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The Role of Electromobility in the Machinery and Equipment Industry

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Decarbonisation of Business Logistics: The Role of Electromobility in the Machinery and Equipment Industry

Abstract
The decarbonisation of business logistics is becoming a strategic necessity to support sustainability within the machinery and equipment manufacturing sector. This paper examines electromobility as a key instrument for reducing carbon emissions in business logistics processes. The paper draws on a structured literature review, which evaluated current knowledge and trends relating to electromobility and its application in logistics, and builds upon primary empirical research carried out through a questionnaire survey involving 62 companies operating in Slovakia. This combined methodology enabled a comprehensive exploration of current adoption practices, anticipated benefits, and the main barriers associated with the implementation of electromobility in business logistics. The findings reveal that adoption drivers differ by enterprise size: medium-sized enterprises place greater emphasis on environmental sustainability and CO_2 reduction, while large enterprises prioritise long-term cost savings, although both recognise the value of environmental benefits. Implementation is still in an early phase, with partial deployment being most common and a substantial proportion of enterprises actively planning future integration. The most promising application areas are local and short-haul transport, alongside intra-company material handling, reflecting current technological capabilities. Key challenges include insufficient charging infrastructure and limited vehicle range, while high investment costs remain the primary financial barrier. Overall, the findings of the paper confirm that coordinated policy action, infrastructural development, and technological advancement are essential for accelerating the transition to low-carbon logistics in this industrial sector.

Key Word: Decarbonisation, Sustainable Logistics, Electromobility, Machinery And Equipment Industry

JEL Classification: O33, Q55, R41

Introduction

Business logistics in the machinery and equipment industry is characterised by the movement of both heavy and delicate components among suppliers, manufacturers, and distributors. Traditionally reliant on fossil-fuel-powered vehicles, the sector's transition

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to electromobility is vital for decarbonisation. The imperative to decarbonise business logistics is intensified by global climate commitments aiming to reduce greenhouse gas (GHG) emissions, with the machinery and equipment industry being a significant contributor through its complex supply chains and energy consumption patterns. Electromobility, the adoption and integration of electric vehicles (EV) and electric-powered machinery emerges as a critical technology facilitating the transition to low-carbon logistics in this sector.

Recent developments in EV technology, including battery management, charging infrastructure, and powertrain efficiency, have enabled wider application of electric trucks and forklifts in industrial logistics. Innovative optimisation algorithms that incorporate dynamic load factors, integrated slow and fast charging, and vehicle-to-grid interaction significantly improve operational efficiency while minimising costs and battery degradation, factors crucial for industrial adoption in machinery transport and warehousing contexts (Wu and Tian, 2024). Complementing these advances, contemporary reviews of the Green Vehicle Routing Problem position emission minimisation alongside cost and service objectives, demonstrating how modern metaheuristics reduce CO_2 through consolidation, speed smoothing, and stop sequencing (Garside et al., 2024), while freight eco-routing studies show that algorithmic route choice can cut fuel use and emissions, with realised benefits contingent on congestion, time-window constraints, and driver adherence (Pahwa et al., 2024). These advancements allow logistics operators to schedule charging during low electricity price periods and balance energy storage with operational demands, incentivising EV deployment at scale.

Electromobility forms a core component of Green Supply Chain Management (GSCM) initiatives in manufacturing industries. Green supply chains benefit from lowering GHGs. From the extraction of raw materials to the ultimate delivery to the end users, a supply chain includes the activities related to the movement and transformation of items as well as the information flows that go along with them (Pacura et al., 2024). GHGs in supply chains can be reduced by streamlining these processes and making use of new technologies. For example, logistics operations can make use of greener vehicles, such as e-bikes, electric trucks, and hydrogen-powered vehicles. Spatial modulation (SM) and index modulation (IM) are two examples of green supply technologies that can be useful. These cutting-edge communication technologies can help monitor vehicle conditions, optimise routes, and increase the efficiency of information transmission (Li et al., 2023; Wen et al., 2019). The machinery and equipment industry benefits from Industry 4.0 technologies, such as IoT, Big Data, and blockchain, to enable data-driven decision-making for fleet management, energy usage, and sustainability reporting (Labaran and Masood, 2023). At the data layer, IoT telemetry enables near-real-time monitoring of logistics-related emissions, shifting reporting from periodic estimation to continuous measurement and creating rapid feedback loops for operational abatement (Yin et al., 2024; Sepanosian et al., 2024). In parallel, digital-twin models of logistics assets and flows provide a “simulate-before-deploy” environment in which charging layouts, fleet schedules, and consolidation policies can be stress-tested against energy and emissions KPIs, de-risking investments in electrified operations (Liu et al., 2024; Rigó et al., 2024). For credible disclosure and incentive alignment, blockchain-based measurement–reporting–verification frameworks secure emissions data and automate crediting,

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strengthening trust in decarbonisation claims across multi-actor transport chains (Merlo et al., 2025). Taken together, these elements: optimisation, IoT sensing, digital twins, and blockchain MRV - constitute a complementary Industry 4.0 stack that operationalises low-carbon logistics by coupling data-driven decision support with verifiable outcomes (Fernando et al., 2021).

Policy instruments that support infrastructure rollout, especially high-capacity and standardised charging stations are fundamental for upscaling electromobility (Kraemer et al., 2023). Coupling these efforts with rational electricity pricing aligned with social marginal costs, as well as with cleaner electricity generation, enhances the environmental benefits of using EVs in logistics (Rapson and Muehlegger, 2023). The ultimate goal of every enterprise for long-term survival is sustainability in all its aspects: economic, environmental, and social (Fidlerová et al., 2022). Sustainability issues are therefore closely linked to the future development of the enterprise.

1. Methods of Research

This paper employed a mixed-method approach combining a structured literature review with primary empirical research to comprehensively examine the role of electromobility in reducing carbon emissions within business logistics in the machinery and equipment industry. The literature review was conducted following systematic search and screening procedures to identify relevant peer-reviewed journal papers. The aim was to evaluate the current state of knowledge, emerging trends, and technological developments in electromobility, as well as its potential applications in logistics processes. The insights from the literature review provided the theoretical and conceptual framework for designing the empirical research component.

The primary data collection was based on a structured questionnaire survey targeting enterprises operating in the machinery and equipment industry in Slovakia. A total of 62 enterprises participated, representing a range of geographical regions and organisational sizes. The survey results were analysed using descriptive statistical methods to determine percentage distributions and differences between medium-sized and large enterprises.

2. Results of the Research

The research sample consisted of 62 enterprises operating in the machinery and equipment industry in Slovakia. In terms of company size, no small enterprises (0.00%) participated, while 12 medium-sized enterprises (19.35%) and 50 large enterprises (80.65%) were represented. The geographical distribution of respondents covered all Slovak regions, with the largest share from the Bratislava Region (24.19%), followed by the Žilina Region (19.35%) and the Trenčín Region (16.13%). Smaller proportions were recorded in the Trnava Region (14.52%), the Košice Region (9.68%), and the Nitra and Prešov Regions (6.45%). The Banská Bystrica Region accounted for the lowest representation (3.23%).

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Regarding the primary business focus, the overwhelming majority of respondents were engaged in manufacturing machinery and equipment (82.26%), while smaller shares were active in repair and maintenance of machinery (12.90%) and in logistics and transport services for machinery (4.84%). No respondents fell into the "other" category. In terms of sustainability orientation, more than half of the enterprises reported having a strong sustainability strategy with defined targets (56.45%), while 37.10% enterprises had undertaken some initiatives without a formal strategy. Only 6.45% enterprises indicated that they were meeting only the minimum regulatory requirements, and none reported having no sustainability measures in place.

The results presented in Table 1 indicate that the primary motivation for adopting electromobility in business logistics varies slightly between medium-sized and large enterprises in the machinery and equipment industry in Slovakia. For medium-sized enterprises, environmental sustainability and CO_2 reduction constitute the most frequently cited driver (41.67%), followed by long-term cost savings (33.33%). In contrast, large enterprises place greater emphasis on the economic dimension, with 40.00% identifying cost savings as their strongest incentive, while environmental considerations rank second at 34.00%. Compliance with legislation and regulations emerges as a moderate influence for both groups, accounting for 16.67% of medium-sized and 20.00% of large enterprises. Company reputation and branding are mentioned least often, reported by just 8.33% of medium-sized and 6.00% of large enterprises.

Tab. 1: Strongest driver for electromobility adoption

Option	Medium-sized	Large
Environmental sustainability and CO_2 reduction	41.67 %	34.00 %
Compliance with legislation and regulations	16.67 %	20.00 %
Long-term cost savings	33.33 %	40.00 %
Company reputation and branding	8.33 %	6.00 %
Total	100.00 %	100.00 %

Source: own elaboration

The data in Table 2 reveal that electromobility integration in business logistics is still in an emerging phase for both medium-sized and large enterprises in the machinery and equipment industry in Slovakia. Partial implementation dominates in both groups, reported by half of medium-sized enterprises (50.00%) and 44.00% of large ones, indicating that many enterprises are in the process of gradual adoption. A considerable share is still at the planning stage, accounting for 33.33% of medium-sized and 36.00% of large enterprises, suggesting a strong pipeline of future initiatives. Fully implemented systems remain relatively uncommon, observed in only 8.33% of medium-sized and 12.00% of large enterprises, reflecting the technological, financial, and infrastructural challenges of complete integration. Notably, the proportion of enterprises with no electromobility adoption is minimal and nearly identical between the two groups (8.33% and 8.00%)

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Tab. 2: Current level of electromobility implementation

Option	Medium-sized	Large
Fully implemented	8.33 %	12.00 %
Partially implemented	50.00 %	44.00 %
Planning to implement	33.33 %	36.00 %
No implementation yet	8.33 %	8.00 %
Total	100.00 %	100.00 %

Source: own elaboration

As shown in Table 3, both medium-sized and large enterprises in the machinery and equipment industry in Slovakia identify local and short-haul transport as the most suitable area for electromobility deployment, with 41.67% and 44.00% respectively selecting this option. Intra-company material handling is the second most frequently mentioned area, cited by 33.33% of medium-sized enterprises and 30.00% of large enterprises, reflecting the practicality of introducing electric solutions in controlled, shorter-range environments. Long-distance transport is considered the least appropriate for electrification at this stage, with only 8.33% of medium-sized and 10.00% of large enterprises identifying it as the primary target, likely due to limitations in range and charging infrastructure. Service and support vehicles hold a similar position in both categories, reported by 16.67% of medium-sized and 16.00% of large enterprises, suggesting a moderate but consistent opportunity for electrification in supplementary operational roles.

Tab. 3: Most suitable logistics area

Option	Medium-sized	Large
Intra-company material handling	33,33 %	30,00 %
Local/short-haul transport	41,67 %	44,00 %
Long-distance transport	8,33 %	10,00 %
Service and support vehicles	16,67 %	16,00 %
Total	100.00 %	100.00 %

Source: own elaboration

Table 4 indicates that insufficient battery charging infrastructure is perceived as the most significant technical barrier to electromobility adoption in logistics, reported by 41.67% of medium-sized enterprises and 36.00% of large enterprises in the machinery and equipment industry in Slovakia. Limited vehicle range emerges as the second most pressing concern, reported by 25.00% of medium-sized and 28.00% of large enterprises, reflecting the ongoing limitations of current battery technologies for longer or more demanding routes. Payload and performance constraints are more frequently mentioned by large enterprises (24.00%) than medium-sized ones (16.67%), likely due to the heavier transport requirements typical in larger-scale operations. Finally, a lack of technical knowledge is recognised as a challenge by 16.67% of medium-sized and 12.00%

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of large enterprises, suggesting that while skills gaps exist, they are considered less critical than infrastructure and technology performance issues.

Tab. 4: Main technical challenge

Option	Medium-sized	Large
Limited vehicle range	25.00 %	28.00 %
Battery charging infrastructure	41.67 %	36.00 %
Payload and performance limitations	16.67 %	24.00 %
Lack of technical knowledge	16.67 %	12.00 %
Total	100.00 %	100.00 %

Source: own elaboration

Table 5 shows that both medium-sized and large enterprises in the machinery and equipment industry in Slovakia generally perceive the economic viability of electromobility for decarbonising logistics as positive but not without reservations. The largest share in both groups rates it as moderately cost-effective, with 41.67% of medium-sized and 40.00% of large enterprises holding this view, suggesting cautious optimism about financial returns. A substantial proportion remains uncertain or expects only break-even outcomes, 33.33% among medium-sized and 36.00% among large enterprises, indicating that many companies are still awaiting clearer evidence of long-term profitability. A smaller share considers electromobility to be very cost-effective (16.67% of medium-sized, 12.00% of large enterprises), while an equally small segment sees it as not cost-effective at all (8.33% of medium-sized, 12.00% of large enterprises).

Tab. 5: Economic viability assessment

Option	Medium-sized	Large
Very cost-effective	16.67 %	12.00 %
Moderately cost-effective	41.67 %	40.00 %
Uncertain or break-even	33.33 %	36.00 %
Not cost-effective	8.33 %	12.00 %
Total	100.00 %	100.00 %

Source: own elaboration

Table 6 illustrates that both medium-sized and large enterprises in the machinery and equipment industry in Slovakia view government and regulators as the most influential stakeholders in accelerating electromobility adoption in logistics, with 41.67% of medium-sized and 44.00% of large enterprises identifying them as key drivers. This highlights the expectation that public policy, regulatory frameworks, and financial incentives will play a decisive role in shaping the pace and scope of implementation. Manufacturers and technology providers are the second most frequently mentioned group, cited by 25.00% of medium-sized and 24.00% of large enterprises, reflecting the importance of technological readiness and product availability. Customers and clients (16.67% of medium-sized, 18.00% of large enterprises) and industry associations

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(16.67% of medium-sized, 14.00% of large enterprises) are seen as having a supportive but less dominant role.

Tab. 6: Stakeholder with the biggest role

Option	Medium-sized	Large
Manufacturers and technology providers	25.00 %	24.00 %
Government and regulators	41.67 %	44.00 %
Customers and clients	16.67 %	18.00 %
Industry associations	16.67 %	14.00 %
Total	100.00 %	100.00 %

Source: own elaboration

Table 7 shows that high purchase and investment costs are perceived as the dominant barrier to electromobility implementation in logistics in the machinery and equipment industry in Slovakia, reported by half of medium-sized enterprises (50.00%) and nearly the same proportion of large enterprises (48.00%). Insufficient charging infrastructure ranks as the second most significant challenge, identified by 25.00% of medium-sized and 24.00% of large enterprises, underscoring the continuing limitations of support facilities. Technical constraints related to vehicle range and load capacity are mentioned by 16.67% of medium-sized and 18.00% of large enterprises, reflecting the performance demands of logistics operations. The least frequently cited barrier is the lack of qualified personnel, reported by only 8.33% of medium-sized and 10.00% of large enterprises, suggesting that workforce capabilities are not currently considered a major obstacle compared to financial and infrastructural issues.

Tab. 7: Biggest overall challenge to implementation

Option	Medium-sized	Large
High purchase and investment costs	50.00 %	48.00 %
Insufficient charging infrastructure	25.00 %	24.00 %
Technical limitations (range, load capacity)	16.67 %	18.00 %
Lack of qualified personnel	8.33 %	10.00 %
Total	100.00 %	100.00 %

Source: own elaboration

Table 8 indicates that both medium-sized and large enterprises in the machinery and equipment industry in Slovakia view environmental and economic outcomes as the primary benefits of electromobility in logistics. Reduced emissions and environmental impact are most frequently cited by medium-sized enterprises (41.67%) and remain a leading factor for large enterprises (36.00%), reflecting the sector's recognition of electromobility's role in achieving sustainability targets. Lower operating costs are the second most important benefit, reported by 33.33% of medium-sized and 34.00% of large enterprises, suggesting that financial efficiency is an equally compelling incentive. Meeting customer or market expectations is mentioned by a smaller proportion of

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respondents (16.67% and 18.00%), indicating that while market pressure plays a role, it is secondary to direct operational and environmental gains. Compliance with regulations is the least frequently cited benefit, noted by 8.33% of medium-sized and 12.00% of large enterprises, which suggests that current adoption is driven more by strategic and economic considerations than by regulatory obligations.

Tab. 8: Most important expected benefits

Option	Medium-sized	Large
Reduced emissions and environmental impact	41.67 %	36.00 %
Lower operating costs	33.33 %	34.00 %
Meeting customer/market expectations	16.67 %	18.00 %
Compliance with regulations	8.33 %	12.00 %
Total	100.00 %	100.00 %

Source: own elaboration

3. Discussion and Conclusion

The findings of this paper reveal that the adoption of electromobility in the machinery and equipment industry in Slovakia is shaped by a complex interplay of environmental aspirations, economic considerations, and policy influences. Medium-sized enterprises demonstrate a stronger inclination towards environmental sustainability and CO_2 reduction as their primary adoption driver, while large enterprises place slightly more emphasis on long-term cost savings, though still recognising the importance of environmental benefits. This divergence may reflect differences in operational scale, investment capacity, and strategic priorities, with larger enterprises potentially better positioned to capitalise on cost efficiencies over time. Implementation levels show that electromobility integration remains in a formative stage, with partial deployment as the prevailing condition. A significant share of enterprises is in the planning phase, suggesting considerable latent growth potential in the near term. The most suitable applications are identified in local and short-haul transport, complemented by intra-company material handling, reflecting a focus on operational environments that align well with current battery range capabilities. However, several constraints persist. Insufficient charging infrastructure is the most frequently cited technical challenge, followed by limited vehicle range. Economic viability is generally viewed with cautious optimism, though one-third of enterprises remain uncertain about profitability. Financial barriers are prominent, with high investment costs being the leading obstacle, underscoring the need for targeted support mechanisms. The expectation that government and regulators will play the most significant role in driving adoption highlights the importance of policy stability, incentive schemes, and infrastructural investment.

The dynamics of electromobility development are also visible in European Union countries. Finland has legally bound carbon neutrality for 2035 and a Fossil-Free Transport roadmap targeting ≥50% cuts in domestic transport GHGs by 2030 (vs. 2005) and a fossil-free transport sector by 2045, signalling strong policy certainty for

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electromobility investment (International Energy Agency, 2023). Austria's long-term climate strategy to 2050 likewise prioritises electrification in transport as part of its neutrality target, reinforcing the role of national roadmaps (Federal Ministry for Sustainability and Tourism, 2020). France has modelled the infrastructure scale-up needed to sustain the transition: ~350,000 public chargers by 2030 (and 5.7–6.0 million total chargers when home/workplace are included), with fast-highway chargers rising to ~4,400 by 2030—a planning baseline that links EV uptake to concrete network growth (International Council on Clean Transportation, 2021). The Netherlands is piloting battery-electric drayage at the Port of Rotterdam to establish business cases and charging logistics for short-haul operations (Smart Freight Centre, 2024). Germany is attacking the principal barrier-en-route charging-via a national programme to install ~350 HDV fast-charging sites covering ~95% of federal highways, aligned with a goal for one-third of heavy road haulage to be electric or run on renewable fuels by 2030 (Alkousaa, 2024). Sweden's system analyses quantify cost-optimal decarbonisation pathways for heavy-duty road transport, finding that BEV-dominant or BEV+FCV mixes can meet long-haul needs under differing infrastructure timings and cost assumptions (Parviziomran and Bergqvist, 2025; de Oliveira Laurin et al., 2025). Spain's grid-facing studies show that achieving ~4 million EVs (~20.7% fleet) will require distribution-network upgrades and enabling regulation, complementing the NECP's target of 5 million EVs by 2030 (Martínez-Lao et al., 2025). The Alternative Fuels Infrastructure Regulation (AFIR) mandates HDV charging hubs at least every 60 km on the TEN-T core and every 100 km on the wider network by 2030, while technical briefs estimate that ~1,000 MCS-equipped stations could enable ~91% of long-haul trucking flows-providing a continental backbone for zero-emission logistics (T&E, 2024; Fraunhofer Institute for Systems and Innovation Research ISI, 2024). Poland's comparative life-cycle assessments show EVs already outperform ICEVs on GHGs under the current grid mix, with further gains expected as the power sector decarbonises (Burchart-Korol et al., 2018). The Czech Republic's recent assessment confirms EV adoption reduces the carbon footprint and urban noise, underscoring environmental co-benefits that complement decarbonisation goals (Turek et al., 2024).

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