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Maintenance Analysis of Multi Mover M600U by Using Reliability Centred Maintenance Method

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Abstract – **PT XYZ is a manufacturing company that provides hot metal transportation handling services and supports Blast Furnace (BF) operations at the Krakatau Posco Plant using heavy equipment, namely Multi Mover M600U. To ensure smooth production processes, effective and efficient maintenance management of the heavy equipment are essential to enhance reliability. This study evaluates potential failure modes, their impacts and appropriate handling measures for the Multi Mover M600U using the Failure Mode and Effect Analysis (FMEA) method. The result of the study shows the highest Risk Priority Number (RPN) value of 350 in the Electrical PLC component, with a total RPN of 777 for the Electrical and Brake systems. These findings indicate that the Electrical and Brake systems have the highest failure rates due to downtime compared to other systems. Through the Reliability Centred Maintenance (RCM) approach, this study proposes a maintenance scheduling plan to minimize the risk of sudden downtimes, and their impacts on time and maintenance costs.**

Keywords - *Downtime, Failure Mode and Effect Analysis, Heavy Equipment Maintenance, Reliability Centred Maintenance, Risk Priority Number.*

INTRODUCTION

The maintenance of industrial equipment plays a pivotal role in sustaining operational efficiency and productivity within modern manufacturing industries. Across various sectors, including manufacturing and energy production, equipment reliability is essential to ensuring smooth production processes, workplace safety and operational stability [1]. Developing an effective maintenance strategy is fundamental to mitigating unexpected failures, prolonging equipment lifespan and minimizing excessive operational expenses resulting from downtime [2]. In industrial settings, where machine downtime can have a substantial impact on both performance and profitability, implementing a robust maintenance system is a critical necessity [3].

The evolution of technology has led to the increasing adoption of data-driven maintenance strategies, which facilitate more adaptive and real-time maintenance planning based on actual equipment conditions. Studies indicate that such an approach improves the accuracy of maintenance decisions while decreasing the occurrence of sudden equipment failures [4]. For instance, predictive maintenance strategies, such as analysing historical downtime data and failure patterns, enable organizations to anticipate component wear and optimize replacement schedules, thereby reducing unplanned breakdowns [5]. Additionally, proactive maintenance strategies, such as preventive maintenance, have demonstrated effectiveness in enhancing equipment reliability and minimizing unexpected downtime. Regular preventive maintenance schedules, including systematic inspections and component replacements, ensure sustained machine performance and alignment with operational standards [6]. These strategies not only improve operational efficiency but also leverage data driven insights to prioritize critical maintenance tasks, ensuring long-term equipment health and workplace safety [7].

Among various maintenance methodologies, Reliability Centered Maintenance (RCM) is widely recognized for its capability to pinpoint critical components and determine appropriate maintenance

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actions based on risk assessment. Research by [8] highlights that integrating RCM with a structured maintenance schedule significantly reduces downtime and improves overall efficiency. Further studies emphasize that incorporating RCM with Failure Mode and Effects Analysis (FMEA) results in more effective maintenance strategies by enhancing both equipment reliability and cost efficiency in maintenance operations [9], [10], [11].

FMEA has become a fundamental tool in RCM applications due to its ability to systematically detect potential component failures and prioritize maintenance actions based on Risk Priority Number (RPN). [12] advocate for a data-driven FMEA approach, utilizing historical failure data to refine maintenance planning accuracy and transparency. Other researchers have demonstrated that the implementation of FMEA not only decreases the recurrence of failures in critical components but also enhances the reliability and operational efficiency of heavy machinery [13], [14], [15].

Similar conclusions were drawn by [16], who found that integrating RCM and FMEA enables more precise identification of failure root causes, leading to a significant reduction in equipment downtime. This strategic combination has proven effective in boosting productivity and minimizing financial losses due to operational disruptions. Additionally, FMEA plays a vital role in improving product quality and manufacturing efficiency by mitigating the likelihood of defects [17].

Despite the extensive application of RCM and FMEA in various industrial sectors, their utilization in the maintenance of heavy equipment, such as the Multi Mover M600U, remains suboptimal. This study aims to bridge this gap by applying RCM and FMEA methodologies to identify critical components and optimize maintenance scheduling. The expected outcome of this research includes enhanced equipment reliability, reduced downtime, and lower operational costs at PT XYZ. Furthermore, this study intends to establish a comprehensive maintenance framework tailored to the operational requirements of the Multi Mover M600U.

METHOD

Design, Place and Time

The research was conducted at PT XYZ, focusing on the maintenance analysis of the Multi Mover M600U heavy equipment. Data collection and analysis were carried out from January 2023 to March 2023.

Data Types and Sources

This research utilized a combination of primary and secondary data to evaluate the reliability and operational efficiency of the Multi Mover M600U, which served as the dependent variable. The independent variables consisted of historical failure records, maintenance schedules and downtime data collected between January and March 2023. Primary data were obtained through direct field observations and structured interviews with mechanics and shift leaders from the maintenance division. These methods were employed to identify recurring operational issues and gain insights into the challenges faced in maintaining the equipment.

In addition to primary data, this study incorporated secondary data sources, including documented equipment failure reports, maintenance logs and repair histories supplied by PT XYZ. These records were instrumental in validating the research findings and identifying patterns in system performance and failure trends. By integrating multiple data sources, this study ensured a comprehensive assessment of failure modes and maintenance requirements for the Multi Mover M600U.

Research Stages

The research followed a systematic approach, beginning with data collection from both primary and secondary sources. Primary data was obtained through direct field observations and interviews with maintenance personnel, while secondary data included failure reports and maintenance logs. This combination of sources ensured a comprehensive understanding of failure trends and maintenance practices.

After data collection, the next stage involved processing and categorizing failures based on different systems, such as Electrical and Hydraulic components. Downtime metrics were then calculated to quantify operational inefficiencies, providing a clearer picture of which systems contributed most to machine unavailability.

To identify critical failure points, Failure Mode and Effect Analysis (FMEA) was applied. FMEA remains one of the most widely applied and contemporary risk assessment tools, providing a structured framework to prioritize potential failures and enhance system reliability in modern engineering studies [10]. This step helped determine failure modes, root causes and their impacts, with Risk Priority Number (RPN) calculations used to rank failure risks. To further classify these failures, Logic Tree Analysis (LTA) was implemented, grouping issues based on safety concerns, operational disruptions and evidence clarity.

Based on these insights, a maintenance strategy was proposed using Reliability-Centered Maintenance (RCM) principles. RCM has emerged as a state-of-the-art methodology in maintenance research, as it systematically links functional reliability with cost-effective maintenance strategies, surpassing traditional time-based approaches [2]. The strategy emphasized preventive and predictive maintenance schedules for high-RPN components, particularly focusing on the Electrical PLC, which was identified as highly susceptible to failures.

Finally, validation and recommendations were conducted using Fishbone Diagrams and 5W+1H Analysis. These tools helped pinpoint root causes and propose actionable solutions, such as enhanced worker training, revised standard operating procedures (SOPs) and optimized maintenance schedules. The goal was to minimize downtime, improve reliability and ensure more efficient equipment operation.

RESULT AND DISCUSSION

Data Collection

The data processed in this study comprised failure records of the Multi Mover machine, specifically collected from January 2023 to March 2023. The dataset included documented work orders detailing machine malfunctions, repair actions and downtime durations. Below is the summarized failure data for the specified period shown in Table 1.

Table 1 presents a summary of machine failure data for the Multi Mover. The data was collected over a period from January 2023 to March 2023. The availability value of the Multi Mover M600U heavy equipment over three months was calculated based on a loading time of 7 hours per day, with a total loading time over 90 days amounting to:

$$90\ days \times 7\ hours/day = 630 \text{ hours}$$

Table 1. Multi Mover M600U Failure Work Order Data (January–March 2023)

System	Sub-System	Date	Lost Time (Hours)
Steering And Lifting System	Steering Cylinder	10 January 2023	0,5
Electrical And Brake System	Pneumatic Relay	17 January 2023	3
Drive And Hydraulic system	Motor Travel	17 January 2023	1
Drive And Hydraulic system	Engine	23 January 2023	1
Steering And Lifting System	Steering Cylinder	23 January 2023	1
Steel Construction	Remote Control Fuel Pump	27 January 2023	1,5
Drive And Hydraulic system	Motor Travel	01 February 2023	0,5
Steering And Lifting System	Lifting Cylinder	01 February 2023	1
Drive And Hydraulic system	Filter	11 February 2023	0,5
Drive And Hydraulic system	Motor Travel	14 February 2023	1,5
Steering And Lifting System	Lifting Cylinder	19 February 2023	0,5
Drive And Hydraulic system	Engine	20 February 2023	1,5
Drive And Hydraulic system	Motor Travel	22 February 2023	2,5
Steering And Lifting System	Lifting Cylinder	24 February 2023	1
Steering And Lifting System	Steering Cylinder	26 February 2023	0,5
Steel Construction	Remote Control Fuel Pump	28 February 2023	2
Drive And Hydraulic system	Filter	01 March 2023	0,5
Electrical And Brake System	Electrical PLC	02 March 2023	2,5
Steel Construction	Remote Control Fuel Pump	02 March 2023	0,5
Drive And Hydraulic system	Motor Travel	07 March 2023	1
Drive And Hydraulic system	Engine	07 March 2023	1,5
Electrical And Brake System	Chamber Brake	10 March 2023	2
Electrical And Brake System	Pneumatic Relay	12 March 2023	2
Drive And Hydraulic system	Filter	12 March 2023	0,5
Electrical And Brake System	Solenoid	16 March 2023	2
Steering And Lifting System	Steering Cylinder	16 March 2023	0,5
Drive And Hydraulic system	Engine	18 March 2023	1
Electrical And Brake System	Solenoid	22 March 2023	2
Electrical And Brake System	Chamber Brake	25 March 2023	1,5
Total Lost Time			37

Data Processing

The data processing stage involves selecting the system and gathering relevant information, defining system boundaries, describing the system along with its Functional Block Diagram, determining system functions and functional failures, conducting Failure Mode and Effects Analysis (FMEA) and Logic Tree Analysis (LTA), as well as selecting appropriate actions and identifying critical components as shown in Table 2.

Table 2. Work order recap of M600U Multi Mover Damage Data (January-March 2023)

System	Sub-System	Date	Lost Time (Hours)
Electrical And Brake System	Electrical PLC	02 March 2023	2,5
	Chamber Brake	10 March 2023	2
		25 March 2023	1,5
	Pneumatic Relay	17 January 2023	3
		12 March 2023	2
	Solenoid	16 March 2023	2
		22 March 2023	2
Drive And Hydraulic System	Motor Travel	17 January 2023	1
		01 February 2023	0,5
		14 February 2023	1,5
		22 February 2023	2,5
		07 March 2023	1
	Engine	23 January 2023	1
		20 February 2023	1,5
		07 March 2023	1,5
		18 March 2023	1
	Filter	11 February 2023	0,5
		01 March 2023	0,5
		12 March 2023	0,5
Steering And Lifting System	Lifting Cylinder	01 February 2023	1
		19 February 2023	0,5
		24 February 2023	1
	Steering Cylinder	10 January 2023	0,5
		23 January 2023	1
		26 February 2023	0,5
		16 March 2023	0,5
Steel Construction And Controller	Remote Control	28 February 2023	2
	Fuel Pump	27 January 2023	1,5
		02 March 2023	0,5
Total Lost Time			37

To determine the equipment's availability, the following formula was applied:

$$Availability = \frac{Loading\ Time - Downtime}{Loading\ Time} \times 100\% \quad (1)$$

Substituting the values:

$$Availability = \frac{630 - 37630}{630} \times 100\%$$

$$Availability = 94.1\%$$

This indicates that the Multi Mover M600U maintained an availability rate of 94.1%, meaning that 5.9% of the total planned operational time was lost due to equipment failures.

To enhance maintenance efficiency, this study places particular emphasis on failures in the Electrical and Brake systems, as these components contributed the highest recorded downtime, totaling 15 hours. Given their critical role in equipment functionality and safety, targeted maintenance strategies for these systems are essential to minimize future disruptions and improve overall equipment reliability.

Functional Block Diagram

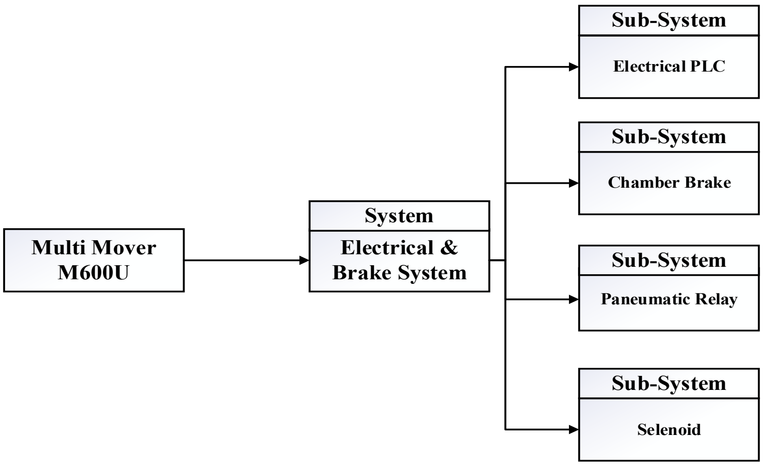

Figure 1. Functional Block Diagram

Figure 1 Functional Block Diagram shows the structure of the Multi Mover M600U, highlighting its Electrical and Brake systems. These consist of key sub systems Electrical PLC, Chamber Brake, Pneumatic Relay and Solenoid each vital for system performance. Their interactions form an efficient functional flow.

Analysis reveals these sub systems as failure prone, affecting reliability. Work Order Data shows the Electrical and Brake systems had the highest downtime (15 hours), primarily due to these components. This data guides the following failure assessment as shown in Table 3.

Table 3. System Functions and Functional Failures (System Electrical And Brake System)

System	Sub-System	Function Description	Function Failure
Electrical And Brake System	Electrical PLC	Controls the automation system of the equipment	Can-bus error
	Chamber Brake	Converts air pressure into mechanical movement	Leaking brake chamber
	Pneumatic Relay	Regulates airflow to the chamber brake	Relay valve has a leak
			Pneumatic pressure low
	Solenoid	Controls the flow of pressurized air to the cylinder	Damaged solenoid socket

Pareto Analysis

The distribution of system failures, categorized by lost operational hours, is detailed in Table 4 and Figure 2, which presents a Pareto diagram illustrating the most failure-prone components.

Table 4. Pareto diagram

No	System	Lost Time (Hours)	Percent	Cumulative
1	Electrical And Brake System	15	41%	41%
2	Drive And Hydraulic System	13	35%	76%
3	Steering And Lifting System	5	14%	89%
4	Steel Construction And Controller	4	11%	100%
Total		37		

From the data presented in Table 4, it is evident that the Electrical and Brake System accounts for the highest downtime, contributing 15 hours of lost operational time, which represents 41% of total failures. This finding highlights the criticality of these components in maintaining the reliability and safety of the Multi Mover M600U.

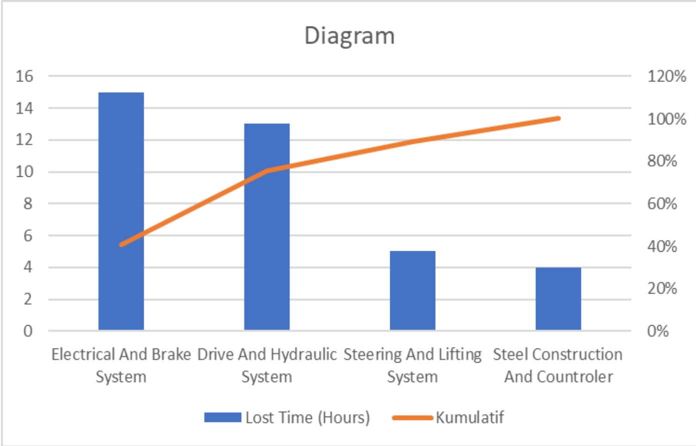

Figure 2. Pareto Diagram

Failure Mode Effect Analysis (FMEA)

The Failure Mode and Effects Analysis (FMEA) was conducted to assess the failure risks associated with critical components of the Electrical and Brake System in the Multi Mover M600U as shown in Table 5. The assessment was done with the help of practitioners who are supervisors from the electrical, operations and mechanical departments. The analysis focused on identifying potential failure modes, their causes and their impact on equipment functionality, allowing for prioritization of maintenance actions based on the Risk Priority Number (RPN).

The RPN value is calculated using the following formula (2).

$$RPN = S \times O \times D \qquad (2)$$

Where:

S (Severity): The impact of failure on equipment operation.

O (Occurrence): The likelihood of the failure occurring.

D (Detection): The ability to detect the failure before it causes severe consequences

Electrical PLC emerged as the most critical component (RPN=350) due to its Can bus error failure mode, causing lifting/steering disruptions and potential engine shutdown. With high severity (S=10) and moderate occurrence/detection (O=5, D=7), it demands urgent preventive action.

Chamber Brake ranked second (RPN=175), where pipe blockages cause leakages, reducing braking efficiency and posing safety risks. Though severe (S=7), its lower occurrence/detection (O=5, D=5) places it at a moderate risk level.

Table 5. FMEA System Electrical And Brake System

Sub-System	Function	Failure Mode	Cause	Effect	S	O	D	RPN
Electrical PLC	Controls the automation system	Can-bus error	Lifting & steering disrupted	Sudden engine shutdown	10	5	7	350
Chamber Brake	Converts air pressure into mechanical motion	Chamber brake leakage	High-pressure pipe blockage	Braking system not optimal	7	5	5	175
Pneumatic Relay	Regulates airflow to the brake system	Relay valve leakage, low pressure	Valve blockage	Weak injection pressure	5	3	7	105
Solenoid	Controls the flow of pressurized air	Damaged solenoid socket	Dust accumulation in piston	Piston jammed, coil burned	7	3	7	147

Pneumatic Relay (RPN=105) faces valve leakage and low pressure, weakening braking performance. While impact is moderate (S=5), its detection difficulty (D=7) necessitates proactive inspections.

Solenoid (RPN=147) is prone to socket damage from dust accumulation, leading to piston jams and coil burnout. With moderate severity (S=7) and detectability (O=3, D=7), regular cleaning is critical to prevent failures.

Logic Tree Analysis (LTA)

After conducting the Failure Mode and Effects Analysis (FMEA), the next step involves applying Logic Tree Analysis (LTA) to systematically assess failure modes in the Multi Mover M600U. The correlation between FMEA and LTA lies in how FMEA identifies potential failure modes and their effects, which serve as input data for the Logic Tree Analysis (LTA). FMEA provides detailed information on failure causes and their impact, which helps build the branches and events in the logic tree structure. This integration allows LTA to visually represent and analyze the pathways from identified failures to overall system faults, enhancing risk assessment and decision-making. This method classifies failures based on three key criteria are evidence clarity, safety impact and operational disruptions. By categorizing failures according to these parameters, maintenance teams can develop targeted intervention strategies to enhance equipment reliability and minimize downtime.

The first criterion, evidence clarity, evaluates how easily a failure can be identified through system diagnostics, operator observations or routine inspections. Failures with clear diagnostic indicators enable quicker corrective actions, whereas intermittent or less obvious issues require advanced monitoring techniques such as predictive maintenance systems. This classification ensures efficient resource allocation for fault detection and resolution.

The second aspect of the analysis is safety impact, which determines the extent to which a failure poses risks to personnel, equipment, or the environment. Failures involving electrical malfunctions or brake system defects, for instance are classified as high priority due to their potential to cause accidents. These critical cases require immediate corrective measures to ensure a safe working environment, aligning with LTA's emphasis on risk mitigation.

The final criterion focuses on operational disruptions, particularly failures that lead to system downtime or performance degradation. Since these failures directly affect productivity and can result in substantial financial losses, they are prioritized in maintenance planning. By proactively addressing failures that cause outages, organizations can maintain smooth production processes and optimize operational efficiency.

Through this structured classification, LTA facilitates data-driven maintenance decisions by balancing urgency with resource efficiency. High-risk failures receive immediate attention, while preventive solutions are designed for less critical cases. Ultimately, this method improves equipment longevity and reduces unplanned downtime through a systematic, risk-based prioritization approach.

The classification results for each failure mode in the Multi Mover M600U are presented in the Table 6 below:

Table 6. LTA System Electrical And Brake System

Sub-System	Failure Mode	Critically Analysis			
		Evident	Safety	Outage	Category
Electrical PLC	Can-bus error	Y	Y	N	A
Chamber Brake	Chamber brake leakage	Y	N	N	C
Pneumatic Relay	Relay valve leakage, low pressure	Y	Y	N	B
Solenoid	Damaged solenoid socket	Y	Y	N	B

The Logic Tree Analysis (LTA) of the Multi Mover M600U highlights critical weaknesses in its Electrical and Brake Systems, allowing for a structured approach to prioritizing maintenance efforts. The Electrical PLC is identified as the most critical component (Category A), where Can-bus failures interfere with lifting and steering functions, potentially leading to sudden engine shutdowns. Although these malfunctions do not result in extended downtime, they pose significant operational safety risks, requiring immediate corrective action.

Failures in the Chamber Brake (Category C) are classified as lower priority in the short term, as they do not immediately jeopardize safety or machine functionality. However, persistent leaks can gradually diminish braking performance, contributing to higher maintenance costs and accelerated component wear over time.

Moderate-risk failures (Category B) in the Pneumatic Relay and Solenoid impact pressure regulation, which may lead to partial system failures without causing an immediate shutdown. However, these issues progressively reduce system reliability, necessitating proactive maintenance to prevent further deterioration.

By employing this tiered classification, the LTA framework ensures urgent intervention for high-risk Electrical PLC failures, while scheduling preventive maintenance for brake system leaks and continuous monitoring of pneumatic components. This structured, risk-based approach enhances both safety and operational efficiency, ensuring long-term equipment reliability.

Task Selection

At this stage, proposed steps are formulated to improve the current maintenance policy by comparing it with the policy derived from the RCM (Reliability-Centered Maintenance) analysis. The objective of this step is to determine the most effective maintenance strategy for the multi mover M600U. The comparison between both policies is presented in the following Table .7.

Table 7.Task Selection Multi Mover M600U

Sub-System	Failure Mode	Previous Maintenance Action	Proposed Maintenance Action
Electrical PLC	Can-bus error	RTF	TD, FF With PRV
Chamber Brake	Chamber brake leakage	RTF	CD With PRV
Pneumatic Relay	Relay valve leakage, low pressure	RTF	FF With PRV
Solenoid	Damaged solenoid socket	RTF	FF With PRV

Based on the results in Table 7, several recommended maintenance actions for the multi mover heavy equipment can be concluded. These include implementing appropriate maintenance strategies, such as Preventive Maintenance and Predictive Maintenance, to enhance reliability and operational efficiency.

Fishbone Diagram

Based on the FMEA analysis, the Electrical and Brake System has a total RPN value of 777, with the Electrical PLC recording the highest RPN value of 350. This indicates that the Electrical and Brake System frequently experiences failures, contributing to the largest downtime compared to other components.

Therefore, an appropriate maintenance scheduling strategy based on FMEA analysis is required to reduce the risk of unexpected downtime in critical components that could lead to time and cost losses due to sub-component replacements. To support further analysis, the Fishbone Diagram on Figure 3 identifies the root causes of failures in the Electrical PLC, considering its highest RPN value.

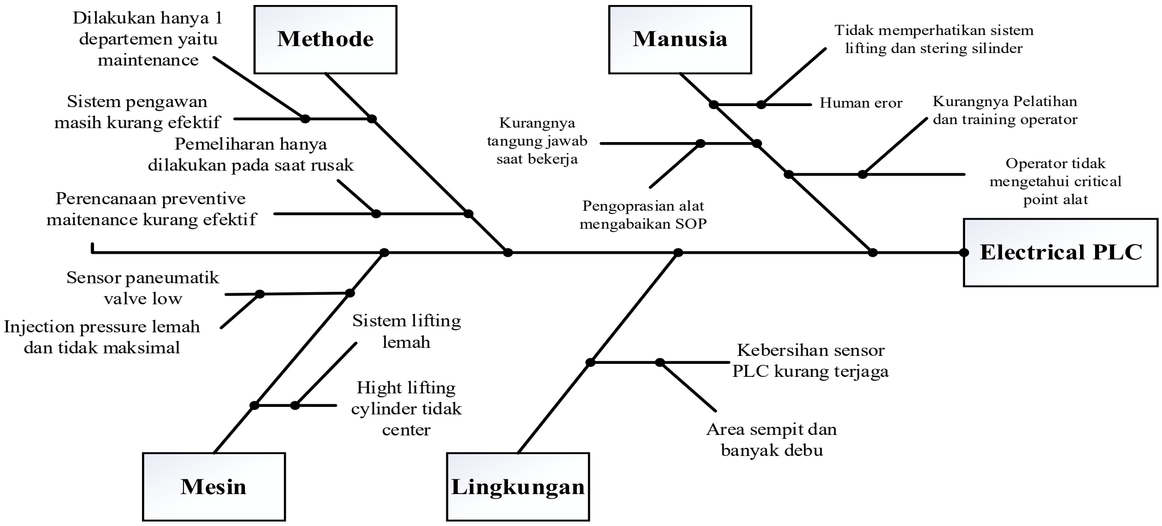

Figure 3. Diagram Fishbone

The fishbone diagram in Figure 3 was created with the help of practitioners who are supervisors from electrical, operations and mechanical departments, visually represents the root cause analysis of Electrical PLC failures in the Multi Mover M600U system. The identified causes are categorized into four primary factors are human, method, machine and environmental influences.

In the human factor, key issues stem from insufficient operator knowledge, lack of proper training, and failure to adhere to standard operating procedures (SOPs). These deficiencies contribute to inefficient system operation, increasing the likelihood of malfunctions. The method-related causes focus on ineffective maintenance strategies, including a reactive approach where repairs are conducted only after failures occur and the absence of a structured maintenance schedule, which accelerates component wear and deterioration.

From a machine standpoint, defective pneumatic sensors and an unstable lifting mechanism play a significant role in Electrical PLC failures. Poorly maintained or damaged sensors disrupt the automated control process, negatively affecting system performance and reliability. Lastly, environmental conditions such as insufficient PLC protection and excessive dust accumulation further increase the risk of system malfunctions by exposing components to contamination and external disturbances.

Overall, Electrical PLC failures arise from a combination of human error, ineffective maintenance practices, mechanical weaknesses and environmental hazards. Mitigating these issues through comprehensive operator training, structured preventive maintenance, machine optimization and improved environmental protection measures can enhance system reliability and reduce operational disruptions.

Analysis Using 5W+1H Method

At this stage, an action plan analysis is conducted using the 5W+1H method, which involves identifying the problem, details of the location and time of failure, the main cause and corrective solutions. This method aims to comprehensively understand the root cause of failures and formulate effective corrective measures.

The problem details column in the table integrates information regarding What, Where, and When, while the Cause and Solution column briefly explains Why and How. This analysis is expected to reduce the likelihood of similar failures in the future and enhance the reliability of the Multi Mover M600U heavy equipment as shown in Table 8.

The 5W+1H analysis provides a structured approach to identifying and resolving key operational challenges in the Multi Mover M600U. By addressing issues related to human error, ineffective maintenance practices, environmental conditions, and mechanical failures, this analysis helps develop targeted corrective actions. Implementing the recommended solutions, such as operator training, preventive maintenance scheduling, and routine inspections, will enhance equipment reliability, minimize downtime, and improve overall operational efficiency.

Table 8. Analysis 5W+1H

Factor	Problem	Problem Details	Cause and Solution
Human	Operator lacks awareness of critical points	Operational errors in Electrical/PLC when handling Can-Bus failure	Lack of training; implement training programs and reinforce SOP compliance
	Human error	Operational errors in Electrical/PLC during equipment usage	Lack of focus on SOP; instill responsibility and improve SOP adherence
	Lack of responsibility	Ignoring SOP during equipment operation	Fatigue and monotony; conduct safety talks and encourage periodic breaks
Method	Ineffective preventive maintenance	Maintenance scheduling not properly implemented for Multi Mover	Maintenance is only performed upon failure; establish a routine preventive maintenance schedule
	Ineffective supervision	Maintenance responsibility for Multi Mover lacks coordination	Responsibility is solely on the Maintenance Division; involve all relevant departments
Environment	Poor cleanliness of cylinders and sensors	Accumulated dust in confined areas of cylinders and sensors	Schedule regular cleaning for hard-to-reach areas
Machine	High lifting cylinder misalignment	Lifting height is inconsistent during operation	Weak lifting system; conduct regular maintenance on the cylinder
	Low pneumatic valve sensor pressure	Weak injection pressure due to valve blockage	Valve obstruction; inspect and maintain the pipe valve system regularly

Discussion

The improvement proposals serve as a continuation of the 5W+1H analysis, focusing on identifying each root cause and clarifying the issues to ensure immediate corrective actions. The following Table 9 presents the proposed improvements for the Multi Mover M600U heavy equipment.

Table 9. Proposed Improvement

Problem	Solution	Proposed Improvement
Operator lacks awareness of critical points	Provide additional training on heavy equipment SOP	Management should organize training sessions led by internal or external experts to enhance understanding of heavy equipment operation
Human error	Instill responsibility and discipline	Conduct additional training to deepen SOP comprehension, especially on the lifting and steering system
Lack of responsibility at work	Utilize rest periods for refreshing	Implement shift briefing/safety talks before work shifts to discuss worker conditions and work-related issues, led by the shift leader
Ineffective preventive maintenance planning	Schedule preventive maintenance regularly	Adjust the preventive maintenance schedule from twice a week to every shift to facilitate component condition monitoring
Ineffective supervision system	Involve all relevant personnel in equipment maintenance	Require operators to inspect equipment at the beginning and end of each shift; maintenance management should conduct periodic checks and establish a preventive maintenance schedule
Poor cleanliness of cylinders and sensors	Improve cleaning in hard-to-reach areas	Implement 5S activities every Friday, clean sensor areas, and schedule unit washing alongside preventive maintenance
High lifting cylinder misalignment	Clean and maintain the cylinder area regularly	Ensure no dust buildup or leakage in the cylinder area to maintain system performance
Low pneumatic valve sensor pressure	Conduct regular inspection and maintenance of valves	Schedule preventive maintenance on sensors and pipes to ensure no dust or leakage disrupts air pressure

Based on the findings in Table 9, several improvement actions for multi mover maintenance have been proposed based on the 5W+1H analysis. These improvements aim to enhance the machine's performance and minimize critical component failures. However, successful implementation requires collaboration among relevant departments, particularly operational management and maintenance management, to ensure the sustainability and effectiveness of the proposed maintenance strategies.

CONCLUSION

Based on the analysis and implementation of the Reliability Centered Maintenance (RCM) method on the Multi Mover M600U at PT XYZ, this study successfully identified critical components with a high risk of failure, particularly in the Electrical and Brake System. Through Failure Mode and Effect Analysis (FMEA), the Electrical PLC was found to have the highest Risk Priority Number (RPN) of 350, indicating that this component is the most vulnerable to failure and requires special attention in maintenance.

The proposed maintenance strategy in this study offers a preventive and predictive maintenance schedule for critical components. Compared to the previous reactive maintenance policy, implementing this strategy is expected to reduce downtime, enhance machine reliability, and lower operational costs caused by unexpected failures.

This study contributes by providing a systematic framework for developing RCM-based maintenance policies in an industrial setting. However, there are some limitations, particularly regarding the scope of application, which is restricted to one type of heavy equipment. Future research could extend the RCM method to various industrial equipment types, allowing for broader findings and improved generalization of results across different sectors.

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