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Container Yard Management Strategy to Support Operational Efficiency and Stacking Capacity

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ABSTRACT

The efficiency of Container Yard (CY) operations plays a vital role in determining the overall performance of seaports. Batu Ampar Port in Batam, Indonesia, has experienced significant growth in container traffic over the past five years; however, operational efficiency has lagged due to limited infrastructure, suboptimal yard management, and minimal technology adoption. This study aims to analyze strategic CY management to improve operational efficiency by identifying current constraints and proposing integrated development strategies. Employing a qualitative descriptive approach within a feasibility study framework, data were collected through field observation, semi-structured interviews with key stakeholders, and document analysis. Findings reveal that Batu Ampar's CY operates with a high yard utilization rate and extended dwell time, caused by outdated manual systems, inefficient container layout, and undertrained personnel. In contrast to global best practices, such as the Port of Singapore, Batu Ampar lacks essential systems like a Terminal Operating System (TOS) and real-time tracking via RFID or GPS. This research recommends adopting digital tools, conducting workforce training, restructuring the yard layout, and fostering public–private investment partnerships. These strategies are expected to reduce congestion, accelerate cargo flow, and enhance overall service reliability. The study contributes theoretically to port logistics literature by emphasizing the multidimensional integration of technology, human resources, and policy, while also offering practical guidance for modernizing medium-scale ports in developing regions.

Keywords:

container, yard, operational, efficiency

Introduction

International trade growth and the development of industrial zones in strategic regions such as Batam have increased the demand for efficient logistics systems and port infrastructure. Batu Ampar, as the main port in Batam, has experienced a significant rise in container traffic, with an average growth rate of 7% per year over the last five years (BPS Kota Batam, 2023). However, this surge in cargo volume has not been matched by adequate capacity and effective Container Yard (CY) management systems.

Several constraints, including limited yard space, inefficient CY layout, and the lack of optimized equipment and digital systems, have resulted in logistics congestion, extended container dwell time,

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and rising port operating costs. This situation has become an urgent issue, impacting not only Batu Ampar's local competitiveness but also the overall performance of Indonesia's logistics sector. Globally, major ports such as Singapore, Rotterdam, and Busan have successfully integrated advanced digital technologies into their CY management systems. Tools such as Terminal Operating Systems (TOS), IoT-based sensors, and real-time container tracking with RFID have been proven to significantly enhance port productivity (Notteboom & Rodrigue, 2022; Zhang et al., 2020). In contrast, Indonesian ports continue to face challenges in adopting such technologies. A study by Putra et al. (2020) revealed that the CY at Belawan Port still relies heavily on manual systems with limited digital adoption, resulting in low yard productivity and high truck turnaround time.

Other studies have highlighted additional constraints. Santoso (2021) pointed out that insufficient workforce training and the lack of integrated inter-port logistics systems are among the primary causes of inefficiency in CY operations. These findings indicate the existence of a research gap in developing multidimensional and contextual CY management strategies, particularly for medium-scale ports like Batu Ampar. Previous studies have tended to focus on single technical approaches, such as yard layout optimization or equipment efficiency, without comprehensively examining the interconnections between technology, operational management, human resources, and port logistics policies (Sari et al., 2020; Utama et al., 2021).

This study aims to analyze strategic CY management to improve operational efficiency at Batu Ampar Port. It evaluates the current conditions of CY operations, identifies key constraints, and formulates strategic solutions through a feasibility study and multidimensional analysis. The scope of the study goes beyond technical aspects, incorporating information technology, human resource management, investment strategies, and sustainable logistics policies. With this approach, the proposed solutions are expected to be both operationally relevant and strategically significant at the national level.

Methodologically, this research employs a qualitative descriptive approach by combining primary and secondary data. Field observations, interviews, and document analysis were conducted to obtain an in-depth understanding of on-site conditions and CY development needs. Theoretically, this study expands perspectives in port management research by integrating the concepts of smart logistics, digital technologies, and system-based port efficiency (Porter, 1985; Chopra & Meindl, 2021). Practically, the results provide valuable insights for policymakers, port authorities, and logistics stakeholders in formulating CY management strategies. The recommended strategies are expected to enhance yard capacity, accelerate cargo flow, and reduce logistics costs. By addressing the complexities and challenges faced by Batu Ampar Port, this study contributes concrete recommendations for developing adaptive, sustainable, and data-driven CY management strategies that support the transformation of Indonesia's ports toward a globally integrated and efficient maritime logistics system.

Method

This study employs a qualitative descriptive approach with a feasibility study design to comprehensively evaluate Container Yard (CY) management strategies at Batu Ampar Port, Batam. This approach was chosen as it enables an in-depth understanding of actual field conditions, structural constraints, and contextual as well as strategic development potentials (Creswell & Poth, 2021). The research design adopts SWOT analysis and gap analysis models to compare existing conditions with global best practices in modern port operations. The population of the study consists of stakeholders directly involved in CY management and operations, including port operators, field workers, logistics

managers, and port regulators (KSOP and BP Batam). Sampling was conducted using a non-probability purposive sampling technique, in which informants were selected based on their role relevance and level of knowledge about CY management systems. A total of 10 key informants were interviewed, comprising 4 port managers, 3 equipment operators, 2 logistics experts, and 1 representative from the local government.

Data collection was conducted through a combination of three methods: (1) field observation, carried out over three working days at Batu Ampar CY to examine operational activities and container movement patterns; (2) semi-structured interviews, conducted face-to-face using an interview guide based on CY performance indicators such as yard utilization rate (YUR), dwell time, and truck turnaround time (TTAT); and (3) document analysis, including internal port reports, development blueprints, and statistical data from official institutions such as BPS and KSOP Batam. The interview instrument was developed based on indicators from Zhang et al. (2020) and adapted to the local context. To ensure data reliability and validity, source and method triangulation as well as cross-checking between informants were applied. Content validity was tested through expert judgment involving two port logistics specialists.

The research procedure was implemented in three stages: preparation of research design and collection of secondary data (May 2024), field observations and interviews (June 2024), and data analysis with the formulation of CY management strategies (July 2024). Each stage was systematically documented through field notes and recorded interviews (with respondent consent). Data analysis employed thematic analysis to identify patterns, relationships, and key issues in CY management. Furthermore, benchmarking with a global reference port (Port of Singapore) was conducted to compare performance and best practices. NVivo 14 software was utilized to manage thematic categories and organize interview quotations systematically. This methodological approach is expected to generate valid and applicable findings, fully addressing the research objectives while providing a strong basis for formulating data-driven and contextually relevant CY development strategies.

Results and Discussion

The Container Yard (CY) at Batu Ampar Port covers an area of more than 200,000 m^2, including approximately 19,500 m^2 of covered warehouse space, and is equipped with modern cargo handling equipment such as quay cranes, reach stackers, and RTGs. The port has experienced an average container throughput growth of 7% per year over the past five years, indicating significant cargo volume expansion. The main issue identified is the imbalance between land capacity expansion and CY operational efficiency in accommodating the surge in container flows.

Table 1. KPI Results

Indicator	Key Findings
Yard Utilization Rate	Average yard utilization is 75–85%, approaching the industry threshold (ideally <80% to avoid bottlenecks).
Container Dwell Time	Average dwell time is 3–5 days, higher than benchmark ports such as Singapore and Malaysia (2–3 days).
Truck Turnaround Time	Average TTAT is 80–120 minutes, exceeding the national efficiency target (ideal <60 minutes).
Yard Crane Productivity	15–20 moves/hour, below the international standard of 25–30 moves/hour.

Note: Figures are based on observations, secondary data, and benchmarking as part of the feasibility analysis.

The storage area is divided into blocks, slots, rows, and tiers to optimize heavy equipment access and vehicle flow. Containers are separated based on status (empty/loaded), type, and destination. However, uneven distribution of volumes has led to congestion in certain areas. The use of systems such as the Terminal Operating System (TOS), RFID, and GPS remains suboptimal, with most processes still semi-manual, resulting in delays and inefficiencies in container tracking and recording.

Key performance indicators (KPIs) show that yard utilization averages 75–85%, approaching the industry threshold where the ideal is below 80% to avoid bottlenecks. Container dwell time averages 3–5 days, which is longer than benchmark ports such as Singapore and Malaysia (2–3 days). Truck turnaround time (TTAT) ranges from 80–120 minutes, exceeding the national efficiency target of less than 60 minutes. Yard crane productivity is 15–20 moves per hour, still below the international standard of 25–30 moves per hour. These figures are based on observations, secondary data, and benchmarking as part of the feasibility analysis.

Problem Analysis

Several factors hinder the effectiveness of CY operations at Batu Ampar Port. First, limited yard space has not been expanded proportionally to match the rapid growth in container volumes. Second, the availability of handling equipment, such as RTGs and reach stackers, remains insufficient, while operating hours are not fully optimized. Third, the lack of integrated information systems among operators often results in delays and miscommunication regarding container data. Finally, human resources face challenges due to insufficient technical training in modern CY management technologies.

Comparison with Previous Studies

This study reinforces findings from the World Bank, which indicate that each additional day of dwell time can increase logistics costs by up to 12%. The higher-than-average dwell time observed at Batu Ampar underscores the urgency of optimizing CY management. Moreover, truck service times are slower compared to regional competitors such as Port of Tanjung Pelepas in Malaysia and the Port of Singapore. The limited adoption of TOS and real-time tracking systems aligns with empirical studies on other Indonesian ports, which also face delays in digital transformation.

Proposed Development Strategies and Impacts

The study proposes several strategies to improve CY performance. These include full digitalization through the implementation of TOS, RFID, and other real-time tracking systems to accelerate identification and scheduling; yard expansion and redesign to accommodate cargo growth and reduce bottlenecks; the addition of handling equipment and optimization of operating hours; technical training for human resources along with SOP reforms based on global best practices; and stronger collaboration with stakeholders to integrate data systems and regulate truck traffic flow.

Socio-Economic Impacts

The implementation of these strategies is expected to strengthen Batu Ampar Port's competitiveness in the region, reduce national logistics costs in line with government targets, and generate a trickle-down effect that supports the economic growth of Batam and its Special Economic Zone.

Main Findings

This study confirms that the operational efficiency of Batu Ampar Port's container yard (CY) remains below industry standards. Yard utilization averages 75–85%, which exceeds the optimal threshold of <80% suggested in terminal efficiency literature [1]. Prolonged yard occupancy contributes to increased container re-handling, reduced spatial flexibility, and escalating operational costs. The average dwell time of 3–5 days also reflects inefficiencies in container flow, particularly when compared to benchmark ports such as Singapore, where containers typically remain in the yard for only 2–3 days [2]. Elevated dwell time not only restricts throughput capacity but also imposes additional costs on shippers and contributes to systemic delays within the supply chain.

Truck turnaround time (TTAT) is another critical bottleneck, with average service duration ranging between 80–120 minutes. This is significantly higher than the Indonesian Ministry of Transportation's efficiency target of <60 minutes [3], and indicates congestion at port gates, inadequate truck appointment systems, and insufficient traffic management. Such delays undermine the competitiveness of Batu Ampar in comparison to regional maritime hubs that have implemented automated gate and scheduling systems. The root causes of these inefficiencies lie in infrastructural limitations, insufficient handling equipment, and the incomplete integration of smart-port technologies. The limited availability of RTGs and reach stackers hinders operational throughput, while partial deployment of Terminal Operating Systems (TOS), Radio Frequency Identification (RFID), and Global Positioning System (GPS) technologies constrains real-time visibility and synchronization across stakeholders. Similar findings have been reported in other Indonesian ports experiencing slow digital transformation [4][5]. Overall, these gaps highlight the urgent necessity for comprehensive modernization strategies, including infrastructure expansion, investment in handling equipment, and accelerated adoption of digital technologies to align Batu Ampar Port with global port efficiency standards.

Theoretical and Empirical Context

The findings are consistent with container terminal efficiency theory, which highlights land-use optimization, fast cargo handling, and integrated information systems as key competitiveness factors (Notteboom & Rodrigue, 2022). Prior studies confirm that dwell time and stacking height strongly influence land-use efficiency. Digitalization—including real-time data systems, TOS integration, and RFID—has been shown to enhance efficiency and reduce human error. However, Batu Ampar's limited adoption of such technologies reinforces structural inefficiencies. Research by Nopparit & Saenchaiyathon (2024) and Tan et al. (2017) also underscores the importance of coordinated container placement, equipment deployment, and operational routing—areas where decision-support systems such as TOS are essential.

Implications

Extended dwell times and low productivity have direct and compounding effects on both operational efficiency and economic performance. Each additional day of container dwell time increases logistics costs by up to 12%, as highlighted in World Bank studies, due to higher storage fees, container detention charges, and disruptions to downstream supply chains. For exporters and importers, these costs translate into reduced price competitiveness of goods in international markets. Over time, such inefficiencies can shift trade flows toward more efficient regional hubs, eroding Batu Ampar's role as a strategic gateway.

The absence of digital integration further magnifies these risks. Without a fully functional Terminal Operating System (TOS), real-time tracking via RFID, or GPS-enabled yard management, the port suffers from delayed information exchange, poor coordination among stakeholders, and frequent re-handling of containers. This increases idle time for trucks, vessels, and yard equipment, creating a ripple effect of delays across the logistics chain. Limited yard capacity compounds the issue, as high utilization rates (75–85%) leave little buffer for peak demand, making the port highly vulnerable to congestion during seasonal or unexpected surges in container traffic.

Globally, leading ports such as Singapore, Rotterdam, and Shanghai demonstrate that automation and system integration are no longer optional but prerequisites for competitiveness. Automated stacking cranes, digital gate appointment systems, and integrated data platforms not only reduce dwell time but also enable predictive analytics to anticipate congestion and optimize yard operations. In contrast, Batu Ampar's slower digital adoption widens the efficiency gap, reinforcing the perception of Indonesian ports as high-cost logistics nodes. The strategic implications are significant. If inefficiencies persist, Batu Ampar risks being bypassed in global shipping routes, reducing transshipment opportunities and diminishing Batam's potential as a regional logistics hub. Conversely, investing in digital integration and capacity expansion could yield substantial benefits: improved supply chain reliability, lower logistics costs, and stronger alignment with Indonesia's national goal of enhancing maritime connectivity and reducing logistics costs to below 20% of GDP.

Influencing Factors

Supporting conditions for improving the Container Yard (CY) at Batu Ampar include the relatively large initial yard space, which provides a foundational capacity buffer for handling growing container volumes. This is complemented by the strong commitment of both the central government and BP Batam to pursue modernization and infrastructure upgrades. Such institutional backing is critical, as port development requires significant investment and coordinated policy support. These favorable conditions suggest that Batu Ampar has the structural and political foundation needed to embark on transformative initiatives, including digitalization, capacity expansion, and public–private partnerships.

However, several constraints threaten to undermine these opportunities. The limited adoption of modern technologies such as Terminal Operating Systems (TOS), Radio-Frequency Identification (RFID), and Global Positioning Systems (GPS) prevents real-time coordination, visibility, and efficiency across yard operations. This technological lag is compounded by the inadequacy of modern handling equipment, with insufficient numbers of Rubber-Tyred Gantry Cranes (RTGs) and reach stackers to meet the rising demand. Furthermore, the workforce's skill level remains below the requirements of a digitally integrated port environment. Training gaps in advanced yard management systems, data-driven decision-making, and equipment operation reduce the overall effectiveness of modernization efforts.

Weak inter-stakeholder coordination represents another significant challenge. The lack of integrated communication and data-sharing protocols among port authorities, operators, trucking companies, and customs offices leads to inefficiencies, delays, and misaligned priorities. This fragmentation not only limits operational efficiency but also hinders the ability to respond collectively to congestion and supply chain disruptions. Prior studies corroborate these challenges, emphasizing that cultural resistance to changes in Standard Operating Procedures (SOPs), reliance on outdated IT systems, and ambiguities in regulatory frameworks often slow down transformation efforts in ports across Indonesia. Such systemic barriers highlight the importance of adopting a holistic strategy—one that

combines investment in technology and equipment with institutional reforms, workforce upskilling, and strengthened governance mechanisms.

Limitations and Future Research

The study faced constraints in primary data collection due to restricted access to real-time operational records and limited benchmarking data. Future research should employ digital simulation models for CY layouts, apply predictive analytics to container flows, and test pilot digitalization projects (e.g., TOS and real-time dashboards) to measure quantifiable efficiency impacts. Comparative analysis across Indonesian and Southeast Asian ports would further refine a best-practice framework.

Conclusion

This study concludes that the management of the Container Yard (CY) at Batu Ampar Port, Batam, faces significant challenges in infrastructure capacity, operational efficiency, and the utilization of information technology. Field findings reveal that high yard utilization and prolonged container dwell time are driven by manual management practices, the absence of digital systems such as the Terminal Operating System (TOS), as well as limitations in equipment and workforce competency. Comparative analysis with international ports shows that Batu Ampar lags behind in the implementation of smart port technologies. Limited investment in container tracking systems and workforce training are identified as the main obstacles. To address these challenges, the recommended strategies include: (1) implementing digital systems based on RFID and GPS, (2) restructuring the CY layout, (3) increasing the capacity and availability of handling equipment, (4) providing technology-oriented workforce training, and (5) introducing investment schemes through public–private partnerships (PPP).

The theoretical contribution of this study lies in integrating a multidimensional approach to port management, linking technology, operational management, and human resources. From a practical perspective, the findings provide a roadmap for port authorities and local governments to enhance port logistics efficiency in a sustainable manner. This study also acknowledges several limitations, including restricted access to internal quantitative port data and time constraints during fieldwork. Therefore, future research is recommended to adopt quantitative approaches using simulation modeling, as well as pilot testing of digitalization initiatives to empirically assess their impact on port efficiency.

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