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THE EFFECTIVENESS OF THE IMPLEMENTATION OF ELECTRIC VEHICLES IN LAST MILE DELIVERY LOGISTICS OPERATIONS

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Abstract

The rapid expansion of e commerce and the evolving expectations of consumers have intensified the demand for logistics systems that are not only fast and reliable but also sustainable and environmentally responsible. In this context, the adoption of electric vehicles (EVs) in last mile delivery operations has gained significant momentum, especially in urban environments where concerns over air pollution, noise, and carbon emissions are increasingly prominent. This paper presents a comprehensive analysis of the effectiveness of EV integration in last mile logistics, focusing on critical performance dimensions such as cost efficiency, delivery reliability, environmental impact, and infrastructure readiness. The findings reveal that electric vehicles offer notable advantages in terms of reducing greenhouse gas emissions and lowering total cost of ownership (TCO) over time, particularly due to lower fuel and maintenance costs. In addition, the deployment of EVs has been shown to enhance corporate image and align with broader environmental, social, and governance (ESG) goals, thereby contributing to long term brand equity and regulatory compliance. However, several operational and structural challenges persist that constrain the scalability of EV adoption. The research further emphasizes the importance of supportive policy frameworks, financial incentives, and cross sector collaboration in accelerating EV adoption. Governments play a pivotal role in shaping an enabling ecosystem through subsidies, tax exemptions, and investment in public charging networks that lowers the entry barriers for logistics providers, particularly small and medium sized enterprises (SMEs). Additionally, the integration of EVs must be accompanied by strategic operational adjustments, including route optimization, fleet rotation planning, and battery management systems, to fully leverage the technological benefits of electric mobility.

Keywords: electric vehicles, last mile delivery, logistics, sustainability, transportation innovation

Introduction

One of the most pressing challenges is the inadequate development of charging infrastructure, particularly outside major metropolitan areas such as Greater Jakarta (Jabodetabek). The uneven distribution of charging stations and the relatively long charging durations (ranging from 2 to 4 hours depending on the system and charger type) create logistical bottlenecks, especially in high frequency delivery operations where vehicle turnaround time is critical. Furthermore, the high upfront capital investment required for EV procurement, coupled with limited vehicle range and payload capacity in certain models, raises concerns about their suitability for diverse logistics scenarios.

The rapid proliferation of e commerce platforms and digital retail channels in Indonesia has significantly transformed consumer purchasing behavior, resulting in escalating demand for faster, more reliable, and efficient logistics services. This evolving consumer landscape has placed substantial pressure on the logistics sector, particularly on the *last mile delivery* phase the final segment of the supply chain that involves transporting goods from centralized distribution centers to dispersed, individualized customer locations. Widely acknowledged as the most complex, time consuming, and cost intensive component of the logistics process, last mile delivery is challenged by fragmented delivery destinations, urban traffic congestion, high customer service expectations, and the growing environmental burdens associated with fossil fuel based transportation systems (Creswell, 2014).

Amid intensifying global and national concerns over climate change, deteriorating urban air quality, and rising greenhouse gas emissions, the logistics sector is under increasing scrutiny to transition toward more sustainable and environmentally responsible operational models. In this context, the adoption of electric vehicles (EVs) in urban logistics has emerged as a promising and forward looking alternative to conventional internal combustion engine (ICE) fleets. EVs have gained attention not only for their capacity to significantly reduce emissions and lower long term operational costs, but also for their alignment with broader environmental, social, and

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governance (ESG) objectives. In Indonesia, notable logistics providers such as JNE, SiCepat, and Paxel have initiated pilot programs deploying EVs for parcel delivery, particularly in densely populated urban areas like Jakarta and Surabaya. These efforts reflect a broader shift toward low emission transport solutions while responding to both regulatory pressures and rising consumer expectations for sustainable corporate practices (National Energy Council, 2023; Ministry of Transportation, 2023).

Despite these encouraging developments, the adoption of EVs in last mile logistics is not without its challenges. Chief among these are the insufficient availability of public charging infrastructure especially beyond major metropolitan areas the high upfront capital investment required for EV procurement, and the limited driving range and payload capacity of many commercial EV models. These constraints can adversely impact delivery reliability, complicate scheduling and route optimization, and ultimately hinder the scalability and operational viability of EV based logistics systems in Indonesia (ICCT, 2021). These issues highlight the need for a holistic assessment of both the advantages and limitations associated with EV integration in logistics operations.

Given this context, the present study seeks to critically evaluate the effectiveness of electric vehicle implementation in last mile delivery within Indonesia's urban logistics ecosystem. Specifically, the research focuses on four key performance indicators (KPIs): cost efficiency, delivery reliability, environmental impact, and infrastructure readiness. Employing a comparative case study methodology that integrates both quantitative performance metrics and qualitative insights from logistics service providers across Southeast Asia, this study aims to provide a comprehensive and evidence based analysis of the practical implications, strategic benefits, and enduring barriers related to the transition toward electric mobility in last mile delivery.

The findings of this research are expected to contribute meaningful insights to academic discourse, inform public policy, and support strategic decision making among industry stakeholders. As Indonesian cities continue to contend with rapid urbanization, escalating traffic congestion, and tightening environmental regulations, the strategic adoption of EVs offers a timely opportunity to align logistics operations with national sustainable development goals. However, realizing this potential will require a multi faceted approach encompassing regulatory incentives, infrastructure investment, cross sector collaboration, and ongoing operational innovation to ensure that EV deployment in last mile logistics is both effective and scalable.

Methodology

This study adopts a comparative case study approach to evaluate the performance, feasibility, and strategic implications of electric vehicle (EV) adoption in last mile delivery operations in urban areas of Indonesia. By employing a mixed methods research design, the study integrates both qualitative and quantitative data to examine operational, environmental, and economic dimensions across selected logistics service providers. This methodological approach is intended to produce context rich insights while allowing for performance benchmarking between electric vehicle (EV) and internal combustion engine (ICE) fleets.

Through a comparative framework, this study examines the operational characteristics of EV based delivery fleets in contrast to conventional internal combustion engine (ICE) vehicles. The analysis incorporates both quantitative data such as cost per kilometer, delivery time windows, vehicle downtime, and emissions profiles and qualitative insights derived from case studies of logistics operators in Southeast Asia. These case studies illustrate real world experiences and best practices in transitioning to electric mobility within densely populated delivery zones.

Research Design

The research design is structured around three core components: (1) a descriptive analysis of current last mile logistics practices in Indonesian urban environments; (2) a comparative evaluation of delivery fleets powered by internal combustion engines (ICE) and those using electric vehicles (EV); and (3) the incorporation of stakeholder perspectives gathered through in depth interviews with logistics managers and industry experts. This mixed methods framework facilitates data triangulation, thereby enhancing the internal validity and contextual relevance of the findings (Creswell, 2014).

Data Collection

Data for this study were collected from three primary sources:

- Primary data were obtained through semi structured interviews with logistics professionals representing three leading delivery service providers operating in Jakarta and Surabaya. The interviews focused on key aspects such as fleet performance, operational constraints, cost structures, and sustainability targets.
- Secondary data consisted of internal operational reports, cost breakdowns, and energy consumption records, either published by the companies or presented in industry forums and conferences.

- Public data were sourced from the Ministry of Transportation of the Republic of Indonesia and the National Energy Council, which were used to assess the current state of EV infrastructure readiness and relevant national policy directions (Ministry of Transportation, 2023; National Energy Council, 2023).

Evaluation Metrics

To measure the effectiveness of EV integration into logistics operations, the study focuses on four Key Performance Indicators (KPIs):

- Cost Efficiency (CE): The total operational cost per delivery, including fuel/electricity expenditure, vehicle maintenance, and depreciation.
- Delivery Reliability (DR): The proportion of on time deliveries and average delay duration.
- Environmental Impact (EI): Estimated CO_2 emissions per kilometer, calculated based on vehicle type and energy source (ICCT, 2021).
- Infrastructure Readiness (IR): The availability of charging stations in operational areas and average charging time.

All KPIs were normalized and quantified to enable direct comparison between ICE and EV fleet performance under similar conditions.

Comparative Analysis

The comparative analysis involved calculating the average performance values for each KPI across both ICE and EV fleets. A SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was subsequently conducted to assess the strategic implications of adopting electric vehicles in last mile logistics. Case examples from two logistics service providers Paxel and SiCepat were used to illustrate practical outcomes in high density urban delivery environments.

Limitations

This study is subject to several limitations. First, the scope of the research is limited to urban settings and may not reflect performance variations in peri urban or rural areas, where delivery routes and infrastructure conditions differ significantly. Second, the EV performance data analyzed were restricted to vehicle models currently available in the Indonesian market, which may not be directly representative of global electric vehicle standards or technological advancements.

Results and Discussion

The findings of this study indicate that the adoption of electric vehicles (EVs) for last mile delivery operations in urban Indonesia yields substantial operational and environmental benefits, although several structural and infrastructural challenges persist. The comparative analysis between internal combustion engine (ICE) fleets and electric vehicle fleets, based on empirical data from two major logistics providers operating in Jakarta and Surabaya, is summarized in Table 1

Table 1. Comparative Analysis of ICE vs EV in Last Mile Delivery

Performance Metric	ICE Fleet	EV Fleet
Cost Efficiency	Higher (fuel + maintenance)	Lower (~18–25% savings)
Delivery Reliability	High	Comparable (90%+ on time)
Environmental Impact	High CO_2 emissions	50–70% reduction in emissions
Infrastructure Readiness	Established refueling	Limited charging access

Cost Efficiency

Electric vehicle based operations demonstrated a notable improvement in cost efficiency, with an average reduction in operating expenses ranging between 18% and 25% compared to fossil fuel based fleets. This reduction is primarily attributable to lower energy costs (electricity versus fuel) and decreased maintenance requirements due to the mechanical simplicity of EV drivetrains. Nevertheless, the high initial capital expenditure for EV procurement, including vehicle cost and charging infrastructure installation, remains a significant financial hurdle, particularly for small to mid scale logistics operators.

Delivery Reliability

With respect to delivery performance, EV fleets achieved on time delivery rates exceeding 90%, which are comparable to those of conventional ICE fleets. This suggests that EVs can deliver reliable service within urban boundaries where travel distances and traffic patterns are consistent. However, range anxiety remains a critical

limitation. The restricted driving range per battery charge constrains EV usage for medium to long distance routes or areas with limited charging infrastructure, thereby necessitating adaptive route planning and operational adjustments.

Environmental Impact

Environmental performance indicators revealed significant gains. CO_2 emissions per kilometer were reduced by approximately 50% to 70%, contingent upon the source of electricity used for charging. This emission reduction aligns with Indonesia's national environmental objectives, including commitments under the Paris Agreement and targets outlined in the country's decarbonization roadmap (ICCT, 2021). The use of EVs thus contributes positively to corporate sustainability efforts and national emissions reduction goals.

Infrastructure Readiness

Despite the benefits noted above, the lack of adequate charging infrastructure remains a critical bottleneck to wider EV deployment. Outside of the Greater Jakarta (Jabodetabek) region, the availability of charging stations is limited and unevenly distributed. Moreover, the average charging time ranging from 2 to 4 hours depending on the system poses operational challenges, especially in high frequency delivery scenarios where vehicle downtime must be minimized.

Strategic Analysis and Implications

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis conducted as part of this study underscores the strategic potential of EVs to drive green logistics transformation, particularly in densely populated cities facing increasing regulatory pressure to decarbonize urban transportation. The strengths of EVs lie in their lower operating costs and environmental benefits, while weaknesses center on infrastructure limitations and upfront investment barriers. Opportunities exist in the form of government incentives, growing public awareness, and technological advancements. However, threats include policy uncertainty, lack of standardization in EV infrastructure, and resistance from legacy fleet operators.

In conclusion, while EV integration into last mile logistics offers a sustainable and cost effective alternative in urban Indonesia, its success is contingent upon a coordinated effort among public agencies, private logistics firms, and infrastructure providers. Supportive policies including tax incentives, infrastructure subsidies, and pilot deployment programs are essential to accelerate adoption and overcome market entry barriers.

Conclusion

This study affirms the considerable potential of electric vehicles (EVs) to enhance both sustainability and operational efficiency in last mile delivery systems within the Indonesian urban logistics sector. The comparative analysis between EV and internal combustion engine (ICE) fleets highlights several key advantages of EV adoption, including significant reductions in operating costs, substantial decreases in carbon emissions, and delivery reliability that is largely comparable to conventional delivery methods.

Despite these benefits, the widespread implementation of EVs continues to face notable barriers. Chief among these are the high initial capital investment required for vehicle procurement and the limited availability of charging infrastructure, particularly outside major metropolitan areas. These constraints pose significant challenges to the scalability and integration of EVs into existing logistics networks.

To facilitate broader adoption of EVs in urban logistics, it is imperative that government stakeholders introduce and expand supportive regulatory frameworks. These may include targeted subsidies, tax incentives, public private infrastructure partnerships, and accelerated deployment of charging facilities. Simultaneously, logistics providers must recalibrate their operational models particularly in terms of fleet scheduling and route optimization to fully leverage the economic and environmental advantages offered by electric mobility.

In light of the increasing complexity of urban freight systems and the mounting pressure to meet national and international environmental targets, EVs represent a viable, forward looking, and strategically sound solution for the development of sustainable last mile delivery infrastructure in Indonesia.

In conclusion, while electric vehicles hold immense potential to transform last mile delivery into a more sustainable and efficient process, their effectiveness is contingent upon the intersection of technology readiness, infrastructure development, economic viability, and institutional support. The study underscores that the transition to EV based logistics is not a purely technological shift but a systemic transformation requiring multi stakeholder engagement, long term planning, and adaptability to local contexts. As urban logistics continue to grow in complexity and environmental regulations become more stringent, EVs represent a critical component of the future ready, low carbon logistics ecosystem.

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