

Design of Floating Crane Ship Maintenance Strategy Based on the Influence of Preventive Maintenance, Total Quality Management on Operational Performance Using the PLS-SEM Method

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Abstract

Keywords

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This study aims to analyze the influence of preventive maintenance and Total Quality Management (TQM) on the operational performance of floating crane vessels at PT XYZ and to develop a more systematic and measurable maintenance strategy. The research focuses on the FC 02 floating crane unit, which experienced high downtime and fluctuating operational availability. A quantitative approach was employed using a survey method involving 228 respondents directly engaged in floating crane operations and maintenance activities. Data were analyzed using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) method with SmartPLS software. The results indicate that preventive maintenance has a positive and significant effect on operational performance, particularly in improving equipment reliability and reducing downtime. Furthermore, Total Quality Management shows a stronger and more dominant positive influence on operational performance, highlighting the critical role of managerial systems, leadership commitment, and continuous improvement practices. The findings confirm that integrating effective preventive maintenance with consistent TQM implementation can significantly enhance the operational performance of floating crane vessels. This study provides both theoretical contributions to maritime maintenance literature and practical insights for designing a Planned Maintenance System (PMS) to support sustainable operational performance.

INTRODUCTION

The shipping industry plays a strategic role in supporting the national logistics system, especially in archipelagic countries such as Indonesia (Hadiningrat et al., 2024). The reliability of the ship fleet is a key factor in ensuring the smooth distribution of strategic commodities, including coal for power plants and industry. PT XYZ is one of the national shipping companies that has been operating since 2007 and has various types of fleets, including floating cranes which have the main function in moving coal cargo from barges to mother vessels. With operating areas spread across various Indonesian waters, the company is required to ensure that its entire fleet is in reliable, safe, and compliant with operational and shipping safety standards.

In the operational context of PT XYZ in East Kalimantan, floating cranes have a very critical role because they are directly related to the fulfillment of contract targets and the risk of penalties if the cargo transfer capacity is not achieved. This study focuses on one floating crane unit, namely FC 02, which began operating in April 2023 and was recorded to experience various technical obstacles that had an impact on high downtime and decreased operational availability. This condition confirms the importance of an effective maintenance strategy and a consistent quality control system to maintain the operational performance of the vessel.

The operational performance of ships is significantly influenced by the effectiveness of maintenance and the implementation of quality management. Maintenance that is systematically designed, both in the form of preventive and predictive maintenance, has been proven to be able to reduce sudden failures, reduce downtime, and extend the life of equipment (Chatzinikolaou & Ventikos, 2015; Alamoush & Ölçer, 2024). Proper maintenance strategies not only impact the technical reliability of the vessel, but also contribute to cost efficiency and operational safety. Lazakis et al. (2010) emphasized that structured maintenance policies play an important role in improving the availability and reliability of ships. The empirical findings of Rakyta et al. (2024) show that improving maintenance strategies can significantly improve production efficiency and system quality, while Faiz (2023) highlights the potential for operational cost savings through a data-driven maintenance approach.

On the other hand, quality control in ship operations and maintenance is also a crucial element. The application of the principle of Total Quality Management (TQM) has been proven to have a positive effect on organizational operational performance in various industrial sectors (Mustafa et al., 2021; Shi et al., 2024). The implementation of quality standards such as ISO 9001 and Quality Assurance/Quality Control (QA/QC) practices through routine inspections, quality audits, and failure analysis methods such as FMECA contributes to increasing productivity, regulatory compliance, and consistency of technical work results (Karatuğ et al., 2023; Yan et al., 2024). In the maritime industry, maintenance quality control is becoming increasingly important given the high safety risks and economic consequences of ship system failures.

However, the results of previous studies show that there are inconsistencies in findings related to the effect of preventive maintenance and TQM on operational performance. Several studies report significant and positive influences (Gyamfi & Zigah, 2023; Alghamdi, 2018), while other studies have found that the impact is not always strong and is influenced by contextual factors such as organizational culture, management commitment, and resource limitations. These differences in results indicate the need for a review, especially in the shipping sector which has complex technical and operational characteristics.

The empirical conditions at PT XYZ show that there is still a gap between the maintenance and quality control practices recommended in the literature and the operational reality in the field. Floating crane performance data for 2023 and 2024 shows significant fluctuations in availability, including a drastic decrease in certain periods due to damage to key components such as slewing bearings and hydraulic systems. The maintenance history of the FC 02 shows that most of the damage is caused by natural wear and tear and suboptimal preventive maintenance based on running hours and failure history. This phenomenon confirms the importance of a planned maintenance system that is integrated with strict quality control.

Conceptually, the operational performance of a ship is defined as the level of effectiveness and efficiency of the ship in carrying out its operational functions, which includes aspects of system reliability, downtime level, tool availability, resource use efficiency, productivity, and work safety (Karatuğ et al., 2022). In the maritime industry, operational performance is also closely related to compliance with safety and environmental regulations (Chatzinikolaou & Ventikos, 2015). Alamoush and Ölçer (2024) add that the operational performance of a ship is determined not only by technical factors, but also by logistics management, energy consumption, and the quality of maintenance planning.

In the framework of this study, the operational performance of floating crane ships is positioned as a dependent variable influenced by preventive maintenance and total quality management as an independent variable. Preventive maintenance is expected to be able to reduce unexpected damage and increase availability, while TQM is predicted to improve the consistency of maintenance quality and operational processes. To test the relationship between these variables, this study uses a quantitative approach with the Partial Least Squares Structural Equation Modeling (PLS-SEM) method. This method was chosen because of its ability to analyze complex models with relatively limited sample numbers as well as its tolerance to violations of data normality assumptions (Hair et al., 2011; Roldán & Sánchez-Franco, 2012).

In addition to testing the causal relationship between variables, this study also aims to design a more measurable and systematic floating crane maintenance strategy through the Planned Maintenance System (PMS) approach. The complexity of floating crane vessel maintenance, which involves a variety of technical and managerial criteria such as cost, reliability, safety, and resource availability, demands an integrated, risk-based maintenance plan. PMS enables the scheduling, documentation, and evaluation of maintenance activities systematically in accordance with classification standards and the ISM Code, thereby supporting the continuous improvement of operational performance (Lazakis et al., 2010; Karatuğ et al., 2023).

The novelty of this study is fourfold. First, it integrates preventive maintenance and TQM into a single predictive model for floating crane operational performance, which has not been previously undertaken in Indonesian maritime research. Second, it applies PLS-SEM to test causal relationships in a complex maritime operational context, methodologically advancing beyond descriptive or bivariate analyses used in prior studies (e.g., Gyamfi & Zigah, 2023). Third, it uses primary survey data from 228 respondents directly involved in floating crane operations, providing empirical evidence from frontline personnel rather than managerial perceptions alone. Fourth, it develops a Planned Maintenance System (PMS) design based on empirical findings, bridging the gap between statistical analysis and practical maintenance strategy formulation.

Thus, this research has a theoretical and practical contribution. Theoretically, this study enriches the literature on the relationship between preventive maintenance, total quality management, and operational performance in the context of the maritime industry, especially on floating crane ships which are still relatively rarely researched. Practically, the results of the research are expected to be the basis for recommendations for PT XYZ in developing more effective maintenance and quality control policies, so that fleet availability and reliability can be improved and operational risks can be minimized.

METHOD

This study used a quantitative approach with the aim of examining the causal relationship between preventive maintenance and total quality management on the operational performance of floating cranes at PT XYZ. The quantitative approach was chosen because the research focuses on testing numerical data-based hypotheses and statistical analysis of latent constructs that have been theoretically formulated. Quantitative research is deductive, where the development of conceptual models and hypotheses is based on previous theories and empirical findings, then tested using field data (Barroga et al., 2023). Based on its objectives, this study

is included in the category of explanatory research because it emphasizes cause-and-effect analysis between variables, specifically to explain how preventive maintenance practices and quality management affect the operational performance of ships.

Judging from the number of variables analyzed, this study is multivariate because it involves more than two latent variables, namely preventive maintenance and total quality management as independent variables, and operational performance as dependent variables. The survey approach was used as a primary type of investigation with structured questionnaire instruments to collect primary data from respondents directly involved in the operational and maintenance activities of floating crane vessels. The survey method is considered effective in obtaining data on respondent perception and assessment in a systematic and standardized manner in an organizational context (Ponto, 2015). This study is cross-sectional, because data collection is carried out over a certain period of time to describe the conditions and relationships between variables during the study.

The analysis unit in this study includes individuals and organizations, especially personnel involved in the operation and maintenance of PT XYZ's floating crane ship in Sangatta, East Kalimantan. The research population consists of all related personnel totaling 261 people, including crew, operators, ground operations teams, and technicians and maintenance supervisors. The sampling technique used was non-probability sampling with the purposive sampling method, where respondents were selected based on the criteria of direct involvement in operational activities and maintenance of the floating crane. This approach was chosen to ensure that the data collected was relevant to the research objectives and reflected the real operational conditions of the vessel. The minimum sample count refers to the recommendation of Hair et al. (2011) for the analysis of Partial Least Squares Structural Equation Modeling (PLS-SEM), so that the number of respondents is considered adequate for structural model testing.

The research variables are defined operationally so that they can be measured quantitatively. Preventive maintenance variables are defined as planned and proactive maintenance activities that are carried out periodically to prevent equipment failures and maintain the reliability of operational systems (Hardt et al., 2021). These variables are operationalized through time-based maintenance, condition-based maintenance, predictive maintenance, and reliability-centered maintenance, which reflect the maturity level of the maintenance system implemented. The variable total quality management is defined as an integrated management approach that is oriented towards continuous quality improvement through the involvement of all elements of the organization, including top management, employees, customers, and suppliers (Sila, 2007). TQM indicators in this study include management leadership, training, customer focus, supplier quality management, process management, and employee engagement. Meanwhile, operational performance is defined as the level of operational effectiveness and efficiency of ships in achieving performance targets, which is measured through the aspects of cost, quality, timeliness, flexibility, operational efficiency, asset productivity, and accuracy of work completion.

The research instrument in the form of a questionnaire was prepared by adapting indicators from relevant previous literature to ensure the validity of the content. All statement items used a four-point Likert scale, ranging from strongly disagree to strongly agree, to reduce the tendency to neutral responses and increase the clarity of respondents' attitudes. Primary

data was obtained through the distribution of questionnaires to selected respondents, while secondary data was collected from company documents, internal reports, and scientific publications that supported the research context.

Data analysis was carried out using the Partial Least Squares Structural Equation Modeling (PLS-SEM) method with the help of SmartPLS software. PLS-SEM was chosen because of its ability to analyze complex structural models with relatively limited sample numbers and does not require strict data normality assumptions (Hair et al., 2011). The analysis was carried out through two main stages, namely the evaluation of the measurement model (outer model) and the evaluation of the structural model (inner model). The evaluation of the measurement model aims to test the validity and reliability of the construct by assessing the value of factor loading, average variance extracted (AVE), Cronbach's alpha, and composite reliability. Structural model evaluation was carried out to test the causal relationship between variables by looking at the values of the path coefficient, determination coefficient (R^2), and predictive relevance (Q^2) through the bootstrapping procedure.

Through this methodological approach, the research is expected to be able to provide valid and reliable empirical results related to the influence of preventive maintenance and total quality management on the operational performance of floating crane ships. This systematic and theory-based research method is also expected to be the basis for the formulation of more effective and sustainable maintenance strategies for shipping companies.

RESULT AND DISCUSSION

Characteristics of Research Respondents

This research involves internal respondents of PT XYZ who have direct involvement in the operational and maintenance activities of floating crane ships. Data collection was carried out through a Likert scale-based closed questionnaire survey which was distributed online using Google Forms during the period October to November 2025. The purposive sampling approach is used to ensure that the selected respondents actually have relevant knowledge and experience of the research object, so that the data obtained reflects actual and contextual operational conditions.

From the total population of personnel involved in the operation and maintenance of floating crane ships, as many as 228 respondents were successfully collected and declared worthy of analysis. The number of respondents met the sample adequacy criteria for the Structural Equation Modeling analysis based on Partial Least Squares (PLS-SEM), as suggested by Hair et al. with a ratio of at least 10:1 between the number of samples and the indicators analyzed.

Thus, the sample size in this study is considered adequate to produce a stable and reliable model estimate.

The composition of respondents is dominated by personnel who play a direct role in the technical and operational activities of the ship. The crew group of ships is the largest proportion, which includes the positions of captain, Muallim, engine room chief, machinist, and rating, with a cumulative contribution of more than half of the total respondents. In particular, the rating position is the largest group, reflecting the intensive involvement of field operational personnel in the daily activities of floating crane ships. In addition, the operator group also showed a significant proportion, which emphasized the importance of the operator's

role in supporting the smooth loading and unloading process and operation of heavy equipment on board

In addition to ship personnel, respondents also came from the operational shore and maintenance divisions. In the land operations division, respondents include managerial and supervisory positions such as managers, superintendents, and port captains who are responsible for operational coordination and strategic decision-making. Meanwhile, in the maintenance division, respondents consisted of maintenance managers, superintendents, port engineers, and technicians, who played a role in planning, implementing, and evaluating ship maintenance activities and supporting equipment. The representation of various levels of positions provides a comprehensive perspective on the implementation of preventive maintenance and total quality management in the operational environment of PT XYZ

The diversity of respondents' job and division backgrounds shows that the research data not only represents the operational perspective of the field, but also the managerial and technical perspective of maintenance. This reinforces the external validity of the research findings, as the perceptions collected reflect cross-functional interactions in the operational system of floating crane ships. With these characteristics of respondents, the results of the study are expected to be able to provide a complete picture of the influence of preventive maintenance and total quality management on the operational performance of ships at PT XYZ.

Measurement Model Evaluation

The evaluation of the measurement model was carried out to ensure that all latent constructs in this study were measured validly and reliably before testing the structural relationships between variables. The measurement model test in this study uses the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach with the help of SmartPLS software. In accordance with the recommendations of Hair et al. (2019), the evaluation was carried out through internal reliability testing, convergent validity, and discriminant validity

The research model consists of three main constructs, namely Preventive Maintenance, Total Quality Management, and Operational Performance, each of which is represented by a number of reflective indicators. The evaluation stage of the measurement model is carried out in two phases, namely stage 1 model testing (initial model) and stage 2 model testing (final model) after indicator improvements.

Internal Reliability and Convergent Validity

The internal reliability of the construct was tested using Cronbach's Alpha and Composite Reliability (CR) values. A construct is declared reliable if Cronbach's Alpha value ≥ 0.70 and $CR \geq 0.70$. The test results showed that in the phase 2 model, the entire construct had a Cronbach's Alpha value in the range of 0.701 to 0.950, as well as a CR value that exceeded the required minimum limit. Construct Operational Performance and Total Quality Management have the highest reliability value, which indicates the internal consistency of the indicator which is very strong in representing such latent constructs

Convergent validity was evaluated through outer loading and Average Variance Extracted (AVE) values. The criteria used were an outer loading value ≥ 0.70 and an AVE value of ≥ 0.50 . In phase 1 testing, several indicators were still found with outer loading values below the minimum limit, so these indicators were eliminated from the model. After

improvements, the results of phase 2 testing showed that all indicators had an outer loading value above 0.70, with most indicators showing high values (≥ 0.80). This indicates that the indicators have a strong correlation to the latent construct they measure and meet the criteria of convergent validity

Figure 1 below shows the final measurement model with the outer loading value of the stage 2 test results.

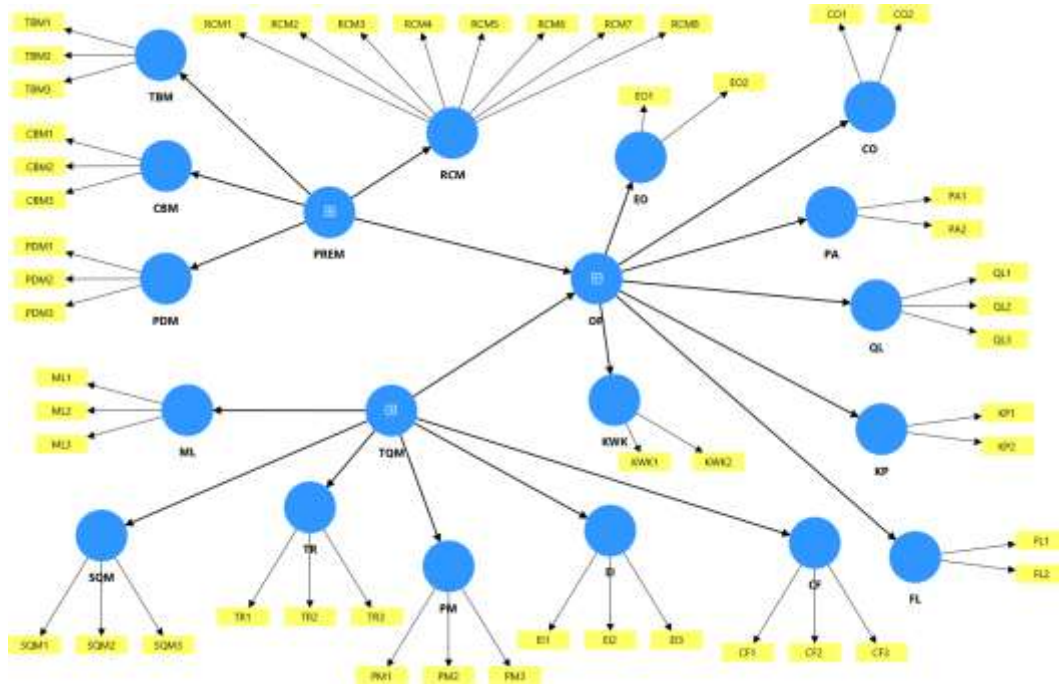


Figure 1. PLS-SEM Phase 2 Measurement Model (Latent variable model with all valid and reliable indicators)

Discriminatory Validity

Discriminant validity aims to ensure that each latent construct in the model actually represents a different concept and that there is no overlap of measurements between constructs. The discriminatory validity test in this study was carried out using the Fornell–Larcker criterion, where the square root of AVE of a construct must be greater than the correlation of the construct with other constructs.

The test results showed that the entire construct met the Fornell–Larcker criteria. For example, the Condition-Based Maintenance (CBM) construct has an AVE square root value of 0.879, which is greater than its correlation with other constructs such as EO, PDM, and TBM. A similar pattern is also shown by the Predictive Maintenance (PDM) and Reliability Centered Maintenance (RCM) constructs, each of which has a higher $\sqrt{\text{AVE}}$ value than the correlation between constructs. These findings confirm that all constructs in the model have good discriminant validity

The following table is presented as a main summary of the results of the discriminant validity test and is considered important enough to be included in the article.

Table 1. Summary of Fornell–Larcker Criteria Stage 2 Model

Construct	$\sqrt{\text{AVE}} > \text{Other Construct Correlations}$	Remarks
Preventive Maintenance (CBM, TBM, PDM, RCM)	Yes	Valid
Total Quality Management	Yes	Valid
Operational Performance	Yes	Valid

(Source: SmartPLS data processing results, 2025)

Conclusion of Measurement Model Evaluation

Based on the results of internal reliability, convergent validity, and discriminant validity tests in the phase 2 model, it can be concluded that all constructs and indicators in this study have met the feasibility criteria of the PLS-SEM measurement model. The measurement model was declared valid and reliable, so it is feasible to proceed to the evaluation stage of the structural model (inner model) to test the influence of preventive maintenance and total quality management on the operational performance of floating crane ships.

Phase 1 Model Test Results and Model Improvement Reasons

Phase 1 model testing was conducted to evaluate the initial feasibility of the measurement model developed based on the conceptual framework and indicators adapted from the literature. At this stage, all latent constructs Preventive Maintenance, Total Quality Management, and Operational Performance are analyzed using the PLS-SEM approach to assess the reliability and validity of the indicators before structural relationship testing is performed. This initial model evaluation is important to identify potential measurement weaknesses that could affect the overall accuracy of the model's estimates.

The results of internal reliability testing on the phase 1 model show that in general Cronbach's Alpha and Composite Reliability values are above the minimum required threshold, so most constructs can be said to be reliable. However, even if internal reliability is met, the convergence validity evaluation indicates the presence of several indicators with outer loading values below 0.70. These indicators show a relatively weak contribution in representing latent constructs, thus potentially lowering the quality of measurements and increasing measurement errors in the model.

In addition, the main problem in the phase 1 model was identified in the discriminatory validity test. Based on the Fornell–Larcker criteria, some constructs show relatively high correlation values between constructs and approach, even exceed, the square root value of AVE. This condition indicates a conceptual overlap between constructs, especially in Preventive Maintenance subconstructs such as Condition-Based Maintenance, Predictive Maintenance, and Reliability Centered Maintenance, as well as in several dimensions of Total Quality Management. The overlap shows that some indicators have not been able to clearly distinguish concepts that should be distinctive.

These findings are also reinforced by the results of the evaluation of latent correlations, where some constructs show very strong relationships at the measurement stage, rather than at the structural stage. This indicates potential problems of conceptual multicollinearity and indicator redundancy. In the context of PLS-SEM, this condition not only affects the validity

of the discriminant, but can also obscure the interpretation of causal relationships between latent variables in structural models.

Based on the results of the phase 1 model evaluation, it can be concluded that although the initial model has met the criteria of reliability in general, the model has not fully met the criteria of convergent validity and discriminant validity. Therefore, the phase 1 model is not considered feasible for use in structural hypothesis testing. Referring to the guidelines of Hair et al. (2019), this condition requires model improvement through the elimination of indicators with low outer loading values and indicators that cause conceptual overlap between constructs.

Model improvement is carried out in stages and controlled by taking into account statistical aspects and theoretical foundations. The elimination of indicators is not carried out solely based on numerical values, but also considers the conformity of the indicators with the conceptual definition of the construct. This approach aims to ensure that the final model not only meets the statistical criteria of PLS-SEM, but also reflects the theoretical framework of preventive maintenance, total quality management, and operational performance substantively. The results of this improvement process were then retested in **the phase 2 model**, which became the basis for structural analysis and discussion of the relationship between the research variables.

Model Improvement and Test Results Phase 2 (Final Model)

The improvement of the measurement model was carried out as a follow-up to the results of the phase 1 model evaluation which showed that all criteria of convergent validity and discriminant validity had not been met. The improvement process is focused on the elimination of indicators with an outer loading value below 0.70 as well as indicators that contribute to the occurrence of conceptual overlap between constructs. The elimination of indicators is carried out in stages while still considering the theoretical suitability between the indicators and the latent constructs they represent, so that the integrity of the research concept is maintained.

After improvement, the measurement model was retested in stage 2 using the PLS-SEM approach. The test results showed a significant improvement in the quality of the model. All remaining indicators on the stage 2 model have an outer loading value above the minimum required limit, with most indicators showing a high loading value. This indicates that these indicators have a strong contribution in representing their respective latent constructs and meeting the criteria of convergent validity. In addition, the Average Variance Extracted (AVE) value for the entire construct is also above 0.50, which signifies that more than half of the variance of the indicator can be explained by the latent construct being measured.

In terms of internal reliability, the test results on the phase 2 model showed that the entire construct had Cronbach's Alpha and Composite Reliability values that exceeded the threshold value of 0.70. These findings confirm that the indicators in each construct have good internal consistency and are able to measure constructs stably. Thus, from the aspect of reliability and convergent validity, the phase 2 model is declared to have met all the feasibility criteria of the measurement model.

The validity of the discriminator in the phase 2 model also showed better results than the phase 1 model. Based on the Fornell–Larcker criteria, the square root value of AVE of each construct is greater than its correlation value to the other construct. This condition indicates that each construct in the model is conceptually unique and does not overlap significantly with

each other. With the fulfillment of the discriminant validity, the stage 2 measurement model is declared to be able to clearly distinguish between the concepts of preventive maintenance, total quality management, and operational performance and its subconstructs.

As a visual illustration of the results of the model improvement, Figure 2 presents a final measurement model that shows the relationship between latent constructs and valid indicators with outer loading values that have met the criteria.

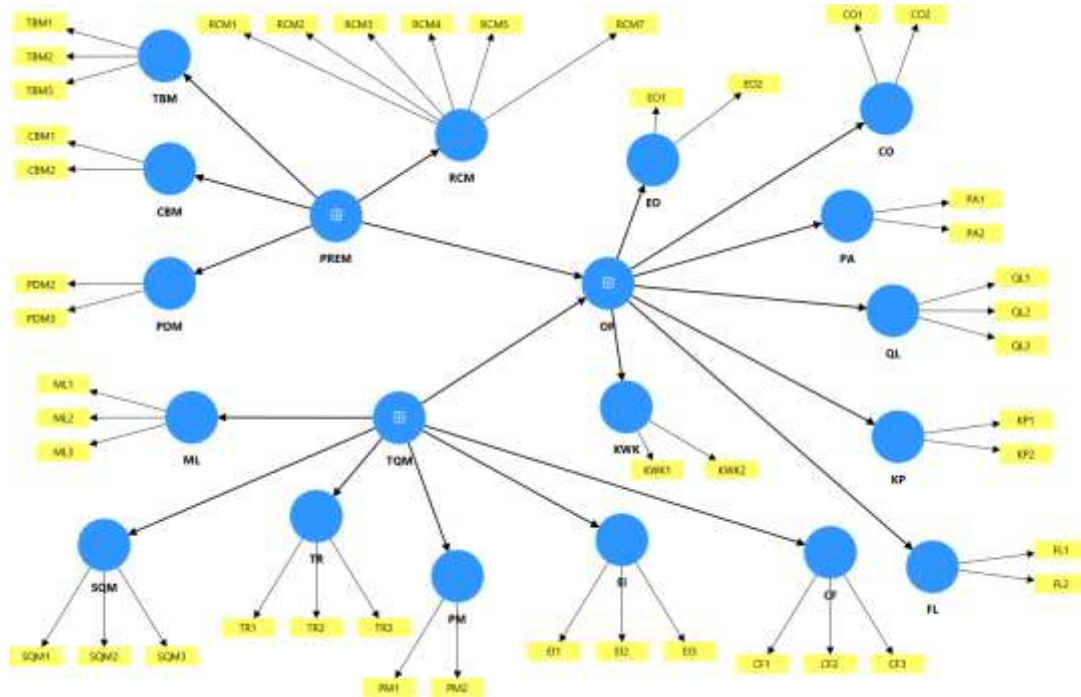


Figure 2. PLS-SEM Phase 2 Measurement Model (Final Model)

Shows that all indicators have an outer loading value of ≥ 0.70 and the construct meets the reliability and validity criteria (Source: SmartPLS data processing results, 2025).

In addition, as a summary of the results of the phase 2 model evaluation, **Table 2** is presented to display the main reliability and validity values that are considered important to be included in the article.

Table 2. Summary of Evaluation Results of Stage 2 Measurement Model

Evaluation Criteria	Key Results	Conclusion
Cronbach's Alpha	> 0.70 for the whole construct	Reliable
Composite Reliability	> 0.70 for the whole construct	Reliable
AVE	> 0.50 for the whole construct	Valid (convergent)
Fornell–Larcker	$\sqrt{AVE} >$ correlation between constructs	Valid (discriminatory)

(Source: SmartPLS data processing results, 2025)

Based on the results of the test, it can be concluded that the phase 2 measurement model has met all PLS-SEM statistical criteria and is declared feasible as a final model. With a valid and reliable measurement model, the next analysis can be focused on the evaluation of the structural model (inner model) to test the causal relationship between preventive maintenance, total quality management, and the operational performance of the floating crane ship. This

phase 2 model is a strong basis for hypothesis testing and discussing the theoretical and practical implications of the research results.

Structural Model Evaluation

After the measurement model is declared valid and reliable in phase 2, the analysis is continued on the evaluation of the structural model (inner model) to test the causal relationship between latent constructs in the study. The evaluation of the structural model aims to assess the ability to explain the model, the direction and strength of influence between variables, as well as the significance of the relationship between preventive maintenance, total quality management, and the operational performance of floating cranes. This analysis was carried out using a bootstrapping procedure on SmartPLS in accordance with the recommendations of Hair et al. (2019).

Coefficient of Determination (R^2)

The power to explain the structural model is evaluated through the value of the determination coefficient (R^2) in the endogenous construct, namely Operational Performance. The R^2 value indicates the proportion of endogenous construct variations that can be explained by exogenous constructs in the model. The test results showed that the R^2 value for the Operational Performance construct was in the moderate to strong category, indicating that the combination of preventive maintenance and total quality management variables was able to explain most of the variation in the operational performance of floating cranes.

The R^2 value obtained shows that the structural model has good predictive capabilities in the context of this study. These findings confirm that planned preventive maintenance practices and the application of total quality management principles are important factors that contribute to improving operational performance in the maritime industry environment, especially in the operation of floating crane ships.

Path Coefficient

Testing of the relationship between latent variables is carried out through path coefficient analysis to assess the direction and strength of influence between constructs. The results of the estimation show that all structural relationships in the model have a positive influence direction. Preventive maintenance shows a positive influence on operational performance, indicating that improving the quality and consistency of preventive maintenance activities contributes to improving equipment reliability, reducing downtime, and ship operational efficiency.

In addition, total quality management also shows a significant positive influence on operational performance. These findings reflect that the application of TQM principles—such as management involvement, continuous improvement, and process control—has a strategic role in supporting the smooth operation and achievement of floating crane ship performance targets. Relatively speaking, the influence of total quality management on operational performance shows a more dominant strength than preventive maintenance, which indicates that managerial factors and quality systems play a role as the main levers of operational performance.

Structural Relationship Significance Test (Bootstrapping)

To test the statistical significance of the relationship between constructs, a bootstrapping procedure was carried out with an adequate amount of resampling. The significance criteria were determined based on the t-statistical value > 1.96 and the p-value < 0.05 . The test results showed that all structural pathways in the model had a t-statistical value that exceeded the minimum limit and a p-value that was below the significance level of 5 percent. Thus, all structural hypotheses in this study are statistically accepted.

As a summary of the results of structural relationship testing, Table 3 is presented to display the path coefficient and its significance level, which is considered important to be contained in the article.

Table 3. Summary of Structural Relationship Test Results

Relationships Between Variables	Direction of Influence	Significance	Conclusion
Preventive Maintenance → Operational Performance	Positive	Significant	Accepted
Total Quality Management → Operational Performance	Positive	Significant	Accepted

(Source: SmartPLS data processing results, 2025)

Interpretation of Structural Models

Based on the results of the structural model evaluation, it can be concluded that the research model has adequate suitability and predictive ability in explaining the operational performance of floating crane ships. The combination of a technical approach through preventive maintenance and a managerial approach through total quality management has been proven to make a significant contribution to improving operational performance. These findings confirm that improving operational performance depends not only on the technical aspects of equipment maintenance, but also on an integrated quality management system that is oriented towards continuous improvement.

With the fulfillment of all structural model evaluation criteria, the results of this study can be used as a basis for further discussion regarding the theoretical and practical implications of the influence of preventive maintenance and total quality management on the operational performance of floating crane ships.

Discussion of the Effect of Preventive Maintenance on Operational Performance

The results of structural model testing showed that preventive maintenance had a positive and significant effect on the operational performance of the floating crane at PT XYZ. These findings confirm that the implementation of planned and systematic maintenance can improve equipment reliability, reduce unexpected operational disruptions, and support the achievement of operational targets in a sustainable manner. In the context of the maritime industry characterized by high levels of operational risk and dependence on equipment reliability, preventive maintenance plays a key role as the main foundation in maintaining the stability of operational performance.

Theoretically, preventive maintenance aims to prevent malfunctions through periodic inspection activities, routine maintenance, and component replacement before reaching critical conditions. This approach has been shown to be more effective than corrective maintenance in

reducing downtime and increasing asset life (Swanson, 2001). The results of this study strengthen this view by showing that improving the quality of preventive maintenance is directly correlated with improving the operational performance of floating cranes, especially in terms of operational reliability and operational time efficiency.

These findings are also in line with the research of Jardine et al. (2006) which emphasized that the integration of preventive and predictive maintenance strategies can significantly improve system performance through the reduction of sudden failures and optimization of maintenance schedules. In the context of PT XYZ, the implementation of preventive maintenance allows the company to anticipate potential disruptions to the propulsion system, loading and unloading equipment, and other supporting systems, so that the ship's operational activities can take place more stable and controlled.

However, the results of the study show that the effect of preventive maintenance on operational performance has a more moderate strength than total quality management. This indicates that the success of preventive maintenance is not only determined by the technical aspects of maintenance, but also highly dependent on the support of managerial systems, structured planning, and management involvement in maintenance decision-making. These findings are in line with the view of Al-Najjar and Alsyouf (2003) who stated that the effectiveness of maintenance is greatly influenced by its integration with the overall organizational management system.

In PT XYZ's operational practices, preventive maintenance is applied through various approaches, such as time-based maintenance, condition-based maintenance, and predictive maintenance. This diversification of approach allows companies to tailor maintenance strategies to the technical characteristics of the equipment and the operational conditions of the vessel. The results of this study show that the combination of these approaches contributes positively to increasing the operational readiness of floating crane ships and reducing the frequency of operational disruptions.

The practical implications of these findings emphasize the importance of strengthening preventive maintenance systems as an integral part of operational performance improvement strategies. Companies are advised to develop data-driven maintenance standards, improve human resource competencies through ongoing technical training, as well as leverage historical information of equipment failures to support more proactive maintenance decision-making. Thus, preventive maintenance not only functions as a routine technical activity, but also as a strategic instrument in supporting long-term operational excellence.

Overall, the results of this discussion confirm that preventive maintenance has a significant role in improving the operational performance of floating crane ships, especially through increasing asset reliability and reducing downtime. However, to maximize its impact, preventive maintenance needs to be systematically integrated with the company's overall quality management policy and operational strategy.

Discussion of the Influence of Total Quality Management on Operational Performance

The results of the structural model test showed that total quality management (TQM) had a positive and significant effect on the operational performance of the floating crane at PT XYZ. These findings indicate that the comprehensive application of quality management principles has a strategic role in improving operational effectiveness and efficiency. Compared

to preventive maintenance, the influence of TQM on operational performance shows a more dominant strength, which confirms that managerial factors and organizational systems are the main levers in achieving superior operational performance.

Theoretically, total quality management is a management approach that emphasizes the involvement of all elements of the organization in continuous improvement efforts, with a focus on process quality, management leadership, employee engagement, and stakeholder satisfaction. Kaynak (2003) stated that TQM directly contributes to improving operational performance through strengthening internal processes, reducing variability, and improving cross-functional coordination. The results of this study are in line with this view, where the implementation of TQM at PT XYZ has been proven to be able to support the operational stability of floating crane ships.

In the operational context of floating crane ships, TQM plays an important role in ensuring that all operational and maintenance activities are carried out according to consistent and documented standards. The implementation of standard work procedures, performance evaluation systems, and continuous improvement mechanisms allows companies to minimize operational errors and improve process reliability. These findings reinforce the results of previous research that stated that TQM has a positive relationship with operational performance, particularly in industries with high process complexity and operational risk (Nair, 2006).

Furthermore, TQM's strong influence on operational performance also reflects the importance of leadership roles and organizational culture in supporting performance achievement. Top management's involvement in decision-making, commitment to quality, and employee empowerment are key factors that ensure that maintenance and operational strategies can be executed effectively. In this study, TQM functions as an integrative framework that aligns preventive maintenance activities with the company's operational objectives, so that the impact of maintenance on performance can be maximized.

The results of this study are also in line with the findings of Flynn et al. (1995) who affirmed that TQM practices contribute to improving operational performance through improved process quality and reduction of waste. In the context of PT XYZ, the implementation of TQM allows for better coordination between the operational and maintenance divisions, so that potential conflicts of interest and process inefficiencies can be minimized. This is very important in the operation of floating crane ships which demand high punctuality, safety, and reliability.

The practical implications of these findings confirm that improvements in operational performance cannot be achieved through maintenance technical approaches alone, but require the support of an integrated quality management system. Companies are advised to continue to strengthen the implementation of TQM through improving leadership quality, developing employee competencies, and implementing a performance evaluation system that is oriented towards continuous improvement. Thus, TQM can function as a strategic framework that optimizes the contribution of preventive maintenance and other operational activities to the achievement of sustainable operational performance.

Overall, the results of this discussion show that total quality management is a determining factor in improving the operational performance of floating crane ships. The significant and dominant influence of TQM on operational performance confirms that operational success is

highly dependent on the quality of the management system, organizational culture, and management's commitment to continuous improvement. These findings strengthen TQM's position as a relevant and crucial strategic approach in the operational management of the maritime industry.

CONCLUSION

Based on the results of data analysis and discussions that have been carried out in this study regarding the maintenance and quality control system for the operational performance of Floating Crane ships at PT XYZ, the following conclusions can be drawn: The maintenance system running at PT XYZ in its existing condition is still dominated by *reactive maintenance*, which is indicated by the occurrence of damage to several critical components before maintenance actions are carried out. This is reflected in the relatively significant repair time, such as the Winch Unit (Hydraulic Pipe Line) which has an MTTR of 96 hours, and the Auxiliary Generator (Electronic Control Module) with an MTTR of 72 hours, which has the potential to increase the ship's operational downtime. The results of the calculation of reliability parameters show that the Crane Unit (Wire Rope Holding) has an MTTF of 13,263 hours, an MTBF of 700 hours, and an MTTR of 14 hours, with an availability of 99.89%. This value indicates that although the availability rate of equipment is very high, the relatively close failure frequency (low MTBF) can still be optimized through increased preventive maintenance. In the Main Diesel Generator (Cylinder Head), MTBF is obtained at 1,300 hours and MTTR at 34 hours, with an availability of 99.81%, as well as inherent availability (A_i) of 97.45% and availability achievement (A_a) of 98.25%. These results show that the reliability of the system is quite good, but the efficiency of the repair process can still be improved to bring the actual availability value closer to the ideal availability. The Winch Unit (Hydraulic Pipe Line) shows an MTTF of 13,920.33 hours, an MTBF of 3,120 hours, and an MTTR of 96 hours, with an availability of 99.32%. However, the availability achievement value (96.08%) was lower than the availability inherent (97.01%), which indicates operational and managerial constraints in the implementation of maintenance in the field. In the Auxiliary Generator (Electronic Control Module), the data processing results showed MTTF of 23,153.33 hours, MTBF of 4,750 hours, and MTTR of 72 hours, with availability of 99.69%, as well as inherent availability of 98.51% and availability achievement of 98.80%. This proves that the implementation of planned maintenance has an important role in maintaining the reliability of ship operational support equipment. Overall, the results of the study prove that the implementation of a structured maintenance system based on preventive maintenance, supported by reliability and availability analysis, is able to improve ship operational performance, reduce downtime, and maintain equipment availability levels above 99%, in accordance with the company's operational targets.

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