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Mapping Technological Innovation for the Implementation of Green Logistics in the Indonesian Courier Express Parcel (CEP) Industry

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Abstract: The rapid growth of the Indonesian Courier, Express, and Parcel (CEP) sector, fueled by e-commerce, has brought economic benefits but also significant environmental challenges. This research explores the potential of technology to implement green logistics practices within the Indonesian CEP industry, contributing to the global sustainability goals. A comprehensive literature review identified key technologies like electric vehicles, drones, AI, IoT, and sustainable packaging as crucial enablers of green logistics. Challenges such as high initial costs and regulatory hurdles were acknowledged. A proposed framework integrating these technologies into CEP operations was refined based on expert interviews, emphasizing the Indonesian context and the need for government support and incentives. The research concludes that a technology-driven approach to green logistics is vital for the CEP sector's sustainable future, highlighting potential benefits and addressing implementation challenges. The refined framework provides a practical roadmap for companies in Indonesia to adopt green technologies and contribute to a greener ecosystem. Future research directions include investigating the economic impact of green logistics on the Indonesian CEP sector and exploring the role of consumer awareness and behavior in driving sustainable practices.

Keyword: Green logistics, CEP (Courier, Express, and Parcel), Technology, Framework

INTRODUCTION

The CEP sector in Indonesia is booming driven by the growth of e-commerce which has a positive impact on the economy and ease of access to goods for the public (Mordor Intelligence 2021) On the other hand, this growth also has significant environmental consequences. Transportation and logistics activities, including courier services, produce greenhouse gas emissions, air pollution, and packaging waste that pollute the environment (McKinnon et al. 2010) This is a serious concern considering its impact on human health and environmental sustainability. In an effort to minimize these negative impacts, green logistics practices offer a way to create a more sustainable delivery system. In relation to realizing the

vision of COP28 which follows the Paris Climate Agreement (Chelly et al. 2019; Rogelj et al. 2016) Not only the government but also the business world is required for the Government and companies to show environmental commitment through concrete actions, such as environmentally friendly logistics practices (Nguyen and Adomako 2022; Van Vo and Nguyen 2023) The obstacles faced by express courier service providers lie in the understanding of the concept of green logistics among business practitioners that are not uniform and comprehensive, the development of new business models for CEP services has not touched on the new concept *of green logistics,* the large operational costs that arise so that there are still not many express courier service companies that are not aware of their role in realizing *green logistics.*

Considering the nature of green logistics as a form of modern logistics (Seroka-Stolka Oksana and Ociepa-Kubicka 2019) of course, it is closely related to the use of technological innovations. As more and more companies move to greener business practices, trends in business models and innovations that help companies create more sustainable business performance are emerging (Ma and Kim 2023; Osman et al. 2023) ranging from the use of robots (Yudiansyah et al. 2020), drones to artificial intelligence (Feng, Lai, and Zhu 2022) Therefore, it is necessary to discuss the implementation of technology in new business models for CEP services, especially in Indonesia.

Several examples of the realization of a joint commitment to the implementation of green logistics have started from Mitsubishi Motors' commitment with several logistics company partners to collaborate to carry out a pilot feasibility study of the *kei-car class EV* in Indonesia with the Mitsubishi Minicab-MiEV model. Commitments such as the Mitsubishi Minicab-MiEV are used for research and utilization of logistics partners in using the electric car for six months in its logistics operations in the Greater Jakarta area. According to the green logistics report (18), DHL's logistics practices are able to reduce greenhouse gas emissions by 450,000 tonnes and reduce energy used in buildings and facilities by 2.4 percent. UPS's green logistics practices can reduce CO2 emissions by up to 21,000 tonnes and save up to 8.3 million litres of fuel. Green practices like this are a good reference for contributions to literature, the business world, the government and society. The problems that will be solved in the application of green logistics in CEP services include what technologies are most suitable to be applied based on the existing literature; what solutions can be proposed to overcome obstacles that hinder the implementation of green logistics; and the right form of logistics model design to integrate these technologies in realizing green logistics practices in courier services. Therefore, this research is needed to answer the existing research gap, namely the alignment of the vision of the green economy in the topic of green logistics in the context of application in the business process of the CEP industry.

In the discussion of green economy, technological innovation, and environmentally friendly logistics that have been implemented in China, it has been proven that in the short and long term, green logistics will encourage technological innovation and the evolution of an environmentally friendly economy (Xu and Li 2024) For this reason, Indonesia as a country with a large CEP service market is expected to do the same. This is considering the opportunities in the implementation of green logistics. The commitment of transportation and logistics business actors is crucial to accelerating the use of the latest innovations and the realization of a "*green*" ecosystem in Indonesia. However, in the application of the green logistics process, it is necessary to identify in what process the use of technology can be applied. This research is a qualitative research with an exportative approach that uses the DSR Analysis Model or known as *the Design Science Research Process Model* (DSRM), which is a qualitative research approach whose object of study is the design process. DSRM is an effective analytical tool for improving the cognitive design process model obtained by observing the design process in various applications.

The development of research on green logistics is widely carried out at home and abroad. Green logistics research currently discusses a lot in general on various industries, but not many studies explore its direct application to the parcel express courier service industry or what is later called (CEP). Several studies on green logistics have been studied from various industries ranging from automotive in India (Chhabra, Garg, and Singh 2017) to e-commerce in China (Yunlin 2023) but also from the transportation industry (Zhang et al. 2014) to mainland Europe (Beškovnik and Twrdy 2012) In Indonesia itself, green logistics research is in a broader scope of discussion, namely *green supply chain* (Ariyanti 2018) and limited to causal relationship analysis (Effendi, Widjanarko, and Sugandini 2021; Firmansyah and Maemunah 2021)), longitudinal studies (Puspani, van Dun, and Wilderom 2022)transportation human resources (Dewi et al. 2023) and *reverse logistics* (Sheu, Chou, and Hu 2005). This makes researchers see a need for research that aims to explore the design of logistics business processes on the specific economic impact of green logistics on Indonesia's CEP sector. This study aims to bridge this gap by analyzing the challenges and opportunities for implementing green logistics technology, especially its application in Indonesia's CEP sector.

METHOD

To achieve the objectives of this research, the Design Science Research (DSR) model, also known as the Design Science Research Process Model (DSRM), was employed. This methodological approach provides a framework for researchers aiming to create and enhance artifacts, objects, or deliverables that address practical problems (Geerts 2011; Takeda, Veerkamp, and Yoshikawa 1990). Its iterative nature and emphasis on evaluation ensure the relevance and effectiveness of the designed solutions. As research needs evolve, DSRM continues to be a robust methodology for generating impactful knowledge across various disciplines (Carstensen and Bernhard 2019).

The first stage of this research commenced with understanding and identifying the challenges encountered in the implementation of green logistics within the CEP industry under existing conditions. This phase involved defining the research problem and objectives, as well as delineating the research scope to ensure focused discussions.

The second stage, "Input," entailed the collection of literature related to the potential, barriers, and opportunities associated with technology adoption in green logistics CEP business processes, mapping the existing conditions, and gathering quantitative data. Both primary and secondary data sources were utilized in this stage. Primary data was obtained through a survey to CEP business operator to gather input for the preliminary design of business processes in the implementation of green logistics within courier, express, and parcel (CEP) services. Secondary data was collected through literature reviews and reports on green logistics implementation in CEP business processes.

The third stage involved the “development” of a preliminary design for green logistics business processes through interview. This stage aimed to produce a final output in the form of a logistics business process design incorporating green logistics concepts within CEP companies. The FGDs were conducted to enhance the validity and reliability of the identified potential opportunities and barriers associated with green logistics implementation.

The fourth stage encompassed the “evaluation" of the logistics business process design with the implementation of green logistics concepts within CEP companies. In-depth interviews with experts and stakeholders were conducted to assess the feasibility of implementing the designed green logistics business process and to identify strategies to support its implementation.

The final stage of this research involved drawing conclusions on the design strategy for implementing the new green logistics CEP business process generated through this research.

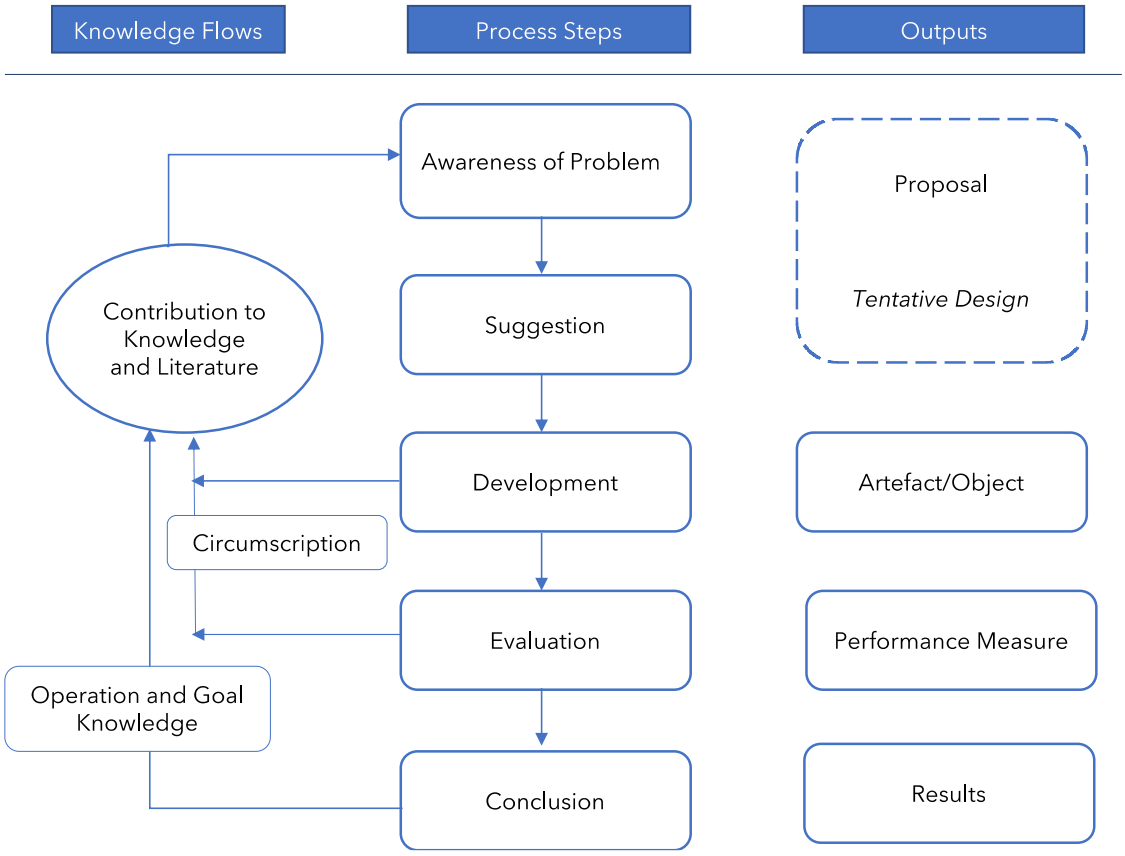


Figure 1. DSRM
Source: Processed by The Authors

RESULTS AND DISCUSSION

This research collected articles from various academic journal for the topic of implementation of technology in logistics sector for greener solution in literature basis data.

Renewable Energy and Electrification

Multiple articles emphasize the importance of renewable energy and electric vehicles in reducing carbon emissions in logistics operations. Electric vehicles (EVs) and renewable energy-powered warehouses (Kumar and Sharma 2024; Smith 2024) reflect a strong focus on sustainable energy solutions. The use of solar and wind energy in logistics (Article 59) further strengthens the case for integrating renewable sources into warehouses and other logistics infrastructure.

AI and Machine Learning

AI-powered solutions are consistently cited (Q. Liu 2024; Tang and Veelenturf 2019) as key to optimizing logistics through route planning, fuel efficiency, and predictive analytics. These technologies help reduce emissions and enhance operational efficiency. Machine learning, often combined with AI (Halverson 2024) is essential in enabling real-time decision-making in logistics, further promoting sustainability by optimizing fuel consumption and reducing operational waste.

IoT and Big Data Analytics

The Internet of Things (IoT) plays a crucial role in improving green logistics practices, as seen in (Jin and Kim 2018; Kolasińska-Morawska et al. 2022; J. Liu et al. 2017; Song and Han 2020) . IoT technologies enhance fleet management, package tracking, and

real-time data analysis, which collectively reduce the carbon footprint of logistics operations. Big data analytics is also instrumental in driving sustainability, particularly by optimizing supply chain management and identifying patterns that lead to resource optimization.

Autonomous Vehicles and Drones

Autonomous vehicles and drones are emerging as promising solutions for reducing emissions, particularly in last-mile delivery (Hasan, Newaz, and Ahsan 2018; Kellermann, Biehle, and Fischer 2020; Kiba-Janiak et al. 2021; Lemardelé et al. 2021; Rodrigues et al. 2022; Tang and Veelenturf 2019) These technologies offer benefits in terms of fuel savings and can reach remote areas, where traditional vehicles may not be efficient. Study (Narayanan, Chaniotakis, and Antoniou 2020) discusses the role of shared autonomous vehicles in reducing fuel consumption and emissions by optimizing delivery routes, a promising area for future logistics solutions.

Blockchain for Transparency and Waste Reduction

Blockchain technology is explored in several articles (Feng, Lai, and Zhu 2022; Tan et al. 2020) for its ability to improve transparency and reduce waste in logistics. This technology helps create a more eco-friendly supply chain by enhancing visibility and ensuring the traceability of goods and emissions throughout the logistics process.

Sustainable Packaging

Innovations in sustainable packaging re crucial to reducing waste in the logistics sector. The use of biodegradable or returnable materials is highlighted as a key strategy in minimizing environmental impact (Doguchaeva, Fedorova, and Mityashin 2022; Kao et al. 2020; Kavitha and Sunderasan 2022; Lai et al. 2022; Li et al. 2021; Miao 2018).

Digital Twins and Smart Logistics

The use of digital twins (Juarez, Botti, and Giret 2021; Orel Šanko, Obrecht, and Cvahte Ojsteršek 2023) and smart logistics technologies (Chung 2021; Hofman 2023)is gaining traction. These technologies allow companies to model logistics operations virtually, improving energy efficiency by predicting outcomes and testing eco-friendly solutions before actual implementation.

Discussion of Trends and Implications

Technological Synergy

Many articles highlight the importance of integrating multiple technologies, such as AI with IoT, or blockchain with AI, to maximize sustainability in logistics. The synergy between these technologies is crucial for creating a more intelligent, eco-friendly logistics network.

Last-Mile Delivery Focus

Last-mile delivery is a major area of concern, with significant technological investments being made to reduce its environmental impact. Route optimization, AI, drones, and autonomous vehicles are frequently mentioned as key to addressing the inefficiencies and emissions generated in last-mile logistics.

Urban and Smart City Logistics

Sustainable logistics solutions are also being tailored to urban environments and smart cities where congestion and emissions are especially high. Smart logistics, driven by AI and IoT, can offer targeted solutions to these densely populated areas.

Challenges and Barriers

While the literature discusses the potential of these technologies, challenges such as high initial costs, regulatory hurdles, and the need for infrastructure development are often implied. Electric vehicles and renewable energy, for instance, require substantial investment in charging and energy storage infrastructure.

Categorization and Proposed Framework

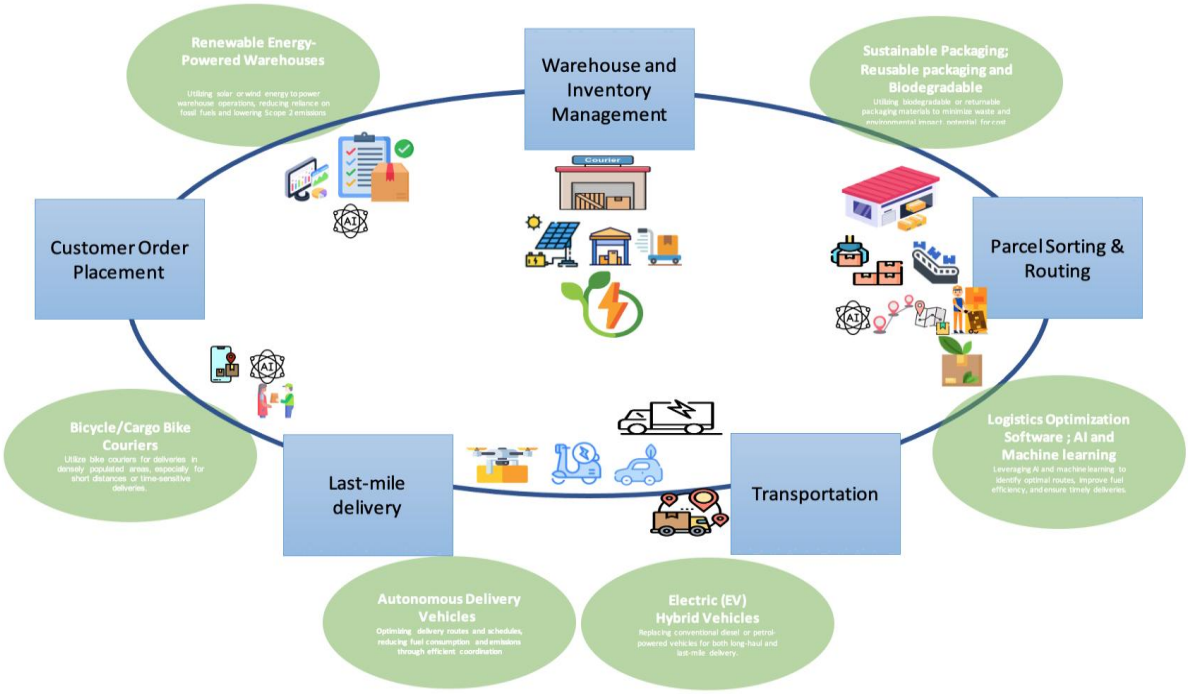
A review of pertinent literature sources on logistics, technology in courier express parcel (CEP) businesses, and green logistics revealed a categorization of technologies applicable to CEP business processes, as illustrated in Table 2.

Table 2. Technology Classification on CEP Business

No	Process Category	Type of Technology	Possible Implementation
1	Last Mile delivery; Transportation	Electric (EV) and Hybrid Vehicles	Replacing conventional diesel or petrol-powered vehicles for both long-haul and last-mile delivery.
2	Transportation	Drones	Delivering goods to remote or hard-to-reach areas, reducing reliance on ground transportation for short distances.
3	Urban Logistics	Bicycle/Cargo Bike Couriers	Utilize bike couriers for deliveries in densely populated areas, especially for short distances or time-sensitive deliveries.
4	Transportation	Autonomous Delivery Vehicles	Optimizing delivery routes and schedules, reducing fuel consumption and emissions through efficient coordination.
5	Packaging	Sustainable Packaging; Reusable packaging and Biodegradable materialas	Utilizing biodegradable or returnable packaging materials to minimize waste and environmental impact, potential for cost savings in the long run, positive brand image.
6	Route Planning & Optimization	Logistics Optimization Software ; AI and Machine learning	Leveraging AI and machine learning to identify optimal routes, improve fuel efficiency, and ensure timely deliveries.
7	Warehousing & Fulfillment	Renewable Energy-Powered Warehouses	Utilizing solar or wind energy to power warehouse operations, reducing reliance on fossil fuels and lowering Scope 2 emissions.

Source: Processed by The Authors

The current research on green logistics for the Courier, Express, and Parcel (CEP) sector highlights an evolving landscape driven by technological advancements aimed at reducing environmental impact. Key themes that emerge from the literature review include the integration of renewable energy, the use of AI and IoT for optimization, the role of autonomous vehicles and drones, and innovations in packaging. Each technology offers a unique solution to addressing the sustainability challenges in CEP operations.



Source: Processed by The Authors

Figure 2. Proposed Framework

The proposed framework, integrating sustainable practices and technological advancements into courier express parcel operations, underscores the industry's potential for transformation. The emphasis on renewable energy, eco-friendly vehicles, and sustainable packaging demonstrates a clear commitment to mitigating environmental impact. This alignment with growing consumer demand for eco-conscious business practices positions such a model for competitive advantage in an increasingly conscientious market.

The literature indicates that green logistics can be significantly enhanced by deploying electric and hybrid vehicles, which directly address fuel consumption and emissions. Various studies discuss the implementation of electric vehicles (EVs) and drones as alternative means of delivery, particularly in the last-mile delivery phase, which has the highest environmental footprint. Renewable energy solutions for warehouses, such as solar or wind energy, provide further opportunities to lower operational carbon emissions.

The role of AI and machine learning in optimizing logistics operations is well-established, especially in route planning, fuel efficiency, and delivery schedules. Many studies emphasize that AI-driven route optimization and predictive analytics can lead to substantial reductions in fuel consumption and emissions. Furthermore, AI can also help balance the logistical network in real-time, improving operational efficiency and minimizing delays. However, the successful implementation of such a technologically advanced framework hinges on overcoming challenges related to the cost of adoption, regulatory compliance, and integration complexity.

IoT has become indispensable in tracking logistics operations and managing the supply chain, enabling real-time data collection that enhances transparency and decision-making. Studies reveal that IoT-enabled systems offer significant benefits in terms of reducing emissions by improving route planning, vehicle management, and cargo handling. Big data analytics also plays a pivotal role by providing insights into customer demands, peak times, and resource allocation, enabling more sustainable logistics.

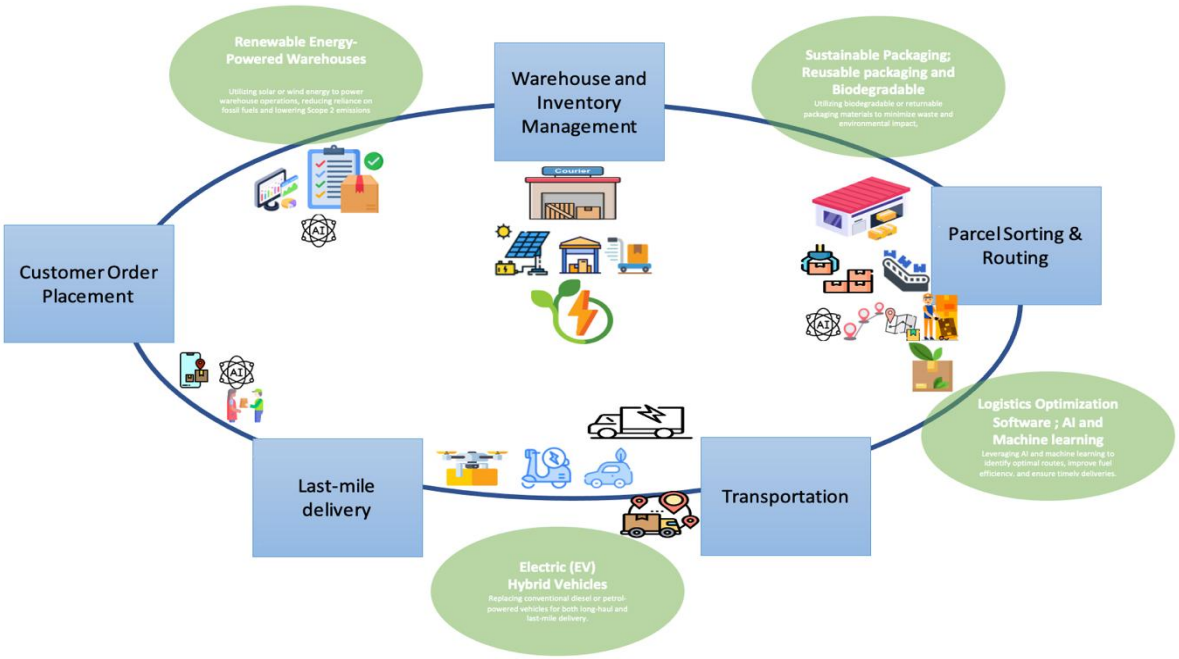
Sustainable packaging technologies are also a critical part of the green logistics framework. The shift towards using biodegradable or reusable materials helps minimize

waste and the environmental footprint associated with packaging in the CEP sector. Studies support that such measures, though initially cost-intensive, result in long-term savings and improve the brand's eco-friendly image. The multi-modal transportation approach, incorporating bicycles, electric vehicles, and potentially autonomous delivery vehicles, showcases the adaptability of the model to diverse delivery needs. This flexibility not only optimizes efficiency but also reinforces the commitment to sustainability. However, the full realization of this vision necessitates addressing regulatory hurdles and ensuring the safe and seamless integration of emerging technologies into existing transportation networks.

While the proposed model presents a promising pathway toward a more sustainable and efficient future for the courier express parcel industry, it is essential to acknowledge its limitations. The upfront investment required for technological adoption and sustainable practices may pose a barrier to entry for smaller players. Additionally, the complexities of integrating various systems and data sources necessitate careful planning and robust technological partnerships.

Refined Framework: Implementation in the Indonesian Context

The proposed framework was evaluated through a series of interviews with industry experts. Following expert interviews conducted to contextualize the green logistics technologies for the Indonesian market, a refined framework was developed. The framework incorporates local business conditions, emphasizing the growing need for electric vehicle adoption, AI for route optimization, and IoT for real-time tracking, which align with the government's sustainability goals. Additionally, the framework advocates for pilot projects on drone deliveries in remote areas and integrating solar energy into warehousing to reduce dependence on fossil fuels. The revised version in figure 2 provides a comprehensive roadmap for companies in Indonesia's CEP sector, aiming to enhance sustainability while balancing cost efficiency and operational scalability. The feedback from industry experts further underscores the importance of regulatory support and incentives to accelerate the adoption of these green technologies in Indonesia.



Source: Processed by The Authors

Figure 3. Refined Framework

The framework recognizes the importance of integrating with e-commerce platforms, not only for efficient order processing but also for promoting sustainable delivery practices. By connecting with e-commerce platforms, CEP providers can encourage customers to opt for eco-friendly delivery options, such as consolidated deliveries, optimized delivery routes, and alternative delivery points. This integration also facilitates the sharing of information about sustainable packaging options and carbon-neutral delivery services.

Addressing the challenges of last-mile delivery in Indonesia, the framework prioritizes green solutions. This includes utilizing electric vehicles (EVs) and hybrid vehicles to reduce emissions and noise pollution in urban areas. Furthermore, the framework explores the potential of cargo bikes and electric scooters for deliveries in densely populated areas, promoting sustainable and efficient transportation. Drone delivery is also considered for its potential to bypass traffic congestion and reduce delivery times, further contributing to lower emissions. Route optimization algorithms, such as Dijkstra's algorithm or the A* search algorithm, are employed to determine the most fuel-efficient routes, minimizing the environmental impact of delivery operations.

Efficient warehouse operations are essential for minimizing waste and promoting sustainability. The framework advocates for the use of Warehouse Management Systems (WMS) to optimize storage space, reduce energy consumption, and minimize unnecessary transportation. Implementing green building practices in warehouse construction, such as using recycled materials and energy-efficient lighting, can further contribute to sustainability. Additionally, the framework encourages the adoption of inventory management practices that minimize waste, such as just-in-time inventory and demand forecasting, to reduce the environmental impact of overstocking and obsolescence.

The framework also emphasizes the importance of sustainable practices in parcel sorting and routing. This includes utilizing energy-efficient conveyor systems and optimizing packaging to minimize waste and material usage. Implementing dynamic routing algorithms, such as Vehicle Routing Problem (VRP) solver can help optimize delivery routes in real-time, reducing fuel consumption and emissions.

The framework promotes a green transportation network that prioritizes sustainability. This includes utilizing EVs and hybrid vehicles for last-mile delivery and exploring alternative fuels and energy-efficient technologies for long-haul transportation. The framework also encourages the use of intermodal transportation, combining different modes like rail, sea, and road transport, to optimize efficiency and reduce the environmental impact of freight movement.

Furthermore, the framework highlights the role of logistics optimization software, AI, and machine learning in promoting sustainable practices. AI-powered demand forecasting models can predict demand fluctuations, optimizing inventory management and reducing waste. Machine learning algorithms can analyze real-time data to optimize delivery routes, minimizing fuel consumption and emissions. By leveraging data-driven insights, CEP providers can continuously improve their operations and reduce their environmental footprint.

The framework strongly emphasizes sustainable packaging and renewable energy sources. This includes promoting the use of biodegradable, recyclable, and reusable packaging materials to minimize waste and pollution. Furthermore, the framework advocates for powering warehouses with renewable energy sources like solar power, reducing reliance on fossil fuels and promoting clean energy adoption.

This green logistics-focused framework provides a roadmap for CEP businesses in Indonesia to operate sustainably, minimize their environmental impact, and contribute to a greener future.

CONCLUSION

The discussion illustrates that adopting a technology-driven approach to green logistics is essential for mitigating the environmental impact of the CEP sector in Indonesia. While initial investments in these technologies might be substantial, the long-term benefits, including cost savings, reduced emissions, and a smaller environmental footprint, make it a compelling strategy for CEP providers. This refined framework, tailored to the Indonesian context, offers a valuable roadmap for future research and practical implementation of green logistics in Indonesia and other developing economies. By embracing technology and sustainable practices, the CEP sector can contribute significantly to a greener and more sustainable future.

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