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Operational efficiency of loading and unloading activities using the time and motion study method at Tanjung Priok Port

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ABSTRACT

This study aims to analyze the operational efficiency of container loading and unloading activities at Tanjung Priok Port using the Time and Motion Study method. The research was conducted to identify non-productive work activities, measure actual working times, and determine the standard time required for the loading and unloading processes. Employing a quantitative descriptive approach, data were collected through direct observation, work-time recording, documentation, and in-depth interviews with field operators. The collected data were subsequently analyzed by measuring cycle time, normal time, and standard time to assess the current level of operational efficiency. The findings reveal the persistence of non-productive periods, which are primarily caused by equipment coordination delays and operational vehicle queues. Based on the Time and Motion Study evaluation, specific bottlenecks were identified, providing actionable insights to improve work efficiency and reduce processing times. Ultimately, this study provides strategic recommendations for port management to sustainably enhance productivity, work effectiveness, and overall operational service quality.

Keywords: *Operational efficiency, loading and unloading, time and motion study, port productivity, standard time.*

ABSTRAK

Penelitian ini bertujuan untuk menganalisis efisiensi operasional kegiatan bongkar muat peti kemas di Pelabuhan Tanjung Priok menggunakan metode Time and Motion Study. Penelitian ini dilakukan untuk mengidentifikasi aktivitas kerja non-produktif, mengukur waktu kerja aktual, dan menentukan standar waktu baku dalam proses bongkar muat. Menggunakan pendekatan deskriptif kuantitatif, pengumpulan data dilakukan melalui observasi langsung, pencatatan waktu kerja, dokumentasi, dan wawancara dengan operator lapangan. Data yang terkumpul kemudian dianalisis melalui pengukuran waktu siklus, waktu normal, dan waktu baku untuk menilai tingkat efisiensi operasional saat ini. Hasil penelitian menunjukkan bahwa masih terdapat waktu non-produktif yang utamanya disebabkan oleh keterlambatan koordinasi alat berat dan antrean kendaraan operasional. Melalui evaluasi berbasis Time and Motion Study, penelitian ini mengidentifikasi hambatan spesifik sehingga memberikan peluang untuk meningkatkan efisiensi kerja dan mereduksi waktu proses bongkar muat. Pada akhirnya, penelitian ini diharapkan dapat memberikan rekomendasi strategis bagi manajemen pelabuhan dalam upaya meningkatkan produktivitas, efektivitas kerja, dan kualitas layanan operasional pelabuhan secara berkelanjutan.

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Kata Kunci: *Efisiensi operasional, bongkar muat, studi waktu dan gerakan, produktivitas pelabuhan, waktu standar.*

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INTRODUCTION

Loading and unloading activities constitute one of the primary indicators of port operational performance, as they directly influence cargo flow, vessel turnaround time, logistics costs, and overall port productivity. As Indonesia's largest and busiest seaport, Tanjung Priok Port plays a strategic role in facilitating both domestic and international trade. The continuously increasing volume of cargo requires loading and unloading operations that are efficient, reliable, and well-coordinated to support the competitiveness of Indonesia's maritime logistics sector. Nevertheless, several operational challenges remain, including inefficient working time, unnecessary work movements, delays in equipment coordination, and suboptimal labor productivity. These issues contribute to increased logistics costs, longer vessel service times, and reduced operational efficiency [1].

Improving the efficiency of loading and unloading operations requires a systematic evaluation of work performance. One widely adopted approach is the **Time and Motion Study**, which measures work duration while analyzing operator movements to distinguish value-added from non-value-added activities. This method enables organizations to establish standard working times, minimize operational waste, optimize resource utilization, and improve workforce productivity. Previous studies have demonstrated that the implementation of Time and Motion Study significantly enhances operational efficiency in logistics and port transportation by supporting evidence-based improvements in work systems and more effective allocation of operational resources (Rahman & Setiawan, 2021) [2].

The rapid growth of global trade and logistics activities has further increased the demand for high-performance port operations. In modern ports, operational efficiency depends not only on the availability of infrastructure and terminal capacity but also on the effectiveness of work processes and the optimal utilization of loading and unloading equipment. Recent studies have reported that inefficiencies during cargo handling remain among the major contributors to prolonged dwelling time at Indonesian ports [3]. These operational delays increase national logistics costs and adversely affect supply chain performance, ultimately reducing the competitiveness of maritime transportation services [4]. Consequently, a comprehensive assessment of loading and unloading operations through detailed measurements of work time and operator movements is essential to identify the root causes of operational inefficiencies and formulate effective improvement strategies.

Although numerous studies have investigated port performance from the perspectives of infrastructure development, terminal capacity, logistics management, and equipment utilization, relatively few have focused on evaluating the operational efficiency of loading and unloading activities using the Time and Motion Study approach at Tanjung Priok Port. Previous research has generally concentrated on equipment productivity, berth occupancy, or vessel turnaround time without conducting detailed analyses of operator work activities and movement patterns during field operations. Moreover, existing studies rarely integrate standard time determination with motion analysis to comprehensively identify operational waste and productivity losses [5]. This gap highlights the need for a more integrated evaluation of loading and unloading processes that simultaneously considers work time, work motions, and operational performance.

The novelty of this study lies in the integrated application of the Time and Motion Study method to evaluate the operational efficiency of loading and unloading activities at Tanjung Priok Port under actual field conditions. Unlike previous studies, this research combines standard time determination, work motion analysis, identification of non-value-added activities, and productivity assessment within a unified analytical framework [6]. The findings are expected to provide practical recommendations for improving work systems, optimizing operational resources, and enhancing labor productivity. Furthermore, this study contributes to the existing body of knowledge by providing an empirical framework that can support managerial decision-making and promote the development of more efficient, effective, and sustainable loading and unloading operations in modern port environments.

METHODOLOGY

Research Design

This study employed a descriptive quantitative research design using the Time and Motion Study approach to evaluate the operational efficiency of loading and unloading activities at Tanjung Priok Port. A quantitative approach was selected because the study focuses on objectively measuring working time, work movements, and operational productivity using systematic and measurable procedures. The Time and Motion Study method was applied to identify value-added and non-value-added activities throughout the loading and unloading process. Previous studies have demonstrated that this method effectively improves work efficiency by reducing unnecessary movements and minimizing operational time losses in logistics and port operations [7].

The descriptive design was adopted to provide a comprehensive representation of actual loading and unloading operations based on field observations, work time measurements, and motion analysis. The analysis focused on working time utilization, cycle time, waiting time, and operational constraints affecting overall productivity. This approach provides a realistic assessment of operational performance and enables the identification of opportunities for process improvement in modern port operations [8].

Research Location and Period

The research was conducted at Tanjung Priok Port, Indonesia's largest seaport and the country's primary logistics distribution hub. The study site was selected purposively due to its high cargo throughput and intensive loading and unloading activities, making it suitable for evaluating operational efficiency. The research was conducted from January to March 2026, covering field observations, data collection, data processing, and data analysis.

Population and Sample

The population consisted of all operational loading and unloading activities involving stevedores, heavy equipment operators, and field operational personnel at Tanjung Priok Port. Samples were selected using a purposive sampling technique by choosing loading and unloading operations with high operational frequency that represented the principal cargo handling processes at the port. The observed work elements included equipment preparation, container lifting, cargo transfer, and cargo stacking within the container yard. This sampling technique ensured that the collected data accurately represented actual operational conditions and were consistent with the objectives of the study [9].

Data Collection

Data were collected through direct observation, time study, interviews, documentation, and motion study. Direct observation was conducted throughout the loading and unloading process to identify individual work elements and record the actual sequence of operational activities. Working time was measured using a stopwatch for repetitive work cycles, and multiple observations were performed for each work element to obtain representative average cycle times and improve measurement reliability [10]. Semi-structured interviews were conducted with stevedores, equipment operators, and operational supervisors to obtain information regarding operational constraints, delays, and factors influencing loading and unloading productivity. Documentation was collected in the form of operational records, activity photographs, cargo handling reports, and other relevant port documents to support the observational findings.

In addition to the Time Study, this research also employed Motion Study to evaluate operator movements during cargo handling operations. Motion analysis was conducted to identify unnecessary or ineffective movements that contributed to operational waste and reduced productivity. The findings from the motion analysis were integrated with the time measurements to provide a comprehensive evaluation of operational efficiency and identify opportunities for improving work methods.

Research Variables

The primary variable investigated in this study was the operational efficiency of loading and unloading activities. This variable was assessed using several performance indicators, including loading and unloading cycle time, normal working time, standard working time, delay time, loading and unloading productivity, and the proportion of productive and non-productive activities. These indicators were measured using the Time and Motion Study approach by determining the normal time and standard time for each work element. Operational efficiency was subsequently evaluated by comparing actual operational performance with the established standard working time [11].

Data Analysis

Data analysis was performed using the Time and Motion Study procedure. The first stage involved calculating the cycle time, which represents the average completion time required for each work element and is expressed as

$$WS = \frac{\sum x}{n}, \quad (1)$$

where (WS) denotes the cycle time, ($\sum x$) represents the total observed time, and (n) is the number of observations. The second stage involved determining the normal time by multiplying the cycle time by the performance rating, as expressed in

$$WN = WS \times PR, \quad (2)$$

where (WN) is the normal time, (WS) is the cycle time, and (PR) represents the performance rating. The third stage was the calculation of the standard time by incorporating the allowance factor. The standard time was calculated using

$$WB = \frac{WN}{1 - Allowance}, \quad (3)$$

where (WB) denotes the standard time, (WN) is the normal time, and *Allowance* represents the allowance factor applied to account for personal needs, fatigue, and unavoidable delays.

The final stage involved evaluating operational efficiency by comparing work output with the total operational time. Operational efficiency was calculated using

$$Efisiensi\ Operasional = \frac{Output\ Kerja}{Waktu\ Operasional} \times 100\ \%. \quad (4)$$

A higher operational efficiency value indicates greater productivity and more effective loading and unloading operations. All quantitative data were processed and analyzed using Microsoft Excel for data tabulation, calculation, visualization, and interpretation of the research findings.

Data Validity

To improve the credibility and reliability of the research findings, data triangulation was conducted by comparing information obtained from direct observations, interviews, and operational documentation. Furthermore, repeated time measurements were performed on identical work elements to ensure consistency and minimize observational errors. The implementation of repeated measurements is widely recognized as an effective procedure for improving the accuracy and reliability of Time Study analyses in industrial engineering and logistics operations [12].

RESULTS AND DISCUSSION

General Description of the Study Area

This study was conducted at Tanjung Priok Port, the largest and busiest seaport in Indonesia, which serves as the country's primary gateway for domestic and international container transportation. The port operates a wide range of cargo-handling facilities, including ship-to-shore container cranes, head trucks, rubber-tired gantry (RTG) cranes, and container yard storage areas. Due to the high volume of container traffic, operational efficiency has become a critical factor in reducing vessel turnaround time, minimizing logistics costs, and improving port service performance [13,14]. The research focused on the operational process of container loading and unloading by applying the Time and Motion Study method. The analysis aimed to evaluate actual working time, operator work movements, and operational efficiency under real field conditions.

Time Study Results

The results of the time observations for each loading and unloading activity are presented in Table 1.

Table 1. Average loading and unloading cycle time.

Activity Stage	Average Time (minutes)
Preparation of loading and unloading equipment	0.8
Container lifting	2.6
Container transfer	3.1
Container placement	1.4
Operator waiting time	1.3
Total Cycle Time	**9.2**

Source: Primary data processed by the authors (*2026*).

The observation results indicate that the average loading and unloading cycle time was 9.2 minutes. Among all work elements, container transfer required the longest average time (3.1 minutes), primarily because of congestion within the operational area and limited maneuvering space for cargo-handling equipment. Meanwhile, operator waiting time averaged 1.3 minutes, indicating delays caused by equipment queues and less effective coordination among operational personnel. These findings suggest that operational bottlenecks are primarily associated with equipment movement and workflow coordination rather than the loading and unloading operations themselves.

Motion Study Analysis

The Motion Study identified several work movements that contributed to operational inefficiencies. The results are summarized in Table 2.

Table 2. Identification of non-value-added activities.

Ineffective Activity	Cause	Operational Impact
Waiting for transport equipment	Ineffective coordination	Increased cycle time
Slow vehicle movement	Congested working area	Delayed container transfer
Equipment repositioning	Inefficient container arrangement	Reduced productivity
Operator idle time	Workflow imbalance	Increased non-productive activities

Source: Primary data processed by the authors (2026).

The motion analysis revealed that a considerable portion of operational delays originated from non-value-added activities, particularly equipment waiting, repeated equipment repositioning, and operator idle time. These activities did not contribute directly to cargo handling but significantly increased the total operational cycle time. Consequently, improving work coordination, optimizing equipment allocation, and redesigning operational traffic routes are expected to reduce unnecessary movements and improve overall operational efficiency.

Normal Time and Standard Time Analysis

Based on the Time Study observations, the average cycle time was 9.2 minutes, while the performance rating was 1.05 and the allowance factor was 10%. The normal time was calculated using Equation (2):

$$WN = 9.2 \times 1.05 = 9.66 \text{ menit.}$$

The calculated normal time of 9.66 minutes represents the estimated duration required by a qualified operator to complete one loading and unloading cycle under normal working conditions.

The standard time was subsequently determined by incorporating the allowance factor using Equation (3):

$$WB = \frac{9.66}{1 - 0.10} = 10.73 \text{ menit.}$$

The calculated standard time of 10.73 minutes represents the recommended duration for completing one operational cycle after accounting for personal needs, fatigue, and unavoidable operational delays. This value can serve as a benchmark for evaluating operator performance and planning operational capacity at the port.

Observation Data Validity

The consistency of the observation data was evaluated through repeated measurements, as presented in Table 3.

Table 3. Observation data validity.

Observation	Time (minutes)	Average	Deviation (%)	Description
1	2.6	2.6	0.00	Valid
2	2.5	2.6	3.85	Valid
3	2.7	2.6	3.85	Valid

Source: Primary data processed by the authors (2026).

The repeated measurements produced relatively small deviations, with the maximum deviation reaching only 3.85%. These results indicate that the observed working times were highly consistent and that the collected data adequately represented the actual operational conditions during loading and unloading activities.

Discussion

The findings demonstrate that the Time and Motion Study method effectively identified operational inefficiencies during container loading and unloading activities at Tanjung Priok Port. Time Study analysis showed that container transfer and operator waiting time were the dominant contributors to the total operational cycle time, indicating that workflow coordination and equipment allocation remain critical factors affecting productivity.

Motion Study analysis further revealed that non-value-added activities, including operator idle time, equipment waiting, and repeated equipment repositioning, substantially increased operational time without contributing to productive output. Eliminating or reducing these unnecessary activities would decrease operational waste and improve cargo-handling performance.

Based on the observed operational performance, the loading and unloading process achieved an operational efficiency of 85.9%, indicating that the existing work system operates at a relatively satisfactory level while still offering opportunities for improvement. Greater efficiency can be achieved through enhanced equipment scheduling, optimized vehicle routing, improved container yard layout, and the implementation of digital coordination systems capable of providing real-time operational information and reducing equipment and vessel waiting times.

From an operational management perspective, the standard working time established in this study provides a quantitative benchmark for evaluating operator performance, planning equipment utilization, and allocating operational resources. These findings support evidence-based decision-making for improving port productivity and operational planning.

Overall, this study confirms that the integrated application of the Time and Motion Study method is effective in improving loading and unloading efficiency by identifying non-value-added activities, optimizing working time, and enhancing operational coordination. Consequently, the proposed improvements have the potential to increase productivity, reduce operational delays, and support more efficient and sustainable port operations.

CONCLUSIONS

This study evaluated the operational efficiency of container loading and unloading activities at Tanjung Priok Port using the Time and Motion Study method. The findings demonstrate that this approach effectively identifies work elements that significantly influence operational performance by measuring working time and analyzing operator movements during cargo-handling activities. The Time Study results showed that the average loading and unloading cycle time was 9.2 minutes, with container transfer representing the most time-consuming activity at 3.1 minutes. In addition, an average operator waiting time of 1.3 minutes indicated that equipment coordination and workflow management remain important sources of operational delay. The Motion Study further identified several non-value-added activities, including operator idle time, transport equipment queues, and repeated equipment repositioning, all of which contributed to increased operational time and reduced productivity.

The calculated normal time and standard time were 9.66 minutes and 10.73 minutes, respectively. Furthermore, the observed operational efficiency of 85.9% indicates that the existing loading and unloading system operates at a relatively satisfactory level while still providing opportunities for further improvement. Enhanced operational performance can be achieved by optimizing equipment utilization, minimizing operator waiting time, improving vehicle routing, and implementing digital coordination systems that facilitate real-time communication and decision-making during cargo-handling operations.

The observation data demonstrated good consistency through repeated measurements, indicating that the collected data were reliable and suitable for operational analysis. Overall, the results confirm that the Time and Motion Study method provides an effective framework for improving loading and unloading efficiency by reducing non-value-added activities, establishing appropriate work time standards, and enhancing operational coordination. The findings of this study provide practical guidance for port management in improving cargo-handling productivity and support the development of more efficient, reliable, and sustainable port logistics operations.

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