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Implementing Lean Port Management to Enhance Operational Efficiency and Reduce Waste in Ship Cargo Handling Operations at Tanjung Perak Port, Surabaya

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ABSTRACT: This research aims to examine the implementation of *Lean Port Management* as an approach to identify and reduce waste in ship cargo handling operations at Tanjung Perak Port, Surabaya. A descriptive mixed-method design was employed by integrating quantitative and qualitative approaches. Data were collected through direct observation, process-time measurement, documentation, and semi-structured interviews with 15 informants representing terminal management, stevedoring companies, ship crews, equipment operators, trucking providers, shipping agents, logistics users, and other relevant stakeholders. Waste was identified using the Lean framework, while operational efficiency was assessed using Process Cycle Efficiency (PCE). The findings show that *waiting* was the most dominant waste, identified by 15 informants (100%), followed by *overprocessing* identified by 6 informants (40.0%), *transportation* by 4 informants (26.7%), and *motion* by 3 informants (20.0%). Meanwhile, *idle* and *underutilization* were each identified by 2 informants (13.3%). These findings demonstrate that operational inefficiencies are primarily associated with waiting time, equipment readiness, truck queues, unnecessary cargo movement, administrative processes, and stakeholder coordination. The research concludes that *Lean Port Management* provides an integrated framework for reducing non-value-added activities through process standardization, resource synchronization, information integration, and continuous efficiency monitoring. The research contributes practical and managerial insights for improving the productivity and competitiveness of ship cargo handling operations at Tanjung Perak Port, Surabaya.

KEYWORDS: Efficiency, Lean Port Management, Port Operations, Ship Cargo Handling, Tanjung Perak Port, Waste, Waiting Time

INTRODUCTION

Seaports are critical nodes in global and regional supply chains because their operational performance directly influences vessel turnaround time, cargo flow, logistics reliability, and overall supply chain competitiveness. In container port operations, however, high cargo throughput does not necessarily indicate efficient performance. Ship cargo handling involves a complex interaction among terminal operators, stevedoring companies, quay cranes, yard equipment, trucks, shipping agents, ship crews, and logistics users, creating multiple opportunities for delays, redundant activities, equipment idleness, unnecessary movement, and process interruptions. These conditions are particularly important at Tanjung Perak Port, Surabaya, one of Indonesia's major maritime gateways, where increasing cargo flows and operational complexity require continuous improvement in the efficiency of loading and unloading processes. Operational inefficiency is therefore not merely a technical problem but also a managerial and systemic issue involving the synchronization of resources, information, processes, and stakeholders.

The conventional evaluation of port performance tends to emphasize productivity indicators such as crane moves per hour, berth occupancy, vessel turnaround time, or cargo throughput. Although these indicators are essential, they may not adequately reveal the sources of operational waste embedded within the process. A process can achieve relatively high productivity while simultaneously generating substantial waiting time, unnecessary transportation, excessive movement, duplicated administrative activities, equipment idle time, and underutilization of human resources. From a Lean management perspective, such activities represent non-value-added or waste-generating processes that consume time and resources without increasing cargo-handling value. Consequently, improving port performance requires a shift from merely measuring output toward systematically identifying where and why operational waste occurs and determining how it can be eliminated.

Recent research demonstrates the growing application of Lean principles, Value Stream Mapping (VSM), Lean Service, Lean Six Sigma, and related process-improvement approaches in port and cargo-handling operations. Daulay et al. (2021) identified transportation and waiting as major sources of waste in container unloading operations, while Ering and Suparno (2021) demonstrated that waiting, equipment problems, truck-related

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constraints, and operational interruptions significantly affect container-handling performance at Tanjung Perak Port. Other research has applied VSM to container loading and unloading processes and shown its potential to distinguish value-added, non-value-added, and necessary but non-value-added activities. Research on port efficiency has also increasingly emphasized digitalization, smart-port technologies, real-time monitoring, automation, and digital twins as mechanisms for improving resource allocation and operational visibility. These developments indicate that port efficiency is increasingly understood as a process-management challenge rather than solely an equipment-productivity issue.

Despite this progress, an important research gap remains. First, much of the existing research focuses on individual sources of inefficiency, such as equipment utilization, waiting time, truck queues, berth performance, or specific cargo-handling stages, rather than examining waste across the interconnected ship cargo-handling process. Second, previous studies frequently apply individual Lean tools, particularly VSM or Lean Six Sigma, without developing an integrated managerial framework that connects waste identification with resource synchronization, process standardization, stakeholder coordination, and continuous improvement. Third, the operational characteristics of Indonesian ports, particularly the interaction among terminal management, stevedoring operations, ship crews, trucking services, equipment operators, and logistics users, remain insufficiently explored from an integrated Lean Port Management perspective. This gap is significant because waste in port operations is rarely generated by a single actor; instead, it often emerges at the interfaces between processes and organizations.

This research addresses these gaps by applying Lean Port Management to systematically identify, classify, and analyze waste in ship cargo handling operations at Tanjung Perak Port, Surabaya. The research integrates quantitative measurements of operational time and process efficiency with qualitative evidence obtained from observations, documentation, and stakeholder interviews. The analysis focuses on identifying dominant forms of waste, determining their operational implications, and evaluating the extent to which non-value-added activities constrain process efficiency. Process Cycle Efficiency (PCE) is employed to distinguish value-added activities from total process lead time, thereby providing a more process-oriented assessment of operational efficiency. Unlike approaches that concentrate only on productivity outcomes, this research examines the underlying flow of activities and the operational causes of waste to formulate practical improvement strategies.

The originality of this research lies in positioning Lean Port Management as an integrated approach for connecting waste identification, process efficiency, resource synchronization, equipment readiness, information integration, and stakeholder coordination within ship cargo handling operations. The research therefore seeks not only to answer what types of waste occur, but also where the waste occurs, why it occurs, and how it can be systematically reduced. Accordingly, the objectives of this research are to: (1) identify and classify waste occurring in ship cargo handling operations at Tanjung Perak Port; (2) determine the dominant sources of operational inefficiency; (3) evaluate process efficiency using Process Cycle Efficiency; and (4) formulate Lean Port Management strategies for reducing non-value-added activities and improving operational performance. The research is guided by the following questions: (1) What types of Lean waste are most prevalent in ship cargo handling operations at Tanjung Perak Port? (2) What operational factors generate the dominant waste? (3) How does the identified waste affect process efficiency? and (4) What Lean Port Management strategies can be implemented to reduce waste and improve the efficiency of ship cargo handling operations? By addressing these questions, the research is expected to provide empirical and managerial contributions to the development of more efficient, synchronized, and continuously improving port operations in Indonesia.

LITERATURE REVIEW

Lean Management and Waste Reduction

Lean Management is a management philosophy aimed at maximizing customer value by systematically eliminating activities that do not create value and continuously improving process flow. The fundamental principle of Lean is that operational performance should not be measured solely by output but also by the ability of an organization to minimize unnecessary activities, reduce process variation, shorten lead time, and utilize resources efficiently. In service and logistics environments, Lean principles have been increasingly adapted because operational waste is often generated through waiting, unnecessary movement, excessive transportation, redundant processing, defects, excessive inventory, overproduction, and underutilization of human resources. The application of Lean therefore provides a process-oriented perspective for identifying inefficiencies that may remain invisible when performance is assessed only through conventional productivity indicators.

In port operations, Lean principles become particularly relevant because cargo-handling processes consist of sequential and interdependent activities. Vessel arrival, berth allocation, documentation, equipment preparation, loading and unloading, truck movement, yard transfer, cargo positioning, and vessel departure must be coordinated to maintain continuous cargo flow. A disruption in one activity can propagate to subsequent activities and create additional waiting, idle time, congestion, and resource underutilization. Consequently, Lean implementation in ports requires attention not only to individual activities but also to the interfaces and dependencies between organizations and operational processes.

Lean Port Management

Lean Port Management can be understood as the adaptation of Lean principles to port management and maritime logistics, with emphasis on improving cargo flow, minimizing operational waste, reducing unnecessary delays, and increasing the efficiency of resources throughout port processes. Unlike conventional port performance management, which frequently emphasizes throughput, berth productivity, crane productivity, or vessel turnaround time, Lean Port Management examines the entire operational flow to determine whether each activity contributes value to the service delivered to the customer.

The complexity of port operations makes this approach particularly important. A port is not a single organizational unit but an ecosystem involving terminal operators, port authorities, stevedoring companies, shipping lines, trucking companies, equipment operators, ship crews, freight forwarders, and cargo owners. Therefore, operational waste may occur not because an individual organization performs poorly, but because coordination between organizations is ineffective. Lean Port Management consequently requires synchronization of people, equipment, information, and operational schedules. This perspective extends the conventional Lean approach from internal process improvement toward inter-organizational process integration.

The development of smart-port technologies has further expanded the potential of Lean-based port management. Recent literature indicates increasing interest in digitalization, automation, real-time monitoring, digital twins, and intelligent resource allocation to improve operational

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visibility and decision-making. Pham (2023), Belmoukari et al. (2023), Li et al. (2023), and Paraskevas et al. (2024) demonstrate that smart-port development increasingly integrates digital technologies with operational optimization. However, technological advancement alone does not automatically eliminate process waste. Digital systems may improve information availability and coordination, but inefficient procedures, redundant activities, equipment constraints, and poor process design can remain. Thus, Lean Port Management can provide the process-improvement foundation upon which digital and smart-port technologies can be effectively utilized.

Lean Waste in Port Operations

Waste identification represents a central component of Lean Management. In the context of port cargo handling, the conventional seven wastes can be adapted to operational characteristics and supplemented by underutilization of human resources. The major categories include waiting, transportation, motion, overprocessing, defects, inventory, overproduction, and underutilization. Among these categories, waiting is particularly critical because port operations involve time-dependent resources such as vessels, berths, cranes, trucks, and terminal labor. When one resource is unavailable, subsequent activities may be forced to wait, increasing vessel turnaround time and operational costs.

Transportation waste occurs when cargo or equipment is moved unnecessarily or over excessive distances. Motion waste refers to unnecessary physical movement by workers or equipment operators. Overprocessing may emerge through duplicated documentation, repeated inspections, unnecessary approvals, or redundant administrative procedures. Defects can involve cargo-handling errors, documentation errors, equipment-related failures, or operational rework. Inventory waste may occur through inefficient yard utilization or excessive cargo accumulation, while underutilization reflects the ineffective use of employee skills, equipment capacity, or available operational resources.

Previous empirical research confirms the relevance of these waste categories in port environments. Daulay et al. (2021), using a Lean Service approach at PT Pelindo I Lhokseumawe, identified transportation and waiting as major sources of waste in container unloading activities. Their findings demonstrated that waste reduction could substantially improve Process Cycle Efficiency and container-handling productivity. Similarly, Ering and Suparno (2021) identified waiting for vessel departure, truck-related problems, container yard loading, unloading idle time, and equipment problems as important operational constraints in domestic container handling at Tanjung Perak Port. These findings indicate that waiting and process interruption are not isolated problems but structural sources of inefficiency within cargo-handling systems.

Recent research has continued to demonstrate the importance of waste-oriented process analysis. Fahreza (2024) found that idle time in bulk cargo unloading was strongly associated with truck availability and operational waiting. Nawawi et al. (2024) identified equipment damage, truck queues, weather, and tidal conditions as factors contributing to delays in container loading and unloading. Kurnianingsih and Rusdianto (2025) further emphasized the importance of effective loading and unloading management for improving operational efficiency. These findings reinforce the argument that operational waste in ports is generated by a combination of technical, organizational, environmental, and coordination factors.

Value Stream Mapping and Process Efficiency

Value Stream Mapping (VSM) is one of the principal Lean tools used to visualize the flow of materials, information, and activities from the beginning to the end of a process. In port operations, VSM can be used to map vessel arrival, berth preparation, cargo-handling activities, transportation, yard operations, documentation, and vessel departure. The principal advantage of VSM is its ability to distinguish value-added activities from non-value-added activities and to identify bottlenecks, waiting points, redundant movements, and process interruptions.

Recent research has demonstrated the applicability of VSM to maritime and port processes. Alamsyah and Marasabessy (2025) applied VSM to container vessel loading and unloading operations at Sunda Kelapa Port and demonstrated its usefulness in identifying opportunities for improving time efficiency. Aminah (2023) similarly applied VSM and Lean Service to container handling and identified waiting, defects, overproduction, inventory, motion, process, and transportation as sources of waste. Ardiansyah (2023) applied Lean Strategy to vehicle terminal operations and demonstrated that separating value-added, non-value-added, and necessary non-value-added activities can provide a clearer basis for operational improvement.

Process Cycle Efficiency (PCE) complements VSM by quantitatively evaluating the proportion of process time that contributes value relative to total lead time. PCE can be expressed as:

PCE = (Value-Added Time / Total Lead Time) × 100%

A higher PCE indicates that a greater proportion of total process time is devoted to value-adding activities, whereas a lower PCE indicates that a substantial proportion of time is consumed by waiting, transportation, inspection, rework, or other non-value-added activities. In the context of ship cargo handling, PCE is particularly useful because it shifts performance analysis from simply asking how much cargo is handled toward asking how efficiently the available operational time is converted into value-producing activity.

Operational Efficiency in Container Port Operations

Operational efficiency in container ports is influenced by the interaction between infrastructure, equipment, human resources, information, and operational planning. Quay Container Cranes (QCC), yard equipment, trucks, berth allocation, yard planning, and vessel schedules must operate as an integrated system. A bottleneck in one component can reduce the effective performance of the entire system.

Research on port efficiency has increasingly moved toward system-level analysis. Ghiara and Tei (2021) highlighted the role of technical efficiency and external factors in port performance, while Adler et al. (2022) demonstrated that specialization, ownership, competition, and regulation can influence port efficiency. Research on terminal operations has also examined automation, bottleneck mitigation, and real-time resource allocation. Van Battum et al. (2022) emphasized bottleneck mitigation as a mechanism for improving container-terminal performance, while Knatz et al. (2022) examined the operational characteristics associated with container terminal automation. Maskuri et al. (2024) specifically investigated the relationship between quay crane efficiency and container loading and unloading time.

These developments demonstrate a transition from isolated productivity measurement toward integrated operational-performance management. Nevertheless, efficiency evaluation based primarily on equipment or terminal-level indicators may not fully explain why process time is lost. Lean analysis addresses this limitation by examining the detailed sequence of activities and identifying the specific forms of waste that consume operational resources.

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Digitalization and the Future of Lean Port Operations

The emergence of Industry 4.0 has introduced new opportunities for improving port operations through real-time data, automation, Internet of Things (IoT), artificial intelligence, digital twins, and advanced decision-support systems. Gao et al. (2023) demonstrated the potential of digital twins for optimizing energy consumption in automated container terminals, while Ding and Voss (2023) highlighted real-time monitoring and resource allocation through digital-twin applications. Basulo-Ribeiro and Teixeira (2024) emphasized the role of Industry 4.0 technologies in supporting logistics toward smart ports.

However, the digital transformation of ports should not be considered a substitute for process improvement. Digitalizing an inefficient process can merely make an inefficient process faster or more visible without eliminating its underlying waste. The integration of Lean principles with digital technologies therefore provides a stronger pathway toward sustainable operational improvement. Lean identifies what should be eliminated, simplified, standardized, or synchronized, while digital technologies can provide the information infrastructure necessary to monitor and optimize the improved process in real time.

Previous Studies and Research Gap

The literature indicates substantial progress in applying Lean, VSM, Lean Service, Lean Six Sigma, and smart-port technologies to maritime and port operations. Existing research has successfully identified waiting, transportation, equipment problems, truck queues, idle time, and other operational constraints as important sources of inefficiency. However, three significant gaps remain.

First, previous research has frequently focused on specific terminal activities or individual waste categories rather than examining waste across the interconnected ship cargo-handling process. Second, many studies emphasize the identification of waste but provide limited integration between waste analysis, process efficiency measurement, root-cause interpretation, and managerial improvement strategies. Third, the organizational complexity of Indonesian port operations remains insufficiently incorporated into Lean analysis. Waste can emerge at the boundaries between terminal management, stevedoring companies, equipment operators, trucking providers, shipping agents, ship crews, and logistics users; therefore, an analysis limited to a single organizational perspective may fail to capture the systemic causes of inefficiency.

This research addresses these gaps by integrating Lean waste identification, operational time measurement, stakeholder perspectives, and Process Cycle Efficiency into a single analytical framework for ship cargo handling operations at Tanjung Perak Port, Surabaya. The research does not merely identify which waste occurs but investigates the dominant waste, its operational causes, its implications for process efficiency, and the managerial mechanisms required to reduce it. The resulting perspective positions Lean Port Management not simply as a collection of Lean tools, but as an integrated management approach linking process flow, resource utilization, stakeholder coordination, information integration, and continuous improvement. This positioning provides a stronger empirical basis for improving the efficiency, reliability, and competitiveness of ship cargo handling operations in Indonesian ports.

MATERIALS AND METHODS

Research Design

This research employed a descriptive mixed-method design integrating quantitative and qualitative approaches to examine operational waste and process efficiency in ship cargo handling activities at Tanjung Perak Port, Surabaya, East Java, Indonesia. The quantitative component was used to measure operational time, including value-added time, waiting time, idle time, transportation time, and total process lead time, while the qualitative component was used to identify the causes of waste, operational constraints, and coordination problems among stakeholders. The combination of both approaches was selected because port cargo handling is a complex socio-technical process in which operational inefficiencies cannot be adequately explained by numerical indicators alone. The research was conducted from October 2025 to March 2026.

Research Location and Operational Context

The research was conducted at Tanjung Perak Port, Surabaya, East Java, Indonesia. The port was selected because of its strategic role in Indonesia's maritime logistics network and the complexity of its ship cargo handling activities. The operational process examined in this research covered the sequence of activities associated with ship cargo handling, beginning with vessel arrival and berth preparation, followed by loading and unloading operations, cargo transfer and transportation, equipment utilization, yard-related activities, documentation and coordination, and ending with completion of cargo operations and vessel departure. The unit of analysis was the operational process rather than the performance of a single organization, allowing the research to capture waste occurring at the interfaces among different operational stakeholders.

Research Materials and Data Sources

The research utilized primary and secondary data. Primary data consisted of direct observations of cargo handling activities, process-time measurements, semi-structured interviews, and field documentation. Process-time observations were used to record the duration of operational activities and identify periods of value-added and non-value-added activity. Interviews were conducted to obtain information concerning operational constraints, equipment readiness, truck availability, coordination mechanisms, administrative procedures, and other factors contributing to waste.

Secondary data were obtained from relevant operational documents and records available during the research period, including cargo-handling records, vessel service records, loading and unloading documentation, equipment utilization information, operational schedules, and other supporting port documents. Secondary data were used to validate field observations and provide additional evidence concerning operational performance. Confidential operational information was not disclosed and was used only for research purposes.

Population and Sampling

The research population comprised stakeholders directly involved in ship cargo handling operations at Tanjung Perak Port. Because not all stakeholders have the same knowledge and operational responsibilities, purposive sampling was applied. Informants were selected based on their direct involvement in, experience with, or knowledge of ship cargo handling processes. A total of 15 informants participated in the research. They represented relevant stakeholder groups, including terminal or port management, stevedoring personnel, operational supervisors or planners, quay

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container crane operators, loading and unloading workers, trucking providers, shipping agents, ship officers or crew, logistics users, and port supervisory personnel.

The selection criteria required informants to have direct operational experience or decision-making responsibilities related to ship cargo handling. This sampling strategy was intended to ensure that the qualitative data reflected different perspectives across the operational chain rather than being dominated by a single organization or occupational group.

Data Collection Procedures

Data collection was conducted systematically through four complementary techniques: observation, process-time measurement, interviews, and documentation. First, preliminary observations were undertaken to understand the actual sequence of cargo handling activities and identify critical operational points. Second, direct time measurements were performed on relevant process activities to determine the duration of value-added and non-value-added activities. Particular attention was given to waiting, equipment idle periods, cargo transportation, unnecessary movement, repeated processing, and operational interruptions.

Third, semi-structured interviews were conducted with the 15 selected informants. The interview questions focused on the occurrence and causes of operational waste, equipment readiness, truck queues, communication and information flow, documentation procedures, resource utilization, operational coordination, and opportunities for process improvement. The semi-structured format enabled the researcher to maintain consistency across interviews while allowing informants to explain specific operational problems based on their experience.

Fourth, relevant documents and field evidence were collected to support and verify observations and interview findings. The data collection process was conducted iteratively, allowing observations and interview findings to be compared during the research process. Data that could not be sufficiently verified through one source were examined against other available sources.

Waste Identification and Classification

Operational waste was identified using the Lean Management framework and adapted to the characteristics of port cargo handling. Eight waste categories were examined: waiting, transportation, motion, overprocessing, defects, inventory, overproduction, and underutilization. The identification process involved matching observed activities and interview statements with the operational characteristics of each waste category.

Waiting referred to periods in which personnel, vessels, equipment, cargo, or processes were unable to proceed because the required resource or activity was unavailable. Transportation referred to unnecessary or inefficient movement of cargo, equipment, or materials. Motion referred to unnecessary physical movement during operational activities. Overprocessing included duplicated, redundant, or unnecessary operational and administrative activities. Defects included operational or documentation errors that generated rework or additional processing. Inventory referred to inefficient accumulation or positioning of cargo and resources, while overproduction referred to activities performed beyond immediate operational requirements. Underutilization represented the ineffective use of available human capabilities, equipment capacity, or other operational resources.

Each identified waste was documented together with its location in the operational process, observed evidence, frequency or occurrence, and potential operational consequences. This procedure enabled the research to distinguish between isolated operational incidents and recurring forms of waste.

Quantitative Analysis

Quantitative analysis was conducted using descriptive statistics and process-efficiency measurements. The primary variables included value-added time (VAT), non-value-added time (NVAT), waiting time, idle time, transportation time, total lead time, and process cycle efficiency. Total lead time represented the total elapsed time required to complete the analyzed operational process, while value-added time represented activities that directly contributed to the completion of ship cargo handling.

Process Cycle Efficiency (PCE) was calculated using the following equation:

PCE = (Value-Added Time / Total Lead Time) × 100%

A higher PCE indicates that a larger proportion of the total process time contributes directly to value creation, whereas a lower PCE indicates that a substantial proportion of operational time is consumed by non-value-added or waste-generating activities. The proportion of each identified waste category was also calculated using descriptive percentages:

Waste Proportion = (Number of Informants Identifying Waste / Total Number of Informants) × 100%

This calculation was used to determine the relative prominence of each waste category based on stakeholder perceptions and field evidence. Quantitative results were presented through frequencies, percentages, process-time comparisons, and PCE measurements.

Qualitative Data Analysis

Qualitative data from observations and interviews were analyzed through a systematic process of data reduction, categorization, coding, interpretation, and synthesis. First, relevant statements and field observations were identified and organized according to operational themes. Second, recurring information was coded into categories corresponding to Lean waste types and their potential causes. Third, relationships among waste categories, operational constraints, and process activities were examined to identify recurring patterns. Finally, the findings were synthesized to establish the dominant sources of inefficiency and their implications for operational performance.

The qualitative analysis focused particularly on the relationship between operational waste and five major dimensions: equipment readiness, resource availability, process standardization, information flow, and stakeholder coordination. This approach enabled the research to move beyond simply identifying waste toward explaining the operational mechanisms through which waste was generated.

Root-Cause Analysis and Improvement Strategy

After waste identification, the dominant sources of inefficiency were examined through root-cause analysis. The analysis considered technical, human, procedural, informational, and organizational factors. Particular attention was given to recurring waiting periods, equipment-related interruptions, truck queues, unnecessary cargo movement, duplicated administrative procedures, and coordination failures.

The root causes were subsequently linked to Lean improvement principles. Proposed improvements included process standardization, synchronization of operational schedules and resources, improvement of equipment readiness, reduction of unnecessary movement, simplification

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of administrative processes, improvement of information integration, and continuous performance monitoring. The improvement strategy was developed based on the relationship between identified waste, its root causes, and the potential feasibility of corrective actions within the port operating environment.

Data Validity and Triangulation

Data validity was strengthened through source and method triangulation. Source triangulation was conducted by comparing information obtained from different stakeholder groups, including port management, stevedoring personnel, equipment operators, trucking providers, shipping agents, ship crews, and other relevant actors. Method triangulation was performed by comparing interview findings with direct observations, process-time measurements, and operational documentation.

The findings were considered sufficiently supported when similar evidence appeared across multiple sources or methods. Contradictory information was not immediately excluded but was re-examined against field observations and available documentation. This procedure was intended to reduce researcher bias and improve the credibility, consistency, and traceability of the research findings.

Research Procedure

The research was conducted through five sequential stages. First, preliminary observation and problem identification were performed to understand the operational flow and determine critical areas of potential waste. Second, primary and secondary data were collected through observation, time measurement, interviews, and documentation. Third, operational activities were mapped and waste was identified and classified according to the Lean framework. Fourth, operational efficiency and the relationship between value-added and non-value-added activities were analyzed using descriptive measures and PCE, followed by qualitative root-cause analysis. Fifth, Lean Port Management improvement strategies were formulated based on the dominant waste, identified root causes, process-efficiency results, and stakeholder perspectives.

The overall methodological framework can therefore be represented as: preliminary observation → process mapping → data collection → waste identification and classification → quantitative efficiency analysis → qualitative root-cause analysis → triangulation → Lean Port Management improvement strategy. This methodological sequence provides a transparent analytical pathway from empirical observation to managerial recommendations and enables the research to be replicated in comparable port cargo-handling environments.

RESULTS

The research was conducted at Tanjung Perak Port, Surabaya, East Java, Indonesia, during October 2025–March 2026. Data were collected during October 2025–March 2026 through direct observation, process-time measurement, operational documentation, and semi-structured interviews with 15 informants involved in ship cargo handling operations. The results are presented through three principal indicators: identification of Lean waste, Process Cycle Efficiency (PCE), and operational performance before and after the implementation of Lean Port Management.

3.1 Identification of Lean Waste

The identification of waste was conducted using the Lean framework adapted to ship cargo handling operations. Each informant could identify more than one waste category based on their operational experience.

Table 1. Identification of Lean Waste in Ship Cargo Handling Operations

No.	Waste Category	Number of Informants	Percentage (%)
1	Waiting	15	**100.0**
2	Overprocessing	6	**40.0**
3	Transportation	4	**26.7**
4	Motion	3	**20.0**
5	Idle	2	**13.3**
6	Underutilization	2	**13.3**

Note: The percentages are based on 15 informants. Each informant could identify more than one waste category.

Waiting was identified by 15 informants (100.0%), followed by overprocessing with 6 informants (40.0%), transportation with 4 informants (26.7%), motion with 3 informants (20.0%), and idle and underutilization with 2 informants (13.3%) each.

3.2 Process Cycle Efficiency

Process Cycle Efficiency was calculated to determine the proportion of total process time represented by value-added activities. The calculation used the following equation:

PCE = (Value-Added Time / Total Lead Time) × 100%

The process-time measurements produced a total lead time of 1,800 minutes, consisting of 1,020 minutes of value-added time and 780 minutes of non-value-added time.

Table 2. Process Cycle Efficiency of Ship Cargo Handling Operations

No.	Process Efficiency Component	Time (minutes)	Percentage (%)
1	Value-Added Time (VAT)	1,020	**56.67**
2	Non-Value-Added Time (NVAT)	780	**43.33**
3	**Total Lead Time (TLT)**	**1,800**	**100.00**
4	**Process Cycle Efficiency (PCE)**	—	**56.67**

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The calculated Process Cycle Efficiency was 56.67%, while non-value-added activities accounted for 43.33% of the total process time.

3.3 Operational Performance Before and After Implementation

The principal operational performance indicators were compared before and after the implementation of Lean Port Management.

Table 3. Operational Performance Before and After Lean Port Management

No.	Performance Indicator	Before Implementation	After Implementation	Change (%)
1	Waiting Time	100%	70%	**−30.0**
2	Lead Time	100%	76%	**−24.0**
3	Crane Productivity	26 boxes/hour	34 boxes/hour	**+30.8**

The results show a 30.0% reduction in waiting time and a 24.0% reduction in lead time. Crane productivity increased from 26 boxes per hour to 34 boxes per hour, representing a 30.8% increase.

The three tables collectively present the principal empirical results of the research. Table 1 presents the identified waste categories, Table 2 presents the measured process efficiency, and Table 3 presents the changes in key operational performance indicators. Interpretation of these results and comparison with previous studies are presented in the Discussion section.

DISCUSSION

4.1 Waiting as the Dominant Source of Operational Waste

The most significant finding of this research is that waiting represents the dominant form of waste in ship cargo handling operations at Tanjung Perak Port, identified by all 15 informants (100.0%). This finding indicates that the principal efficiency problem is not necessarily the physical execution of cargo handling itself, but the interruption and discontinuity of process flow. In a port environment, waiting can occur when vessels, quay cranes, trucks, cargo, labor, documentation, or information are not available at the required time. Because these resources are interdependent, a delay in one activity can immediately create idle time in another activity and subsequently extend vessel turnaround time.

This finding is consistent with Daulay et al. (2021), who identified waiting and transportation as major sources of waste in container unloading operations. It also supports the findings of Ering and Suparno (2021), who identified waiting for vessel departure, truck-related problems, yard loading constraints, unloading idle time, and equipment problems as important factors affecting container-handling performance at Tanjung Perak Port. Similarly, Fahreza (2024) found that truck availability and waiting contributed substantially to idle time during cargo unloading operations. The consistency across these studies suggests that waiting is not an isolated operational problem but a recurring structural characteristic of cargo-handling systems.

However, the 100.0% identification rate in this research provides a particularly strong empirical signal. The finding suggests that waiting should be treated as a primary Lean intervention target, rather than as a secondary consequence of other operational problems. From the Lean perspective, reducing waiting requires the stabilization of process flow and synchronization of resources rather than simply increasing the speed of individual equipment. Therefore, improving crane productivity without simultaneously addressing truck availability, information flow, berth planning, equipment readiness, and stakeholder coordination may produce limited system-level benefits.

4.2 Overprocessing, Transportation, and Motion as Secondary Waste

The second most frequently identified waste was overprocessing, reported by 6 informants (40.0%). In the context of ship cargo handling, overprocessing may occur through repeated documentation, duplicated verification, unnecessary approvals, repeated communication, or procedural activities that do not directly contribute to cargo movement. Although its frequency was lower than waiting, overprocessing represents a significant source of process inefficiency because administrative delays can propagate into physical operations.

Transportation was identified by 4 informants (26.7%), while motion was identified by 3 informants (20.0%). These findings indicate that waste is not limited to time losses but also involves unnecessary movement of cargo, equipment, and workers. Inefficient cargo routes, poorly synchronized truck movements, and unnecessary worker movement can increase operational time without increasing the value delivered to the customer. This finding is consistent with Daulay et al. (2021), who reported transportation as a major source of waste in container unloading operations.

The combined occurrence of waiting, transportation, motion, and overprocessing demonstrates that waste in port operations is interconnected. For example, inefficient truck movement can generate transportation waste, which can subsequently create waiting for cranes or workers. Similarly, repeated documentation can delay operational authorization and generate waiting in subsequent activities. Therefore, waste categories should not be treated independently; they form a chain of operational inefficiencies in which one form of waste can trigger another.

4.3 Process Cycle Efficiency and the Hidden Cost of Non-Value-Added Activities

The Process Cycle Efficiency calculated in this research was 56.67%, meaning that 56.67% of the observed total process time was classified as value-added time, while 43.33% was associated with non-value-added activities. This result provides an important perspective that cannot be obtained from conventional productivity indicators alone.

A port may report high cargo throughput or crane productivity while still losing a substantial proportion of available operational time through waiting, transportation, motion, overprocessing, and idle activities. The PCE result therefore reveals the proportion of process time that is effectively converted into value-producing cargo-handling activity. In this research, almost half of the total process time was outside the value-added component, indicating considerable room for process improvement.

The importance of this finding is supported by previous Lean-based research. Daulay et al. (2021) demonstrated that Lean Service intervention could substantially increase PCE in container unloading operations, from 34.04% to 58.75%. The PCE achieved in this research is within a comparable range, but the comparison should be interpreted carefully because the operational processes, measurement procedures, cargo

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characteristics, and research contexts are different. Nevertheless, both findings reinforce the usefulness of PCE as an indicator for revealing hidden process losses that may be obscured by aggregate productivity measures.

The implication is clear: port efficiency should not be evaluated solely by how much cargo is handled, but by how much of the total operational time actually creates value. PCE provides a practical bridge between Lean waste identification and measurable operational efficiency.

4.4 Operational Performance Improvement

The results indicate a 30.0% reduction in waiting time, a 24.0% reduction in lead time, and an increase in crane productivity from 26 boxes/hour to 34 boxes/hour, equivalent to a 30.8% increase. These changes indicate that the Lean-oriented improvement strategy was associated with measurable improvements in operational performance.

The reduction in waiting time is particularly important because waiting was the dominant waste identified in the research. The reduction therefore addresses the principal source of observed inefficiency rather than focusing primarily on secondary process problems. The simultaneous reduction in lead time suggests that improvements in process flow can produce benefits beyond individual activity performance.

The increase in crane productivity further demonstrates that waste reduction and productivity improvement can occur simultaneously. However, the result should not be interpreted as evidence that crane performance alone caused the reduction in lead time. Port cargo handling is a system of interdependent activities; therefore, improvements in crane productivity are likely to be influenced by the availability of trucks, cargo readiness, equipment condition, work planning, and information coordination.

This finding is consistent with Ering and Suparno (2021), who reported improvements in operational cycle-time performance following Lean Six Sigma interventions in container handling at Tanjung Perak Port. It also aligns with research emphasizing bottleneck mitigation and integrated resource allocation as important mechanisms for improving container-terminal performance (Van Battum et al., 2022). The present research extends this perspective by explicitly linking operational improvement to the identification of Lean waste across multiple stakeholder interfaces.

4.5 Lean Port Management as an Integrated Management Approach

The findings support the argument that Lean Port Management should not be viewed simply as the application of isolated tools such as Value Stream Mapping, 5S, or Lean Six Sigma. The central managerial issue identified by this research is synchronization. Ship cargo handling requires the simultaneous availability of equipment, workers, trucks, cargo, documentation, information, and operational decisions.

Consequently, the most appropriate Lean Port Management strategy is an integrated intervention consisting of five complementary mechanisms: (1) process standardization, (2) synchronization of operational resources, (3) equipment readiness management, (4) information and documentation integration, and (5) continuous performance monitoring. Process standardization reduces variation, resource synchronization reduces waiting, equipment readiness minimizes unexpected interruption, information integration reduces administrative overprocessing, and continuous monitoring enables rapid identification of recurring waste.

This perspective is particularly relevant in the transition toward smart-port operations. Recent studies have emphasized digitalization, automation, real-time monitoring, and digital twins as mechanisms for improving port efficiency (Pham, 2023; Belmoukari et al., 2023; Li et al., 2023; Paraskevas et al., 2024). Nevertheless, digital technology cannot by itself eliminate waste originating from poorly designed processes. The findings of this research suggest that Lean should provide the process-improvement logic, while digital technologies should provide the visibility, connectivity, and real-time control required to sustain that improvement.

4.6 Managerial Implications

The results have several practical implications for port management and cargo-handling stakeholders. First, waiting should become a key performance indicator rather than being treated merely as an operational consequence. Waiting should be monitored by cause, location, duration, and responsible process interface. Second, berth, crane, truck, yard, and labor schedules should be synchronized through integrated operational planning. Third, equipment readiness should be managed proactively through preventive maintenance and pre-operation inspections. Fourth, documentation and approval processes should be simplified and digitally integrated to reduce overprocessing. Fifth, operational performance should be monitored continuously using indicators such as waiting time, lead time, PCE, crane productivity, equipment utilization, and process interruptions.

The findings also have implications for inter-organizational governance. Because port waste frequently occurs at the boundaries between organizations, improvement cannot be assigned exclusively to terminal management or stevedoring companies. Effective waste reduction requires shared performance targets and coordinated responsibilities among terminal operators, stevedoring companies, trucking providers, shipping agents, ship crews, equipment operators, and other stakeholders. Thus, Lean Port Management should be implemented as a cross-organizational improvement system, rather than as an internal efficiency program of a single organization.

4.7 Theoretical and Research Contribution

The theoretical contribution of this research lies in extending the application of Lean principles from conventional manufacturing and service processes toward the multi-actor operational environment of port cargo handling. The research demonstrates that Lean waste in ports is simultaneously temporal, physical, informational, technical, and organizational. Waiting and idle time represent temporal waste; transportation and motion represent physical waste; overprocessing reflects informational and administrative waste; while underutilization represents ineffective use of organizational resources.

The research consequently positions Lean Port Management as a broader process-management framework that connects waste identification with process efficiency and stakeholder coordination. The integration of waste analysis and PCE also provides a more comprehensive perspective than relying solely on conventional port productivity indicators. This contributes to the growing literature on port efficiency by emphasizing the importance of the process flow underlying performance outcomes.

4.8 Limitations of the Research

Several limitations should be acknowledged. First, the research was conducted at one major Indonesian port, Tanjung Perak Port, Surabaya; therefore, the findings may not be directly generalizable to ports with substantially different cargo characteristics, infrastructure, operating systems,

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or institutional arrangements. Second, the qualitative component involved 15 purposively selected informants. Although they represented different stakeholder groups, the sample does not statistically represent the entire population of port workers and users.

Third, operational performance in ports is affected by external conditions, including weather, tides, vessel characteristics, cargo characteristics, equipment condition, traffic density, and schedule changes. These factors may influence process-time measurements and cannot always be fully controlled in an operational port environment. Fourth, the measurement of waste based partly on stakeholder identification may contain perceptual bias. Although triangulation among interviews, observations, and documentation was applied, future research could strengthen the analysis through larger longitudinal datasets and automated operational records.

Finally, the before-and-after performance comparison provides evidence of operational improvement but does not establish a causal relationship as strongly as a controlled experimental or longitudinal design would. Future research should therefore examine Lean Port Management using larger multi-port datasets, repeated measurements across different vessel and cargo conditions, statistical significance testing, and integration with real-time digital-port data. Such research could further determine whether the observed improvements are sustainable over time and transferable to other Indonesian and international port environments.

4.9 Overall Discussion

Taken together, the findings demonstrate that the central challenge in ship cargo handling at Tanjung Perak Port is not simply insufficient operational capacity, but the presence of waste within the process flow. The dominance of waiting, the 43.33% proportion of non-value-added process time, and the measurable improvements in waiting time, lead time, and crane productivity collectively demonstrate the relevance of a Lean-based approach to port operational improvement. The key implication is that sustainable efficiency cannot be achieved merely by increasing equipment capacity; it requires the systematic elimination of activities that consume time and resources without creating value. Lean Port Management therefore provides a practical managerial framework for transforming fragmented cargo-handling activities into a more synchronized, transparent, and continuously improving operational system.

CONCLUSION

This research concludes that the implementation of Lean Port Management provides a practical and systematic approach for identifying and reducing operational waste in ship cargo handling activities at Tanjung Perak Port, Surabaya. The empirical findings demonstrate that waiting is the dominant form of waste, identified by 15 informants (100.0%), followed by overprocessing (40.0%), transportation (26.7%), motion (20.0%), idle (13.3%), and underutilization (13.3%). The Process Cycle Efficiency of 56.67% indicates that a substantial proportion of total process time remains associated with non-value-added activities. Following the Lean-oriented improvement measures, waiting time decreased by 30.0%, lead time decreased by 24.0%, and crane productivity increased from 26 to 34 boxes/hour, representing a 30.8% improvement. These findings demonstrate that port efficiency is strongly influenced by process flow, resource synchronization, equipment readiness, information integration, and coordination among operational stakeholders rather than by equipment productivity alone.

The primary contribution of this research is the development of an integrated Lean Port Management perspective that connects waste identification, process efficiency measurement, operational improvement, and stakeholder coordination within ship cargo handling operations. Practically, port managers should prioritize waiting-time reduction, synchronize berth–crane–truck–yard resources, standardize operational procedures, strengthen equipment-readiness management, simplify administrative processes, and integrate operational information through digital systems. From a policy perspective, port authorities and terminal operators should establish cross-organizational performance standards based on measurable indicators such as waiting time, lead time, PCE, equipment utilization, and cargo-handling productivity. Future research should extend the analysis to multiple ports and longer observation periods, incorporate larger operational datasets and real-time digital-port data, and employ longitudinal or quasi-experimental designs to test the sustainability and causal effects of Lean Port Management interventions. Further research should also investigate the integration of Lean Port Management with Industry 4.0 technologies, digital twins, artificial intelligence, and predictive analytics to develop a more adaptive, data-driven, and continuously improving port operational system.

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