firms are less willing to invest in EFVs when uncertain about the reliability of both the technology and the supporting infrastructure (Pelletier et al., 2018).

The social dimension of EFV adoption is equally critical. Societal perceptions of electric vehicles as environmentally friendly and efficient have been shown to influence company decisions, particularly when customers demand greener supply chains (Saxena & Yadav, 2023). These social pressures, when combined with regulatory frameworks, create a powerful incentive structure for adoption. However, such pressures are unevenly distributed globally. In many developing economies, consumer awareness and demand for sustainable logistics remain limited, weakening the social impetus for EFV adoption. This underscores the importance of public awareness campaigns and educational initiatives as complementary tools to technical and economic policies.

Policy interventions have been widely recognized as effective levers for overcoming economic and infrastructural barriers. Qiao and Raufer (2022) highlighted how comprehensive incentive packages, including subsidies, tax reductions, and road access privileges, significantly accelerated EFV uptake in Chinese cities. Similarly, regulatory measures such as Low Emission Zones (LEZs) have been shown to directly encourage adoption by restricting diesel vehicle access in cities like London and Paris (Iwan et al., 2021). These findings confirm earlier assertions by Goulianou et al. (2024) that policy support functions as a systemic driver that can reshape market dynamics. Yet, as Bastida-Molina et al. (2022) pointed out, the misalignment between national and local policies often dilutes policy effectiveness, suggesting the need for multi-level governance approaches to harmonize regulatory environments.

The integration of EFVs within urban freight systems also illustrates how systemic and technological factors intersect. For example, infrastructure deployment strategies, such as

strategically placed charging hubs, not only alleviate range anxiety but also create efficiencies in last-mile delivery (Iwan et al., 2021). However, the success of such strategies depends on coordination among multiple stakeholders, including municipal governments, private energy providers, and logistics operators. Golińska-Dawson and Sethanan (2023) emphasized that fragmented stakeholder interests often prevent the development of coherent strategies, illustrating the systemic complexity inherent in EFV adoption. Paddeu et al. (2018) similarly observed that collaborative governance models are essential to overcome institutional silos and ensure effective policy and infrastructure integration.

Potential solutions to the barriers identified in this review must therefore address both systemic and operational dimensions. Expanding charging infrastructure emerges as the most immediate and impactful strategy, as highlighted by Pelletier et al. (2018) and confirmed by subsequent studies. Qiao and Raufer (2022) argued that widespread availability of charging stations builds operator confidence and reduces logistical disruptions. However, infrastructure expansion must be paired with financial incentives to offset the high initial costs of EFVs, particularly for small and medium-sized enterprises (Pietrzak et al., 2021). Subsidies, grants, and tax incentives can lower entry barriers, while regulatory mechanisms such as LEZs create additional pressure to transition away from conventional vehicles (Chakravarthy et al., 2025). Importantly, these solutions require coordinated implementation across local and national levels of government to ensure coherence and long-term effectiveness.

While the technological and economic solutions are well-documented, the role of innovative policy design remains underexplored. For example, dynamic pricing for electricity during off-peak hours could incentivize efficient charging practices and reduce strain on urban power grids. Similarly, integrating EFVs into smart city frameworks that utilize data-driven fleet management systems could enhance operational efficiency and reduce perceived risks associated with adoption (Winkler et al., 2022). These emerging approaches point to the necessity of coupling EFV adoption with broader innovations in urban infrastructure and governance.

Despite these insights, limitations in the existing body of research are apparent. Much of the literature remains focused on technical and economic analyses, with limited attention paid to social and behavioral dimensions (Sayarshad et al., 2021). As Morganti and Browne (2018) noted, the fragmented nature of urban freight systems necessitates a more holistic approach that incorporates behavioral studies, stakeholder dynamics, and institutional analysis. Additionally, the majority of existing studies are localized in scope, often focusing on specific cities or regions, which constrains the ability to generalize findings globally. This limitation is particularly evident in the lack of comparative research across diverse geographic and economic contexts, as highlighted in recent global reviews (Chakravarthy et al., 2025).

Future research must therefore adopt multidisciplinary and longitudinal approaches. Studies that integrate technical, economic, and social perspectives can provide a more comprehensive understanding of adoption dynamics. Longitudinal evaluations of policy interventions, such as subsidies and LEZs, are necessary to assess their sustained effectiveness over time. Comparative case studies across regions with differing infrastructural and policy contexts can also illuminate best practices and transferable strategies. Furthermore, the role of emerging technologies, such as high-capacity batteries, wireless charging, and vehicle-to-grid systems, represents a fertile area for

exploration (Winkler et al., 2022). These innovations could redefine the parameters of EFV adoption by reducing range anxiety, lowering operational costs, and enhancing integration with urban energy systems.

Finally, there is a clear need to examine the systemic implications of EFV adoption within broader sustainability agendas. Linking EFVs to circular economy strategies, renewable energy transitions, and sustainable urban planning could help situate them as integral components of holistic sustainability frameworks. This would not only strengthen the case for adoption but also provide a platform for cross-sectoral collaboration in addressing the multifaceted challenges of urban freight decarbonization.

CONCLUSION

This study highlights that the adoption of Electric Freight Vehicles (EFVs) in urban logistics is shaped by a multifaceted interplay of technological, economic, infrastructural, and policy factors. Findings indicate that limitations in battery capacity and the persistence of range anxiety continue to restrict operator confidence, while insufficient charging infrastructure remains a significant bottleneck in many regions. Despite these challenges, long-term operational benefits such as reduced maintenance and stable energy costs make EFVs a promising alternative to conventional freight vehicles. Economic barriers, particularly high upfront investments, still constrain small and medium-sized enterprises, yet policy incentives and financial subsidies have demonstrated substantial potential to offset these obstacles. Regulatory measures such as Low Emission Zones, combined with strong governmental support, further accelerate adoption, especially in contexts where infrastructure expansion and institutional coordination are prioritized. The results also emphasize the uneven global landscape, with advanced economies demonstrating faster adoption due to robust policy frameworks and infrastructural readiness, while developing economies continue to struggle with financial and systemic limitations.

The urgency of transitioning to sustainable freight systems underscores the need for comprehensive interventions. Policy strategies must integrate infrastructure expansion with financial incentives and regulatory frameworks to create enabling conditions. Future research should adopt longitudinal and multidisciplinary approaches to evaluate the long-term effectiveness of policies, explore innovative charging technologies, and examine the behavioral and social dimensions of adoption. Strengthening public awareness and cross-sector collaboration will be essential in bridging gaps and accelerating the global transition to sustainable urban logistics.

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