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INTEGRATION OF ELECTRIC VEHICLES INTO FREIGHT ROAD TRANSPORT: CHALLENGES AND SELECTION CRITERIA

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Abstract. In the rapidly developing and dynamically changing global logistics sector, freight transport businesses are increasingly investing in the renewal of vehicles used in daily freight operations. This trend is particularly evident in the segment of road freight transport. Business organizations involved in freight transportation by trucks are not only allocating relatively large investments for the regular renewal of their vehicle fleets, but also increasingly opting for transport powered by alternative energy sources, in response to tightening environmental standards.

Electric vehicles are gradually becoming one of the most popular modern choices for road freight transport. Their integration into freight trucking operations significantly reduces pollutant gas emissions typical of freight transport activities and helps optimize the daily operational costs of trucks. However, the integration of modern electric vehicles into road freight transport also faces specific challenges. A detailed analysis of these challenges enables logistics business owners to better assess the advantages and disadvantages of electric vehicles when integrating them into long-distance freight transport. This article aims to explore the essential challenges of integrating electric vehicles into the freight truck transport segment and to present scientifically grounded criteria for evaluation of electric trucks, which will enable a more efficient selection process when incorporating electric trucks into standard freight transportation activities.

Keywords: freight transportation, logistics, electric freight trucks, electric vehicles

INTRODUCTION

The modern and rapidly growing logistics sector holds strategic importance within the global service business sphere. It has been preliminarily estimated that the total value of the global logistics sector in 2023 amounted to USD 9.41 trillion. According to expert forecasts, the global value of the logistics sector is expected to grow by approximately 49.6% between 2023 and 2028, reaching USD 14.08 trillion by 2028 (Statista Research Department, 2025). In the rapidly expanding logistics sector, road freight transport plays a particularly significant role in terms of operational volume and market value. The global market value of the road freight transport segment reached USD 2.73 trillion in 2024. For this logistics field, an overall value growth of over 35% is projected during the 2024–2032 period (Fortune Business Insights, 2025).

The dynamically growing road freight transport segment is currently encountering increasingly specific challenges. One of the most important trends is the expansion of Logistics 5.0 solutions, especially among large transport companies. Major freight transport businesses are actively integrating artificial intelligence solutions into route and cargo planning, applying digital twin technologies, and expanding the use of other IoT technological solutions in standard operational processes. This trend of technological advancement is driving significant investments in logistics and data transmission infrastructure and is widening the technological gap between large and small-to-medium-sized logistics enterprises, thereby limiting the latter's competitive opportunities in the market (Nicoletti, 2025).

Tightening environmental regulations are also becoming an increasingly significant operational challenge for the growing truck freight transport sector. In recent years, approximately 140 countries of various economic development levels worldwide have already adopted or are considering the adoption of net-zero environmental policies. The main objective of these policies is to achieve a balance between total emitted and removed greenhouse gas emissions (Morris et al., 2023).

Environmental standards are being tightened particularly actively in a number of economically developed countries that have set clear deadlines for implementing net-zero policies. One such region is the European Union. The EU has legally committed to achieving net-zero targets by 2050. Increasingly emission-reducing environmental standards are also prompting changes in the transport sector. A particularly relevant regulatory development for road freight transport is the EU regulation (EU) 2024/1610 adopted in 2024. This regulation mandates a gradual reduction of CO2 emissions by up to 90% (compared to 2019 levels) for all newly manufactured and newly registered medium and heavy-duty truck models by 2040 (European Parliament and Council of the European Union, 2024).

Technological progress, the need for IoT system integration, and the tightening of emission-related environmental standards are all encouraging businesses engaged in road freight transport to integrate electric vehicles into their fleets. Manufacturers are increasingly adapting electric trucks for long-distance routes, and the operational costs of electric trucks are significantly lower than those of modern diesel trucks (Danielis et al., 2025). Nevertheless, the integration of electric trucks into modern logistics businesses operating long-haul routes presents specific challenges. Even experienced actors in the freight transport sector may find it difficult to effectively identify the key challenges of integrating electric transport and to define evaluation criteria that would help select electric trucks best suited to the specific needs of their operations.

This article seeks to present an effective analysis of the core challenges associated with the integration of electric transport and to propose essential electric truck selection criteria. These criteria are intended to assist freight transport companies in effectively selecting vehicles that meet their operational requirements. To achieve this objective, the following tasks are set: (1) define the key challenges of integrating electric transport relevant to the freight transport sector; (2) identify and justify the main criteria for evaluating and selecting electric trucks; and (3) summarize the gathered information with a focus on road freight transport businesses.

Research methods: To identify and substantiate the key challenges of integrating electric transport into freight trucking operations and to establish the main criteria for evaluating and selecting electric vehicles, the methods of scientific literature review, analysis, and systematization were applied.

KEY CHALLENGES OF ELECTRIC VEHICLE INTEGRATION IN FREIGHT TRANSPORT BUSINESSES

In order to more effectively determine the key criteria for evaluating and selecting electric vehicles and define the main principles for choosing electric trucks for freight transport businesses of various sizes, it is first appropriate to examine the primary challenges of integrating electric vehicles. To accomplish this task, the latest academic literature from logistics, finance, transport engineering, and related fields was analysed. Based on this literature, the following key challenges of integrating electric trucks into long-distance freight transport have been identified and described.

Relatively high acquisition costs of electric trucks. One of the main factors limiting the rapid expansion of electric transport in the context of long-haul trucking is the relatively high acquisition and overall cost of electric trucks. When comparing the usual prices of modern electric trucks with diesel heavy truck alternatives, the acquisition costs (CAPEX) of electric vehicles typically exceed those of diesel trucks by a factor of 2 to 2.5. Although, in the context of light and medium-duty trucks, electric vehicles have demonstrated economic competitiveness since 2021 in terms of total cost of ownership (TCO), in the heavy-duty truck segment, expert assessments suggest that the total costs of electric vehicles (compared to diesel alternatives) may remain uncompetitive for decades to come (Danielis et al., 2025).

The growing popularity of long-haul electric truck acquisition is actively linked to two reasons. Electric trucks already have significantly lower operating costs than their diesel counterparts; moreover, in the context of tightening environmental standards, zero-emission electric vehicles are gaining importance as a strategic advantage. It is anticipated that electric trucks—officially recognized as a net-zero transportation option—will remain the most economically viable and environmentally friendly transport alternative in the coming years, surpassing other options such as hydrogen-powered trucks (Basma et al., 2023).

Underdeveloped charging infrastructure for electric trucks. A key challenge limiting the integration of electric transport into heavy-duty long-haul freight operations is the lack of charging infrastructure tailored to electric vehicles—particularly electric trucks. Reviewing expert academic literature reveals a global shortage of charging stations and a relatively low level of adaptation to the charging power requirements of heavy-duty electric freight vehicles. Additionally, existing electricity supply infrastructure is often outdated or insufficiently powerful to support the installation of specific charging stations for heavy trucks (e.g., limited capacity of current transformers, inadequate protection systems for high-load charging points, lack of dynamic load balancing solutions, etc.) (Sauter et al., 2021).

Moreover, certain pricing models of existing charging services are not well-suited for long-haul electric trucks. Energy providers typically apply time-of-use tariffs at charging stations. These pricing schemes increase electricity prices during peak demand periods. While this strategy helps redirect light vehicle charging demand to off-peak hours, for long-haul trucks—operating on strict schedules and predefined routes—such flexibility is often not feasible. Consequently, time-based pricing frequently results in significantly higher operating costs for transport companies (Al-Hanahi et al., 2021).

Relatively short range per single charge. This remains one of the most pressing challenges for integrating electric transport into standard long-haul freight logistics. Although new electric truck models advertise ranges of 400–500 km per charge, real-world usage often results in 20–30% shorter distances. Compared to typical industry requirements—achieving a minimum 800 km (500 miles) range between fuelings under full payload—this shorter range is a major operational constraint. In markets like the European Union, where 78% of freight transport routes are under 800 km, shorter electric truck ranges necessitate more frequent charging, resulting in increased idle time and reduced transport efficiency (Danielis et al., 2025).

Relatively long charging times for electric vehicles. Recent academic studies on electric long-haul truck charging times and operational performance reveal that for every hour spent performing freight-generating activities on highways, an additional 19–25 minutes are required for charging. These studies indicate that while long-haul electric truck usage is technologically feasible, the 16–32% increase in total transport time—compared to diesel alternatives—significantly reduces their appeal in terms of operational efficiency (Cheng, Lin, 2024).

Therefore, businesses acquiring electric trucks for long-distance freight operations should anticipate that vehicle charging will consume a considerable portion of overall operational time. To address this, companies are advised to align charging schedules with loading/unloading activities and driver rest breaks to reduce downtime and improve overall workflow efficiency.

KEY EVALUATION-SELECTION CRITERIA FOR ELECTRIC TRUCKS

Having identified and substantiated the key challenges of integrating electric transport into long-haul freight activities, it is now purposeful to define and discuss the main criteria for evaluating and selecting electric trucks. Based on these criteria, freight transport companies will be able to more effectively integrate electric trucks into daily operations, optimize vehicle investment and operating costs, and maximize truck utilization.

Detailed analysis of financial and operational costs. When selecting the most efficient electric truck for daily long-distance freight transport, it is essential to assess not only the vehicle's purchase price (capital expenditure) but also the preliminary operating costs. This category includes indicators such as the cost of electricity required for driving, repair and maintenance expenses, and indirect costs related to battery wear and other expenses. Financial analysis and calculations of vehicle return on investment should also include specific incentives increasingly applied to commercial electric transport (e.g., VAT exemptions, road tax reductions, registration fee discounts, etc.) (Danielis et al., 2025). When comparing electric trucks with traditional fuel alternatives, it is advisable not only to compare the current investment and operating costs but also to consider the potential impact of tightening environmental standards and the introduction of emission-related taxes on the economic efficiency of transport operations (Grzelakowski, 2025).

Distance covered per full charge. For long-distance freight operations, it is crucial to evaluate the distance an electric truck can cover on a single charge. Manufacturers usually indicate a theoretical maximum range based on ideal driving conditions (economical speed, optimal weather, flat terrain, partially loaded trailers, etc.). Therefore, it is important to not only rely on the theoretical range declared by the manufacturer but also to estimate the actual driving range under real-world working conditions.

Consistently operating with fully loaded trailers significantly reduces the real driving range and accelerates battery wear. Expert studies also show that winter conditions and hilly terrain can reduce the range of electric commercial vehicles by 7–9%, while aggressive driving may decrease the range by up to 20% (Dollinger, Fischerauer, 2021).

Forecasted transport distances and expected truck load level. To effectively select a specific electric truck model, it is necessary to assess the anticipated distances the vehicle will regularly travel on designated routes, as well as the expected truck load level. Both aspects of this evaluation criterion are directly influenced by the battery capacity, weight, and distribution within the vehicle. Heavier electric truck batteries (3.5–5 tons) typically feature larger capacities (600–800 kWh), enabling freight transport over long distances (400–500 km). However, considering the maximum permissible vehicle and cargo weight limits, heavier batteries also reduce the maximum cargo weight that can be transported (McNeil et al., 2023). For this reason, a proper evaluation of the truck's battery weight-to-power ratio allows the selection of vehicles better suited to the anticipated distance and cargo weight requirements.

Battery charging time and availability of charging infrastructure. When planning the acquisition of electric trucks for long-haul freight transport, it is essential to assess the expected battery charging time and the condition of the charging infrastructure. This includes modeling potential strategies to optimize charging time (e.g., charging during mandatory driver rest breaks or loading/unloading operations) and evaluating the availability of charging infrastructure along the planned routes. Although electric truck charging is significantly more complex and time-consuming than refueling diesel or gasoline trucks, expert calculations show that the use of special charging stations with at least 1 MW capacity can significantly reduce charging time (Zähringer et al., 2022).

Currently, the most widespread charging solutions include Overnight chargers (50–150 kW), which provide a deep charge (80–100%) but require around 8 hours, and Opportunity fast chargers (150–350 kW), which allow for faster charging (approximately 0.5 hours), though they only bring the battery level to about 20–60%. The most advanced 750 kW – 3 MW Opportunity ultra-fast chargers can enable electric trucks to reach a 60–80% charge within 0.5 hours, but their availability remains extremely limited (Bernard et al., 2022). Considering the technical aspects of charging infrastructure and the relatively long charging time required for electric vehicles, companies planning to acquire electric trucks should assess both the expected distances and stop frequencies, as well as the accessibility and capability of charging infrastructure to meet daily vehicle charging needs.

CONCLUSIONS

1. Upon identifying the key challenges hindering the smoother integration of electric trucks into the freight transport sector, it was observed that the main problematic factors are related to the relatively high acquisition costs of electric trucks, the comparatively long charging periods of electric vehicles, and the insufficiently developed and inadequately modern electric vehicle charging infrastructure. It was also determined that, based on current long-haul freight transport trends, the distances that electric trucks can cover on a single charge remain insufficient for some freight companies operating over longer distances.
2. After defining and describing the main evaluation and selection criteria for electric trucks, it was concluded that potential buyers of such vehicles should focus on parameters such as a detailed analysis of the financial and operational costs of the vehicle, the technical parameters of the battery (capacity-to-weight ratio), the truck's charging duration, the state of the existing charging infrastructure, the planned distances of typical freight transport routes, and the vehicle's load level.

3. In identifying the integration challenges and effective selection criteria for electric trucks, it was also found that this type of vehicle features not only limiting factors but also distinct advantages. The presented theoretical review highlights several benefits of long-haul electric trucks that are particularly important to freight companies, such as relatively low operating costs (compared to diesel trucks) and opportunities to reduce transportation expenses through better compliance with new environmental standards—achieved via lower emissions taxes, value-added tax (VAT) exemptions, and road toll incentives.

REFERENCES

Statista Research Department. (2025). Size of the logistics industry worldwide 2018-2028. Prieiga per internetą: https://www.statista.com/statistics/943517/logistics-industry-global-cagr/

Fortune Business Insights. (2025). Freight trucking market size, share & industry analysis, by truck type, by end user... and regional forecast, 2025–2032. Prieiga per internetą: https://www.fortunebusinessinsights.com/industry-reports/freight-trucking-market-105069

Nicoletti, B. (2025). *Artificial Intelligence for Logistics 5.0: From Foundation Models to Agentic AI*. Springer Nature.

European Parliament and Council of the European Union. (2024 a). Regulation (EU) 2024/1610 of the European Parliament and of the Council of 14 May 2024. Official Journal of the European Union, L series, 2024/1610. http://data.europa.eu/eli/reg/2024/1610/oj

Danielis, R., Niazi, A. M. K., Scorrano, M., Masutti, M., & Awan, A. M. (2025). The Economic Feasibility of Battery Electric Trucks: A Review of the Total Cost of Ownership Estimates. Energies, 18(2), 429. https://doi.org/10.3390/en18020429

Basma, H., Buysse, C., Zhou, Y., & Rodríguez, F. (2023). Total cost of ownership of alternative powertrain technologies for Class 8 long-haul trucks in the United States. White Paper.

Sauter, V., Speth, D., Plötz, P., & Signer, T. (2021). *A charging infrastructure network for battery electric trucks in Europe* (No. S02/2021). Working Paper Sustainability and Innovation. https://doi.org/10.24406/publica-fhg-301099

Al-Hanahi, B., Ahmad, I., Habibi, D., & Masoum, M. A. (2021). Charging infrastructure for commercial electric vehicles: Challenges and future works. Ieee Access, 9, 121476-121492. doi: 10.1109/ACCESS.2021.3108817

Cheng, X., & Lin, J. (2024). Is electric truck a viable alternative to diesel truck in long-haul operation?. *Transportation Research Part D: Transport and Environment*, *129*, 104119. https://doi.org/10.1016/j.trd.2024.104119

Grzelakowski, A. S. (2025). Market and regulatory challenges of the EU road freight transport transformation towards zero emissions.

Dollinger, M., & Fischerauer, G. (2021). *Model-Based Range Prediction for Electric Cars and Trucks under Real-World Conditions. Energies 2021, 14, 5804*. https://doi.org/10.3390/en14185804

McNeil, W. H., Tong, F., Harley, R. A., Auffhammer, M., & Scown, C. D. (2023). Corridor-level impacts of battery-electric heavy-duty trucks and the effects of policy in the United States. Environmental Science & Technology, 58(1), 33-42. https://doi.org/10.1021/acs.est.3c05139

Zähringer, M., Wolff, S., Schneider, J., Balke, G., & Lienkamp, M. (2022). Time vs. capacity—The potential of optimal charging stop strategies for battery electric trucks. Energies, 15(19), 7137.

Bernard, M. R., Tankou, A., Cui, H., & Ragon, P. L. (2022). Charging Solutions for Battery-Electric Trucks. *ICCT, Washington, USA*.