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Optimizing Container Crane Performance: Enhancing Loading and Unloading Productivity at PT. Kaltim Kariangau Terminal

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ABSTRACT – Container terminals are critical nodes in global trade, where productivity hinges on the efficiency of handling equipment like container cranes. At PT. Kaltim Kariangau, a terminal jointly managed by PT. Pelindo and the East Kalimantan provincial government, operational challenges persist despite infrastructure enhancements. In 2023, an additional crane was introduced to the terminal, increasing the total to three. However, issues such as prolonged idle times and equipment malfunctions adversely impacted crane efficiency. This research evaluates crane performance using BCH (Box/Crane/Hour) and BSH (Box/Ship/Hour) metrics to assess their effect on loading and unloading productivity. The analysis reveals that in 2023, the average crane performance was 27 boxes/hour, a level classified as good. Paradoxically, overall productivity declined post-crane addition compared to prior operations. Using regression analysis, the study identifies a strong positive correlation ($R = 0.7316$) between crane performance and terminal productivity, with a coefficient of determination (R^2) indicating that crane efficiency accounts for 54% of productivity variations. The findings highlight that improved crane performance directly enhances operational output, where each unit increase in BCH corresponds to a 1.809-unit rise in productivity. Hypothesis testing confirms that crane performance significantly influences loading and unloading efficiency. These results underscore the need for effective equipment utilization and maintenance strategies to optimize terminal operations. The research concludes that while infrastructure upgrades are essential, addressing operational inefficiencies is critical to achieving sustainable productivity improvements.

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INTRODUCTION

In supporting the equitable distribution of development results, maritime transport plays a crucial role as a link between regions, particularly in facilitating trade. With its large carrying capacity and relatively low costs, maritime transport serves as the backbone of goods distribution, especially in island nations like Indonesia. Ports, as key points for cargo transfer, do not only function as places where ships dock but also as hubs for the loading and unloading of goods [1]. The improvement of port quality can facilitate distribution to remote areas, encourage regional economic development, support the implementation of green ports for sustainability, and provide a positive impact on the national economy [2].

The performance of ports is a key factor in improving the competitiveness of producers in both domestic and international markets. Efficient distribution strengthens market integrity and enhances economic integration. Therefore, enhancing port performance must be prioritized to support regional growth and contribute to national economic development [3]

PT. Kaltim Kariangau Terminal, a container port jointly managed by PT. Pelindo and the East Kalimantan Provincial Government, has three main business segments: container terminal, bulk terminal, and multi-purpose terminal. To support the improvement of loading and unloading productivity, the performance of equipment is crucial. However, research indicates several challenges, such as high idle time and crane malfunctions. These issues result in decreased Box/Crane/Hour (BCH) standards and overall productivity, which also affects other indicators like Box/Ship/Hour (BSH). The waiting time for cranes due to truck queues at the dock further impacts terminal performance [4].

This study aims to: a) Evaluate the performance of the container crane using the BCH indicator at PT. Kaltim Kariangau Terminal; b) Compare crane performance before and after the addition of loading equipment; and c) Analyze the impact of container crane performance on loading and unloading productivity.

Ports are critical infrastructure that supports the movement of goods through maritime transport, starting from the origin port to the destination port. Ports have several primary functions, including acting as interfaces between various parties, gateways for goods entering and leaving, industrial entities supporting the economy, and meeting points for different modes of transport [5].

The operational performance of a port encompasses services for vessels and goods, as well as the utilization of facilities and equipment during a certain period. For example, the efficiency of container handling involves moving containers from the ship to the dock, then to the stacking yard or transport trucks. High performance levels reflect fast and efficient services [6].

Loading and unloading productivity impacts the smooth operation of ships, costs, and time efficiency. Key productivity indicators include: a) Effective Time (ET): The actual working time used without interruptions, such as idle time or shift changes; b) Berthing Working Time (BWT): The time from the first to the last container being loaded/unloaded; c) Berthing Time (BT): The total time a ship is docked, from the first rope tying to the final untie; d) Box/Crane/Hour (BCH): The number of containers moved per crane per hour; e) Box/Ship/Hour (BSH): The average loading/unloading speed per ship per hour [7].

These indicators help terminals improve operational efficiency, reduce costs, and minimize unloading/loading time, ultimately contributing to overall productivity [8].

In port operations, the performance of container cranes is essential for optimizing productivity. Cranes serve as one of the primary tools for transferring containers from ships to the terminal and vice versa. Inefficiencies or equipment malfunctions can severely hinder productivity, leading to delays and increased operational costs. Moreover, factors such as crane breakdowns and operational delays caused by truck congestion at the dock can further exacerbate these challenges [9].

To address these issues, port management must focus on the maintenance and optimization of container handling equipment, particularly cranes. Ensuring that cranes are operating at peak efficiency can significantly reduce idle time and increase the overall throughput of the terminal. This is especially crucial for a busy container terminal like PT. Kaltim Kariangau Terminal, where efficient container handling is essential to meet the demands of both domestic and international shipping [10].

The impact of improved container crane performance is not limited to productivity alone but also extends to cost reduction. As cranes become more efficient, the time spent on each container is minimized, allowing for faster turnarounds and reducing the number of operational hours needed for unloading and loading. This efficiency translates into lower operational costs, which can enhance the competitiveness of the terminal, benefiting both the terminal operators and the shipping companies using the port [11].

Furthermore, enhancing crane performance can lead to improvements in related port operations, such as truck scheduling, container stacking, and overall terminal management. With better equipment performance, ports can achieve a smoother flow of operations, reducing congestion and increasing the speed at which goods are processed. This creates a more attractive environment for shipping lines, port users, and stakeholders, reinforcing the role of the port as a key driver of economic growth and trade efficiency [12] .

METHOD

Data Collection Techniques

This study employs a literature review method as the initial step to identify and assess relevant information regarding the performance of container cranes in loading and unloading operations. This technique involves the collection and in-depth analysis of existing written sources, such as academic journals, reference books, research reports, and other official documents related to the operational efficiency of cargo handling equipment. The primary aim of this approach is to establish a strong theoretical foundation while also identifying research gaps that could be explored further in this study.

Additionally, direct field observations are conducted to gather empirical data regarding the operational performance of container cranes during the loading and unloading activities. This method allows the researcher to record operational details, including usage patterns, idle times, and the efficiency of the cranes in supporting terminal productivity. Such systematic observation provides a concrete understanding of how the crane's performance contributes to the overall success of operations at PT. Kaltim Kariangau Terminal.

To complement the observational data, interviews are conducted with employees who hold direct responsibility for managing and monitoring container crane performance. The aim of the interviews is to uncover qualitative information about the equipment's productivity, technical challenges frequently encountered, and the measures implemented to enhance operational efficiency. This approach enriches the research data by providing practical insights from on-the-ground experiences.

Sampling Technique

According to Arikunto [13], the population in this study refers to the entire dataset related to the performance of container cranes based on the Box/Crane/Hour (BCH) indicator, as well as the productivity of loading and unloading

operations at PT. Kaltim Kariangau Terminal. The population under analysis includes data spanning from January to December 2023.

The sampling technique used in this study is a saturated sampling method, where all elements of the population are included as samples in the research. Consequently, the sample comprises data on container crane performance (BCH) and vessel unloading productivity for the period from February to December 2023. This approach is chosen to ensure that the study results accurately reflect the characteristics of the entire population, leading to more robust and reliable findings.

Research Variables

The variables in this study are divided into independent and dependent variables, which are interconnected in measuring the effectiveness of terminal operations. The independent variable is the performance of the container handling equipment, specifically the container crane, which is measured using the Box/Crane/Hour (BCH) indicator [14]. This performance is considered a key factor influencing the efficiency of loading and unloading operations at the terminal. On the other hand, the dependent variable is the productivity of loading and unloading activities, which reflects the operational success of the terminal in managing cargo handling activities. This productivity is measured based on the vessel performance data at PT. Kaltim Kariangau Terminal, providing a real-world picture of how the crane's performance impacts the overall terminal efficiency.

Data Analysis Techniques

For data analysis, simple linear regression is employed to identify the influence of container crane performance (the independent variable) on the productivity of unloading operations (the dependent variable) [15]. The main objective of this analysis is to quantify the causal relationship between these two variables and predict the impact of crane performance improvements on terminal operational productivity. Additionally, correlation coefficients are used to assess the strength of the relationship between the performance of the container crane and the unloading productivity. The correlation value gives an indication of how closely related the two variables are, forming the basis for further interpretation of the crane's operational effectiveness in enhancing productivity.

Subsequently, the coefficient of determination is used to measure the extent to which the variability in unloading productivity can be explained by the performance of the container crane. This coefficient reflects the quantitative influence of crane efficiency on the terminal's operational success. A high coefficient of determination would suggest that crane performance is a significant factor driving overall productivity, while a low value would indicate that other factors may also play a considerable role in shaping the terminal's performance.

Hypothesis Testing Using ANOVA (F-test)

To validate the relationship between the two variables, hypothesis testing is performed using a one-way ANOVA (F-test). This test evaluates the significance of the influence that container crane performance has on unloading productivity across the entire terminal operation. If the calculated F-value (F-hitung) exceeds the critical F-value from the F-distribution table (F-tabel), the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. In this case, the acceptance of H1 would indicate that the performance of the container crane has a significant impact on the productivity of unloading operations at PT. Kaltim Kariangau Terminal. The analysis of variance (ANOVA) not only tests the statistical significance of the independent variable's effect but also provides an indication of whether the proposed model for understanding the relationship between crane performance and productivity is appropriate. If the F-test confirms the model's validity, it would solidify the argument that optimizing container crane performance is crucial for enhancing the productivity of loading and unloading operations at the terminal.

RESULTS AND DISCUSSIONS

Performance of Container Crane (BCH) at PT. Kaltim Kariangau Terminal

In 2023, the performance of the container cranes at PT. Kaltim Kariangau Terminal was recorded at an average of 27 boxes per hour (BCH). This figure indicates that the performance of the container handling equipment at the terminal falls within the "Good" category, in accordance with the operational standards set by the company. This performance level suggests that the container cranes have been functioning efficiently, contributing positively to the overall smoothness of cargo handling processes at the terminal.

The average of 27 boxes per hour reflects a high level of operational efficiency, demonstrating that the terminal is performing well in terms of handling cargo. This productivity is crucial for maintaining the flow of goods, ensuring timely delivery and unloading of containers. Efficient crane performance is directly correlated with the overall success of port operations, as it plays a significant role in optimizing the throughput of goods.

Achieving an average of 27 boxes per hour highlights the capability of PT. Kaltim Kariangau Terminal to handle a substantial volume of containers, showcasing the effective use of its equipment in meeting the demands of shipping operations. This level of performance is not only indicative of the terminal's operational capacity but also serves as a benchmark for future improvements.

The performance of container cranes is one of the key factors determining the overall productivity of the terminal. High crane performance ensures that ships are unloaded and loaded swiftly, minimizing the time vessels spend at the dock. This contributes to the efficient turnaround time of vessels, which is a critical aspect of port management and logistics.

In addition to supporting the smooth flow of cargo, the efficient operation of container cranes also impacts the cost-effectiveness of terminal operations. By maximizing the handling capacity of the cranes, the terminal reduces labor costs and increases the profitability of its operations. The better the crane performance, the lower the operational costs and the higher the return on investment in equipment.

The performance of the container cranes is directly linked to several factors, including the condition of the equipment, operator skills, and maintenance practices. Regular maintenance and timely repairs are essential to ensure that the cranes perform at optimal levels. Furthermore, well-trained crane operators are crucial to ensuring that the equipment is used efficiently, minimizing downtime and preventing accidents.

To further understand the variations in crane performance throughout 2023, Table 1 below provides detailed data regarding the performance of the container cranes over the course of the year. The table illustrates the fluctuations in performance, shedding light on periods of higher or lower productivity and offering valuable insights into the operational dynamics at PT. Kaltim Kariangau Terminal.

Table 1. Recapitulation of container crane performance in 2023

Month	Ship Call	Total Box of		Box/Container/Hour	Effective	Description Based on BCH Standard
		Loading	Unloading	(BCH)	Time (ET)	(27 Box/Hour)
January	41	7243	7244	28	13	Fulfilled
February	41	7791	6671	30	11	Fulfilled
March	46	7570	7845	28	11	Fulfilled
April	37	6465	6424	27	12	Fulfilled
May	40	6146	6358	29	11	Fulfilled
June	42	7474	7537	28	13	Fulfilled
July	42	7481	7668	26	14	Not Fulfilled
August	43	7765	7857	25	14	Not Fulfilled
September	44	7531	7803	26	13	Not Fulfilled
October	48	8511	8416	27	14	Fulfilled
November	44	7665	8192	24	17	Not Fulfilled
December	45	8363	8668	22	18	Not Fulfilled
Average	**42,6**	**7267**	**7071**	**27**	**13**	

Based on the data obtained, the performance of the container crane exhibited significant fluctuations throughout 2023. The average productivity was recorded at 27 boxes per hour, which aligns with the established performance standards for the year. The average number of vessel arrivals (calls) was noted at 42.6 per month, with the total volume of cargo handled reaching 7,262 boxes per month. This data provides a clear overview of the operational output during the year, though it also reveals important insights into fluctuations in crane performance during different periods.

From January to June, crane performance consistently met the established standard of 27 boxes per hour, suggesting that operations were running smoothly within the expected parameters. However, after June, a noticeable decline in productivity began to emerge. This drop in performance continued through the second half of the year, indicating that operational challenges were increasing as time went on. The productivity levels that had once been stable saw significant variation starting in the mid-year months.

A marked decrease in crane productivity became particularly evident starting from July. The productivity per hour dropped noticeably, and this trend persisted through the months of August, November, and December. The decline in performance was more pronounced during the final months of the year, with December seeing the steepest drop in productivity. By December, productivity had fallen to 22 boxes per hour, a significant decrease from the earlier months.

The causes behind this reduction in productivity were multifaceted. One of the primary factors contributing to the decline was the increase in the volume of cargo being handled. As the volume of cargo grew, it became increasingly difficult for the cranes to handle the load within the same timeframe, causing a strain on the operational capacity of the equipment. This imbalance between the rising demand for services and the crane's capacity to meet it led to a noticeable drop in efficiency.

In addition to the higher volume of cargo, several operational constraints further exacerbated the situation. One of the most significant factors was the frequent technical disruptions affecting the cranes, which caused delays in the

loading and unloading processes. These technical difficulties led to extended downtime for repairs, reducing the overall operational efficiency and contributing to the decline in productivity.

Furthermore, the extended waiting times for trucks—often referred to as "waiting truck" delays—added to the operational challenges. These delays caused the cranes to remain idle for prolonged periods, further affecting the overall crane performance. Truck scheduling and logistics management issues led to bottlenecks that disrupted the efficient flow of operations at the terminal.

Additionally, weather conditions during the last months of the year had a considerable impact on crane productivity. Adverse weather, including heavy rain and storms, made crane operations more difficult, particularly in terms of safety and operational capacity. This factor compounded the already existing operational issues, leading to a further decline in the cranes' efficiency during the months of November and December.

As a result of these combined factors—higher cargo volume, technical disruptions, truck waiting times, and weather conditions—the crane performance in the second half of the year was significantly reduced. These challenges not only affected the productivity levels but also highlighted the vulnerability of terminal operations to various external and internal factors. It is essential to address these issues to prevent further declines in productivity in the future.

In conclusion, the fluctuation in crane performance during 2023 reflects a complex interplay of factors. While the first half of the year saw operations running smoothly, the second half was marked by various challenges that hindered performance. Understanding the causes of these issues and developing solutions will be crucial in improving productivity and efficiency in the years to come.

The insights drawn from this data emphasize the need for a more robust approach to managing operational challenges, including better maintenance protocols for the cranes, improvements in logistics and scheduling, and better planning for external factors such as weather conditions. These measures will be essential in optimizing container crane performance and ensuring that the terminal can handle the increasing volume of cargo efficiently in the future.

Comparison of Performance Before and After the Addition of Container Cranes at PT. Kaltim Kariangau Terminal

An analysis of the productivity data for container cranes at PT. Kaltim Kariangau Terminal reveals a notable decline in performance following the addition of new cranes. During the period from 2020 to 2021, before the additional crane units were introduced, the performance of the existing container cranes was superior compared to the performance observed in 2022 and 2023 after the new cranes were added. This decrease in performance suggests that, despite an increase in the number of cranes, the operational effectiveness did not improve as expected.

Several factors may have contributed to this decline in performance, including extended waiting times, operational disruptions, or suboptimal management of the newly added cranes. The introduction of additional cranes was intended to enhance operational capacity, but the results indicate that other factors—such as efficiency in crane deployment and maintenance—may not have been adequately addressed. Consequently, a more in-depth analysis is needed to identify the root causes of this decline and to take corrective measures to improve crane productivity.

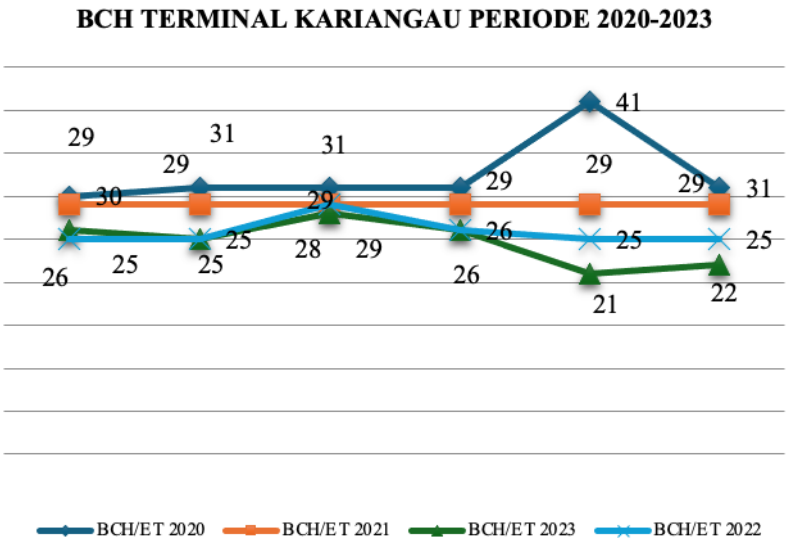

Figure 1. The productivity of container cranes at PT. Kaltim Kariangau 2020 to 2023

The available figure 1 illustrates the graph of the productivity of container cranes at PT. Kaltim Kariangau Terminal from the second half of 2020 to 2021, before the increase in the number of cranes, as well as the crane performance during the period of 2022 to 2023, after the addition of the new equipment. The data presented in the graph shows a significant improvement in crane performance during 2020 and 2021. The highest recorded performance occurred in November 2020, with a rate of 41 boxes per hour (box/hr). The average performance for 2021 was recorded at 29 box/hr, despite only having two cranes in operation. This achievement reflects a high level of efficiency in operations and the optimal utilization of the existing equipment.

However, the crane performance in 2022 and 2023 showed a marked decline compared to the previous years. In 2022, the average performance dropped to just 26 box/hr, failing to meet the established standards. Although there was a slight improvement in 2023, with an average of 27 box/hr, the performance still fell short of optimal expectations. These figures highlight that while the fleet of cranes expanded, the overall productivity did not improve as anticipated, underlining the need for further investigation into the operational and managerial factors influencing crane performance.

This situation suggests that the mere addition of new equipment is not sufficient to automatically increase productivity. It emphasizes the importance of effective management, maintenance strategies, and optimized operational practices to fully leverage the potential of additional resources. Thus, a thorough review of operational processes and strategic adjustments are necessary to restore and enhance crane productivity at the terminal.

The Impact of Container Crane Performance on Loading and Unloading Productivity at PT. Kaltim Kariangau Terminal in 2023

a. Simple Linear Regression Analysis

The results of the simple linear regression analysis reveal a significant positive relationship between the independent variable (container crane performance) and the dependent variable (loading and unloading productivity). The regression equation derived is Y=17.774+1.809XY = 17.774 + 1.809XY=17.774+1.809X, where the regression coefficient for the container crane performance (X) is 1.809. This indicates that for every unit increase in container crane performance (measured in Box/Crane/Hour or BCH), loading and unloading productivity will increase by 1.809 units. In other words, as the performance of the container crane improves, its contribution to increased productivity also grows, which, in turn, enhances the overall operational efficiency of the terminal. This underscores the importance of improving the performance of handling equipment to support smooth operations at container terminals.

b. Correlation Coefficient

The correlation coefficient analysis yields a value of 0.7316, indicating a strong, positive, and direct relationship between container crane performance and loading and unloading productivity. This value suggests a significant correlation between the two variables, meaning that as crane performance improves, the level of productivity also increases. Therefore, container crane performance plays a crucial role in enhancing output and operational efficiency in the loading and unloading process at the terminal.

c. Coefficient of Determinatio

The statistical calculation of the coefficient of determination reveals that approximately 54% of the variation in loading and unloading productivity can be explained by container crane performance. This highlights the significant influence of crane performance on productivity at PT. Kaltim Kariangau Terminal. In essence, a large portion of terminal productivity is influenced by the optimization of container crane performance. However, the analysis also indicates that 46% of the variation in productivity is influenced by other factors not addressed in this study. This suggests that, while container crane performance is a key determinant, other factors must also be considered to achieve more comprehensive productivity improvements.komprehensif.

d. ANOVA One-Way Significance Test (F-Test)

In the ANOVA analysis, the calculated F-value is 8.80, while the F-table value at a 0.05 significance level is 4.26. By comparing the calculated F-value with the F-table value, it is clear that the F-value (8.80) exceeds the F-table value (4.26), leading to the rejection of the null hypothesis (H0) and acceptance of the alternative hypothesis (H1). This confirms that there is a significant impact of the independent variable (container crane performance) on the dependent variable (loading and unloading productivity). Consequently, the simple linear regression model used in this study is valid and relevant in describing the relationship between container crane performance and productivity at the terminal.

CONCLUSION

Based on the analysis and discussion, three key conclusions can be drawn. First, the performance of container cranes significantly impacts loading and unloading productivity at PT. Kaltim Kariangau Terminal. The simple linear regression analysis indicates a positive and significant relationship, where each one-unit increase in container crane performance (measured in Boxes/Crane/Hour or BCH) contributes to a 1.809-unit increase in productivity. Thus, enhancing container crane performance can improve overall operational efficiency. Second, fluctuations in crane performance and factors causing declines were observed. While the average performance at the start of 2023 met operational standards at 27 boxes/hour, a significant decrease occurred in subsequent months, particularly in December. This decline was attributed to factors such as increased cargo volumes exceeding crane capacity, more frequent technical disruptions, prolonged truck queues, and adverse weather conditions, all of which must be addressed to maintain consistency and improve equipment efficiency. Third, adding more cranes does not always correlate with improved performance. Despite adding new cranes during 2022–2023, overall crane performance decreased compared to 2020–2021, suggesting that operational effectiveness did not align with expectations. This highlights the need for a deeper analysis of factors like increased wait times and operational disruptions to enhance overall productivity.

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