

Implementation of Green Logistics on the Development of Cargo Logistics in the Free Trade Zone Area: A Case Study of PT Bandara Internasional Batam

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Abstract

This study examines the implementation of green logistics at PT Bandara Internasional Batam to evaluate its role in supporting the development of cargo logistics in the Free Trade Zone (FTZ) area. Using a qualitative case study approach, data were collected through in-depth interviews with key informants, direct field observations, and document analysis. The data were analyzed using the Miles and Huberman model, which consists of data reduction, data display, and conclusion drawing. The findings reveal that the adoption of green logistics practices at PT Bandara Internasional Batam has not yet been fully optimized. Although initiatives such as a semi-automated Warehouse Management System (WMS) and document digitalization (paperless system) have been introduced, significant barriers remain, including high investment costs, limited infrastructure, and insufficient human resource capacity. The analysis highlights that outdated cargo facilities, low environmental awareness among workers and service users, and incomplete digital transformation contribute to the slow progress of green logistics implementation. Comparisons with practices in other international airports demonstrate the importance of modern technology adoption, stronger regulatory support, and cultural change in advancing sustainable logistics. This study contributes theoretically by expanding knowledge on the application of green logistics in the aviation sector within a developing country context. Practically, it provides actionable recommendations for PT Bandara Internasional Batam, policymakers, and industry stakeholders to enhance operational efficiency, reduce environmental impact, and strengthen competitiveness in the FTZ area.

Keywords: Green Logistics, Cargo Logistics, Free Trade Zone, Warehouse Management System, Paperless

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INTRODUCTION

The rapid growth of global trade and air transportation has intensified the movement of goods across countries, making cargo logistics a crucial component of the aviation sector. However, this development has also created pressing environmental challenges. Air cargo operations contribute significantly to energy consumption, carbon emissions, and waste generation, which highlights the urgency of implementing sustainable practices (Safira et al., 2024). In this context, the concept of green logistics emerges as a strategic approach to align economic efficiency with environmental responsibility (Akmal, 2019).

Green logistics refers to the integration of environmentally friendly principles into supply chain and logistics activities with the aim of reducing ecological impacts while maintaining operational efficiency. Operationally, it encompasses strategies such as energy-efficient transportation, waste management, eco-friendly packaging, route optimization, and the digitalization of documents to reduce paper dependency (Adelina et al., 2024; Sadam et al., 2023). Beyond its environmental dimension, green logistics also addresses social and economic sustainability by enhancing service quality, reducing costs in the long run, and improving corporate reputation (Karaman et al., 2020).

Despite its strategic importance, the implementation of green logistics in Indonesia remains limited. In the Free Trade Zone (FTZ) areas, including Batam, challenges such as outdated infrastructure, limited technology adoption, and low awareness among industry actors hinder progress (Purnomo et al., 2022). Ideally, airports and cargo terminals should integrate modern Warehouse Management Systems (WMS), renewable energy usage, and paperless processes to minimize their ecological footprint. However, in practice, these measures are still at an early stage in Indonesia, reflecting a significant gap between global best practices and local realities (Kuruvilla et al., 2020).

The air cargo sector has a direct link to environmental concerns because its operations rely heavily on fossil fuel-based equipment, large-scale facilities, and intensive document management. These activities not only generate high emissions but also contribute to inefficiencies in energy use and waste disposal. Addressing these issues requires not only technological improvements but also behavioral change and stronger institutional support (Jinru et al., 2022).

PT Bandara Internasional Batam (PT BIB) was selected as the case study for this research because it manages Hang Nadim International Airport, one of the busiest airports in Indonesia's FTZ area and a critical gateway for cargo distribution. The airport is undergoing significant transitions, including the relocation to a new cargo terminal and the gradual introduction of semi-automated WMS and digital document systems. These initiatives make PT BIB a relevant and strategic site for analyzing the opportunities and barriers in adopting green logistics practices in Indonesia (Achir et al., 2022; Noerhaeni & Dewantari, 2024).

Previous studies on green logistics in the aviation and airport sectors emphasize both the opportunities and challenges of adopting sustainable practices. For example, Adelina et al., (2024) highlight the role of eco-friendly logistics in reducing environmental impacts, while Safira et al., (2024) identify high investment costs and low public awareness as persistent obstacles. Similarly, international studies (Kuruvilla et al., 2020; Jinru et al., 2020; Suryan et al., 2024) underscore the importance of integrating renewable energy, digitalization, and collaborative policies to achieve sustainability goals. However, most of these studies remain theoretical or policy-oriented, with limited focus on empirical implementation in developing country contexts, particularly within FTZ areas.

This gap highlights the need for case studies that examine how green logistics is applied in practice, what barriers are encountered, and what strategies can be adopted to overcome them. Specifically, there is limited literature that systematically investigates the transformation of airport cargo terminals in Indonesia toward sustainable operations (Richnák & Gubová, 2021).

Based on the above background, this research seeks to address the following problem statements:

1. How is green logistics currently implemented in the cargo operations of PT Bandara Internasional Batam?
2. What are the main obstacles PT Bandara Internasional Batam faces in adopting green logistics practices?
3. What strategies can be proposed to enhance the implementation of green logistics in the FTZ area?

By addressing these questions, this study aims to provide both theoretical contributions to the literature on sustainable logistics in aviation and practical insights for policymakers, airport operators, and industry stakeholders in developing effective strategies for greener logistics systems.

Previous research tended to be theoretical and descriptive, whereas contemporary studies are more application-oriented and data-driven. Modern research emphasizes the importance of collaboration between the public and private sectors to achieve sustainability goals in logistics. Current studies also identify practical challenges in implementing green logistics in the FTZ area, such as a lack of infrastructure and low awareness among industry players about the importance of environmentally friendly practices. Based on the literature review presented, the research framework designed for this study is as follows:

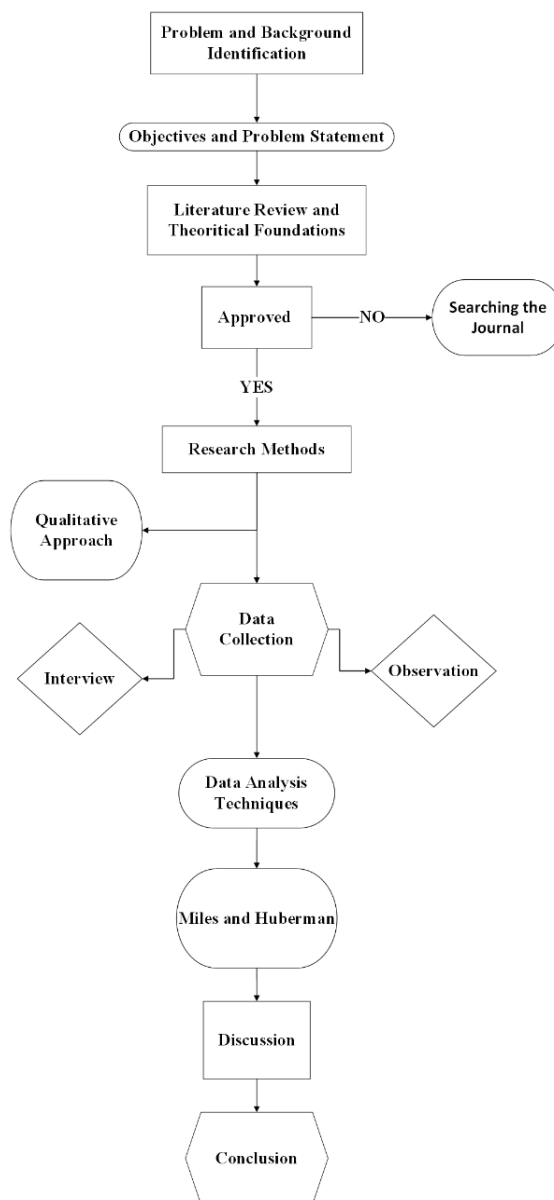


Figure 1. The Research Framework

RESEARCH METHOD

Research Design

This research adopts a qualitative case study approach to explore the implementation of green logistics at PT Bandara Internasional Batam. The qualitative approach was chosen because it allows for an in-depth understanding of complex social and organizational phenomena, particularly in relation to sustainability practices within the logistics sector.

The study focuses on PT Bandara Internasional Batam, which manages Hang Nadim International Airport located in the Free Trade Zone (FTZ) of Batam. The airport plays a strategic role as a regional cargo hub and is currently undergoing transitions in infrastructure modernization and the partial implementation of green logistics initiatives.

Informants were selected using a purposive sampling technique based on their knowledge, experience, and involvement in cargo logistics operations at PT Bandara Internasional Batam. The criteria for selecting informants included:

1. Position and role in the organization (managers, analysts, and staff directly engaged in logistics operations).
2. Experience in handling cargo operations and exposure to green logistics initiatives.
3. Relevance to the research objectives, particularly in relation to warehouse management, documentation systems, and environmental practices.

Based on these criteria, three categories of informants were identified:

1. Key Informant: Senior personnel with decision-making authority.
2. Primary Informant: Staff with operational responsibility in cargo logistics.
3. Supporting Informant: Individuals with technical or analytical roles.

According to Hidayat et al. (2022), the research subjects or respondents are individuals who serve as sources of information in a study. Informants are individuals selected as subjects in a research project because they possess knowledge, experience, or insights relevant to the phenomenon or issue being studied. The following are the selected informants who have been identified:

Table 1. Informants or Research Subjects

No	Informant Name	Type of Informant	Position
1	Daniel Christian	Key Informant	Analyst
2	Wayan Wijana	Primary Informant	Senior Manager
3	Ibrahim	Supporting Informant	Analyst

This study employs the data analysis technique developed by Miles and Huberman, which consists of three main processes that occur simultaneously: data reduction, data display, and conclusion drawing or verification. Qualitative data analysis is a continuous, iterative, and ongoing process. The stages of data reduction, data display, and conclusion drawing/verification represent the success of the analysis as a series of interconnected activities. However, the other two aspects remain important components of the field context (Nurfariadah & Arnesih, 2019).

Data reduction is the process of selecting, focusing, simplifying, abstracting, and transforming raw data obtained from field notes. This process occurs continuously throughout the implementation of qualitative research. The transformation or reduction of data continues until the final stage, which is the preparation of a complete research report. (Nurfariadah & Arnesih, 2019).

The second important stage in the analysis is data display. This refers to an organized collection of information that allows for conclusion drawing and decision making.

According to (Nurfariadah & Arnesih, 2019), the third step in qualitative data analysis is drawing conclusions and verifying data. From the beginning of data collection, a qualitative analyst begins to search for meaning in the obtained data by noting patterns, regularities, explanations, configurations, causal flows, and emerging propositions. Initial conclusions drawn are tentative and may change if strong evidence is not found in subsequent stages of data

collection. However, if these initial conclusions are supported by valid and consistent evidence during further data collection, they become credible. Therefore, conclusions in qualitative research can answer the initial research questions, but they may also change, as research problems and questions in qualitative studies are often provisional and evolve based on field findings.

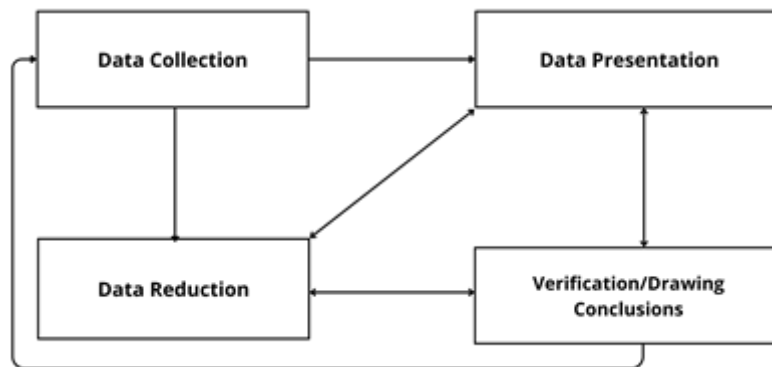


Figure 2. Miles and Huberman's Data Analysis Model

Data Collection Techniques

Data were collected through three complementary techniques:

1. In-depth interviews with selected informants using a semi-structured interview guide. The interview guide was developed based on the research questions and covered themes such as cargo operations, green logistics practices, barriers to implementation, and strategic opportunities.
2. Field observations of daily cargo operations at Hang Nadim Airport to capture real practices and identify gaps between stated policies and operational realities.
3. Document analysis of organizational reports, regulatory documents, and internal policies related to cargo logistics and environmental management.

Research Instruments

The main research instrument was the interview guide, which contained open-ended questions structured around four dimensions:

1. Implementation of green logistics practices.
2. Perceptions of obstacles and challenges.
3. Evaluation of Warehouse Management Systems (WMS) and paperless initiatives.
4. Recommendations for strengthening sustainable logistics.

Data Analysis Techniques

The data analysis employed the Miles and Huberman model, which consists of three stages:

1. Data Reduction: Selecting, simplifying, and coding data from interviews, observations, and documents into meaningful categories.
2. Data Display: Organizing the data in tables, matrices, and narrative descriptions to facilitate pattern identification.
3. Conclusion Drawing and Verification: Interpreting the data, identifying emerging themes, and verifying findings through continuous comparison with the collected evidence.

Data Collection

The data collection process combined in-depth interviews, field observations, and document analysis. Interviews were conducted with three categories of informants: a key informant (senior analyst), a primary informant (senior manager), and a supporting informant (analyst). These informants were chosen because of their direct involvement in cargo logistics

operations and their knowledge of the implementation of sustainability practices at PT Bandara Internasional Batam.

Field observations were carried out during operational activities at the cargo terminal to document the conditions of facilities, warehouse systems, and employee behavior in relation to environmental practices. In addition, organizational documents, internal reports, and relevant regulations were reviewed to complement the primary data.

Data Analysis Process

The data analysis followed the Miles and Huberman (1994) model, which consists of three interactive stages:

1. Data Reduction

Raw data from interviews, observations, and documents were organized and coded into categories. For example, responses related to environmental practices were coded under “Green Logistics,” while challenges in digitalization were coded under “WMS and Paperless System”.

The table below presents an example of the categorization process:

Table 2. Coding and Data Reduction

Category	Code	Example Quote (Informant)	Interpretation
Green Logistics	Waste Management	“Many cargo users still throw waste improperly and some still smoke in prohibited areas.” (D. Christian, Interview, June 3, 2025)	Show low awareness and lack discipline, creating obstacles for green logistics
Warehouse Management System	Manual Processes	“Currently, most of our warehouse operations are still manual, and this causes delays in tracking and retrieving cargo.” (D. Christian, Interview, June 3, 2025)	Indicates inefficiency and high risk of human error due to lack of automation
Paperless System	Document Reliance	“Invoices and weighing slips are still issued manually, which makes the process slower.” (W. Wijana, Interview, June 3, 2025)	Shows incomplete digitalization and dependence on physical documents.
Infrastructure	Outdated Facilities	“The facilities we use are mostly inherited from previous management and are not up to date.” (Ibrahim, Interview, June 3, 2025)	Highlights barriers caused by old equipment and lack of modernization.

2. Data Display

Data were then presented in the form of tables and narrative summaries to show connections between categories. For example, a matrix was created to display barriers and their implications: outdated infrastructure produces inefficiency; low awareness generates environmental pollution; manual systems result in administrative delays.

Supporting informants noted: “Although the new cargo terminal has been built, the supporting systems like WMS and paperless operations are not yet fully functional, so inefficiency still occurs” (Ibrahim, interview, June 3, 2025).

3. Conclusion Drawing and Verification

Through iterative analysis, recurring patterns were identified, such as the dependency on outdated infrastructure, the low level of environmental awareness, and the limited human resource capacity for digital transformation. Verification was carried out by triangulating sources, comparing interview data with observation findings and documents.

For instance, while official policy documents emphasize commitment to sustainable practices, observations revealed improper waste disposal and smoking in prohibited areas, showing a gap between formal policies and actual practices.

The analysis revealed significant discrepancies between theoretical frameworks of green logistics and the actual practices at PT Bandara Internasional Batam. Theoretically, green logistics emphasizes energy efficiency, waste management, and digitalization (Adelina et al., 2024; Safira et al., 2024). However, in practice, PT BIB's cargo operations remain largely dependent on conventional systems and outdated equipment.

- a. Theoretical expectation: WMS should ensure efficiency, accuracy, and integration with customs systems.
- b. Practical reality: PT BIB still relies on manual documentation and human labor, leading to inefficiency and higher risks of errors.
- c. Theoretical expectation: Green logistics reduces environmental pollution through waste management and behavioral compliance.
- d. Practical reality: Observations found persistent littering and smoking in prohibited areas, indicating low awareness among staff and users.

These findings highlight the implementation gap between policy aspirations and ground-level practices, underscoring the need for stronger institutional capacity, investment, and cultural change.

RESULTS AND DISCUSSION

Result

In this section, the researcher will discuss in detail the findings obtained from the study based on the results of interviews with the informants.

Table 3. Research Findings

No	Aspects	Key Findings
1	Operational Constraints	Outdated cargo infrastructure/facilities and equipment, customs procedures, and licensing processes
2	Green Logistics	Many still dispose of cargo waste improperly and smoke in undesignated areas
3	Warehouse Management System (WMS)	Cargo processing is still conventional or manual and not yet systematic
4	Barriers to WMS Implementation	High investment costs; no operators with specific expertise in implementing the WMS have been found
5	Paperless System	There is still a reliance on manual documents for invoices and weighing slips

The parties selected as data sources who can provide information about the research problem are as follows:

1. Based on the research conducted by interviewing informants from PT Bandara Internasional Batam named Daniel Christian, Wayan Wijana, and Ibrahim, the researcher obtained a lot of information regarding findings that have not yet been addressed by PT Bandara Internasional Batam. The results of the research are as follows:

- a. Operational Constraints

Field findings show that cargo operations at PT Bandara Internasional Batam still face several significant obstacles. Outdated infrastructure and equipment, inherited from the previous management, remain in use. These facilities are no longer aligned with technological advancements, which results in slower processing times, higher risks of cargo damage, and greater reliance on manual labor. "Currently, PT BIB still uses facilities,

warehouses, and cargo equipment that were previously managed by BP Batam.” (Daniel Christian, Interview, June 3, 2025).

The inefficiencies caused by outdated infrastructure mirror challenges reported in other developing countries, where modernization of logistics facilities often lags behind demand. In comparison, airports such as Singapore Changi and Incheon International Airport have invested heavily in automated cargo handling systems, which enable higher efficiency and sustainability through reduced carbon emissions.

The interview results obtained from the key informant Daniel Christian explain that, “Currently, PT BIB still uses facilities, warehouses, and cargo equipment that were previously managed by BP Batam.” (D. Christian, Interview, June 3, 2025). At the same time, informants Wayan Wijana and Ibrahim (interview, June 3, 2025) also explained that, “Of course, as in other regions, logistics operations in Batam are not free from several constraints and influencing factors. Although Hang Nadim Airport has an adequate runway, supporting facilities such as logistics warehouses, modern warehousing systems, and specialized handling equipment for certain cargo still need to be improved. The licensing and customs clearance processes also sometimes pose challenges”.

Field findings indicate that in cargo operational activities, there are still several significant obstacles, one of which is the inadequate condition of infrastructure and supporting facilities. Many of the cargo equipment currently in use are outdated and have not been updated in line with technological advancements, which affects the efficiency of loading and unloading processes and handling of goods. This condition causes longer processing times, increased risk of damage to goods, and requires more labor compared to using modern systems and equipment. This impacts the efficiency and effectiveness of loading and unloading processes as well as goods distribution.

b. Implementation of Green Logistics

Although PT BIB has expressed commitment to green logistics, actual practices in the field remain limited. Issues such as improper waste disposal and smoking in prohibited areas persist, reflecting low environmental awareness among both employees and cargo users. “We invited external consultants on hazardous waste and environmental issues, but many users still throw garbage carelessly and smoke in undesignated areas.” (Daniel Christian, Interview, June 3, 2025).

This contrasts with airports like Amsterdam Schiphol, which has established strict waste management systems, and Zurich Airport, which enforces zero-tolerance policies on smoking and improper waste disposal, supported by continuous education programs.

The interview results obtained from the key informant Daniel Christian (interview, June 3, 2025) explain that, “Regarding green logistics, in our opinion, PT BIB is currently very concerned about it. This is evidenced by the fact that we have invited several external consultants related to waste management, hazardous materials (B3), environmental issues, as well as the regulation of habits among cargo service users who still often litter and many still smoke in outdoor areas. However, PT BIB is still in the process of improving towards the green logistics stage.” Furthermore, the key and supporting informants also explained that, “Certainly, PT Bandara Internasional Batam fully understands the importance of the Green Logistics concept in facing global challenges related to sustainability and logistics efficiency. However, many bad habits that could impact the terminal area are still found. Green Logistics is an effort we can make to reduce the environmental impact of logistics activities by improving energy efficiency, reducing carbon emissions, and managing waste more responsibly.” (Wijana & Ibrahim, interview, June 3, 2025).

The implementation of the green logistics concept still faces various challenges in the field. One of the main issues is the low environmental awareness among workers and logistics service users. There are still bad habits among both workers and logistics service users that do not align with sustainability principles. One common problem is the improper disposal of cargo waste or trash around warehouse and terminal operational areas. This not only causes environmental pollution but can also affect occupational health and safety in the surrounding areas. Additionally, the habit of smoking in prohibited areas, including near storage areas, poses an additional risk to health and safety at work and reflects the incomplete implementation of environmentally friendly logistics principles.

c. Warehouse Management System (WMS)

The introduction of WMS at PT BIB remains partial and has not yet been implemented comprehensively. Cargo handling and warehouse operations still rely heavily on manual processes, leading to inefficiency, delays, and frequent errors. “Currently, most of our warehouse operations are still manual, and this causes delays in tracking and retrieving cargo.” (Daniel Christian, Interview, June 3, 2025).

In contrast, airports such as Hong Kong International Airport have long adopted fully automated WMS that integrate with customs systems and digital tracking platforms, significantly reducing reliance on paper and minimizing errors.

The warehouse management system (WMS) has not been optimally implemented in the cargo logistics process. Most of the warehouse management activities, from recording to arranging the position of goods, are still carried out conventionally or manually. The irregularity in this system causes low work efficiency and a high potential for human error, especially in recording and tracking the position of goods. Reliance on manual work also slows down the distribution process and hinders data integration that could otherwise be carried out digitally and in real-time.

d. Barriers to WMS Implementation

Three main obstacles hinder WMS adoption at PT BIB:

- 1) High investment costs (estimated IDR 30 billion or more).
- 2) Unprepared human resources, as operators lack sufficient technical competencies.
- 3) Limited technology infrastructure, such as high-speed internet and server capacity.

“We need operators capable of carrying this out, but we also see that implementing this requires a very significant cost.” (Daniel Christian, Interview, June 3, 2025). These barriers align with findings by Safira et al. (2024), who emphasize that initial investment costs and low awareness remain primary challenges in implementing sustainable logistics in developing economies.

Of course, there are definitely obstacles related to technical aspects. First, we need to find operators capable of carrying this out, because we see that implementing this requires a very significant cost, approximately 30 billion IDR or more.” Additionally, the key and supporting informants also explained that, “Regarding the implementation of the Warehouse Management System (WMS) in the Free Trade Zone (FTZ) area, PT Bandara Internasional Batam faces several barriers. Technology infrastructure such as high speed internet networks and hardware supporting the WMS are not yet fully optimal. This affects the smooth operation of the system, especially for real-time data processing. WMS operations require personnel with specialized skills, particularly in managing semi-automated to automated technology. There is still a competency gap that needs to be addressed through continuous training.” (Wijana & Ibrahim, interview, June 3, 2025).

One of the main obstacles in implementing the WMS system is the lack of personnel with specialized skills in this field. The current operators do not yet have adequate

technical competencies to operate or utilize the WMS optimally. As a result, despite the desire to implement this system, the process is hindered by limited training, socialization, and support from trained human resources who are capable of adapting to new technology. Furthermore, the cost of implementing the WMS is still considered quite high.

e. Paperless System

Although the paperless initiative is recognized as a key step in green logistics, its implementation is still minimal at PT BIB. Most logistics documents, such as invoices and weighing slips, are still issued manually, slowing administrative processes and causing data management inefficiencies. “Currently in Batam, cargo documents that we need to issue are still handled manually. For example, invoices or receipts are still written manually.” (Daniel Christian, Interview, June 3, 2025). Meanwhile, airports such as Frankfurt Airport and Dubai International Airport have fully digitized documentation processes, enabling seamless electronic customs clearance and reducing paper usage by more than 80%.

Furthermore, informants Wayan Wijana and Ibrahim (interview, June 3, 2025) explained that, “Many employees understand the importance of implementing a paperless system to support work efficiency and environmental sustainability. Employees also realize that the paperless system aligns with Green Logistics initiatives and can reduce environmental impact caused by excessive paper use. However, currently, in many logistics activities, physical document proofs are still issued for every document. Therefore, excessive paper use is still commonly encountered.”

Efforts to implement a paperless system in logistics document management are still not fully operational. In practice, there is still a high dependence on physical documents, such as invoices and weighing slips. This indicates that the digitalization of documents has not yet been fully implemented comprehensively and still requires system improvements as well as changes in work culture. Dependence on manual documents not only slows down administrative processes but also carries the risk of losing or damaging important data.

2. Based on the research findings obtained from interviews with informants from PT Bandara Internasional Batam named Daniel Christian, Wayan Wijana, and Ibrahim, the researcher concludes the potential impacts related to the findings that have not yet been addressed by PT Bandara Internasional Batam. The impacts arising from each of these findings are as follows:
 - a. Decrease in operational efficiency: The use of outdated equipment that does not follow technological advancements results in slower loading and unloading processes. Consequently, logistics turnaround time increases, hindering the smooth flow of inbound and outbound goods distribution at the airport.
 - b. Increased risk of cargo damage: The lack of specialized handling equipment and inadequate infrastructure increases the potential for damage, especially for cargo requiring special care such as perishable goods, electronics, or special cargo.
 - c. Impact on customer trust: Delays, damage risks, and unreliable logistics processes can reduce customer satisfaction and trust (both export-import and domestic), which ultimately may lead to a decline in cargo volume handled.
 - d. Environmental pollution in operational areas: Improper disposal of cargo waste and trash by workers and users causes garbage accumulation around warehouses and terminals. This pollutes the airport environment and worsens the aesthetics, air quality, and soil conditions.
 - e. Failure to meet environmental standards: Non-compliance with environmental management standards (e.g., hazardous waste management, smoke free zones, waste treatment) could result in violations of government regulations or international

standards. This may lead to administrative sanctions, fines, or revocation of operational permits.

- f. Obstacles to full transition toward green logistics: Low environmental awareness among workers and service users is a major barrier to achieving green logistics transformation. Efforts such as improving energy efficiency, waste management, or emission reduction are difficult to implement without changes in culture and operational discipline.
 - g. Low warehouse operational efficiency: Manual warehouse management results in longer and suboptimal work times. Processes such as recording, item placement, and cargo retrieval take more time compared to automated and integrated systems.
 - h. Hindered data and digital system integration: The use of conventional systems makes it difficult to integrate warehouse management with other systems such as customs, inventory management, or shipment tracking. This slows down digitalization and innovation of overall logistics services.
 - i. Delays in goods distribution: Manual systems slow down the entire workflow from receipt, storage, to dispatch of goods, ultimately hindering distribution and reducing PT BIB's competitiveness as a logistics service provider.
 - j. Delayed logistics digitalization: Limited technology infrastructure and unprepared workforce hinder the transition from manual to digital systems. This slows down PT BIB's progress in fully implementing modern technology based logistics management.
 - k. Continued reliance on manual systems: Because the WMS has not been fully implemented, warehousing and logistics activities still rely on manual methods. This dependency results in ongoing issues with efficiency, accuracy, and speed in logistics operations.
 - l. Administrative inefficiency: Dependence on physical documents such as invoices, receipts, and weighing slips causes administrative processes to be slower and less practical. Data entry and document distribution take longer compared to instantly accessible digital systems.
 - m. High risk of data loss and damage: Physical documents are vulnerable to damage, loss, or storage negligence. This can disrupt workflows, impede document tracking, and potentially cause conflicts or administrative errors in logistics processes.
 - n. Increased operational costs: Large scale use of paper adds costs for stationery, printing, and archive storage. In contrast, digital systems can save long-term costs by reducing the need for physical materials and administrative labor.
 - o. Slow transition to full digitalization: System and work culture unpreparedness to adopt paperless processes delays the digital transformation that should support logistics service integration. This hampers innovation and efficiency in comprehensive logistics information management.
3. Based on research findings obtained through interviews with informants from PT Bandara Internasional Batam, namely Daniel Christian, Wayan Wijana, and Ibrahim, it can be deduced that the failure to implement green logistics at PT Bandara Internasional Batam is caused by three main issues: (1) outdated technology and infrastructure, (2) low environmental awareness at the operational level, and (3) suboptimal digitalization systems and human resource competencies. Each of these elements has significant implications for the sustainability of the logistics system in the free trade zone area.

The following are the main findings and implications that led to the failure to achieve green logistics, analyzed using a deductive-analytical approach based on interview findings with the informants.

- a. Lagging Infrastructure and Operational Technology

Although green logistics emphasizes energy efficiency and process optimization, field observations reveal that most of the equipment used is outdated and environmentally unfriendly. This results in slow loading and unloading processes, excessive energy consumption, and high labor demand, which contradict the efficiency principles of green logistics.

Implication: Slow operational activities, energy inefficiency, and an increased corporate carbon footprint due to the use of conventional heavy equipment.

b. Low Environmental Awareness in the Workplace

The behavior of workers and logistics service users that contradicts sustainability principles such as littering and smoking in prohibited areas—demonstrates that the work culture does not yet support the implementation of green logistics.

Implication: Environmental pollution in terminal and warehouse areas, increased risk of workplace accidents, and the company's failure to establish a clean and safe logistics ecosystem

c. Suboptimal System Digitalization and Limited Human Resource Competence

The warehouse management system (WMS) and paperless systems have not been running optimally. The continued dominance of manual processes indicates that digital transformation has not been fully accepted or supported by competent human resources. Another major obstacle lies in the high cost of technology implementation and the lack of training.

Implication: Logistics processes inefficient, prone to human error, difficult to monitor in real time, and pose a risk of losing important data. This contradicts the principles of green logistics, which promote efficiency and the use of environmentally friendly technology.

Discussion

Based on the findings from the interview data analysis with the informants, it can be concluded that there are several key aspects that have not yet been fully implemented by PT Bandara Internasional Batam (PT BIB) in optimizing cargo operations at Hang Nadim Airport. The interview findings indicate that most of the infrastructure and cargo equipment used by PT Bandara Internasional Batam (PT BIB) are inherited from the previous management and have not undergone significant upgrades. According to (Kuruvilla et al., 2020), this condition contradicts the fundamental principles of green logistics, which aim to reduce environmental impact through operational efficiency, the use of clean energy, and the modernization of logistics systems. Furthermore, according to (Siddiqui et al., 2024), It explains that several cities in China have taken concrete steps by strictly implementing environmentally friendly logistics practices as an effort to address this issue. The success of these implementations indicates that similar approaches have the potential to be applied more broadly across other regions in China. Therefore, the consistent and comprehensive adoption of green logistics practices throughout the country is believed to significantly contribute to the reduction of carbon emissions in the logistics sector, while also supporting the achievement of sustainable development goals in the future.

Furthermore, according to informants Wayan Wijana and Ibrahim, although Hang Nadim Airport has an adequate runway, supporting facilities such as modern logistics warehouses, up-to-date warehouse management systems, and specialized handling equipment for certain types of cargo are still not optimally available. These findings indicate that PT BIB has not made sufficient investments in the modernization of logistics infrastructure, both in terms of technology and physical facilities. The equipment currently in use is considered outdated and does not keep up with the latest technological developments, thereby hindering loading and unloading efficiency and increasing the risk of cargo damage.

The handling process also becomes slower and requires more labor, which ultimately has a negative impact on the efficiency and effectiveness of goods distribution. Furthermore, the use of renewable energy can reduce daily carbon emissions as a form of mitigation against global climate change and support sustainability efforts in the airport's surrounding environment (Pinatik et al., 2023). This highlights the need for strategic action by PT BIB to modernize logistics facilities and equipment as part of efforts to develop a more professional and competitive cargo system, especially in the Free Trade Zone area.

Therefore, in 2025, PT BIB began relocating the old cargo terminal to a newly completed cargo terminal. Previously, the old cargo terminal covered only 1,600 m². However, the new cargo terminal is significantly larger, covering around 9,600 m². With this considerably larger facility, PT BIB has started to simulate a semi-automatic system concept, which still requires human labor for tasks such as data entry, weighing, and random document checks. Consequently, in this new cargo terminal, PT BIB is also beginning to implement a semi-automatic system connected to the Warehouse Management System (WMS), including components such as a sortation system, pallet tracking system, autogate system, and also the online temporary storage facility (TPS).

Consequently, PT BIB has not yet fully implemented a comprehensive green logistics system and still needs to adopt a more systematic approach through the strengthening of internal regulations, continuous education for all stakeholders, and stricter operational oversight in order to create an environmentally friendly and sustainable logistics ecosystem. In addition, the suboptimal implementation of green logistics practices at PT Bandara Internasional Batam contributes to the increased release of toxic substances and harmful gases, such as carbon dioxide and methane, into the air. These activities have adverse effects on human health, as they can trigger the emergence of serious illnesses such as stroke and chronic obstructive pulmonary disease (COPD). Ultimately, this condition threatens the social sustainability aspect of the company (Nwaulune et al., 2023). In addition, the implementation of green logistics practices can lead to operational efficiency and cleaner production (Karaman et al., 2020).

In response to various operational obstacles identified through the research data analysis, PT Bandara Internasional Batam has begun implementing a forward-looking strategic plan. First, it is revitalizing environmentally friendly logistics facilities and infrastructure by renewing and replacing outdated cargo equipment with energy-efficient technologies such as electric forklifts, automated conveyors, and smart warehouse systems. Second, the company is establishing strategic partnerships with potential investors to develop supporting infrastructure such as servers, networks, and cloud-based software that are also energy-efficient. In addition to enhancing operational effectiveness, the use of this technology aligns with the principles of Green Logistics by reducing the consumption of physical resources such as paper and fuel. Third, PT BIB is gradually implementing an integrated paperless system across all logistics processes, especially at the Cargo Terminal.

This transformation can begin with the digitization of key documents such as invoices, receipts, and weighing slips through secure, cloud-based electronic systems that are easily accessible to service users. The use of digital signatures and integration with electronic customs systems can also accelerate document processing without the need for physical printouts. To support this implementation, PT BIB provides technical training to all employees to ensure they can operate the software and fully understand the digital document procedures. According to (Richnák & Gubová, 2021), stated that effective collaboration among various parties within the green logistics supply chain plays a crucial role in reducing operational costs and improving overall service efficiency. Through coordinated cooperation, companies can avoid process duplication, optimize resource utilization, and minimize the negative impact of the bullwhip effect. Therefore, strong collaboration in the implementation of green logistics not only supports cost savings but also contributes to enhanced service quality and long-term operational sustainability.

Furthermore, (Jinru et al., 2022), highlighted that green logistics plays a strategic role in enhancing supply chain flexibility while also supporting environmental sustainability, particularly in developing countries. The implementation of green logistics principles enables companies to be more adaptive to market dynamics and changing demand, as well as to manage operational risks more efficiently. In addition, green logistics encourages the use of environmentally friendly technologies and more sustainable operational practices, such as energy efficiency, waste reduction, and optimization of distribution processes. Therefore, the integration of green logistics into the supply chain not only enhances a company's competitiveness but also directly contributes to environmental preservation efforts and the achievement of sustainable development goals in developing nations.

Another study conducted by (Suryan et al., 2024), on the implementation of eco green airports in reducing carbon emissions: a systematic review, states that the application of eco green airport strategies requires the use of renewable energy, energy efficiency, waste management, green transportation, greening initiatives, and proper water management. This aims to minimize environmental pollution caused by airport operational activities and reduce costs so that the savings can be redirected to more urgent needs. Although there are still challenges in implementing eco airports, collective commitment and continuous innovation can help achieve the goal of significantly reducing carbon gas emissions.

Another study conducted by (Zulfikri, 2024), entitled *Integrating Green Procurement and Logistics: Overcoming Barriers for Sustainable Supply Chains* explains that, on the green logistics side, commonly used strategies include route optimization, load consolidation, and the use of transportation management technologies to reduce greenhouse gas emissions. According to (Zulfikri, 2024), the study highlights the role of information technology in enabling real-time monitoring and improving sustainable logistics performance. Furthermore, (Trivellas et al., 2020) also revealed that the use of environmentally friendly packaging has a positive relationship with the improvement of both the financial and social performance of a company. This indicates that the implementation of green packaging not only helps reduce negative environmental impacts but also adds value to the company in terms of economic gains and social reputation. Green packaging can enhance cost efficiency through the use of lighter and more biodegradable materials, while also strengthening the company's image among consumers who are increasingly concerned about sustainability issues. Therefore, sustainable packaging strategies significantly contribute to enhancing a company's competitiveness in an increasingly competitive market.

Another study conducted by (Wang et al., 2020) emphasizes that the implementation of green logistics through the use of environmentally friendly packaging (eco-packages) and the adoption of Smart and Sustainable Transportation (SST)-based routing models has a significant impact on enhancing overall logistics performance. This strategy has proven effective in optimizing operational cost efficiency by minimizing unnecessary resource use and reducing negative environmental externalities such as carbon emissions and air pollution. Moreover, this approach also contributes to improving synchronization between logistics processes, resulting in a more coordinated, responsive, and timely flow of goods and information. Thus, the adoption of sustainability-based technologies and strategies not only supports operational efficiency but also strengthens the company's position in meeting the growing market demand for environmental and social responsibility.

The findings of this study indicate that the implementation of green logistics at PT Bandara Internasional Batam is still at an early stage. Several initiatives, such as the partial adoption of a Warehouse Management System (WMS) and efforts to introduce a paperless system, demonstrate the company's awareness of the importance of sustainability. However, various obstacles remain, including outdated infrastructure, high investment costs, limited human resource capacity, and low environmental awareness among stakeholders.

Comparison of Theory and Practice

Theoretically, green logistics emphasizes efficiency, environmental protection, and technological innovation (Adelina et al., 2024; Jinru et al., 2022). In practice, however, PT BIB still struggles to align with these principles. While the concept of WMS should enhance real-time accuracy, integration, and efficiency, its current implementation remains limited and manual. Similarly, paperless initiatives intended to reduce ecological footprints are hindered by cultural and infrastructural barriers. This reflects a significant implementation gap between theoretical expectations and field realities.

Supporting and Inhibiting Factors

Supporting Factors:

1. The existence of a new cargo terminal with larger capacity (9,600 m²).
2. Institutional awareness of the importance of green logistics, demonstrated by inviting external consultants on waste and hazardous material management.
3. The government's regulatory framework, which increasingly promotes sustainability in aviation and logistics.

Inhibiting Factors:

1. Outdated infrastructure and equipment inherited from previous management.
2. High costs of technology adoption (e.g., semi-automated WMS requires investment of ~IDR 30 billion).
3. Insufficiently trained human resources, particularly in managing digital and automated systems.
4. Low cultural awareness of sustainability, as evidenced by improper waste disposal and smoking in prohibited areas.

Strategic Recommendations

Based on the findings and comparisons with international best practices, the following recommendations are proposed:

1. **Infrastructure Modernization**
Invest in environmentally friendly equipment such as electric forklifts, automated conveyors, and renewable energy sources.
2. **Comprehensive WMS Implementation**
Prioritize full integration of WMS with customs and inventory systems to minimize manual processes.
3. **Paperless Transformation**
Develop a cloud-based digital documentation platform to accelerate administrative efficiency and reduce paper waste.
4. **Capacity Building**
Provide continuous training for employees to operate automated systems and internalize sustainability practices.
5. **Cultural Change Initiatives**
Establish strict internal regulations on waste disposal and smoking, accompanied by awareness campaigns and sanctions for violations.
6. **Strategic Partnerships**
Collaborate with international airports, technology providers, and government institutions to benchmark and adapt best practices.

Theoretical, Practical, and Policy Implications

1. **Theoretical Implications**
This study expands the literature on green logistics by providing empirical evidence from a developing country's FTZ context, which has been relatively underexplored.
2. **Practical Implications**

For PT BIB, the findings highlight the importance of digitalization, infrastructure modernization, and employee training to achieve sustainability. For other logistics companies, the results offer concrete steps to align operational efficiency with environmental goals.

3. Policy Implications

For the government and FTZ administrators, the study underscores the need for supportive policies such as tax incentives for green investments, stricter environmental regulations, and the development of eco-friendly infrastructure in FTZ areas.

CONCLUSION

This study examined the implementation of green logistics at PT Bandara Internasional Batam within the context of the Batam Free Trade Zone. Based on the findings, several key conclusions can be drawn:

1. Current Implementation

Green logistics practices at PT BIB remain limited and fragmented. While initiatives such as partial WMS adoption and paperless trials indicate awareness of sustainability, operational realities are still dominated by manual systems, outdated infrastructure, and low environmental awareness.

2. Operational Gaps

Significant gaps exist between theoretical expectations of green logistics—such as efficiency, digitalization, and environmental protection—and the actual practices observed in the field. These gaps are reflected in inefficient warehouse operations, incomplete waste management, and reliance on manual documentation.

3. Barriers and Drivers

The main barriers include high costs of technology adoption, insufficiently trained human resources, and weak enforcement of sustainability culture. Conversely, supporting factors include the availability of a new cargo terminal, institutional awareness, and regulatory support from the government.

4. Comparative Insights

Compared to international airports such as Singapore Changi, Incheon, and Amsterdam Schiphol, PT BIB lags significantly in terms of automation, digitalization, and waste management practices, highlighting the urgent need for modernization.

Recommendations and Solutions

1. For PT BIB

- a. Accelerate the full integration of WMS and develop a comprehensive paperless system to minimize inefficiency.
- b. Modernize cargo equipment and adopt eco-friendly technologies (e.g., electric forklifts, renewable energy).
- c. Establish strict internal sustainability policies and provide continuous training programs for employees and cargo users.

2. For Government and Policymakers

- a. Provide tax incentives or subsidies to support green investment in FTZ areas.
- b. Enforce stricter environmental regulations for aviation and logistics operators.
- c. Facilitate knowledge-sharing partnerships between Indonesian airports and international benchmarks.

Contributions of the Study

1. Theoretical Contribution

Expands the body of knowledge on green logistics by presenting empirical evidence from a developing country's FTZ context, which remains underexplored in prior studies.

2. Practical Contribution

Provides actionable solutions for PT BIB and other logistics operators in Indonesia, particularly regarding digitalization, infrastructure modernization, and cultural change toward sustainability.

3. Policy Contribution

Offers insights for government agencies and FTZ administrators to design supportive policies, such as incentives for green investment and enforcement of sustainability standards.

Research Limitations

1. The study relied primarily on qualitative data from a limited number of informants, which may not fully capture the perspectives of all stakeholders.
2. The analysis focused on a single airport, limiting the generalizability of findings to other contexts.

Future Research Directions

1. Expand the scope to include multiple airports in Indonesia for comparative analysis.
2. Employ mixed-method approaches combining qualitative and quantitative data to strengthen the validity of findings.
3. Explore customer and cargo user perspectives to gain a more holistic understanding of green logistics implementation.

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