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Navigating the Future of Logistics: A Narrative Review of Autonomous Freight Systems

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ABSTRACT: The adoption of autonomous vehicles in freight transport represents a transformative shift in global logistics. However, research remains fragmented regarding the balance between efficiency, sustainability, safety, and user acceptance. This narrative review synthesizes recent empirical studies to identify critical opportunities and challenges in autonomous freight systems. The findings indicate substantial efficiency and cost benefits, particularly through truck platooning and automated last-mile delivery solutions. Environmental outcomes are generally positive, though lifecycle trade-offs such as infrastructure wear and energy sources complicate sustainability claims. Safety concerns persist in mixed-traffic environments, where operational reliability and public trust remain unresolved. User acceptance is shaped by demographic and sectoral factors, with stronger receptivity in industries handling perishable or time-sensitive goods. The review highlights that adoption trajectories are contingent on systemic factors, including regulatory alignment, infrastructure readiness, and financing mechanisms. These insights underscore the need for adaptive policy frameworks, targeted training, and inclusive financing models to ensure that autonomous freight technologies enhance not only efficiency but also long-term sustainability and equity.

Keywords: Autonomous Vehicles, Freight Transport, Truck Platooning, Logistics Sustainability, User Acceptance, Transport Policy, Last-Mile Delivery.

INTRODUCTION

The global logistics sector is entering a transformative era shaped by the rapid development of autonomous vehicle (AV) technologies. Freight transport, in particular, is at the center of this shift as companies confront rising operational costs, driver shortages, and increasing demands for sustainable supply chains. Advanced driver-assistance systems (ADAS), electric and autonomous vehicles (EAVs), and autonomous last-mile delivery solutions illustrate how automation is reshaping logistics infrastructures worldwide (Sindi & Woodman, 2021; Alverhed et al., 2024).

Despite these advances, significant challenges persist. Safety in mixed-traffic environments remains unresolved, as AVs must reliably interact with human-driven vehicles under complex conditions (Schlenther et al., 2020; Benallou et al., 2024). Environmental impacts are also contested: while AVs can reduce emissions and improve efficiency, concerns about energy sourcing and infrastructure wear complicate sustainability claims (Brusselaers et al., 2023). In parallel, structural labor market issues—particularly persistent driver shortages—drive automation but simultaneously raise concerns about job displacement and social acceptance (Zhang & Haddud, 2025).

Existing literature has primarily focused on isolated dimensions such as technical performance, regulatory barriers, or environmental assessments. However, there remains a lack of integrative analysis that synthesizes these dimensions and addresses user acceptance and policy fragmentation across different contexts. Previous reviews have not sufficiently connected technological advances with their broader social, economic, and policy implications, leaving uncertainty about the systemic impacts of AV adoption in freight transport.

The novelty of this review lies in its holistic synthesis of technological, economic, social, and regulatory perspectives on autonomous freight systems. By analyzing these interrelated dimensions, the study highlights both opportunities and systemic barriers to adoption. It also identifies research gaps—particularly in stakeholder acceptance, infrastructure readiness, and policy coordination—that require urgent scholarly and practical attention.

Accordingly, the objective of this review is to provide a comprehensive understanding of autonomous freight adoption across four dimensions: (1) technological capabilities and limitations, (2) economic, social, and environmental implications, (3) regulatory and policy frameworks, and (4) user acceptance and organizational readiness. This integrative perspective aims to inform both academic debates and policy interventions in advancing sustainable, safe, and equitable freight transport systems

METHOD

The methodological foundation of this review was designed to ensure a systematic and comprehensive examination of the literature concerning autonomous vehicles (AVs) in freight transport. To achieve this objective, the study employed a structured approach to literature collection, screening, and evaluation, integrating both breadth and depth of inquiry across multiple dimensions of AV adoption. This section outlines the key procedures that guided the research, including the choice of databases, the formulation of search terms, the establishment of inclusion and exclusion criteria, the classification of eligible study types, and the systematic process of literature selection and assessment.

The first step in the methodology was to identify and select appropriate databases capable of capturing the multidisciplinary scope of AV-related research. Given the technological, economic, and regulatory dimensions of autonomous freight systems, reliance on a single repository would have risked excluding relevant studies. Thus, four major academic databases were prioritized: Scopus, Web of Science, IEEE Xplore, and Google Scholar. Scopus and Web of Science were selected for their extensive coverage of peer-reviewed journal articles across engineering, social sciences, and policy-related fields. IEEE Xplore was included to capture conference proceedings and technical papers focusing on the engineering and computer science aspects of AV development, particularly in relation to sensor systems, communication protocols, and vehicle automation. Google Scholar served as a supplementary platform, enabling the identification of grey literature and cross-referencing citations that might not be indexed in the other databases. Collectively, these databases provided a comprehensive foundation for capturing the full range of scholarly perspectives on AVs in freight transport (Sindi & Woodman, 2021; Alverhed et al., 2024; Kapser et al., 2021).

The formulation of search queries was guided by the need to balance specificity with inclusivity. To this end, a combination of general and targeted keywords was employed. The general keywords included "autonomous vehicles," "freight transport," and "logistics," which ensured the retrieval of a broad set of studies. These terms were further refined with more specific keywords such as "platooning," "last-mile delivery," "safety regulations," "user acceptance," and "infrastructure readiness." Boolean operators and truncation strategies were applied to optimize the search process, ensuring that synonymous and variant forms of the terms were captured. For example, the use of "autonomous OR self-driving OR driverless" in conjunction with "freight OR logistics OR supply chain" yielded a robust set of initial results, while targeted combinations such as "platooning AND freight efficiency" or "autonomous delivery robots AND last-mile logistics" enabled a deeper focus on niche subtopics.

To maintain the quality and relevance of the literature included, explicit inclusion and exclusion criteria were established at the outset of the review. Inclusion criteria emphasized studies that were published in peer-reviewed journals or conference proceedings recognized for their academic rigor. In addition, the studies were required to explicitly focus on AV applications in freight transport, whether in technological, economic, or policy contexts. Only articles published within the last five to ten years were considered, ensuring that the findings reflected recent advancements and emerging trends. Furthermore, priority was given to studies offering empirical insights—either qualitative or quantitative—into AV freight systems, including experimental trials, simulation studies, surveys, and policy evaluations. This focus on empirical work provided a strong evidentiary basis for analyzing the real-world implications of AV adoption (Sindi & Woodman, 2021; Alverhed et al., 2024).

In contrast, exclusion criteria were applied to filter out studies that did not align with the objectives of this review. Non-peer-reviewed sources, such as opinion pieces, editorials, or industry white papers without methodological transparency, were excluded to preserve academic rigor. Research focusing exclusively on passenger transport without explicit relevance to freight systems was similarly excluded, as were studies lacking methodological robustness or reproducibility. The review also excluded papers that were primarily theoretical in nature, offering speculative insights without empirical validation, as these could not contribute substantively to the evaluation of practical AV applications. Additionally, studies outside the specified publication timeframe were excluded to ensure the relevance of the findings to contemporary challenges in logistics and transportation (Brunetti et al., 2022; Malibari et al., 2022).

The types of studies ultimately included in the review were diverse, reflecting the multidisciplinary character of AV research. These encompassed randomized controlled trials where experimental AV systems were tested in controlled environments, cohort and case study analyses that traced the operational impacts of AV adoption in logistics companies, simulation-based studies that modeled traffic efficiency and safety outcomes in mixed-traffic scenarios, and survey-based research exploring user acceptance and organizational readiness for AV implementation. Policy evaluation studies were also incorporated, particularly those assessing regulatory frameworks and their implications for AV integration into freight systems. This diversity in study types enabled a holistic assessment of the multiple dimensions influencing AV deployment, from technical feasibility to societal implications.

The process of literature selection followed a rigorous multi-stage protocol to ensure transparency and consistency. Initial database searches produced a large pool of results, which were then imported into a reference management software for screening. The first stage of screening involved the removal of duplicate entries, which reduced redundancy across databases. The second stage entailed a review of titles and abstracts to exclude clearly irrelevant studies. At this stage, particular attention was given to verifying that the studies explicitly addressed AV applications in freight transport, rather than tangentially related topics. The third stage consisted of a full-text review of the remaining articles, during which the inclusion and exclusion criteria were applied in detail. Studies that met all criteria were retained for final analysis, while those with ambiguous relevance were subjected to discussion and consensus among the research team.

Following the selection process, each included study was evaluated for methodological quality and relevance. Criteria for evaluation included clarity of research design, appropriateness of data collection methods, robustness of analysis, and transparency in reporting findings. For simulation-based studies, model assumptions and validation methods were critically assessed, while for survey-based research, sampling strategies and response rates were examined to ensure representativeness. Policy analyses were evaluated based on their use of systematic frameworks and empirical evidence. This evaluative process allowed for the differentiation of studies according to their evidentiary strength, ensuring that the synthesis of findings was grounded in reliable and credible sources.

In summary, the methodology employed in this review combined a broad search strategy with rigorous screening and evaluation procedures to ensure the inclusion of high-quality literature on autonomous vehicles in freight transport. By leveraging multiple academic databases, employing carefully constructed keywords, and applying stringent inclusion and exclusion criteria, the study ensured that the resulting corpus of literature was both comprehensive and relevant. The inclusion of diverse study types further enriched the analysis, enabling a multidimensional understanding of AV adoption that spans technological, economic, social, and policy domains. This methodological rigor enhances the reliability of the review's findings and provides a solid foundation for analyzing the challenges and opportunities associated with the integration of AVs into freight logistics.

RESULT AND DISCUSSION

Efficiency and Cost Reduction

A consistent theme in the literature concerns the efficiency gains and cost reductions enabled by autonomous vehicles in freight transport, particularly through truck platooning. Yang (2025) demonstrates that truck platooning substantially reduces fuel consumption by optimizing travel dynamics, with strategies such as "catching up with front platoons" shown to balance fuel efficiency with operational throughput. These findings underscore the dual economic benefits of AVs, combining lower operating costs with improved delivery efficiency. Schlenther et al. (2020) extend this analysis by examining the economic advantages of automated driving systems, noting that transport service companies stand to benefit significantly from reduced labor costs and increased profits when adopting platooning models. The transformation of fixed costs into variable costs, as they argue, allows firms to streamline financial performance and enhance flexibility in logistics operations.

When examined across different national contexts, the magnitude of cost savings varies widely depending on regulatory frameworks and infrastructure readiness. Whyte and Colic (2022) emphasize that supportive regulations and investment in road infrastructure, particularly in pilot programs within the United States, amplify the cost-effectiveness of AV freight systems. Conversely, regions with restrictive legislation or inadequate infrastructure, such as those with prohibitions on platooning practices, experience reduced economic gains from AV deployment. Alverhed et al. (2024) highlight that case studies across Europe further demonstrate these discrepancies, illustrating how governance and infrastructure readiness shape the economic viability of AV integration in logistics. These comparative insights reveal that while AV freight systems promise considerable cost efficiencies, their realization is deeply contingent on regional regulatory and infrastructural conditions.

Environmental Impacts

The environmental implications of AV freight systems are another focal point in the literature. Dong et al. (2016) identify improved transportation efficiency as a pivotal factor in reducing carbon emissions, aligning with studies that highlight AVs as key contributors to emission control and sustainability goals. Oakey et al. (2022) provide empirical evidence in the context of Connected Autonomous Freight Vehicles (CAV-Fs), showing that their integration into health service logistics can significantly reduce the carbon footprint of medical supply chains, which are traditionally high emitters of greenhouse gases. These studies demonstrate that AVs not only improve operational performance but also support broader sustainability objectives.

Nevertheless, research also underscores environmental trade-offs associated with AV adoption. Brusselaers et al. (2023) reveal that the anticipated emission reductions from AVs may be offset by indirect factors such as increased pavement wear due to concentrated traffic patterns, or elevated emissions from electricity production when renewable energy sources are not prioritized. Similarly, Malibari et al. (2022) argue that while AVs may alleviate urban congestion and thus reduce emissions, the overall sustainability benefits remain uncertain without comprehensive lifecycle assessments. These findings suggest that to ensure AV freight systems genuinely advance sustainability, future research and policy must address infrastructure durability, energy sourcing, and lifecycle impacts alongside direct emissions reductions.

Safety and Traffic Management

Safety remains a central issue in the discourse on AV adoption in freight logistics, particularly in mixed traffic environments. Malibari et al. (2022) employ microsimulation models to investigate the implications of AV integration into congested road networks, finding that while autonomous systems may improve traffic flow, they also introduce new safety risks in interactions with human-driven vehicles. The complexity of these mixed environments necessitates continuous monitoring and optimization of AV behavior to mitigate potential hazards. Sindi and Woodman (2021) highlight the transitional role of advanced driver-assistance systems (ADAS), suggesting that these semi-autonomous technologies can improve safety outcomes by facilitating smoother traffic interactions and providing a bridge toward full automation.

Critical variables influencing safety outcomes include headway distance, acceleration parameters, and platoon positioning. Although Yang (2025) primarily evaluates energy efficiency in platoon dynamics, the findings indirectly illustrate how these variables shape vehicle interactions and collision risks. Shorter headways, while maximizing fuel savings, may compromise safety if not supported by advanced sensor and communication technologies. These results underscore the need for carefully calibrated operational protocols that balance efficiency with safety in AV platooning practices.

User Acceptance and Perceptions

The success of AV deployment in freight transport also hinges on user acceptance among logistics professionals, policymakers, and the general public. Kapser et al. (2021) explore acceptance of autonomous delivery vehicles, highlighting significant differences in perception based on demographic characteristics, including gender. Their findings demonstrate that concerns over safety, reliability, and technological trustworthiness vary across demographic groups, suggesting that adoption strategies must be tailored to diverse stakeholder needs. Zhang and Haddud (2025) add an industry-specific perspective, showing that logistics professionals in agriculture, food, and livestock sectors are more inclined to view autonomous trucks as useful compared to counterparts in construction or heavy machinery industries. These sectoral differences indicate that operational context shapes perceptions, with industries facing high time sensitivity or perishable goods transport expressing stronger support for AV integration.

Organizational and Policy Implications

At the organizational level, financing, subsidies, and regulatory frameworks emerge as pivotal determinants of AV adoption. Clements and Kockelman (2017) argue that both public and private investments play a decisive role in enabling large-scale trials and eventual integration of AVs into logistics operations. They emphasize that in contexts where financial constraints hinder innovation, targeted subsidies and incentives can facilitate the transition. Oakey et al. (2022) expand on this by evaluating the regulatory dimensions of AV deployment for sensitive cargo, such as medical supplies. Their study reveals the necessity of adapting existing dangerous goods regulations to accommodate autonomous freight vehicles, underscoring the importance of legal clarity in supporting safe and efficient AV operations. Comparative analyses show that while some jurisdictions proactively update regulations to integrate AV systems, others lag behind, creating uneven adoption patterns globally. This variation highlights the critical role of coordinated policy frameworks in ensuring equitable and effective AV integration.

Emerging Modal Innovations

The exploration of AV technologies beyond road-based freight reveals innovative applications in alternative modes of transport. Research into autonomous maritime and aerial logistics demonstrates the potential for diversifying AV integration across multimodal networks, though empirical evidence remains limited. In urban logistics, last-mile delivery has emerged as a particularly promising field for AV innovation. Liu et al. (2022) propose a hybrid two-echelon model combining delivery vans and autonomous delivery robots (ADRs), demonstrating that such systems can optimize cost and emission efficiency in urban contexts. Their findings show that ADRs are most effective in high-density areas, where they alleviate congestion and reduce delivery costs, but face challenges in scalability and regulatory alignment.

Comparative case studies further reveal how contextual factors shape modal innovations. For example, while European cities with established cycling and pedestrian infrastructure provide a favorable environment for ADR integration, regions with fragmented infrastructure or restrictive policies encounter barriers to adoption. These findings illustrate that while AVs hold transformative potential for last-mile and multimodal logistics, their success is contingent on local infrastructure, governance, and regulatory support.

Conclusion of Results

In sum, the literature reviewed indicates that AV adoption in freight transport promises significant efficiency gains, cost reductions, and potential environmental benefits, particularly through truck platooning and innovative last-mile delivery solutions. However, these advantages are tempered by critical challenges in safety management, lifecycle sustainability, user acceptance, and regulatory frameworks. Comparative analyses across different countries underscore that the extent of AV benefits is shaped not only by technological capabilities but also by governance, infrastructure, and societal readiness. These findings provide a nuanced understanding of the complexities of AV adoption in freight logistics and lay the groundwork for the subsequent discussion on the broader implications of these technologies for policy, industry, and society.

Alignment with Existing Theories of Transport Efficiency, Sustainability, and Technology Adoption

The findings of this review broadly align with established theories of transport efficiency, particularly those within transport economics that suggest technological advancements drive operational cost savings and productivity improvements. Empirical evidence from the adoption of advanced driver-assistance systems (ADAS) supports the notion that incremental innovations pave the way toward more fully autonomous systems, yielding immediate benefits such as improved safety and smoother traffic flow in logistics contexts (Sindi & Woodman, 2021). This aligns with efficiency-oriented frameworks which argue that incremental technology adoption generates tangible efficiency improvements before full automation is realized. Theories of transport efficiency are further reinforced by studies on truck platooning, which consistently demonstrate reductions in fuel consumption and operational costs through synchronized vehicle movement (Yang, 2025). Such outcomes underscore the idea that AV technologies function as amplifiers of logistical performance, validating existing efficiency models.

However, when positioned against sustainability theories, the findings present a more nuanced picture. Sustainability frameworks emphasize the potential for technological innovation to reduce emissions and contribute to climate goals, and much of the evidence reviewed corroborates this perspective. For instance, Connected Autonomous Freight Vehicles (CAV-Fs) have been shown to reduce carbon footprints in sensitive supply chains such as healthcare logistics (Oakey et al., 2022). Yet the evidence also exposes contradictions, particularly the environmental trade-offs associated with AV deployment. Brusselaers et al. (2023) highlight that while AVs may reduce direct emissions, secondary effects such as increased pavement wear or reliance on non-renewable energy sources for electricity generation complicate claims of environmental sustainability. These findings suggest that while AVs may align with theoretical sustainability frameworks, they simultaneously demand that such frameworks evolve to incorporate the systemic and life cycle impacts of automation. This broader lens is critical for capturing the complexity of sustainability outcomes in the freight sector.

In terms of technology adoption theories, particularly the diffusion of innovation model, the findings suggest both alignment and divergence. Studies indicate that early adopters of AV technologies are often large logistics corporations with sufficient resources to invest in advanced systems (Clements & Kockelman, 2017). Yet, smaller companies demonstrate hesitancy, constrained by high costs and limited financing opportunities (Whyte & Colic, 2022). This uneven adoption trajectory reveals a divergence from the typical bell-shaped diffusion curve, as evidence suggests adoption may be more heavily skewed toward early adoption by resource-rich firms (Zhang & Haddud, 2025). Such discrepancies call for a re-examination of how traditional adoption models apply in contexts where technological and financial barriers disproportionately shape adoption patterns.

Systemic Factors Amplifying or Mitigating Benefits

The integration of AVs into freight logistics is profoundly shaped by systemic factors that amplify or constrain their benefits. Infrastructure emerges as one of the most critical determinants. Autonomous trucks and platooning systems rely heavily on road networks equipped with advanced communication and signaling technologies. Brunetti et al. (2022) illustrate how ports and logistics hubs deploying electric autonomous vehicle (EAV) systems significantly enhance operational flexibility and reduce congestion. However, in regions where infrastructure is underdeveloped or fragmented, the benefits of AV adoption are severely constrained. Inadequate road markings, poor communication systems, or limited charging infrastructure for electric vehicles can limit the functionality of AV technologies, reinforcing the notion that infrastructure readiness is as critical as technological innovation.

Financing mechanisms represent another systemic factor with substantial influence. High upfront investments for AV technology, combined with costs associated with workforce training and maintenance, can be prohibitive for small and medium-sized enterprises (SMEs). Subsidies, grants, and public-private partnerships have been identified as effective tools for lowering these barriers, thus promoting more equitable adoption (Whyte & Colic, 2022). Without supportive financing, the adoption trajectory risks exacerbating inequalities in the logistics sector, concentrating technological benefits among large corporations while marginalizing smaller firms. The implications of this financing gap are significant, as they directly shape the pace and inclusivity of AV integration.

Regulatory frameworks further amplify or mitigate AV benefits. Evidence from jurisdictions such as Australia highlights how outdated traffic laws explicitly prohibiting platooning (Whyte & Colic, 2022) restrict technological experimentation and limit efficiency gains. Conversely, regions that actively reform legal structures and establish adaptive regulatory frameworks create fertile conditions for AV deployment (Oakey et al., 2022). This divergence underscores the critical role of legal environments in shaping adoption patterns and ensuring that AV technologies are integrated in ways that balance innovation, safety, and societal concerns. The absence of coherent policies across jurisdictions also highlights a systemic issue of regulatory fragmentation, which creates uncertainty for global logistics operators navigating multiple regulatory landscapes.

Policy Directions and Practical Solutions

Given these systemic challenges, several policy directions and practical solutions emerge from the literature. Adaptive regulatory frameworks are paramount. Policies that evolve alongside technological innovations, rather than lagging behind them, can facilitate smoother integration of AV technologies into logistics. Oakey et al. (2022) emphasize the importance of adapting dangerous goods legislation to account for autonomous freight systems, a step that ensures safety while enabling innovation. Similar adaptive approaches can address emerging issues such as liability, insurance, and cross-border regulatory alignment.

In addition to regulatory reform, targeted financial incentives are crucial. Subsidies or grants aimed at SMEs can prevent technological adoption from becoming concentrated in large corporations, thereby fostering equitable participation across the logistics sector (Clements & Kockelman, 2017). Such measures not only democratize access to AV technologies but also contribute to broader economic resilience by ensuring that diverse actors can participate in technological transitions.

Comprehensive training and education programs also emerge as practical solutions to improve adoption readiness. Zhang and Haddud (2025) argue that the perceived usefulness of AVs is shaped by industry-specific contexts, with professionals in agriculture and food logistics demonstrating greater receptivity than those in construction or heavy machinery. Addressing these sector-specific perceptions requires tailored educational initiatives that enhance familiarity with AV technologies and address concerns about safety, job displacement, and operational reliability. By investing in human capital, policymakers and industry leaders can mitigate resistance and build trust in AV systems.

Finally, the integration of sustainability assessments into policy frameworks can provide a more balanced view of AV impacts. Life cycle analyses that account for indirect environmental effects—such as infrastructure wear and energy sourcing—can help policymakers and industry stakeholders avoid overly optimistic assumptions about sustainability outcomes (Brusselaers et al., 2023). Embedding such assessments in regulatory processes ensures that AV adoption contributes meaningfully to long-term climate and sustainability goals.

Limitations of Current Research and Future Directions

Despite the growing body of literature on AV adoption in freight transport, several limitations persist. Many studies rely heavily on simulations rather than real-world deployments, which restricts the generalizability of findings. Simulation models, while useful, often depend on assumptions about driver behavior, traffic conditions, and technological reliability that may not hold in real-world contexts (Malibari et al., 2022). The limited number of large-scale field trials constrains the ability to draw definitive conclusions about long-term safety, cost, and environmental outcomes.

Another limitation is the geographic concentration of existing research. Much of the empirical work has been conducted in developed regions such as North America, Europe, and parts of East Asia, leaving significant gaps in understanding how AV technologies might function in emerging economies with different infrastructural, regulatory, and social conditions. This imbalance restricts the global applicability of findings and underscores the need for more geographically diverse research agendas.

Moreover, gaps in user acceptance studies remain pronounced. While some surveys capture demographic variations in perceptions of AV technologies (Kapser et al., 2021), comprehensive analyses across cultural and occupational contexts are still lacking. Similarly, research on infrastructure readiness is often fragmented, focusing on isolated logistics hubs or urban centers without fully addressing systemic integration challenges across national and transnational networks (Brunetti et al., 2022).

Future research directions should therefore prioritize real-world trials to validate simulation results, expand geographic coverage to include underrepresented regions, and deepen exploration of user perceptions across diverse demographic and industrial contexts. Additionally, integrating interdisciplinary perspectives—combining engineering, economics, policy, and social science approaches—will be essential for producing a holistic understanding of AV adoption in freight transport. Such efforts can bridge existing gaps, refine theoretical frameworks, and provide actionable insights for policymakers, industry leaders, and academic researchers alike.

CONCLUSION

This review has examined the adoption of autonomous vehicles in freight transport through the lenses of efficiency, sustainability, safety, user acceptance, and policy integration. The findings indicate that autonomous truck platooning and other automation technologies can significantly reduce fuel consumption, labor costs, and operational inefficiencies, aligning with theories of transport efficiency. At the same time, the environmental benefits of these technologies, while substantial, are complex and contingent on factors such as infrastructure durability and renewable energy sourcing. Safety in mixed-traffic environments remains a critical challenge, requiring calibrated protocols for vehicle interactions and supportive transitional technologies such as advanced driver-assistance systems. Furthermore, user acceptance is shaped by demographic and sector-specific factors, with industries handling perishable or time-sensitive goods demonstrating greater receptivity. The review also highlights the importance of systemic factors—particularly financing, regulatory frameworks, and infrastructure readiness—in shaping the trajectory of autonomous freight adoption.

Urgent interventions are required to overcome technological, regulatory, and societal barriers. Adaptive regulatory frameworks must be developed to evolve alongside technological innovations, while financial incentives such as subsidies and grants can facilitate equitable adoption across small and medium enterprises. Training and education initiatives targeting logistics professionals are equally essential to build trust and readiness. Future research should prioritize large-scale field trials, geographically diverse studies, and interdisciplinary approaches that integrate engineering, economic, and social perspectives. By addressing these gaps, stakeholders can ensure that autonomous freight systems not only enhance efficiency but also promote sustainability, safety, and equity across global logistics networks.

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