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Performance Evaluation of Fixed Crane Operations Using Overall Equipment Effectiveness Method in Port Container Handling Activities

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ABSTRACT

Efficient container handling is crucial to maintaining productivity and competitiveness in port operations. This study evaluates the performance of fixed crane equipment using the Overall Equipment Effectiveness (OEE) method to identify factors contributing to productivity loss. Data were collected through observation, interviews, and operational records, focusing on loading time, downtime, operation time, processed amount, and defect rate. The analysis assessed three OEE indicators: availability, performance efficiency, and quality rate. Results revealed that crane availability ranged from 84–86%, performance efficiency from 14–21%, and quality rate remained at 100%. The overall OEE value of 12–18% was significantly below the world-class standard of 85%, indicating low operational efficiency. The primary causes of reduced effectiveness included operator negligence, overloading, and insufficient radiator maintenance. To enhance reliability, the study suggests introducing a 200-hour preventive maintenance schedule emphasizing radiator inspection, operator training, and strict load monitoring. The research demonstrates that applying the OEE framework allows port managers to quantify equipment performance, identify major loss sources, and implement targeted strategies to reduce downtime and improve throughput in container handling operations

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INTRODUCTION

Port operations play a critical role in global logistics and supply chain performance, where equipment reliability and operational efficiency directly determine cargo throughput and service quality [1]. The growing demand for containerized trade has increased the operational load on port handling equipment, making maintenance and performance optimization essential for sustainable productivity [2]. Among various types of handling equipment, the fixed crane is one of the most vital assets, as it supports continuous loading and unloading of containers between vessels and storage areas. However, recurrent equipment failures and downtime can significantly disrupt port operations, leading to economic losses and decreased competitiveness in the maritime sector [3].

Equipment failures in port operations are often caused by inadequate maintenance practices, operator negligence, and mechanical deterioration. These issues reduce the availability of machinery and affect the smooth flow of container handling activities [4]. In many ports, maintenance activities remain largely preventive and reactive rather than predictive, leading to unscheduled breakdowns and inefficient resource utilization [5]. The absence of systematic performance measurement tools makes it difficult to quantify the true impact of downtime and identify specific loss factors [6]. Consequently, the overall efficiency of container handling operations remains below optimal levels [7].

To address these challenges, the Overall Equipment Effectiveness (OEE) method provides a comprehensive framework to evaluate equipment performance based on three key dimensions: availability, performance efficiency, and quality rate [8]. OEE is widely adopted in manufacturing industries to assess the effectiveness of production equipment and identify sources of productivity losses [9]. Applying OEE in port operations offers similar advantages by quantifying operational performance, monitoring machine reliability, and supporting maintenance decision-making [10]. The method helps identify whether low performance originates from mechanical inefficiencies, operational delays, or quality-related issues.

Despite the recognized benefits of OEE, its application in port container handling systems remains limited, particularly in developing countries where maintenance systems are often underdeveloped [11]. Many studies have focused on OEE implementation in manufacturing plants, but empirical research in maritime logistics is relatively scarce [12]. Therefore, evaluating fixed crane performance using the OEE framework provides new insights into port equipment management and offers a practical approach for improving operational reliability [13]. The study contributes to bridging this research gap by adapting the OEE method to the port context, demonstrating how data-driven performance analysis can guide maintenance improvements.

This research aims to evaluate the performance of fixed crane operations in port container handling activities through the OEE method. Specifically, it seeks to (1) calculate the values of availability, performance efficiency, and quality rate; (2) identify the primary causes of downtime and productivity loss; and (3) propose improvement strategies for maintenance management [14]. By systematically analyzing performance indicators, the study provides quantitative evidence on the current condition of port handling equipment and highlights areas requiring operational enhancement [15].

The findings of this study are expected to contribute both theoretically and practically. From an academic perspective, it expands the understanding of OEE application beyond traditional manufacturing, positioning it as a useful diagnostic tool in service-oriented operations such as port logistics. From a managerial perspective, the results provide actionable recommendations for maintenance scheduling, operator supervision, and performance monitoring. Ultimately, the study aims to support port authorities in achieving higher equipment reliability, reduced downtime, and improved overall productivity in container handling operations.

RESEARCH METHODS

1. Research Design

This study employed a quantitative descriptive research design to evaluate the operational performance of fixed cranes in port container handling activities using the *Overall Equipment Effectiveness (OEE)* method. The approach focused on identifying productivity losses, analyzing

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downtime factors, and assessing equipment reliability. The OEE method was selected because it provides a comprehensive measure of machine effectiveness through three key indicators availability, performance efficiency, and quality rate which together reflect the overall productivity of port handling equipment.

2. Research Object and Location

The research was conducted at a major Indonesian port engaged in container loading and unloading operations. The study focused on the fixed crane unit used in port container handling, as this equipment plays a critical role in maintaining throughput and operational continuity. The research observed regular handling operations for both full and empty containers during a three-month period, from June to August 2023.

3. Data Collection Methods

Data collection involved both qualitative and quantitative techniques.

- Observations were conducted to document the operational behavior of fixed cranes, focusing on occurrences of breakdowns and causes of downtime.
- Interviews with maintenance and operations personnel were carried out to gather insights regarding maintenance practices and operational constraints.
- Quantitative data were obtained from production and maintenance records, including variables such as loading time, downtime, operation time, processed amount, cycle time, and defect amount.

This combination of data collection methods ensured a comprehensive understanding of the operational conditions and maintenance effectiveness.

4. Data Analysis Procedure

The Overall Equipment Effectiveness (OEE) analysis was applied to quantify the level of equipment efficiency. The calculation followed standard formulas, as shown below:

$$OEE = Availability(\%) \times Performance(\%) \times Quality(\%) \quad \text{……(1)}$$

- Availability measures the proportion of time the equipment is available for operation:

$$Availability = \frac{\text{Loading Time} - \text{Down Time}}{\text{Loading Time}}\ x\ 100\% \quad \text{……(2)}$$

- Performance Efficiency measures how effectively the equipment performs relative to its designed speed:

$$Performance = \frac{\text{Processed Amount} - \text{Ideal Cycle Time}}{\text{Operation Time}}\ x\ 100\% \quad \text{……(3)}$$

- Quality Rate evaluates the proportion of defect-free output:

$$Quality = \frac{\text{Processed Amount} - \text{Defect Amount}}{\text{Processed Amount}}\ x\ 100\% \quad \text{……(4)}$$

5. Supporting Tools and Analysis Framework

To identify the root causes of performance losses and frequent breakdowns, the study utilized a Fishbone Diagram (Ishikawa) analysis. This tool categorized potential problem sources into three main factors—machine, method, and material—helping to visualize the relationship between operational issues and their underlying causes. The analysis identified key issues such as radiator water depletion, operator error during luffing, and overloading beyond crane capacity.

6. Data Processing and Interpretation

The collected data were processed and analyzed monthly to determine OEE values and their components. The results showed availability rates between 84–86%, performance efficiency ranging from 14–21%, and a quality rate of 100%, resulting in overall OEE values between 12–18%. These results were then compared with the World Class Manufacturing standard (OEE ≥ 85%) to evaluate performance gaps. The findings were interpreted to develop maintenance recommendations, including implementing a 200-hour preventive maintenance cycle, enhancing operator supervision, and improving radiator inspection routines.

RESULTS AND DISCUSSION

Measuring overall equipment effectiveness (OEE) requires several data sets, including input data, to calculate effectiveness. The data was taken from production activity reports from June to August

2023. The data collected included loading time, downtime, processed quantity, cycle time, and defect quantity.

1. Equipment Availability

The analysis of equipment availability reflects the proportion of time the fixed crane was operational relative to its planned production time. The results show that availability values ranged from 84% to 86% between June and August 2023. These values fall below the *World Class Manufacturing* standard of 90%, indicating that unplanned downtime remains a major issue in port operations. Frequent equipment stoppages were primarily caused by radiator water depletion, excessive loads, and operator negligence during lifting operations. This implies that maintenance and operational readiness have not yet achieved optimal synchronization. A structured preventive maintenance plan, especially focused on critical components such as the radiator system, is therefore required to minimize downtime and maintain stable operational capacity.

Table 1. Availability

Availability			
Month	*Loading Time* (Minutes)	*Downtime* (Minutes)	*Availibility Rate*
June	1442	208	86%
July	958	140	85%
August	955	150	84%

2. Performance Efficiency

Performance efficiency measures the operational speed of the crane relative to its designed cycle time. The recorded performance values ranged from 14% to 21%, significantly lower than the international benchmark of 95%. This low efficiency suggests that the crane's operational time is not being utilized effectively, possibly due to inefficient handling sequences, load management errors, and delays caused by operator inattention. Moreover, inconsistent scheduling of loading and unloading activities contributed to idle time between vessel arrivals. These findings indicate that operator training, load optimization, and real-time monitoring systems are essential to enhance cycle time utilization and overall handling productivity.

Table 2. Performance Efficiency

Performance Efficiency			
Month	*Processed Amount*	*Ideal Cycle Time* (Menit)	*Operation Time*
June	4335	4	1240
July	3809	4	824
August	4218	4	817

3. Rate of Quality Product

The quality rate of fixed crane operations consistently reached 100% during the observation period, indicating that all container-handling activities were executed without defects or rejected outputs. This demonstrates that, despite operational inefficiencies, the process maintained a high level of accuracy and reliability in handling containers. The stable quality rate reflects adherence to safety and operational standards, particularly in terms of container placement and mechanical precision. This consistency suggests that the technical performance of the equipment remains reliable, and that the main area for improvement lies in operational and maintenance efficiency rather than quality output.

Table 3. Rate of Quality Product

Rate of Quality Product			
Month	*Processed Amount*	*Deffect Amount*	*Rate of Quality Product*
June	4335	0	100%
July	3809	0	100%
August	4218	0	100%

4. Overall Equipment Effectiveness (OEE) Performance

The integration of the three OEE components availability, performance, and quality resulted in overall effectiveness values between 12% and 18%, far below the World Class OEE standard of 85%. This finding indicates significant potential for productivity improvement in port crane operations. The sharp contrast between the near-perfect quality rate and low performance efficiency underscores the dominance of time-related losses, particularly due to unplanned stoppages and slow cycle execution. Such inefficiencies hinder throughput and reduce the competitiveness of port operations. Addressing these losses requires a systematic and data-driven maintenance program that aligns operational schedules with preventive maintenance intervals.

Table 4. Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE)				
Month	*Availibility Rate*	*Performance Efficiency*	*Rate of Quality Product*	OEE (%)
June	86%	14%	100%	12%
July	85%	18%	100%	15%
August	84%	21%	100%	18%

5. Root Cause Analysis

A Fishbone (Ishikawa) Diagram was employed to identify the root causes of recurrent breakdowns. The analysis categorized the main contributing factors into three domains: machine, method, and material. Machine-related issues included radiator leakage and luffing radius errors; method-related factors involved overloading and poor adherence to standard operating procedures; while material-related issues were linked to insufficient radiator fluid checks. These factors collectively led to repeated equipment failures and downtime. Implementing a 200-hour preventive maintenance schedule, coupled with enhanced operator supervision and routine radiator inspection, was proposed as a practical mitigation strategy. Such an approach can improve operational continuity and reduce equipment wear.

6. Discussion

Based on the OEE table, the machine's effectiveness is below the standard OEE value, and its availability is between 84% and 86%, well below the ideal availability value of 90%. This indicates that the fixed crane's readiness level for use is below 90%. Furthermore, this level of availability indicates a balance between operating time and load time, with operating time affected by machine downtime. The fixed crane's performance efficiency is between 14% and 21%, well below the standard performance value of 95%. The rate of product quality or production is running at an optimal level.

This indicates inefficient machine usage due to inadequate capacity. The fixed crane's efficiency is between 12% and 18%, still below the ideal effectiveness of 85%. Based on the OEE calculation, the radiator hose on fixed crane 2 should be replaced and the radiator water refill schedule included in the 200-hour maintenance to minimize breakdowns caused by depleted radiator water.

CONCLUSION

The evaluation of fixed crane performance using the Overall Equipment Effectiveness (OEE) method revealed that the operational efficiency of port container handling equipment remains far below the world-class benchmark. The findings showed that equipment availability ranged between 84% and 86%, performance efficiency between 14% and 21%, and quality rate consistently at 100%, resulting in an overall OEE value of 12% to 18%. These results indicate that the main source of performance loss lies in equipment downtime and suboptimal operational speed rather than in product quality. The root causes of inefficiency were traced to poor maintenance scheduling, operator negligence, and inadequate monitoring of critical components such as radiator systems.

To enhance equipment effectiveness, a structured preventive maintenance plan including a 200-hour maintenance interval focused on radiator inspection and load control should be implemented. Strengthening operator supervision, improving work discipline, and integrating real-time monitoring systems are also necessary to minimize breakdowns and optimize throughput. From a managerial standpoint, applying the OEE framework provides a reliable quantitative tool to measure performance, identify productivity losses, and guide continuous improvement strategies. Therefore, systematic OEE-based maintenance management can serve as an effective approach to increasing fixed crane reliability, ensuring operational continuity, and enhancing port productivity in the long term.

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