DIJEMSS: Dinasti International Journal of Education Management and Social Science
E-ISSN: 2686-6331
P-ISSN: 2686-6358
DINASTI PUBLISHER
https://dinastipub.org/DIJEMSS dinasti.info@gmail.com +62 811 7404 455

**DOI:** https://doi.org/10.38035/dijemss.v7i1.5555
https://creativecommons.org/licenses/by/4.0/
**Received:** 15 September 2025 | **Revised:** 24 September 2025 | **Accepted:** 31 October 2025

# Proposed Improvements of Air Conditioner Preventive Maintenance In The Coal Mining Industry By Utilizing DMAIC Methodology

**Isadora Rahmawati[1], Dermawan Wibisono[2]**
[1]School of Business and Management, Institut Teknologi Bandung, Bandung, Indonesia, 29123403@mahasiswa.itb.ac.id
[2]School of Business and Management, Institut Teknologi Bandung, Bandung, Indonesia, dwibisono@sbm-itb.ac.id

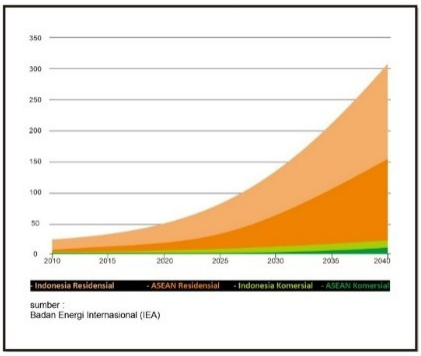
Corresponding Author: 29123403@mahasiswa.itb.ac.id[1]

**Abstract:** The air conditioner (AC) serves as an enabling facility to support the continued operation of coal mining activities at PT Bukit Asam, Tbk (PTBA) Tanjung Enim site, particularly at the substation, mine switch station, server room, and other work facilities. Although Preventive Maintenance (PM) of AC has been fully implemented every month, the Corrective Maintenance (CM) rate remains high. This research aims to determine the causes of the high number of work orders (WO) for CM in AC, how to design an appropriate PM and CM schedule that can be implemented to be more effective in reducing failure rates, and recommendations that can be propose to improve the reliability of AC systems in coal mining areas. The method used is the DMAIC (Define–Measure–Analyze–Improve–Control) approach, combined with FMEA (Failure Mode and Effects Analysis) and risk-based maintenance principles. Data was analyzed from the monthly report, work order history from July to December 2024, observations, and semi-structured interviews with related management and users in the operational department. Research findings indicate that 55% of activities are non-value-added, while only 45% of activities are value-added. FMEA analysis identified several failure modes, including filters that easily become dirty, the lack of PM monitoring and evaluation, not yet to conduct an environmental risk assessment for air conditioner maintenance on the mining site, and the movement between departments is far away. The implementation of risk-based maintenance for work order CM, from January to June 2025, has classified risks into high, moderate to high, moderate, and low to moderate risk locations that directly impact operations, and has positive results with a sigma level increasing from 2.88 to 3.29. Propose improvement recommendations include reorganizing the PM schedule by location and implementing digital tagging forms for units to report maintenance activities.

**Keywords:** Air Conditioner, Preventive Maintenance, Corrective Maintenance, Six Sigma, DMAIC, FMEA, Risk-Based Maintenance

## INTRODUCTION

Indonesia, being a tropical country, experiences consistently hot temperatures and high humidity levels throughout the year. These conditions create a significant need for comfort in residential, office, and industrial facilities. Air conditioners (ACs) are one of the main solutions for creating a comfortable environment, while also supporting work productivity, especially in the mining industry. Based on data from APITU Indonesia, the estimated demand for air conditioner units in Southeast Asia, particularly in Indonesia, will continue to increase, as shown in Figure 1 below:




Source: (Pri Nurhartono (APITU Indonesia), 2020)

**Figure 1 Forecast of air conditioner unit demand in Southeast Asia, particularly Indonesia**

Based on Menteri Kesehatan Republik Indonesia (2023) in accordance with the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementation Regulation of Government Regulation Number 66 of 2014 on Environmental Health, Chapter III on Health Promotion Measures, Section on Prevention of Air Quality Deterioration caused by biological pollution sources, it is recommended to clean air conditioners regularly at least once every 3 (three) months or in accordance with the maintenance instructions for the air conditioner being used. As an implementation measure of the Minister of Health's mandate, the Engineering & Manufacturing Department (E&M) is responsible for maintaining and repairing air conditioners in the PTBA mining area. Currently, preventive maintenance is preferred to corrective maintenance, as the latter causes unscheduled downtime that can disrupt production and cause significant economic losses (Tingginehe et al., 2021).

### Background

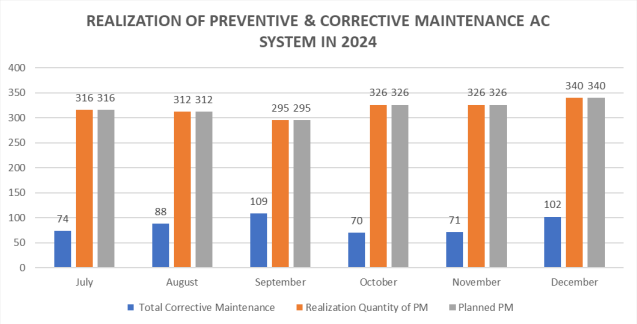
PT Bukit Asam Tbk (PTBA) is one of the oldest coal mining companies in Indonesia, located in one of the regencies in South Sumatra province. PTBA operates with an open-pit mining method that has been in operation since 1919. In 1918, the Tanjung Enim Mining Unit had an open pit area, there are of the West Block areas consisting of Air Laya Mine (TAL) and Muara Tiga Besar (MTB), while on the East Block areas consisting of West Banko, Central Banko A and Central Banko B. Finally, in 2023, PTBA further strengthened its role by joining the MIND ID holding, which increased production capacity, cost efficiency, and funding, making it an essential part of the national energy industry (PT Bukit Asam Tbk, 2024).

### Business Issue

The Engineering & Manufacturing Department, under the Maintenance Division, is responsible for maintaining and repairing air conditioners (ACs) in the coal mining areas of the east and west blocks. In addition to performing preventive maintenance, it also carries out corrective maintenance such as troubleshooting, repairs, relocation, dismantling, and installation, in accordance with requests from user departments in the mining areas. Air

conditioner maintenance carried out by the AC & Electronics Reparation Sub-Section plays an important role, especially at substations, mine substations (MSS), coal handling & transportation facilities, mine control centers (MCC), warehouses, and other work facilities.

Considering the importance of air conditioner maintenance at mining sites and the high risks posed by inadequate maintenance, appropriate preventive measures must be taken. The target for AC maintenance implementation in 2024 has been achieved every month; however, there is still a high number of Corrective Maintenance Work Orders (WOs) in several months. Therefore, preventive maintenance improvements are necessary to address these challenges and maximize maintenance functions, thereby reducing the number of Corrective Maintenance (CM) Work Orders and potentially decreasing maintenance costs. The following is the total data for the implementation of PM and CM Work Orders for air conditioners in 2024.

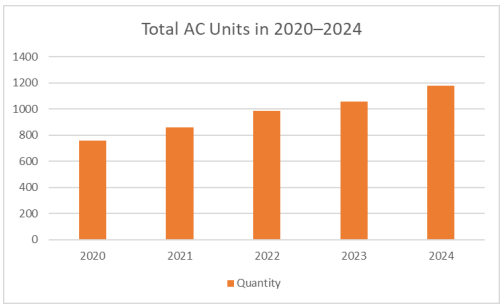



Source: Research Results

**Figure 2 Realization of Preventive and Corrective Maintenance AC System in 2024**

Based on Figure 2, the realization of PM and CM on AC systems in PTBA's coal mining areas, specifically in the eastern and western blocks, showed a consistent PM realization rate every month in 2024. However, this condition does not fully reflect the effectiveness of the PM strategy implemented. Sample data from July to December 2024 shows a high proportion of Corrective Maintenance (CM) occurring monthly, with over 50 units addressed per month, despite the implementation of PM to the maximum extent possible.

Every year, as production targets increase, so does the need for additional buildings or containers as operational sites for coal production, thereby increasing the number of air conditioner units that require routine maintenance. The following is the number of air conditioner units from 2020 to 2024 in the PTBA mining area. As shown in Figure 3 below, the number of air conditioner units at PTBA's coal mining sites undergoing maintenance has increased annually, in line with the rise in coal production targets.

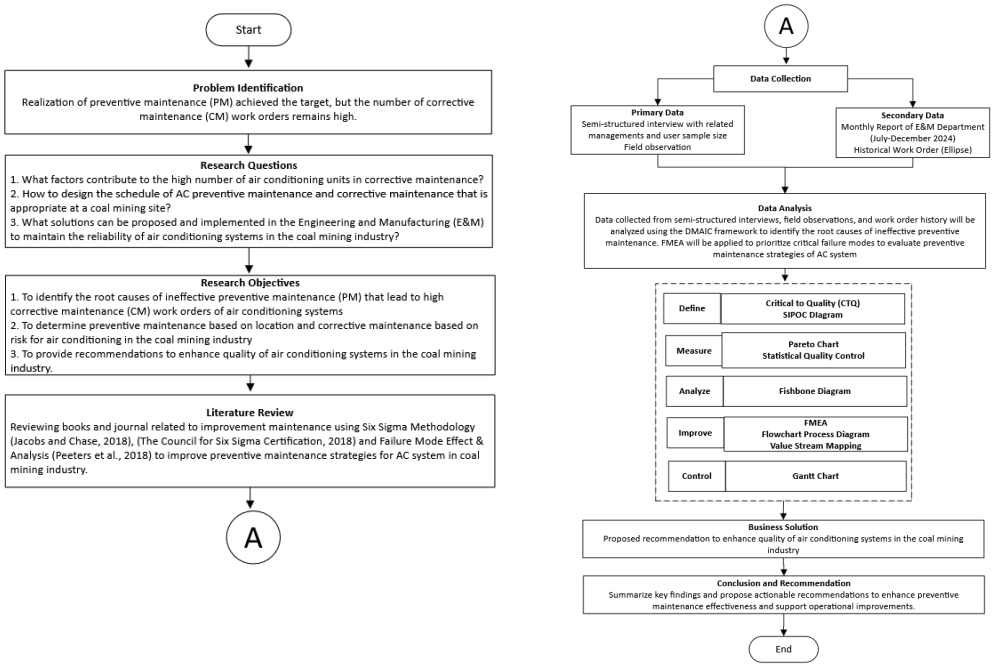



Source: Research Results

**Figure 3 Total AC units in 2020-2024 in the coal mining industry of PTBA**

## METHOD

The research design used the Six Sigma methodology approach, specifically the DMAIC (Define, Measure, Analyze, Improve, and Control) framework, starting with defining the problems that address business issues. Data collection was conducted through primary data in the form of semi-structured interviews and a questionnaire with Sub Section Head and Section Head involved, focusing on their respective fields and the problems often encountered during Preventive Maintenance and Corrective Maintenance, as well as with a sample of user departments in the mining area. Data was analyzed using a Fishbone Diagram to identify the root causes of the problems. After identifying the main factors causing the ineffectiveness of the PM, an analysis is conducted to determine what needs to be prioritized for maintenance, using the FMEA (Failure Mode and Effects Analysis) method, which will then produce a Risk Priority Number (RPN). Figure 4 below shows the research design proposed by the author.




Source: Research Results

**Figure 4 Research Design Method**

### Data Collection Method

In this study, the Data collection consisted of two types: primary and secondary data. Primary data were obtained through semi-structured interviews and a questionnaire with the Engineering & Manufacturing Planning Section Head, the Electricity Repair Section Head, and the AC Reparation Sub-Section Head, who are responsible for executing preventive AC maintenance, as well as four respondents who are users in specific divisions representing Coal Handling Operations, CHF Electrical Maintenance, SHE Corporate, and Mining Division. Secondary data was obtained from the company's internal reports for 2024, which were also sourced from the work order history in the Enterprise Resource Planning (ERP) application, Ellipse.

### Data Analysis Method

The analysis method used in this study utilizes the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) approach to identify problems, determine root causes,

propose solutions, and control improvement results in air conditioner (AC) maintenance within coal mining areas.

**A. Define**

In the Define stage, the main problem was defined as the high number of Corrective Maintenance Work Orders (CM WOs), which served as an indicator of the ineffectiveness of the preventive maintenance (PM) process for the air conditioners in the mine. The Critical to Quality (CTQ) approach was used to identify user requirements for PM service quality, and a SIPOC Diagram was used to map the process from start to finish.

**B. Measure**

The Measure phase aims to measure the baseline condition of the AC maintenance process. Data is collected through Historical Work Order CM and PM realization. Next, a Pareto Chart is used to identify the most dominant problems, both in terms of the type of damage and the AC components that have the most frequent problems.

C. **Analyze**

During the Analyze stage, the root causes of the AC PM's ineffectiveness were identified. A Fishbone Diagram is used to map out the main contributing factors based on categories such as people, methods, machines, materials, and environment.

D. **Improve**

The Improve stage focuses on developing and implementing solutions that have been designed based on the results of previous analyses and formulating recommendations for improvements, including FMEA (Failure Mode and Effect Analysis) to assess the risk of failure of each factor, measure the severity, likelihood, and the ability to detect frequently occurring damage, propose design of PM schedule improvements and prioritization solutions for corrective maintenance work orders, propose improvements to the PM and CM process flowchart.

E. **Control**

The Control phase aims to ensure that the improvements achieved can be maintained on an ongoing basis. In this phase, designs that have been implemented and proven effective for corrective maintenance will be monitored, and preventive maintenance schedule designs will be propose that are appropriate for the conditions in the coal mining area.

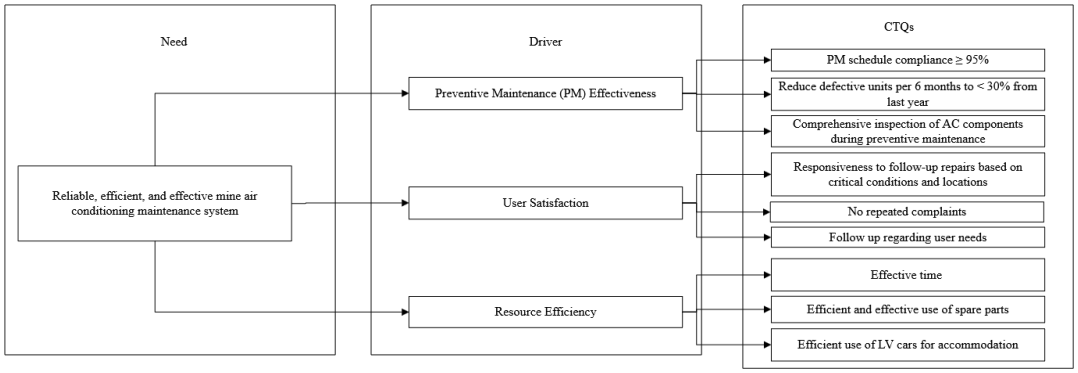
## RESULTS AND DISCUSSION

The results of this analysis are closely related to the effectiveness of maintenance activities, particularly in reducing the number of AC breakdowns and lowering the WO CM rate. The findings from this process will be used to develop recommendations for improving the current AC preventive maintenance system.

### Define Phase

### Critical to Quality (CTQ)

CTQ (Critical to Quality) refers to factors or parameters that are the primary drivers of quality in a process or organization. CTQ is usually a key measurable metric that indicates whether customers will be satisfied or not. The following Figure 5 is a CTQ Tree for air conditioner maintenance in coal mines:




Source: Research Results

**Figure 5 Critical to Quality Tree of the AC System**

## SIPOC Diagram

SIPOC stands for suppliers, inputs, process, outputs, and customers. Suppliers are the people, processes, and organizations that supply inputs to the process. Customers are the people, processes, and organizations that use the outputs of the process. The process itself is a series of steps that take inputs and transform them into outputs. SIPOC diagrams are highly flexible and scalable, enabling them to comprehensively illustrate processes and operations, which aids in cross-functional discussions, such as who is responsible for what, and how processes relate to customers and suppliers. The following is Table 1 of the SIPOC diagram for mine air conditioner maintenance:

**Table 1 SIPOC of AC's Maintenance Department**

| Suppliers | Inputs | Process | Outputs | Customers |
|---|---|---|---|---|
| - AC Technician<br>- Vendor | - Preventive Maintenance schedule (PM)<br>- Email request from user | Shown in Table 2 | - The AC unit normally operated<br>- PM realization achieved<br>- Historical maintenance unit | - User department of PTBA in mining site |

Source: Research data

**Table 2 AC's Maintenance of SIPOC Process Steps**

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |
|---|---|---|---|---|
| Planning | Maintaining | Repairing | Reporting | Finishing |

Source: Research data

## Preventive Maintenance Schedule Existing

Preventive maintenance activities on the air conditioners in the mining area are currently divided into two PM work groups and one Corrective Maintenance (CM) group. Each group consists of four technicians and is supported by one light vehicle (LV) for mobilization to the location. The first and second teams are assigned to perform Preventive Maintenance at the West Block and East Block locations, while the third team is assigned to perform Corrective Maintenance if there are work orders at the West Block or East Block locations.

The current PM scheduling is categorized based on the total number of units divided by the number of days in a month. For the West Block area, preventive activities are carried out repeatedly every 4 months, while in the East Block, the preventive cycle is carried out more frequently every 3 months. The difference in PM frequency is based on the distribution of units across each block. It takes into account the proportional workload of technical personnel, assuming that each group can complete 9 to 13 AC units per day. However, the frequency of

preventive maintenance for air conditioners in the west block is longer than in the east block, resulting in a significant number of corrective maintenance work orders.

## Measure Phase

### Pareto Chart Calculation for Defect Type

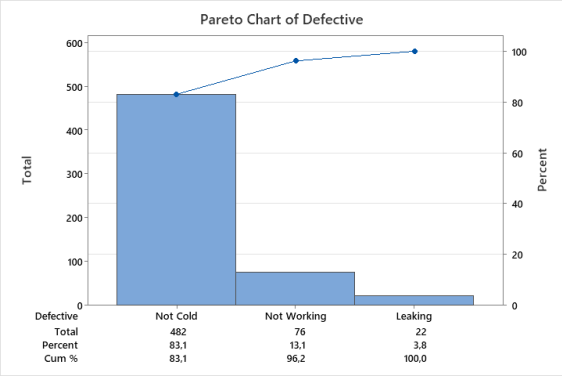
The Pareto principle, also known as the 80/20 rule, states that approximately 80% of effects come from 20% of causes, aiming to identify several vital inputs or root causes that have the most significant impact on results. Table 3 below shows the total defects in the corrective maintenance work order of AC units:

**Table 3 Total Defects in the Corrective Maintenance of AC Units**

| Period | Total Unit of CM | Number of Defective Units | | | | | | Total defective (unit) |
|---|---|---|---|---|---|---|---|---|
| | | Not Cold | | Not Working Properly | | Leaking | | |
| | | West Block | East Block | West Block | East Block | West Block | East Block | |
| Jul-24 | 74 | 29 | 31 | 5 | 4 | 2 | 3 | 74 |
| Aug-24 | 88 | 45 | 32 | 5 | 2 | 3 | 1 | 88 |
| Sep-24 | 109 | 63 | 31 | 5 | 7 | 2 | 1 | 109 |
| Oct-24 | 70 | 27 | 28 | 7 | 5 | 0 | 3 | 70 |
| Nov-24 | 71 | 26 | 30 | 6 | 5 | 2 | 2 | 71 |
| Dec-24 | 102 | 40 | 50 | 5 | 4 | 2 | 1 | 102 |
| **Total for each Block** | | **230** | **202** | **33** | **27** | **11** | **11** | **514** |
| **Total West and East Block** | | **432** | | **60** | | **22** | | **514** |

Source: Research data

Based on Table 3, it can be seen that the total number of damages in corrective maintenance (CM) activities for AC units during the period from July to December 2024 reached 514 units, spread across the West Block and East Block areas. The following Figure 6 is a Pareto chart of complaints or repair requests from users:




Source: Research Results

**Figure 6 Pareto Chart**

Based on the results of a Pareto Chart of user complaint defect data and the number of corrective maintenance (CM) work orders, it was found that defects in the "Not Cold" category were the dominant cause, with 482 incidents or 83.1% of the total number of problems. This

indicates that most units experienced performance issues in producing cold air in accordance with operational standards. The other two categories of causes, namely "Not Working" (13.1%) and "Leaking" (3.80%), contributed to 16.9% of the total AC unit performance disruptions. Thus, based on the Pareto principle (80/20), it can be concluded that the main focus of improvement should be directed at the "Not Cold" cause, because improving this has the potential to reduce the majority of CM loads.

## Statistical Quality Control

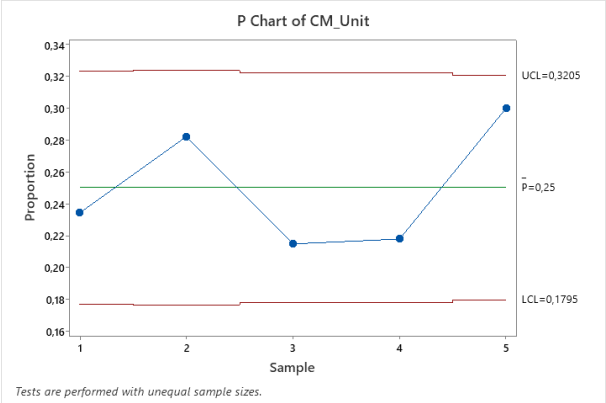
Statistical quality control (SQC) is a technique designed to evaluate quality from the perspective of conformity, assessing how well performance meets the specifications set during the design of components or services provided (Jacobs & Chase, 2018). Below is Table 4, which shows the total number of defective AC units after being revised out of control in September 2024.

**Table 4 Total Defective Units AC After Revised Out of Control**

| Period | Preventive Maintenance (unit) | Defective (unit) |
|---|---|---|
| Jul-24 | 316 | 74 |
| Aug-24 | 312 | 88 |
| Oct-24 | 326 | 70 |
| Nov-24 | 326 | 71 |
| Dec-24 | 340 | 102 |
| **Total** | **1620** | **405** |

Source: Research data

Then, a Revised-P-chart was performed at the third point, which was September 2024, from the out-of-control value. Table 4 presents the controlled p-chart, which will be used to calculate the DPMO and Sigma Level before improvement. The following is Figure 7 of the revised P-Chart of Units AC in Corrective Maintenance.




Source: Research Results

**Figure 7 Revised P-Chart of Units AC in Corrective Maintenance**

## DPMO and Sigma Level of Existing Performance

There are 83.333 Defects Per Million Opportunities (DPMO) that experience damage or defects with a Sigma Level of around 2.88. This reflects a low process capability, requiring improvements in the effectiveness of preventive maintenance to reduce the level of corrective maintenance (CM).

$$DPMO = \frac{Number\ of\ defects}{Number\ of\ opportunities\ x\ Numberof\ Units}\ X\ 1{,}000{,}000$$

$$DPMO = \frac{405}{3\ x\ 1620}\ x\ 1{,}000{,}000$$

$$DPMO = \frac{405}{4860}\ x\ 1{,}000{,}000$$

$$DPMO = 83{,}333$$

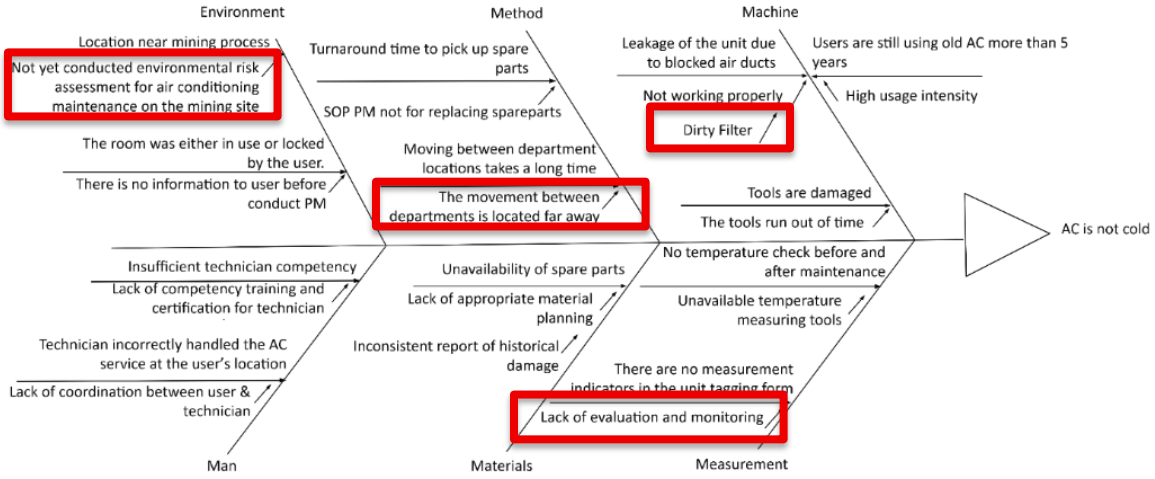
Sigma Level = NORMSINV (1-$\frac{83,333}{1,000,000}$ ) + 1,5

Sigma Level = 2.88

## Analyze Phase

### Cause & Effect / Fishbone Diagram

In the Analyze phase, root cause analysis is performed based on data collected through semi-structured interviews involving internal management and users. Based on data obtained by interviewing regarding potential problems arising from ineffective preventive maintenance of air conditioners, the following is the result of a root cause analysis using a fishbone diagram, as shown in Figure 8 below.




Source: Research Results

**Figure 8 Cause-Effect / Fishbone Diagram**

The severity level was assessed by seven respondents to reflect the overall impact, while the occurrence and detectability were evaluated by three respondents from the E&M Department who understood the technical processes. The RPN value was obtained by multiplying the average scores. Among the 12 root causes identified, the analysis prioritized the four causes with the highest RPN: dirty filters, not having yet conducted an environmental risk assessment for AC maintenance, the movement between departments is located far away, and a lack of evaluation and monitoring.

## Improve Phase

### Failure Mode and Effects Analysis (FMEA)

In this study, Failure Modes will be the potential root causes that may occur, and Failure Effects will be the causes of damage. Meanwhile, in the study Peeters et al. (2018) FMEA is used as part of a risk-based maintenance approach in the precision engineering industry. This study emphasizes the importance of integrating FMEA results with historical data and risk management. Furthermore, the root causes have been identified through semi-structured interviews with Section Heads and Sub-Section Heads. The scale used is a 1-5 Likert scale, and the FMEA Assessment Result is shown in Table 5:

**Table 5 FMEA Assessment Result**

| No | Potential Failure Mode | Potential Effects of Failure | S | O | D | RPN | Current Control |
|---|---|---|---|---|---|---|---|
| 1 | Not yet conducted an environmental risk assessment for air | F. AC is not cold<br>G. Opportunity loss of coal production | 4,14 | 4,67 | 1,67 | 32,22 | H. Prioritize work orders based on the location that |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | conditioner maintenance on the mining site | | | | | | impacts operations. |
| **2** | There is no information to the user before conducting PM | I. User not on standby because the room is locked<br>J. Delayed maintenance work<br>K. User submitted multiple service requests | 3,14 | 2,67 | 1,67 | 13,97 | L. Providing users with email notifications that the PM will be carried out. |
| **3** | Lack of competency training and certification for technicians | M. Poor maintenance quality<br>N. Incorrect work procedures<br>O. Repetitive work | 4,86 | 2,67 | 1,67 | 21,59 | P.Sharing knowledge with experienced technicians. |
| **4** | Lack of coordination between the user & technician | Q. Technician mishandled maintenance at the user's location<br>R. Delayed maintenance work | 3,43 | 3,00 | 1,00 | 10,29 | S.Users provide contact numbers for PIC users who can be contacted for maintenance. |
| **5** | Inconsistent report of historical damage | T. Loss of unit maintenance history<br>U.Unknown material requirements | 4,29 | 3,67 | 1,00 | 15,71 | V. Historical records have not been routinely kept.<br>W. Accelerating procurement or direct purchases through POs. |
| **6** | Dirty filter | X. AC leak<br>Y. AC is off and cannot operate | 4,57 | 5,00 | 1,00 | 22,86 | Z. PM frequency for the West Block location is every 4 months, and for the East Block location is every 3 months. |
| **7** | The tools run out of time. | AA. Delayed maintenance work<br>BB. Prolonged AC downtime | 4,14 | 2,67 | 1,00 | 11,05 | CC. Purchasing new tools |
| **8** | High usage intensity | DD. Decreased AC performance<br>EE. Frequent breakdowns | 4,14 | 2,33 | 1,33 | 12,89 | FF. Providing recommendations to users to rejuvenate units |
| **9** | SOP PM is not for replacing spare parts | GG. Time wasted due to the turnaround time to pick up spare parts | 4,00 | 2,00 | 1,00 | 8,00 | HH. Technicians travel back and forth from the user's location to the workshop and vice versa |
| **10** | The movement between departments is located far away. | II. Moving between department locations takes a long time<br>JJ. Waste of time and fuel costs for LV cars | 3,57 | 4,00 | 3,33 | 47,62 | KK. Locations on the PM schedule that have not been completed are worked on using |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | the overtime system |
| **11** | Unavailable temperature measuring tools | LL. Expected AC maintenance quality does not meet user expectations | 4,43 | 2,00 | 1,33 | 11,81 | MM. Self-checks by technicians without using measuring instruments |
| **12** | Lack of evaluation and monitoring | NN. No continuous improvement<br>OO. There are no measurement indicators | 4,43 | 4,33 | 1,33 | 25,59 | PP. Reporting on realization at the end of each month |

Source: Research data

**Design of Risk-Based Maintenance for Corrective Maintenance in the Coal Mining Site**

In coal mining environments, most air conditioning units operate under extreme conditions, including exposure to coal dust. In some locations, they must operate 24 hours a day. This requires a corrective maintenance approach that prioritizes immediate risk-based handling to minimize downtime. Risk-Based Maintenance (RBM) is a strategic approach that integrates risk assessment into maintenance planning to improve system safety and reliability. This methodology focuses on identifying and evaluating the risks associated with each failure mode, and then designing a maintenance strategy that prioritizes preventing failures with a high level of risk (Arunraj & Maiti, 2007).

**Table 6 Risk Assessment for Work Order Corrective Maintenance**

| No | Group Locations | Failure Effect | Potential Impact | Category | Recommendation Actions |
|---|---|---|---|---|---|
| 1 | Substation | The air conditioner is off, not cooling, and leaking | Electrical components overheat. | High | Handling within <12 hours |
| 2 | Mine Switch Station | | Electrical components overheat. | High | Handling within <12 hours |
| 3 | Server Room | | Data center storage electrical components overheat. | High | Handling within <12 hours |
| 4 | TLS and Dump Hopper Cabin Operator | | This disrupts the comfort and productivity of coal delivery operators. | Moderate to High | Handling within <24 hours |
| 5 | Storage Warehouse Room | | The material has specific requirements and specifications for storage at cold temperatures. | Moderate to High | Handling within <24 hours |
| 6 | Health Clinic | | Medicine storage rooms have specific requirements and specifications for storing medications at cold temperatures. | Moderate to High | Handling within <24 hours |
| 7 | Operator dispatcher | | Interferes with comfort at work | Moderate | Handling within <36 hours |
| 8 | Mine Control Center | | Interferes with comfort at work | Moderate | Handling within <36 hours |
| 9 | Office | | Interferes with comfort at work | Low to Moderate | Handling within <48 hours |
| 10 | Mining Container | | Interferes with comfort at work | Low to Moderate | Handling within <48 hours |

Source: Research data

**Table 7 Total Defective Units AC after implementing Risk-Based Maintenance Revised P-Chart**

| Period | Preventive Maintenance (unit) | Defective (unit) |
|---|---|---|
| Jan-25 | 320 | 31 |
| Mar-25 | 339 | 41 |
| Jun-25 | 348 | 44 |
| **Total** | **1327** | **147** |

Source: Research data

Sigma Level after implementing risk-based maintenance for Corrective Maintenance:

$$DPMO = \frac{Number\ of\ defects}{Number\ of\ opportunities\ x\ Numberof\ Units}\ X\ 1{,}000{,}000$$

$$DPMO = \frac{147}{3\ x\ 1327}\ x\ 1{,}000{,}000$$

$$DPMO = \frac{147}{3981}\ x\ 1{,}000{,}000$$

$$DPMO = 36{,}925$$

$$Sigma\ Level = NORMSINV\left(1-\frac{36{,}925}{1{,}000{,}000}\right) + 1{,}5$$

Sigma Level = 3.29

According to the data, the Sigma Level is approximately 3.29, indicating an improvement in process capability from the previous level of 2.88. Therefore, a risk-based maintenance improvement approach can reduce defects, accompanied by preventive maintenance, which is already running quite well but needs further improvement.

**Propose Design Location-Based for Preventive Maintenance Schedule in the Coal Mining Site and Improvement of the Flow Chart for Preventive Maintenance of AC Units**

Improvement flow diagram of PM AC Units to reduce lead time, including the process of traveling to the Warehouse at the beginning of the month, the addition of checking the temperature before and after the maintenance process to ensure clear measurement indicators during maintenance, and completing the tagging unit form. Grouping AC units based on proximity can increase productivity and help complete tasks within the scheduled period. Sample calculation of the proposed design lead time for a Location-Based Preventive Maintenance Schedule at a coal mining site shows that it can reduce lead time by up to 8,493 minutes, with a process time effective for approximately 11,570 minutes per month.

**Propose Improvement for Digital Tagging Unit AC System**

To enhance the effectiveness of preventive maintenance for air conditioner units, technology-based improvements are necessary to minimize the potential for recurring failures. This can be achieved by applying tags each time preventive and corrective maintenance is carried out, allowing for the identification of frequently encountered problems. This approach aims to integrate the unit number on each air conditioner using a QR Code, so that information related to location, maintenance history, inspection schedule, and condition status can also be accessed by management.

**Control Phase**

**Implementation Plan**

The implementation plan to improve the effectiveness of air conditioner maintenance at mining sites will be explained as follows:

1. The design of risk-based maintenance for corrective maintenance at the coal mining site has been implemented in corrective maintenance work orders from January to June 2025.

2. Propose an implementation plan for process improvement in the preventive and corrective maintenance flowchart to reduce lead time or NVA activities by making improvements to the steps, including providing a buffer stock of spare parts before performing maintenance, sending information to users regarding the Preventive Maintenance Schedule plan, checking the temperature before and after maintenance, and filling out the tagging unit form.
3. Propose the implementation of a Location-Based Preventive Maintenance Schedule at the Coal Mining Site to optimize time, route efficiency, and maintenance effectiveness.
4. Propose an improvement for the Digital Tagging Unit AC System to reduce the potential for repeated failures by implementing tagging or recording every time preventive and corrective maintenance has been carried out.
5. Propose to implement Key Performance Indicators (KPIs) as performance indicators for control based on customer satisfaction evaluations, which is expected to provide continuous improvement input to enhance the effectiveness of AC unit preventive maintenance.

## CONCLUSION

Regarding the issue of ineffective preventive maintenance of air conditioner units, the common failure request from work orders CM was that the AC was not cooling. Then, 12 causes have been identified. It was found that the highest RPN value from FMEA there are 4 (four) root causes need to be solved, including the filters becoming dirty, the lack of PM monitoring and evaluation, not having yet conducted an environmental risk assessment for air conditioner maintenance on the mining site, and the movement between departments is far away.

The design of scheduling for air conditioners in coal mines utilizes a Risk-Based Maintenance strategy for corrective maintenance work orders, where repairs are prioritized based on the high, moderate to high, moderate, and low to moderate operational risk impacts. Meanwhile, preventive maintenance involves implementing a Location-Based Maintenance Schedule based on the proximity of the mine location every three months. Propose an improvement in the use of digital tagging units that integrate QR codes and databases on each unit, enabling the digital documentation of maintenance and repair history data to monitor maintenance costs for AC units in each department.

**Table 8 Summary of Current Condition and the Propose Improvement**

| Aspect | Current Condition | Propose Improvement | Explanation |
|---|---|---|---|
| Not yet conducted an environmental risk assessment for air conditioning maintenance on the mining site | Prioritize work orders based on the location that impacts operations. | Prioritize risk-based maintenance for corrective maintenance of locations with high, moderate to high, moderate, and low to moderate risk that impact operational. | Effectiveness.<br>Minimizing downtime due to AC damage before total failure occurs. |
| Dirty filter | PM frequency for the West Block location is every 4 months, and for the East Block location is every 3 months. | Propose increasing the maintenance frequency to every 3 months in each block. | Effectiveness.<br>Increase the number of units PM each month and implement in accordance with the regulations of the Minister of Health. |
| The movement between departments is located far away | Locations on the PM schedule that have not been completed are worked on using the overtime system | Rescheduling PM based on department location proximity | Efficient and effective.<br>Reduce the time and cost wasted. |

| | | | |
|---|---|---|---|
| Lack of evaluation and monitoring | Reporting on realization at the end of each month | • Technicians report PM results daily using digital tagging unit form.<br>• Conduct PM evaluations at the end of the month<br>• Propose to implement Key Performance Indicators (KPIs) for control | Efficient and effective.<br>• Technicians report PM and CM results daily using the digital tagging unit form.<br>• Conduct PM evaluations at the end of the month.<br>• To assess technician performance based on user satisfaction |

## REFERENCE


Albahrani, M., Alhabobi, M., Mccabe, K., Ali, A., & Linton, A. L. (2021). Implementing Six Sigma to Improve A/C Repair Requests Turnaround. *Proceedings of the First Central American and Caribbean International Conference on Industrial Engineering and Operations Management*, 306–319.

Alqahtani, A. Y. (2020). 2020 IEEE International Symposium on Systems Engineering (ISSE). *Improvement of Maintenance Orders Lead Time in Public Universities: DMAIC Approach*. https://doi.org/10.1109/ISSE49799.2020.9272017

Arunraj, N. S., & Maiti, J. (2007). Risk-based maintenance-Techniques and applications. *Journal of Hazardous Materials*, *142*(3), 653–661. https://doi.org/10.1016/j.jhazmat.2006.06.069

Jacobs, F. R., & Chase, R. B. (2018). *OPERATIONS AND SUPPLY CHAIN MANAGEMENT* (Fifteenth). McGraw-Hill Education.

Menteri Kesehatan Republik Indonesia. (2023). *BERITA NEGARA REPUBLIK INDONESIA* (Patent 2). www.peraturan.go.id

Peeters, J. F. W., Basten, R. J. I., & Tinga, T. (2018). Improving failure analysis efficiency by combining FTA and FMEA in a recursive manner. *Reliability Engineering and System Safety*, *172*, 36–44. https://doi.org/10.1016/j.ress.2017.11.024

Pri Nurhartono (APITU Indonesia). (2020, November 10). *Prakiraan Kebutuhan unit AC di Asia Tenggara khususnya Indonesia*. International Energy Agency (IEA). https://apitu.org/artikel/prakiraan-kebutuhan-unit-ac-di-asia-tenggara-khususnya-indonesia/

PT Bukit Asam Tbk. (2024). *Energi Tanpa Henti, Terus Tangguh Menatap Masa Depan*. https://www.ptba.co.id.

Roidelindho, K. (2017). Pengukuran Waktu Standar Perawatan Air Conditioning (AC) Pada Kawasan Industri Batamindo. *Jurnal Industri Kreatif (JIK) No.1*, *1*, 31–38. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://download.garuda.kemdikbud.go.id/article.php?article=1097165&val=16448&title=Pengukuran%20Waktu%20Standar%20Perawatan%20Air%20Conditioning%20AC%20Pada%20Kawasan%20Industri%20Batamindo

Tingginehe, B. Y., Rarasati, A. D., & Ichsan, M. (2021). Schedule maintenance management system for HVAC system in restaurant: A review. *IOP Conference Series: Materials Science and Engineering*, *1098*(2), 022071. https://doi.org/10.1088/1757-899x/1098/2/022071

Wibisono, A. G., Rasyid, A., & Palapa, R. (2022). Analysis of Maintenance Management Implementation in VAC System. *Proceedings of the 5th International Conference on Industrial & Mechanical Engineering and Operations Management*, 701–709.