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Analysis of Factors Causing Delays in Ballast Pump Repair Using The Kaiser-Meyer-Olkin and RCA Methods at KM XXX at PT XYZ

Febian Rizky Purnama, Mega Cattleya PA Islami

Industrial Engineering Department, Universitas Pembangunan Nasional Veteran Jawa Timur, Surabaya
Koresponden email: 22032010201@student.upnjatim.ac.id, mega.cattleya.ti@upnjatim.ac.id

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Abstract

The shipping sector is a crucial element in a nation's shipping operations, particularly in ensuring the optimal performance of essential components such as ballast pumps. However, the repair time for the ballast pumps on the KM XXX ship at the PT XYZ shipyard often exceeds the initial estimate (seven working days), resulting in financial losses and increased waiting time for the ship at port. This study is designed to identify the main determinants behind the delays in ballast pump repairs and formulate strategic recommendations to optimize maintenance effectiveness. The analytical methods applied include Kaiser-Meyer-Olkin (KMO) for factor analysis and Root Cause Analysis (RCA) supplemented by a Fishbone Diagram to determine the root cause of a problem. By determining the main factors and root causes, this study presents detailed and systematic improvement recommendations. These recommendations are designed to optimize the effectiveness of ballast pump maintenance and mitigate adverse consequences on ship operational performance.
Keywords: *ballast pump, kaiser-meyer-olkin, root cause analysis, shipyard*

Abstrak

Sektor perkapalan merupakan elemen krusial dalam operasional pelayaran suatu negara, terutama untuk menjamin kinerja maksimal komponen esensial seperti pompa balas. Akan tetapi, durasi perbaikan pompa balas di kapal KM XXX pada galangan PT XYZ kerap melampaui estimasi awal (tujuh hari kerja), yang berujung pada kerugian finansial dan peningkatan waktu tunggu kapal di pelabuhan. Studi ini dirancang untuk mengidentifikasi determinan utama di balik penundaan perbaikan pompa balas serta merumuskan rekomendasi strategis guna mengoptimalkan efektivitas pemeliharaan. Metode analisis yang diterapkan mencakup *Kaiser-Meyer-Olkin* (KMO) untuk analisis faktor dan Analisis Akar Penyebab (*Root Cause Analysis* - RCA) yang dilengkapi dengan Diagram Tulang Ikan (*Fishbone Diagram*) guna menentukan sumber pokok suatu persoalan. Melalui penentuan faktor-faktor utama dan akar permasalahan, studi ini menyajikan rekomendasi perbaikan yang rinci dan sistematis. Rekomendasi tersebut dirancang untuk mengoptimalkan efektivitas pemeliharaan pompa balas serta memitigasi konsekuensi buruk terhadap kinerja operasional kapal.
Kata Kunci: *galangan kapal, kaiser-meyer-olkin, pompa ballast, root cause analysis*

1. Introduction

Industrial progress, both at national and international levels, results in an increasing need for labor and the use of industrial tools and materials [1]. The transformation of the shipping industry from the First Industrial Revolution to the Third Industrial Revolution has brought competitive advantages to maritime and shipping businesses [2]. The progress of a defense industry is also influenced by the development and application of technology [3]. This situation has a positive contribution to efforts to increase the competitiveness of the shipping industry or shipbuilding sector in Indonesia. Therefore, Indonesian shipyard companies are required to progress further by improving the quality of their services to create their own satisfaction to customers and contribute business to the maritime industry.

Every component of the ship has a vital role, especially in ensuring operational safety, one of which is the "ballast pump", the ballast pump is used to move seawater (called ballast water) into or out of the ship's ballast tanks. Ballast water functions as a ballast that can be adjusted to achieve optimal ship operational conditions. To maintain its reliability, this component needs to undergo a routine maintenance process including replacing parts that have begun to deteriorate such as seals that have been worn out. However, the ballast pump repair process on KM XXX carried out by the PT XYZ shipyard.

Project scheduling often faces various obstacles, including delays in project duration beyond the initial estimate, resulting in delayed completion. This situation has the potential to have negative financial consequences for the company [4]. However, in its implementation, this industry still faces various challenges, such as project delays, cost overruns, and inconsistent quality of results [5]. Delays in completing a construction project can result in financial deficits for both the contractor and the project owner. This facilitates the identification of critical sectors requiring revitalization to streamline the completion time [6]. One of the major contributors to the delays in this project was the failure to account for the inherent risks associated with completing tasks that emerged during the construction process [7]. Consequently, it is important to conduct job training to prevent delays in repairs. Job training refers to the behavior of the workforce as observed through a systematic, one-way process that aims to enhance operational objectives and yield an effective process [8]. Human resources refer to individuals in the population who have the capacity and desire to participate in economic activity, collectively known as the labor force [9]. Job satisfaction is an emotional disposition of affection for one's work, reflected through work ethic [10].

Data collected from direct interviews with the Workshop Head and the planning team indicated that the initial estimate for the repair of the ballast pump on KM XXX was seven working days. However, the actual repair of the ballast pump took far longer than the estimated time set by the planning team. This phenomenon resulted in a longer ship docking process and delays. Therefore, identifying the factors causing delays in ballast pump repairs, as well as finding appropriate solutions, is crucial to improve maintenance effectiveness and prevent negative impacts on ship operations. This study focuses on an in-depth analysis of the main factors causing delays in the ballast pump repair process on KM XXX, with the aim of providing recommendations for improvements to improve ballast pump maintenance efficiency.

2. Research method

The Kaiser-Meyer-Olkin index is used to assess the suitability of an analysis. The Measure of Sampling Adequacy (MSA) is an index that compares the partial correlation coefficients for each variable, which serves to evaluate the adequacy of the sample. Bartlett's Test of Sphericity is employed to assess the interdependence among unrelated variables within a population [11]. Root cause analysis using the Root Cause Analysis (RCA) method is obtained by calculating the most common words using a word cloud. The most common words obtained through the word cloud can be analyzed using a Fishbone diagram [12]. Fishbone Diagram, also known as Cause and Effect Diagram, is a methodology utilized to facilitate problem solving through causal analysis of a condition presented in a visual format resembling the skeleton of a fish [13].

2.1 Data Collection

The data for this research comprises both primary and secondary sources [14]. Primary information is data obtained directly through various collection methods such as surveys, interviews and observations, which are then adapted to specific needs [15]. Secondary data refers to research data acquired indirectly through an intermediary medium. This implies that the data is not collected directly by the researcher but rather from pre-existing sources, such as documents, literature, or data previously compiled by others [16]. The primary data in this study were obtained through interviews and a questionnaire survey using a Likert scale. The objective was to identify factors causing delays. Respondents in this study included all parties involved in the Ballast Pump repair, including Project Managers, technicians, foremen, and planners. Secondary data collected was the repair schedule for the KM XXX vessel. The data variables utilized in this study are as follows:

Table 1. Variables and Attributes

No.	Variable	Attribute	Code
XI	Material	1. Error in ordering the type or size of material	X1.1
		2. The amount of material does not match the requirements	X1.2
		3. Delay in delivery of materials	X1.3
X2	Management	1. Poor communication between repair teams	X2.1
		2. Changes in the scope of work	X2.2
		3. Low level of worker safety	X2.3
X3	Labor	1. Inadequate quality or skills of the workforce	X3.1
		2. Level of discipline of workers in the	X3.2

No.	Variable	Attribute	Code
		field	
		3. Lack of manpower	X3.3
X4	Tools and Facilities	1. Lack of necessary repair tools at the location for repairs	X4.1

This study utilized parameters determined through in-depth discussions with Workshop Leaders and implementers, which were then incorporated into a survey instrument. The data obtained from this survey were then analyzed using SPSS (Statistical Product and Service Solution) software. The initial analysis step included the Kaiser-Meyer-Olkin (KMO) Test, which plays a role in evaluating the adequacy of the data to ensure its suitability for Factor Analysis. After the factors contributing to the delay were identified, the Root Cause Analysis (RCA) method was applied. RCA is a structured method designed to find the fundamental causes of a problem, explaining not only the 'what' and 'how' of an event, but more essentially, the 'why' of it. In implementing this RCA technique, a Fishbone Diagram was used.

3. Results and Discussion

3.1 Normality Test

Based on **Figure 1**, the SPSS output from the normality test using the one-sample Kolmogorov-Smirnov test shows that each question attribute is normally distributed, based on the significance value of Asymp. Sig. (2-tailed) for each question which is greater than 0.05.

One-Sample Kolmogorov-Smirnov Test

		X1.1	X1.2	X1.3	X2.1	X2.2	X2.3	X3.1	X3.2	X3.3	X4.1
N		15	15	15	15	15	15	15	15	15	15
Normal Parameters[a,b]	Mean	4,47	4,47	4,33	4,00	3,73	4,13	4,20	4,27	4,27	3,87
	Std. Deviation	,640	,743	,900	1,069	1,163	,915	,862	,799	,884	1,246
Most Extreme Differences	Absolute	,331	,363	,304	,292	,203	,295	,290	,287	,263	,218
	Positive	,234	,237	,229	,225	,203	,225	,185	,179	,203	,182
	Negative	-,331	-,363	-,304	-,292	-,197	-,295	-,290	-,287	-,263	-,218
Kolmogorov-Smirnov Z		1,282	1,408	1,177	1,130	,784	1,142	1,123	1,113	1,020	,846
Asymp. Sig. (2-tailed)		,075	,038	,125	,155	,570	,148	,160	,168	,249	,471

a. Test distribution is Normal.
b. Calculated from data.

Figure 1. KMO Test and Bartlett's Test

3.2 Processing Using the Kaiser-Meyer-Olkin (KMO) Method

Based on **Figure 2**, factor analysis can be continued in this investigation, because the KMO Measure of Sampling Adequacy value is 0.571 which is greater than 0.50, and the Barlett's Test of Sphericity (Sig.) value is 0.000 which is less than 0.05.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,571
Bartlett's Test of Sphericity	Approx. Chi-Square	45,471
	df	45
	Sig.	,000

Figure 2. KMO Test and Barlett's Test

Anti-image Matrices

		X1.1	X1.2	X1.3	X2.1	X2.2	X2.3	X3.1	X3.2	X3.3	X4.1
Anti-image Covariance	X1.1	,424	,069	,074	,050	,080	,204	-,137	,066	-,089	-,134
	X1.2	,069	,418	,005	,100	,033	-,008	-,001	-,127	-,219	-,089
	X1.3	,074	,005	,430	-,065	-,091	,044	-,085	-,071	-,159	,063
	X2.1	,050	,100	-,065	,828	,014	-,062	,124	-,136	-,040	-,082
	X2.2	,080	,033	-,091	,014	,494	-,059	-,094	-,048	,129	,160
	X2.3	,204	-,008	,044	-,062	-,059	,374	-,168	,188	-,053	-,107
	X3.1	-,137	-,001	-,085	,124	-,094	-,168	,235	-,140	-,003	-,089
	X3.2	,066	-,127	-,071	-,136	-,048	,188	-,140	,391	,004	,009
	X3.3	-,089	-,219	-,159	-,040	,129	-,053	-,003	,004	,401	,095
	X4.1	-,134	-,089	,063	-,082	,160	-,107	-,089	,009	,095	,352
Anti-image Correlation	X1.1	,476[a]	,163	,174	,084	,174	,512	-,433	,163	-,215	-,348
	X1.2	,163	,687[a]	,011	,169	,073	-,020	-,004	-,314	-,536	-,233
	X1.3	,174	,011	,745[a]	-,108	-,198	,110	-,269	-,174	-,383	,163
	X2.1	,084	,169	-,108	,375[a]	,022	-,111	,281	-,240	-,070	-,153
	X2.2	,174	,073	-,198	,022	,584[a]	-,137	-,275	-,110	,290	,383
	X2.3	,512	-,020	,110	-,111	-,137	,338[a]	-,565	,491	-,137	-,294
	X3.1	-,433	-,004	-,269	,281	-,275	-,565	,552[a]	-,460	-,009	-,309
	X3.2	,163	-,314	-,174	-,240	-,110	,491	-,460	,596[a]	,010	,023
	X3.3	-,215	-,536	-,383	-,070	,290	-,137	-,009	,010	,604[a]	,254
	X4.1	-,348	-,233	,163	-,153	,383	-,294	-,309	,023	,254	,600[a]

a. Measures of Sampling Adequacy(MSA)

Figure 3. Anti-image Matrices

Referring to **Figure 3**, the results of the sample adequacy (MSA) measurement are displayed. An MSA value exceeding 0.50 indicates that the data is suitable to proceed to the factor analysis stage. Based on this visualization, it was identified that variable X1.1 has an MSA value of 0.476; variable X1.2 is 0.687; variable X1.3 is 0.745; variable X2.1 is 0.375; variable X2.2 is 0.584; variable X2.3 is 0.338; variable X3.1 is 0.552; variable X3.2 is 0.596; variable X3.3 is 0.604; and variable X4.1 is 0.600. Based on these indicators, all question variables meet the criteria for factor analysis.

Descriptive Statistics

	N	Mean	Std. Deviation	Variance
X1.1	15	4,47	,640	,410
X1.2	15	4,47	,743	,552
X1.3	15	4,33	,900	,810
X2.1	15	4,00	1,069	1,143
X2.2	15	3,73	1,163	1,352
X2.3	15	4,13	,915	,838
X3.1	15	4,20	,862	,743
X3.2	15	4,27	,799	,638
X3.3	15	4,27	,884	,781
X4.1	15	3,87	1,246	1,552
Valid N (listwise)	15			

Figure 4. Output Descriptive Statistics

Based on **Figure 4**, it is observed that there are mean, standard deviation, and variance values. The mean is defined as the sum of all numbers divided by the quantity of those numbers. The mean value represents the middle value of each variable for all participants.

Table 2. Descriptive Statistics

Variable	Question	Mean	Ranking
X1.1	Errors in ordering type/size	4,47	1
X1.2	Inadequate quantity of materials	4,47	2
X1.3	Delays in material delivery	4,33	3
X3.2	Field worker discipline	4,27	4
X3.3	Labor shortage	4,27	5
X3.1	Inadequate worker quality/skills	4,20	6
X2.3	Job safety level	4,13	7
X2.1	Poor communication between repair teams	4,00	8
X4.1	Lack of necessary repair tools on site for repairs	3,87	9
X2.2	Changes in the scope of repairs	3,73	10

Based on **Table 2**, it can be seen that the influencing factors are sorted by the highest average value (mean). The results of data processing show that variable X1.1, namely errors in ordering the type or size of components, is the main cause of delays in ballast pump repair work, with an average value of 4.47. Next, the mismatch of the amount of material with the needs is in second place with an average value of 4.47. Delays in material delivery are in third place with an average value of 4.33. In fourth place is the level of discipline of the workforce in the field, with an average value of 4.27, which is the same value as the factor of lack of labor. Then, in sixth place is the quality/skills of the workforce is inadequate with a mean value of 4.20. Then, the level of work safety also has an influence but is not significant with a mean of 4.13. Then in eighth place is poor communication between the repair team with a mean of 4.00. Next, ninth is the lack of necessary repair tools at the location for repairs with a mean of 3.87. And in tenth place is the change in scope of improvement with a mean value of 3.73.

3.3 Proposed Improvements Using the Root Cause Analysis (RCA) Method

Based on **Figure 5**, an analysis was conducted of the determinants that resulted in delays in ballast pump repairs. Regarding environmental aspects, there are several contributors to delays, namely errors in material ordering specifications, mismatching the quantity of material ordered with actual needs, and delays in the material delivery process, all of which can hinder the smooth progress of repairs. Furthermore, in the

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management realm, ineffective communication between repair teams, modifications to the scope of work, and issues related to operational safety levels also have the potential to slow repair progress.

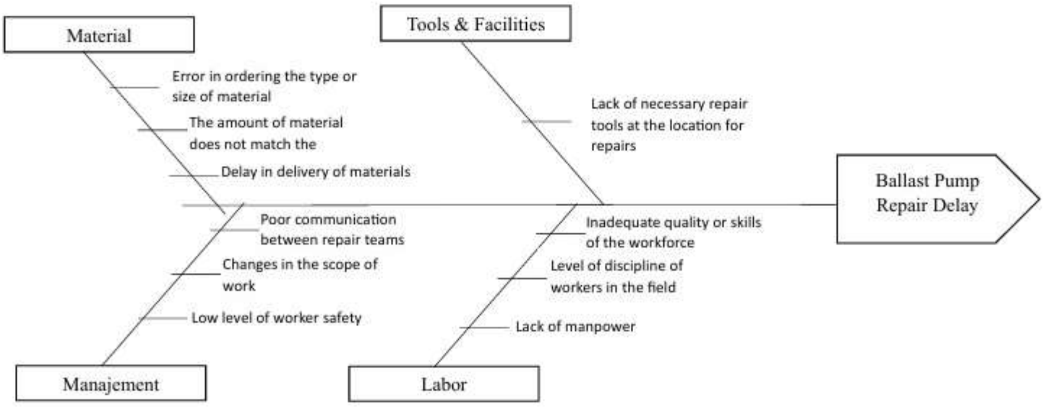

Figure 5. Fishbone Diagram

Finally, in the equipment and facilities category, the inadequate availability of repair tools on site is a significant obstacle, which specifically impacts the assembly phase during the repair process. Furthermore, regarding human resource factors, there are several relevant causes, including inadequate workforce quality or competence, worker discipline at the project site, and a shortage of labor. These factors can have a significant impact. Given that human resources are the parties that carry out all activities in a project, aspects of workforce development and management require in-depth attention from management.

Table 3. Proposed Improvements

No	Problems	Proposed Improvements
1.	Error in ordering the type or size of material	Implement a double-check system by at least two individuals/departments before issuing a purchase order (PO). Use clear, standard material codes. For example, M-01 issued by the Planning and Control Department and an ordering checklist.
2.	The amount of material does not match the requirements	Perform accurate material requirements calculations based on the latest Bill of Materials (BOM) and job designs.
3.	Delay in material delivery	Replace or add vendors/suppliers with better delivery track records. Have a logistical backup plan for critical materials.
4.	Poor communication between repair teams	Implement standard communication procedures (SOPs) with a centralized communication platform. For example, a project chat group. Hold short daily coordination meetings (daily briefings) to align work and identify bottlenecks.
5.	Changes in scope of work	Establish a formal process for requesting changes to the scope of work (Change Requests), including impact analysis, such as cost, time, and materials, and obtaining approval from relevant management before execution..
6.	Low level of worker safety	Conducting routine Safety Induction (K3) training and daily Toolbox Meetings before starting work. Implementing stricter K3 supervision in the field and imposing strict sanctions for violations. And providing adequate and high-quality Personal Protective Equipment (PPE).
7.	Inadequate quality or skills of the workforce	Conduct ongoing technical training and certification programs, such as welding and installation training. Conduct pre-employment skills assessments and provide training as needed.
8.	Level of discipline of workers in the field	Establish clear work regulations and enforce a consistent reward and punishment system. Implement more structured attendance and performance recording, such as daily attendance records or work progress reports.
9.	Lack of labor	Conduct accurate workload analysis to predict workforce needs. Proactively recruit and train staff. Consider using additional, trusted subcontractors for peak workloads.
10.	Lack of necessary repair tools on site for repairs	Conduct regular equipment inventories and ensure calibration and maintenance. Establish expedited equipment requisition and procurement procedures to ensure the availability of essential equipment on the job site.

4. Conclusion

Due to the delay in the ballast pump repair process, which was originally scheduled to take only 7 days, the delay resulted in the ship being delayed from docking. Analysis using the Kaiser-Meyer-Olkin (KMO) and Root Cause Analysis (RCA) methods found that the main cause of the delay was errors in ordering the type/size of materials and the amount of materials that did not meet the requirements. Incorrect ordering of the type/size resulted in the ballast pump repair being ineffective, while the incorrect amount of materials further hampered the work. In addition, other factors that caused the delay in sequence were late delivery of materials, the level of discipline of the workforce in the field, lack of labor, inadequate quality/skills of the workforce, the level of job security, poor communication between the repair team, lack of necessary repair tools on site for repairs, and changes in the scope of repairs. Furthermore, the identified elements will be evaluated to formulate improvement recommendations through the application of the Root Cause Analysis Method. Specific recommendations will be provided for each element that has gone through the analysis process. This is expected to contribute to increasing the effectiveness of PT XYZ in implementing improvements, especially in future projects.

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