Journal of International Conference Proceedings (JICP) Vol. 6 No. 7, pp. 218-238, December, 2023
P-ISSN: 2622-0989/E-ISSN: 2621-993X
https://www.ejournal.aibpmjournals.com/index.php/JICP

Evaluation of Implementation of Maintenance Management System for Working Vessels of PT Timur Bahari to Improve Company Financial Performance

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ARTICLE INFORMATION

Publication information

Research article

HOW TO CITE
Febriansyah, E. H. & Latief, Y. (2023). Evaluation of Implementation of Maintenance Management System for Working Vessels of PT Timur Bahari to Improve Company Financial Performance. *Journal of International Conference Proceedings*, *6*(7), 218-238.

DOI:
https://doi.org/10.32535/jicp.v6i7.2828

Received: 30 October 2023
Accepted: 28 November 2023
Published: 30 December 2023

ABSTRACT

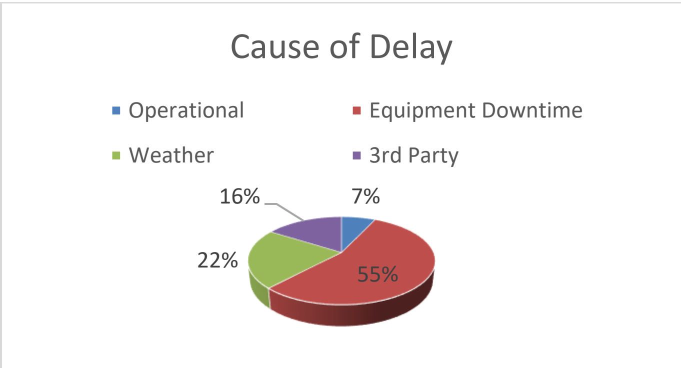
The working vessel is an important asset for marine contractors, including PT Timur Bahari. It plays important role as main equipment for marine constructions, crew accommodation, and marketing tools for the company. Recognizing the pivotal role of working vessel, any downtime would result in unproductive and reducing company's revenue. On the other hand, uptime is expected to always be at the high level so that working vessels becomes vital to the company's financial performance. The study utilizes survey methods, literature reviews, and case study. The conclusion of this study demonstrates that integrating the maintenance management system with the business process can significantly enhance the company's financial performance.

Keywords: Business Process, Downtime, Financial Performance, Maintenance Management System, Uptime, Working Vessel

INTRODUCTION

The working vessel plays an important role for marine contractors, its roles as main equipment utilized for marine constructions, crew accommodation, and marketing tools for the company. Recognizing the pivotal role of working vessel, therefore the implementation of maintenance management system becomes vital to the company's financial performance. The aim of maintenance is to reduce the failures on the equipment and to avoid breakdowns that may lead disruption during operational (Jimenez et al., 2020). Maintenance holds crucial roles in reducing operational cost and maximize the reliability of a complex engineering system (Yu et al., 2016). High cost of corrective maintenance forces company to develop preventive maintenance approach (Nguyen et al., 2015). However, to implement the full scale of preventive maintenance to each working vessel will causing high costs. The approach by minimizing the replacement of spare parts which not so urgent while maintaining the operation of equipment would be ideal to do, or it commonly known as condition based on maintenance (Prajapati et al., 2012). It is why the research is important to contribute to (case study) PT Timur Bahari for having focus on maintenance management system to improve the company financial performance. Equipment downtime is the biggest factor in PT Timur Bahari which contribute to project delay as shown on the following chart.

Figure 1. Cause of Delay in PT Timur Bahari Projects (2021-2022)



The causes contributing to project delays in PT Timur Bahari between January 2021 and May 2022, as depicted in Figure 1, are outlined as follows.

Operational Factors
Delays attributed to operational factors involve technical issues within the scope of work, such as methods, work phases, or insufficient resources, leading to project delays.

Equipment Downtime
Delays attributed to equipment downtime factors involves work stoppages due to equipment issues, specifically working vessels experiencing breakdowns or undergoing maintenance. This high number of equipment downtime caused by various issues such as vessel age, excessive usage due to project requirements or demands, difficult in acquiring suitable spare parts, procurement processes for vessel consumable which not meeting specifications, vessels crew capabilities, engine modifications, docking time delays, repair costs exceeding the budget, and inconsistencies in regular maintenance.

Weather
Delays attributed to weather factors involve work stoppages due to adverse weather conditions posing risks to working vessels or crew/workers.

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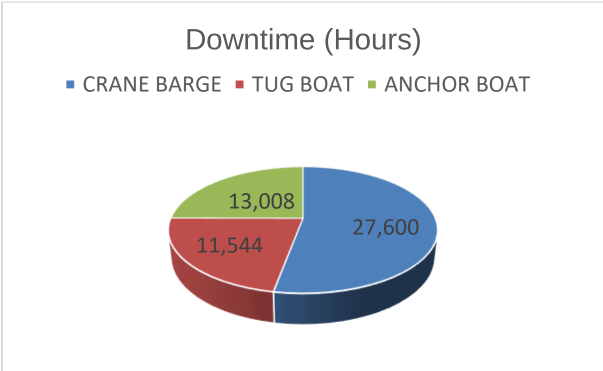
Third Party
Delays attributed to third party factors involves work stoppages due to interruptions by external entities, such as harbor master, the Indonesian navy, project owners, consultants, or local government entities.

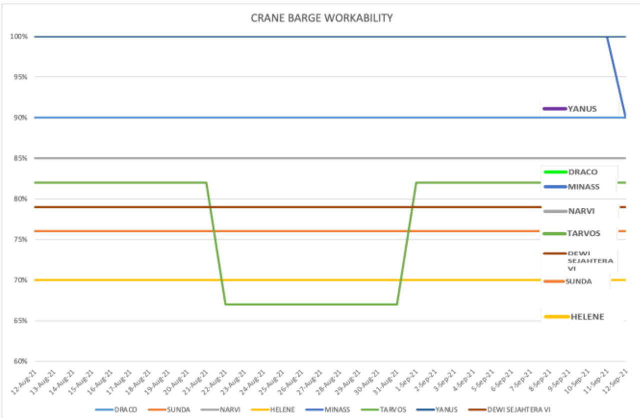
According to monthly report of PT Timur Bahari (2021-2022), from the total number of working vessels owned by PT Timur Bahari, crane barge, tugboat, and anchor boat are type of working vessels with the most of total downtime as shown on the following figure.

Figure 2. Total Downtime PT Timur Bahari (2021 – 2022)



The high equipment downtime is caused by the implementation of maintenance management system which not optimum, this is reflected by the availability or workability rate of the working vessels. For example, the following is graphic of workability rate for working vessel type crane barge and tugboat of PT Timur Bahari.

Figure 3. Vessel (Crane Barge) Workability PT Timur Bahari (2021)



The graphic shows that the availability of crane barge majority is lesser than 85%. The low availability rate has an impact to the productivity and company revenue. This reinforce the statement that the implementation if maintenance management system is not optimum therefore the availability rate is below expectation (lesser than 85%).

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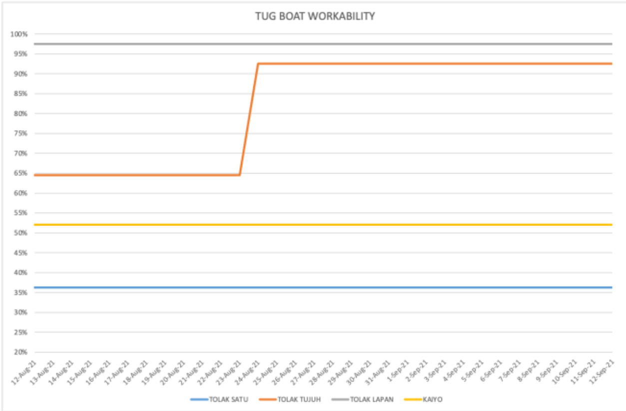
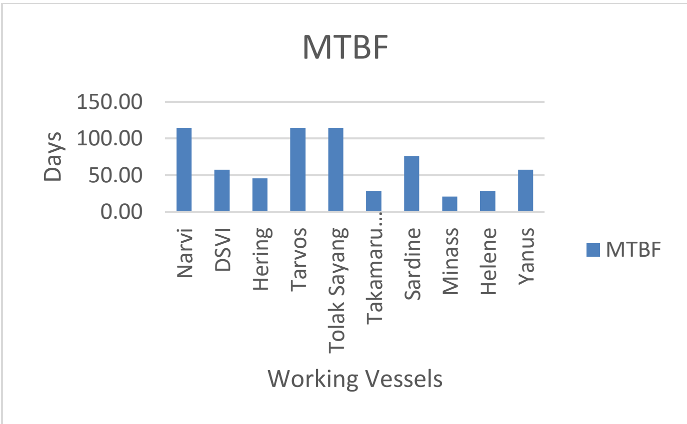
Figure 4. Vessel (Tugboat) Workability PT Timur Bahari (2021)



The graphic shows that the availability of tugboat majority is lesser than 85%. The low availability rate has an impact to the productivity and company revenue. This reinforce the statement that the implementation of maintenance management system is not optimum therefore the availability rate is below expectation (lesser than 85%).

In addition, low Mean Time Between Failures (MTBF) causing problem both for project and the company. The MTBF condition of PT Timur Bahari working vessels for the period between January 2021 and May 2022 can be seen in the following figure.

Figure 5. MTBF of PT Timur Bahari Working Vessels



This condition aligns with PT Timur Bahari Financial Performance (liquidity) which most of the liability is overdue more than 3 months (please refer to table below).

Table 1. Sample Summary of Overdue Invoices (October 2021)

Date Payment	Description	Inv. Date	No. Invoice	Amount (IDR)	Amount Transfer	Over Due (IDR)
01/09/21	Food allowance period 01-15 September 2021 for vessel Kaiyo and additional purchase of red ginger	01/09/21		6,052,000	6,052,000	0
01/09/21	Food allowance period 01-15 September 2021 for vessel Tolak 1 and additional purchase of red ginger	01/09/21		6,140,000	6,140,000	0
01/09/21	Food allowance period 01-15 September 2021 for maintenance - Yepta Ganna	01/09/21		660,000	660,000	0
01/09/21	Food allowance period 01-15 September 2021 for diver -helene 1	01/09/21		1,320,000	1,320,000	0
01/09/21	Food allowance period 01-15 September 2021 for diver - helene 2	01/09/21		4,620,000	4,620,000	0
01/09/21	Food allowance period 01-15 September 2021 for vessel Helene and additional purchase of red ginger	01/09/21		10,760,000	10,760,000	0
07/09/21	Fresh water for Draco,Helene,Batara,Capitol,Sunda,Sandidewa,Capitol 08/09/21	30/08/21	957/INV/TKPJ/VIII/2021	53,300,000	53,300,000	8
08/09/21	Sparepart and maintenance for Tolak satu	15/06/21	202106081	3,100,000		85
08/09/21	Sparepart and maintenance for Tolak 7	18/06/21	202106107	8,402,000		82
08/09/21	Sparepart and maintenance for Kaiyo	17/07/21	202107080	31,995,000	55,032,000	53

08/09/21	Sparepart and maintenance for Tolak satu	02/08/21	202108007	1,585,000		37
08/09/21	Sparepart and maintenance for Tolak 7	02/08/21	202108002	9,950,000		37
08/09/21	part and maintenance for MT 16	22/06/21	00340/GJ M/06/2021	5,742,000		78
08/09/21	part and maintenance for MT 16	22/06/21	00341/GJ M/06/2021	23,276,000	47,426,500	78
08/09/21	part and maintenance for MT 16	22/06/21	00342/GJ M/06/2021	8,508,500		78
08/09/21	part and maintenance for MT 16	22/06/21	00343/GJ M/06/2021	9,900,000		78
08/09/21	Sparepart and maintenance for Tolak Satu	30/06/21	238B/IN-TGS/VI/21	186,765,260	186,765,260	70
08/09/21	Lub oil sae 40 kaiyo	03/08/21	21.128250 92	11,216,000	11,216,000	36
08/09/21	Sparepart and maintenance kaiyo	03/08/21	147/PTTG SI/VIII/202 1	28,160,000	28,160,000	36
09/09/21	Dp 35% crankshaft & main bearing pocket inspection for Tolak 1	01/09/21	R284.09/2 1	18,250,925 8	17,919,090	8
09/09/21	PPh 23 2% Rp 331,835	01/09/21		331,835 8		8
10/09/21	Avanza Veloz No Pol B 2945 UOP period 19/08/21-18/09/2021	19/08/21	711053935 4	5,500,000	5,940,000	22
10/09/21	PPN 10% Rp 550,000	19/08/21		550,000		22
10/09/21	PPh 23 2% Rp 110,000	19/08/21		110,000		22

Liquidity commonly used to measure the company’s short-term liabilities, and a high level of liquidity represents company’s strong financial condition (Muslimah et al., 2022). This indicates that maintenance management system has correlation and impact to financial performance. According to (Accorsi et al., 2019) accident and unplanned machinery failures causing significant repair cost, and in many cases stop operation leading to revenue loss. 71% of failures occurred in the naval industry is random failures, therefore traditional preventive maintenance approach is insufficient (Allen, 2001). To enhance company’s liquidity, evaluation of implementation of maintenance management system is necessary.

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LITERATURE REVIEW

Derived from various literature sources, eight critical aspects of maintenance management system were identified.

Maintenance Policy

The purpose of development of maintenance policy is to optimize the decision making of predictive maintenance. There are two categories of maintenance policy; based on control limit and based on cost balancing (Vu et al., 2021). According to policy based on control limit, system is maintained during inspections from predicted health condition reaching a critical threshold (Vu et al., 2021). While policy based on cost balancing, maintenance decisions are made by comparing expected cost from those options (Vu et al., 2021).

Implementation of good performance of system for maintenance policy, requires to be integrated with business process management of the company (Mishra et al., 2006). In developing and implementing policies, a foundational basis for policy making is necessary. According to (Vrignat et al., 2021), an information system serves as the cornerstone for effective maintenance policy management. Once this foundational basis is established, executing maintenance policy strategies requires business process management to enhance company efficiency by governing modeled, automated, integrated, monitored, and continuously optimized business processes (Vrignat et al., 2021). Maintenance decisions are made by comparing the expected costs between ‘preventive maintenance’ and ‘no preventive maintenance’ at each inspection interval. These decisions also consider the system failure risks in subsequent operational periods and the loss of productivity due to system degradation (Lu et al., 2007).

The concept of maintenance policy is requiring integration between maintenance management system with the company business process as its foundation.

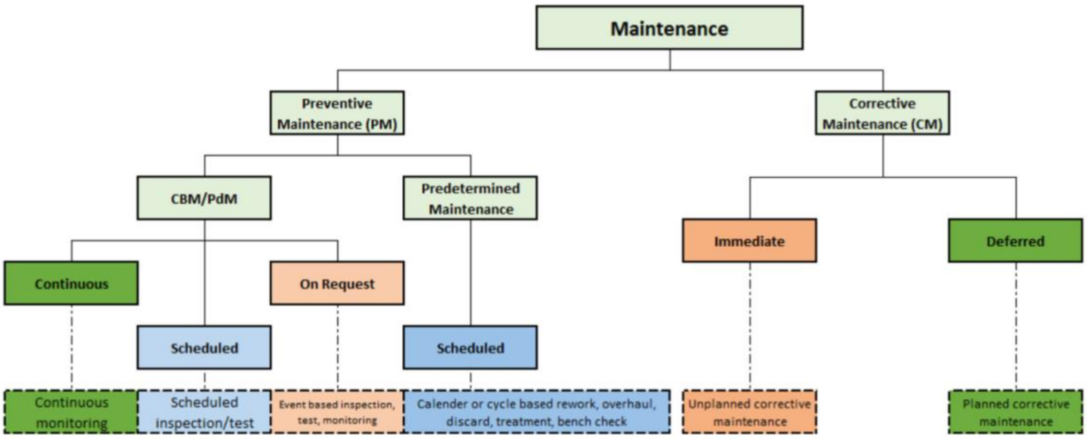
Funding Sources

According to (Roda & Macchi, 2016), there are four principles of funding for company assets oriented towards: Lifecycle orientation, system orientation, risks orientation and asset-centric orientation. Following the decision-making basis to fund a maintenance activity, the subsequent step involves the realization of the allocated funds. In general, various types of funding sources and financing are available, categorized broadly into two main categories: equity and loan / debt (Bahaswan et al., 2020). According to the Indonesian dictionary, equity refers to ownership in the form of monetary value or can be termed as capital. On the other hand, debt, as per the Indonesian dictionary, is money borrowed from others or the obligation to repay what has been received. The crucial point for funding sources is not merely where the funding originates, but rather the necessity of a specific budget allocation for maintenance.

Standard Operating Procedure

The Standard Operating Procedure (SOP) for maintenance holds considerable significance in ensuring the structured scheduling and comprehensibility of maintenance activities, thereby facilitating the execution of tasks by individuals involved (Suwandari & Riantini, 2019). The guidelines or Standard Operating Procedure established as reference frameworks and workflow procedures related to maintenance must adhere to the specific type of maintenance involved. According to European standards (CEN, 2017), maintenance, based on its terminology, can be categorized into several types, as indicated in the diagram below.

Figure 6. Types of Maintenance Adopted from Maintenance Terminology



Source: (CEN, 2017).

The standard operating procedures developed for each type of maintenance will vary due to the distinct requirements and characteristics of each maintenance type. In its implementation, the maintenance management system should achieve several objectives, including: improving maintenance costs (more optimal), reducing downtime by scheduled preventive maintenance, extending equipment lifespan, storing historical data to assist in maintenance planning and budgeting, and generating maintenance reports. Considering the above description, the developed standard operating procedure should encompass four crucial aspects according to (Wireman, 1994); work order, maintenance stores control, preventive maintenance, and maintenance reporting.

Furthermore, the development of maintenance standard operating procedures also requires techniques, as suggested by (Fernandez-Barrero et al., 2021). Techniques based on statistical trends (such as Mean Time Between Failures) need to be utilized to develop maintenance procedures. And a web-based maintenance can reduce number of activities in the standard operating procedure and time processing, the maintenance performance is considered more effective (Pangastuti & Latief, 2021). A well-structured maintenance guideline can adapt to the conditions of working vessels, thereby helping to reduce maintenance costs.

Organization Structure
In executing and implementing the maintenance management system, there is a need for a specific allocation of human resources responsible for performing tasks and taking accountability. According to (Wireman, 1994), the establishment of a maintenance committee comprising engineering, maintenance, stores (inventory), accounting, and data processing is essential. The objective of this committee include: reviewing the recording system and administrative procedures, planning the system objectives concerning work order processes, maintenance stores, preventive maintenance, cost control, and reporting, Identifying the needs for computerized systems, identifying vendors meeting the objectives, and evaluating the systems and vendors (Wireman, 1994).

There is no doubt about the importance within a company to control equipment, maintenance, and materials. However, equally relevant is the need to control worker performance (Castillo-Martinez et al., 2020). Fundamentally, the maintenance management system requires a dedicated team to operate effectively.

Maintenance Interval

Scheduling maintenance activities is a preventive measure against equipment failure (Alsyouf, 2006). Maintenance scheduling is a process that assigns maintenance tasks over team in accordance with applicable maintenance requirements. Every vessel comes with its maintenance cycle (Deris et al., 1999).

An important point to note is that establishing maintenance interval is the earliest preventive step necessary to avoid unforeseen equipment failures.

Maintenance Schedule

After establishing the maintenance interval for each vessel component, the next crucial step is the execution of the maintenance activities themselves. Maintenance activities performed based on the maintenance schedule or time intervals must adhere to the specified time frames to prevent failures. Prognostic maintenance planning allowing for predictive and preventive maintenance activities to be carried out before any failures occur (Vrignat et al., 2021).

Data Base

Not all vessel components have clear guidelines from their respective manufacturers, especially for those categorized as old or unique components. Therefore, determining their maintenance interval and procedures can be obtained by reviewing historical data related to those components. Historical data plays a role in identifying patterns, trends, and correlations among components, which can be as reference for future (Jimenez et al., 2020).

It is crucial to thoroughly record every incident or failure of vessel component. This aligns with the input necessary for identifying patterns and correlations within the collected historical data.

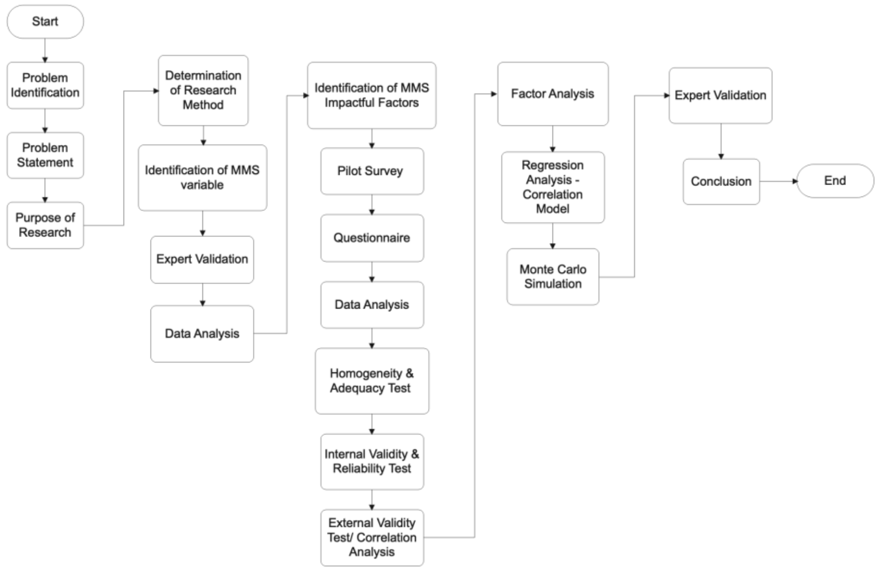
Communication

In implementing the maintenance management system, effective communication among maintenance personnel and relevant stakeholders is crucial. Good communication is expected to facilitate the flow of information, instructions, and coordination about activities. Communication is a process of conveying messages or information from one party to another with the goal of achieving a shared perception or understanding (Emery et al., 1970); (Suryawan, 2021). According to (Sahputra, 2020) and (Suryawan, 2021), in achieving organizational goals, management of communication becomes a core element that optimizes human resources and technology through communication strategies to enhance effectiveness and efficiency. Communication dimension; internal, external, formal, informal, hierarchy, official, unofficial, written or oral (Project Management Institute, 2017).

RESEARCH METHOD

In general, the sequence of this research is following the flow chart in figure below.

Figure 7. Work Sequence of the Research



Problem Identification
Identify the phenomena that require the study of the maintenance management system for working vessels and assesses the impacts of these phenomena.

Identification of Maintenance Management System Variables
Identify key factors within a program based on the literature reviews.

Initial Expert Validation
The variables which had been compiled from literature reviews then being checked and validated by the experts of marine construction.

Data Analysis
All the result data from expert validation to be analyzed and prepared for the questionnaire.

Identification of Maintenance Management System Impactful Factors
From the variables obtained, then identification of impactful factors among them are necessary.

Pilot Survey
Pilot survey is required to represent the intended respondent understanding on the questionnaire, to check the effectiveness of the instrument (questionnaire).

Questionnaire
To gather opinions and feedback from respondents in regard variables of maintenance management system, and how its correlation with the financial performance.

Statistical Test Series
The data collected from respondents being tested by series of statistical test including homogeneity test, data adequacy test, validity test, reliability test, and correlation analysis.

Factor Analysis
The remaining or the uneliminated variables after series of statistical test then grouped into several latent variables.

Regression Analysis
To generate the correlation equation correlation model between the maintenance management system and financial performance.

Monte Carlo Simulation
Simulation on the regression equation to check and see the distribution, then to prove the impact of maintenance management system on the financial performance.

Final Expert Validation
To validate the result of this study.

RESULTS

Variables of maintenance management system were identified from literature reviews and validated by the experts shown on the following table.

Table 2. Independent Variables of Maintenance Management System

Code	Independent Variables
X1.1	Leadership and Commitment
X1.2	Role, Responsibility, and Authority of Organization
X1.3	Optimum Maintenance Decision
X1.4	Integrated to Business Process
X1.5	Proper Information System
X1.6	Risk Based
X2.1	Maintenance Budget
X3.1	Provided Work Order
X3.2	Maintenance Stores Control
X3.3	Preventive Maintenance
X3.4	Maintenance Report
X3.5	Statistical Trends Based
X4.1	Maintenance Committee
X4.2	Duties and Responsibilities of Each Position
X5.1	Categories of Maintenance Level
X5.2	Maintenance Cycle of Each Component
X6.1	Operational Requirement
X6.2	Spare Parts Availability Status
X6.3	Dockyard Availability
X7.1	Correlation of Each Component
X8.1	Communication Strategy
X8.2	Communication Plan

Homogeneity Test
Questionnaire sent to 32 respondents who work in the marine constructions industry. The respondents divided into three categories, refer to their positions, experience, and education level. Data is considered homogeneous if the Asymp. Sig. value is greater than 0.05. From these three categories the result of homogeneity test is found all homogeneous as shown on the following tables.

Table 3. Homogeneity Test for Job Position Category

Indicator	Kruskal-Wallis H	df	Asymp. Sig.	Conclusion
X1.1	0.344	2	0.842	Homogeneous
X1.2	4.824	2	0.09	Homogeneous
X1.3	1.172	2	0.557	Homogeneous
X1.4	1.211	2	0.546	Homogeneous
X1.5	1.085	2	0.581	Homogeneous
X1.6	1.5	2	0.472	Homogeneous
X2.1	0.052	2	0.974	Homogeneous
X3.1	0.812	2	0.666	Homogeneous
X3.2	0.569	2	0.753	Homogeneous
X3.3	2.368	2	0.306	Homogeneous
X3.4	0.797	2	0.671	Homogeneous
X3.5	2.666	2	0.264	Homogeneous
X4.1	0.252	2	0.882	Homogeneous
X4.2	1.834	2	0.4	Homogeneous
X5.1	2.978	2	0.226	Homogeneous
X5.2	0.672	2	0.714	Homogeneous
X6.1	3.058	2	0.217	Homogeneous
X6.2	2.449	2	0.294	Homogeneous
X6.3	2.305	2	0.316	Homogeneous
X7.1	1.295	2	0.523	Homogeneous
X8.1	2.058	2	0.357	Homogeneous
X8.2	1.635	2	0.441	Homogeneous

Table 4. Homogeneity Test for Work Experience Category

Indicator	Kruskal-Wallis H	df	Asymp. Sig.	Conclusion
X1.1	0.262	2	0.877	Homogeneous
X1.2	4.817	2	0.09	Homogeneous
X1.3	0.695	2	0.706	Homogeneous
X1.4	0.215	2	0.898	Homogeneous
X1.5	0.254	2	0.881	Homogeneous
X1.6	0.802	2	0.67	Homogeneous
X2.1	3.128	2	0.209	Homogeneous
X3.1	2.333	2	0.311	Homogeneous
X3.2	1.068	2	0.586	Homogeneous
X3.3	0.339	2	0.844	Homogeneous
X3.4	0.165	2	0.921	Homogeneous
X3.5	1.152	2	0.562	Homogeneous
X4.1	1.363	2	0.506	Homogeneous
X4.2	3.456	2	0.178	Homogeneous
X5.1	2.824	2	0.244	Homogeneous
X5.2	0.878	2	0.645	Homogeneous
X6.1	3.231	2	0.199	Homogeneous

Indicator	Kruskal-Wallis H	df	Asymp. Sig.	Conclusion
X6.2	0.314	2	0.855	Homogeneous
X6.3	2.232	2	0.328	Homogeneous
X7.1	2.692	2	0.26	Homogeneous
X8.1	1.794	2	0.408	Homogeneous
X8.2	2.817	2	0.244	Homogeneous

Table 5. Homogeneity Test for Education Level Category

Indicator	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)	Exact Sig. [2*(1-tailed Sig.)]	Conclusion
X1.1	74	129	-1.745	0.081	.151b	Homogeneous
X1.2	79.5	332.5	-1.572	0.116	.219b	Homogeneous
X1.3	105	160	-0.228	0.82	.857b	Homogeneous
X1.4	110	363	0	1	1.000b	Homogeneous
X1.5	96.5	349.5	-0.607	0.544	.589b	Homogeneous
X1.6	100.5	155.5	-0.437	0.662	.704b	Homogeneous
X2.1	95	150	-0.775	0.438	.562b	Homogeneous
X3.1	89.5	342.5	-0.909	0.364	.411b	Homogeneous
X3.2	82.5	335.5	-1.197	0.231	.269b	Homogeneous
X3.3	78	133	-1.553	0.121	.204b	Homogeneous
X3.4	77.5	132.5	-1.635	0.102	.190b	Homogeneous
X3.5	102.5	355.5	-0.345	0.73	.764b	Homogeneous
X4.1	68.5	321.5	-1.871	0.061	.092b	Homogeneous
X4.2	100.5	353.5	-0.453	0.65	.704b	Homogeneous
X5.1	77.5	330.5	-1.441	0.15	.190b	Homogeneous
X5.2	94	347	-0.718	0.473	.535b	Homogeneous
X6.1	97.5	152.5	-0.593	0.553	.617b	Homogeneous
X6.2	105.5	160.5	-0.233	0.816	.857b	Homogeneous
X6.3	87	340	-0.988	0.323	.366b	Homogeneous
X7.1	85	338	-1.14	0.254	.325b	Homogeneous
X8.1	98	351	-0.528	0.597	.646b	Homogeneous
X8.2	67	320	-1.885	0.059	.084b	Homogeneous

The result of homogeneity test which all the variables is homogenous means all the variables can be used for the subsequent statistical test.

Data Adequacy Test

All the data then need to be checked whether data is adequate to support this study. The data is considered adequate if KMO (Kaiser-Meyer-Olkin) value is greater than 0.5. The result of data adequacy test is shown on the following table.

Table 6. Data Adequacy Test (KMO and Bartlett's Test)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.515
Bartlett's Test of Sphericity	Approx. Chi-Square	414.685
	df	231
	Sig.	.000

The obtained KMO value is 0.515 which means these data is adequate to be used.

Validity Test

The homogeneous data then need to be checked whether data is valid. Data is considered valid if pearson correlation value is greater than r table 0.349 (obtained from 95% level of confidence and 32 respondents). This validity test result can be seen from the following table.

Table 7. Validity Test

Indicator	Pearson Correlation	Sig.	r Table	Conclusion
X1.1	0.314	0.080	0.349	Valid
X1.2	0.159	0.384	0.349	Invalid
X1.3	0.494	0.004	0.349	Valid
X1.4	0.716	0.000	0.349	Valid
X1.5	0.692	0.000	0.349	Valid
X1.6	0.698	0.000	0.349	Valid
X2.1	0.408	0.021	0.349	Valid
X3.1	0.665	0.000	0.349	Valid
X3.2	0.637	0.000	0.349	Valid
X3.3	0.667	0.000	0.349	Valid
X3.4	0.45	0.010	0.349	Valid
X3.5	0.643	0.000	0.349	Valid
X4.1	0.26	0.151	0.349	Invalid
X4.2	0.438	0.012	0.349	Valid
X5.1	0.684	0.000	0.349	Valid
X5.2	0.661	0.000	0.349	Valid
X6.1	0.581	0.000	0.349	Valid
X6.2	0.628	0.000	0.349	Valid
X6.3	0.581	0.000	0.349	Valid
X7.1	0.714	0.000	0.349	Valid
X8.1	0.556	0.001	0.349	Valid
X8.2	0.462	0.008	0.349	Valid

The invalid variables are then removed from the data for the subsequent tests.

Reliability Test

After validity test is carried out, reliability test is followed. Reliability test use the valid data (variables) only. The data is considered reliable if Cronbach's Alpha value is greater than 0.6. The following table shows the result of reliability test.

Table 8. Reliability Test

Cronbach's Alpha	N of Items
.900	20

Based on the Cronbach's Alpha value 0.9, means the data is reliable to be used for this study.

Correlation Analysis

This analysis is needed to know how strong the correlation between valid variable of maintenance management system and financial performance. The correlation strength of each valid variable is presented by the following table.

Table 9. Correlation Strength

Variable	Correlation Coefficient	Correlation Strength
X1.1	0.246	Weak
X1.3	0.471	Moderate
X1.4	0.573	Strong
X1.5	0.480	Moderate
X1.6	0.483	Moderate
X2.1	0.381	Moderate
X3.1	0.684	Strong
X3.2	0.679	Strong
X3.3	0.469	Moderate
X3.4	0.554	Strong
X3.5	0.386	Moderate
X4.2	0.267	Weak
X5.1	0.571	Strong
X5.2	0.684	Strong
X6.1	0.511	Strong
X6.2	0.513	Strong
X6.3	0.564	Strong
X7.1	0.506	Strong
X8.1	0.436	Moderate
X8.2	0.461	Moderate

Correlation coefficient strength is referred to (de Vaus, 2002) range as follow.

Table 10. Correlation Strength Scale

Coefficient	Correlation Strength
0.00	No Correlation
0.01 – 0.09	Non-significant Correlation
0.10 – 0.29	Weak Correlation
0.30 – 0.49	Moderate Correlation
0.50 – 0.69	Strong Correlation
0.70 – 0.89	Very Strong Correlation
>0.90	Almost Perfect Correlation

There are two variables which has weak correlation, they are X1.1 and X4.2. These variables are eliminated for the next analysis due to its correlation strength.

After the required statistical tests, then the uneliminated variables or data is being analyzed to distribute into variable group, and based on the rotated component matrix that five variable groups were identified by factor analysis, the result is in the table below.

Table 11. Variable Grouping by Factor Analysis

Variable Group	Code	Independent Variables
1 Preventive Maintenance	X1.3	Optimum Maintenance Decision
	X1.5	Proper Information System
	X1.6	Risk Based
	X3.3	Preventive Maintenance
	X6.2	Spare Parts Availability Status
	X7.1	Correlation of Each Component
2 Integrated Business Process	X1.4	Integrated to Business Process
	X3.1	Provided Work Order
	X3.2	Maintenance Stores Control
	X5.1	Categories of Maintenance Level
3 Maintenance Report	X2.1	Maintenance Budget
	X3.4	Maintenance Report
	X6.1	Operational Requirement
4 Communication	X6.3	Dockyard Availability
	X8.1	Communication Strategy
	X7.2	Communication Plan
5 Maintenance Cycle	X3.5	Statistical Trends Based
	X5.2	Maintenance Cycle of Each Component

The variable group obtained from factor analysis we rename it with X1, X2, X3, X4, and X5. Regression analysis was carried out to get the correlation equation model between maintenance management system (variable X or independent) and financial performance (variable Y or dependent), and the equation is as follow:

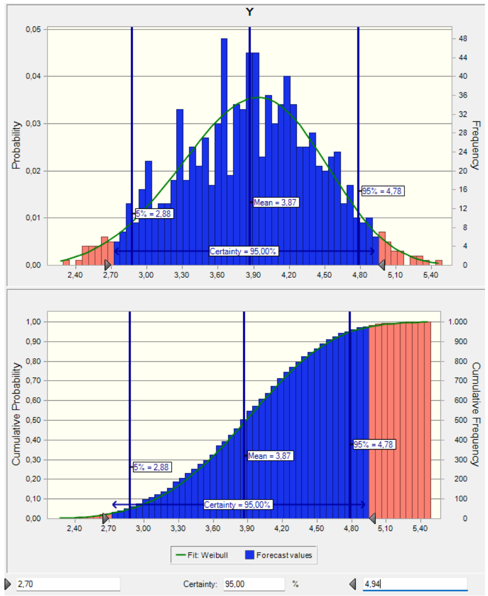
$$y = 4.406 + 0.134X1 + 0.251X2 + 0.182X3 + 0.178X4 + 0.168X5 \tag{1}$$

y = Financial Performance
X1 = Preventive Maintenance variable group
X2 = Integrated Business Process variable group
X3 = Maintenance Report variable group
X4 = Communication variable group
X5 = Maintenance Cycle variable group

The regression equation then being simulated by Monte Carlo method using the random number from analysis factor for the 1,000 trials at the 95% confident level, and it shows result as follow.

Journal of International Conference Proceedings (JICP) Vol. 6 No. 7, pp. 218-238, December, 2023
P-ISSN: 2622-0989/E-ISSN: 2621-993X
https://www.ejournal.aibpmjournals.com/index.php/JICP

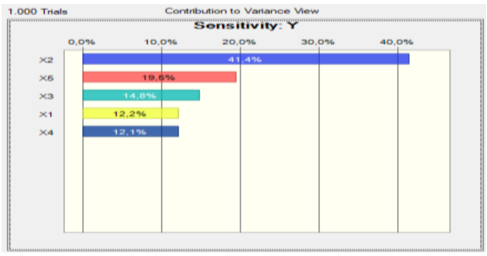
Figure 8. Distribution of Monte Carlo Simulation



This data distribution is using 1 to 5 as a scale to indicate the level of impact. With the certainty level of 95%, the simulation results as follow: certainty range is from 2.70 to 4.94, mean is 3.87, median is 3.89, standard deviation is 0.58, and for percentile 95%, forecasted value is 4.78. From the above result data, correlation equation model at the percentile 95% shows that this model has result 4.78 out of 5 which is high correlation.

In addition, Monte Carlo simulation also shows the X2 variable group is the most sensitive or the most impactful to the result. Please see the figure below.

Figure 9. Percentage of Sensitivity



DISCUSSION

If we look to the regression equation (1), the coefficient of X2 is 0.251 which bigger than the other four. From this we can define that X2 (variable group Integrated Business Process) has the biggest impact for the result of y (Financial Performance). This result is also aligned with the Monte Carlo simulation that mention X2 is the most sensitive variable with 41.4%. The most sensitive means the fluctuation of group X2 will have a substantial impact on y (Financial Performance).

How it can be this way? Let’s see the variables that categorized in the group X2 and addressed it individually. Group X2 consist of as follows.

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Integrated to Business Process
Executing a maintenance strategy requires a regulated, modeled, automated, integrated, monitored, and continuously optimized business process according to (Vrignat, Kratz, & Avila, 2021). Therefore, it is reasonable that the integration of maintenance management system with business process becomes vital and significantly impactful on financial performance.

Provided Work Oder
Work order is closely related to the scheduling and planning of the vessel's maintenance itself. Work orders are issued if they align with the predetermined plan or schedule. As (Vrignat, Kratz, & Avila, 2021) suggest, effective maintenance is prognostic before a failure occurs. This implies that work order will always be based on a prognostic schedule, significantly impacting financial performance. Without work order, the maintenance process for the vessel lacks a clear scheduling basis, potentially leading to maintenance being performed only after a failure occurs.

Maintenance Stores Control
In the operation of a work vessel, the availability of spare parts becomes crucial as a preventive measure in case of any failure, allowing downtime to be minimized. According to (Deris, Omatu, Ohta, Kutar, & Samat, 1999), the availability of spare parts forms the basis for maintenance planning and scheduling. Therefore, the flow of incoming and outgoing spare parts is highly important and requires control.

Categories of Maintenance Level
(Pideksa, 2015) states that the level of maintenance typically varies from one company to another, depending on different needs. Certainly, decisions regarding this maintenance level are influenced by several factors, and cost considerations are among them.

If we only focus on the dominant variables which categorized in the variable group X2 (Integrated Business Process), the abovementioned four variables can solve some of the problems stated in the introduction. Here is the explanation:

Integrated Business Process
Maintenance that integrated with business process can contribute to solve problems as follows. Excessive usage due to project requirements or demands, this problem can be avoided if maintenance is involved during the tender in the business process by proper resource allocation. Procurement process for vessel consumable not meeting specification, this problem can be avoided by setting and following rules and procedures of the company during the vendor selection as per company business process. Crew capabilities, maintenance shall be involved during recruitment of vessel crew to avoid under-skill crew is recruited which this process is also part of company business process. Docking time delay, normally this happens because of conflict with project schedule. Everything related to project preparation or tender process shall be well planned according to company business process. Repair costs exceeding the budget, by integrating maintenance into business process it can be avoided because the procedures stated in the business process in regard the financial payment process must be checked prior to execution. Inconsistence in regular maintenance, scheduling for maintenance can be integrated in the business process so it is become mandatory which all relevant department is highly aware about it.

Provided Work Order

Work order can contribute to solve problems as follows. Engine modification, any maintenance activity which follow work order will be based on data and requirement, so the unnecessary modification should be avoided. Docking time delay, same as above work order run by data and requirement including data of maintenance interval which docking is one of this part. Repair cost exceeding the budget, if the maintenance activity follows the work order which data-based, maintenance will be carried out only for the order stated in the work order.

Maintenance Stores Control

Maintenance stores control at least can contribute to solve one problem repair cost exceeding the budget, usage of proper dose of spare parts is really important. Just use for the necessary needs, to reduce costs.

Categories of Maintenance Level

Same as above, this can contribute to solve one problem, namely repair cost exceeding the budget, to set and to decide what level of maintenance that is going to conduct based on costs consideration.

CONCLUSION

It can be concluded that the implementation of maintenance management system significantly impacting the financial performance, as proved by the Monte Carlo simulation results and the regression equation.

PT Timur Bahari should pay more attention to variables categorized in the integrated business process group. This is because synchronization across every element of the company is necessary for the maintenance management system to enhance financial performance, as modeled in the regression equation. The factors that categorized in this group are integrated to business process, provided work order, maintenance stores control, and categories of maintenance level.

LIMITATION

The study covers only the technical aspects of maintenance management system for working vessels, the strategic aspects are excluded. The financial performance used for the case study is only liquidity.

ACKNOWLEDGMENT

Gratitude is extended to PT Timur Bahari for the participation as the research subject and generously providing invaluable data, contributing to the further advancement of knowledge.

DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflict of interest in the process of preparing this study.

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