

# Analysis of Reliability Centered Maintenance of Air Conditioning Facilities

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## ABSTRACT

The Faculty of Engineering is one of the faculties that was established at Mulawarman University. The Faculty of Engineering provides air conditioner facilities to support thermal comfort in the campus space. It is known that there is no maintenance program for air conditioner facilities in the building. Maintenance is carried out in a corrective manner, which means that the air conditioner facility is used until it is damaged, and then when there is damage, repairs are made. Corrective maintenance is a poor maintenance strategy because it causes high operational costs, unknown machine health conditions, downtime, work safety is not guaranteed, and there are no labor planning & maintenance costs. A total of 236 air conditioner units installed in each room are in good condition, decreased reliability conditions, and in damaged condition (cannot be used at all). As a result of this corrective maintenance, a number of problems were found in the air conditioner facility. Air conditioners were found that did not have any effect in the room, had leaks, could not turn on, buzzing machines, and so on. Air conditioner damage makes the room temperature unstable and causes physical and mental discomfort to users. So, it is necessary to plan a maintenance program for air conditioner facilities to maintain machine reliability and extend machine life. Based on the existing problems, Reliability Centered Maintenance (RCM) and Failure Mode Effect and Analysis (FMEA) analysis are carried out to identify functional failures, failure rates, and the recommended maintenance actions for air conditioner critical components.

## Keywords:

Air conditioner; failure mode effect and analysis (FMEA); maintenance management; reliability centered maintenance (RCM)

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## 1. Introduction

In this era of globalization, humans are always trying to find comfortable conditions for their environment, and almost everyone spends 90% of their time and activities inside buildings or rooms. Regulating indoor temperature is very important for optimal comfort and health. Temperature and humidity levels that are too high or low can cause physical discomfort (sweating, easily tired, lack of oxygen so that it becomes easily drowsy), mental discomfort (the emergence of various kinds of negative suggestions for the user), disease disorders (heat cramps, heat rash, chilblain, frostbite and so on). Therefore, the need for room comfort made an increase in the need for air conditioning machines. An air conditioner is a tool used to regulate or condition air, which includes air circulation, adjusting air humidity, regulating air cleanliness, and purifying air (purification) so that temperature, humidity, and air circulation remain comfortable and controlled. Currently, air conditioners have become a basic need for room

coolness. This can be proven by many air conditioners used in offices, hotels, hospitals, schools, shopping centers, and small-scale buildings such as private homes.

The Faculty of Engineering is one of the faculties that was established at Mulawarman University. The Faculty of Engineering provides split-type air conditioner facilities in every room to support the smoothness of academic activities and fulfill thermal comfort. A total of 236 units of air conditioners installed in the Faculty of Engineering with current conditions are divided into 3 conditions, namely 200 units in good condition, 7 units in reduced reliability, and 29 units in damaged condition (not usable at all). The form of maintenance carried out previously is corrective maintenance. Corrective maintenance is a poor maintenance strategy because it operates the machine until it is damaged, and then maintenance, repair, or replacement is carried out. As a result of this improper maintenance, there are a number of problems that occur in air conditioner facilities such as air conditioners installed in the room but not having any effect, leaks, buzzing engine, inability to turn on, and so on. The malfunction of the air conditioner makes the room temperature unstable and causes physical & mental discomfort to the user, which interrupts work and academic activities.

Therefore, it is necessary to plan a maintenance program for air conditioner facilities to maintain machine reliability and extend machine life. Reliability is the probability for a unit or system to function normally when used under certain operating conditions for a certain period. Just like humans, machines will have degraded reliability as their age increases. Machine reliability can also decrease due to continuous use without proper maintenance and decreased reliability affects machine performance. Based on the existing problems, Reliability Centered Maintenance (RCM) and Failure Mode Effect and Analysis (FMEA) analysis are carried out to identify functional failures, failure rates and selection of the best maintenance actions for air conditioner facilities.

## 2. Literature Review

According to [Pranowo \(2019\)](#), maintenance is a series of activities carried out to restore or maintain the machine in an operational and safe condition, and if damage occurs, it can be controlled. Maintenance affects the level of availability, production costs, and safety of operations. These factors will affect the company's profitability. The maintenance process also helps keep facilities and equipment from damage. Maintenance is closely related to preventive and corrective measures:

1. Inspection is the act of checking the machine to find out whether the machine system is in normal condition.
2. Service is an action intended for machines that have been scheduled in the machine maintenance book.
3. Replace, is the act of replacing damaged engine components and this activity can be carried out according to urgency or according to preventive planning.
4. Repair is the act of repairing the machine when damage occurs.
5. Overhaul is a large-scale repair action that is usually carried out at the end of a certain period.

According to [Ahmadi \(2017\)](#), Reliability Centered Maintenance (RCM) is defined as a process used to determine what must be done so that each physical asset can continue to do what its users want in its operational context. Fundamentally, the RCM methodology recognizes that all equipment in a facility does not have the same level of priority. RCM recognizes that the design and operation of equipment are different, so there are different chances of failure. The RCM approach to maintenance programs views a facility as not having financial and resource limitations, so it needs to be prioritized and optimized. In summary, RCM is a systematic approach to evaluating a facility and its resources to produce high reliability and cost-effectiveness. The stages in the Reliability Centered Maintenance (RCM) method:

1. System selection and information collection.  
Information gathering serves to get a deeper picture and understanding of the system and how the system works.
2. System boundary definition.  
System boundary definition is used to define the boundaries of a system to be analyzed with RCM, containing what should be included and not included in the system so that all functions can be clearly known, and the formulation of a good and correct system boundary definition will ensure the accuracy of the system analysis process.

3. System description and functional block diagram.  
System description and block diagram is a representation of the main functions of the system in the form of blocks.
4. System functions and functional failures.  
System function is the performance expected by the system to operate. Functional failure is defined as the inability of a component or system to meet the expected performance standard.
5. Failure Mode Effect and Analysis (FMEA).  
Failure Mode Effect Analysis (FMEA) is a methodology used to evaluate failures that occur in a system, design, process, or service.
6. Logic Tree Analysis (LTA).  
Preparation of Logic Tree Analysis (LTA) is a qualitative process used to find out the consequences caused by each failure mode.
7. Task selection.  
Action selection is the last stage of the RCM analysis process. This process will determine the appropriate action for a particular failure mode.

According to [Situngkir \(2018\)](#), the Failure Mode Effect and Analysis (FMEA) method is a method that can be used to identify the cause and impact of each potential failure mode on equipment components by explaining in detail and systematically the level of failure levels, so that proper prevention or repair can be carried out. FMEA identifies information from each type of failure, including the cause of failure, impact of failure, and recommended actions. Furthermore, to determine the priority level that is considered to have a high risk of each failure, the Risk Priority Number (RPN) method is used. The RPN value comes from multiplying the severity of each failure impact, the probability of occurrence of each cause of failure, and the probability of detection of each cause of failure. The steps in working on the FMEA method are as follows ([Hisprastin, 2021](#)):

1. Conduct a process or product review.  
The team reviews the blueprint for product FMEA or flowchart for process FMEA. For products, the team must directly see the product or product prototype. As for the process, the team must trace the process of production activities to find out the flow and process that occurs.
2. The FMEA team conducts brainstorming.  
Brainstorming provides ideas related to the causes of product or process failures discussed. The ideas are categorized by failure type or failure severity.
3. Determine the level of severity.  
The severity level is an estimate of the severity of the consequences if the failure occurs in the form of a score. The factors that play a role in determining the severity level for product analysis are the consequences to the customer, while for process analysis, it is the consequences to the process.
4. Determine the level of occurrence.  
The level of occurrence is the frequency of failures that occur in the form of a score. The level of occurrence is determined by looking at the failure track record for the past year.
5. Determine the level of detection.  
The level of detection is how likely it is to be able to detect a failure or the consequences of a failure in the form of a score. The key is to identify the current controls that can detect failures or the effects of failures.
6. Calculating RPN.  
RPN is the relationship between three variables, namely severity, occurrence, and detection, which shows the level of risk that leads to corrective action. The RPN value is obtained by multiplying the severity, occurrence, and detection values.
7. Determining failure priority for action.  
Actions are determined based on the priority level of failure through the RPN value.
8. Perform actions to reduce risk.  
Actions are taken based on recommended actions from the FMEA team.

### 3. Methodology

This research involved a preliminary study, a literature review, and an empirical study. The data collection stage is carried out in accordance with the research needs, namely primary data and secondary data which are described as follows.

#### 3.1 Primary Data

The methods used in collecting primary data are direct observation techniques (observation), interviews and questionnaires to the parties concerned. Primary data in this study are as follows:

1. Observation: Researchers made observations to see and know firsthand the actual conditions of the air conditioner facilities and made calculations for the number of air conditioner units in the Faculty of Engineering Building.
2. Interviews: Interviews were conducted to gather information about air conditioner maintenance. Interviews were conducted with Mr. Aminuddin, S. Sos. as sub-coordinator of general and finance, Mr. Sumadi as the technician in charge of directly repairing air conditioners, and Mr. Dian Sucipto as the Panasonic air conditioner vendor.
3. Questionnaires: The sampling technique used to select questionnaire respondents in this study was the judgment sampling technique. The system of judgment sampling is the withdrawal of samples based on considerations based on certain criteria. Certain criteria selected as a respondent is someone who is an expert in air conditioner maintenance and experienced as an air conditioner technician at the Faculty of Engineering, namely Mr. Sumadi. The questionnaire was prepared based on the Failure Mode and Effect Analysis (FMEA) method, which was modified based on the researcher's case study. The method analyzes the results obtained, namely the severity (S), occurrence (O), and detection (D) values for each potential failure. The questionnaire is filled out by respondents by considering a scale value of 1-10.

#### 3.2 Secondary Data

Secondary data is data obtained through intermediary media or indirectly owned by institutions related to the topic being studied. The secondary data needed in this study are company profiles, data on damage time and length of repair of air conditioners, and data on the frequency of damage to air conditioner components.

This study used the RCM method to determine what must be done to ensure that each physical asset continues to work as desired or a process to determine the maintenance that must be done so that it can increase the lifetime of a machine. The RCM method has the following steps ([Ahmadi, 2017](#)):

1. System selection and information gathering.  
Information gathering serves to get a deeper picture and understanding of the system and how the system works.
2. System boundary definition.  
Used to define the boundaries of a system that will be analyzed with RCM, containing what must be included and what is not included in the system.
3. System description and functional block diagram.  
System description and block diagram is a representation of the main functions of the system in the form of blocks that contain the functions of each subsystem that make up the system.
4. System functions and functional failures.  
System function is the performance that the system is expected to be able to operate. Functional failure is defined as the inability of a component or system to meet the expected performance standard.
5. Failure Mode Effect and Analysis (FMEA).  
Failure Mode Effect Analysis (FMEA) is a methodology used to evaluate failures that occur in a system, design, process, or service. Identification of potential failures is done by giving a value or score for each failure mode based on the occurrence rate, severity, and detection rate. One technique that is widely used to conduct a qualitative assessment of system reliability. FMEA I includes identifying the causes of failure and the effects of failure. In FMEA, the calculation of Risk Priority Number (RPN) is carried out to determine the priority level of

a failure. RPN is a relationship between three variables, namely severity, occurrence and detection, which shows the level of risk that leads to corrective action.

6. Logic Tree Analysis (LTA).

The preparation of Logic Tree Analysis (LTA) is a qualitative process used to determine the consequences of each failure mode. The purpose of LTA is to classify failure modes into several categories so that a priority level can be determined later for handling each failure mode based on its category. Criticality analysis places each failure mode into one of four categories, as follows:

- Evident: under normal conditions, is the operator aware of the fault in the system?
- Safety: does this failure mode cause safety issues?
- Outage: does this failure mode cause all or some part of the machine to stop?
- Category, which is the categorization obtained after answering the questions asked in the component section. Category is divided into 4, namely:
  - Category A (safety problem), namely components that can cause safety problems to operators and the environment.
  - Category B (outage problem) is a component that can cause failure of all or part of the system.
  - Category C (economic problem) is a component that can cause failure in all or part of the system but causes losses to the company due to reduced component function.
  - Category D (hidden failure) is a component whose functional failure is not realized and is difficult for the operator to detect because it is hidden from the operator's vision.

7. Task selection.

Task selection is the last stage of the RCM analysis process. This process will determine the appropriate action for a particular damage mode. In its implementation, action selection can be done in four ways, namely:

- Time Directed (TD).  
An action aimed at direct prevention of the source of equipment damage based on the time or age of the component.
- Condition Directed (CD).  
An action that aims to detect damage by checking the tool. If the inspection finds symptoms of equipment damage, then proceed with repair or replacement of components.
- Failure Finding (FF).  
An action that aims to find hidden equipment damage by periodic inspection.

## 4. Results

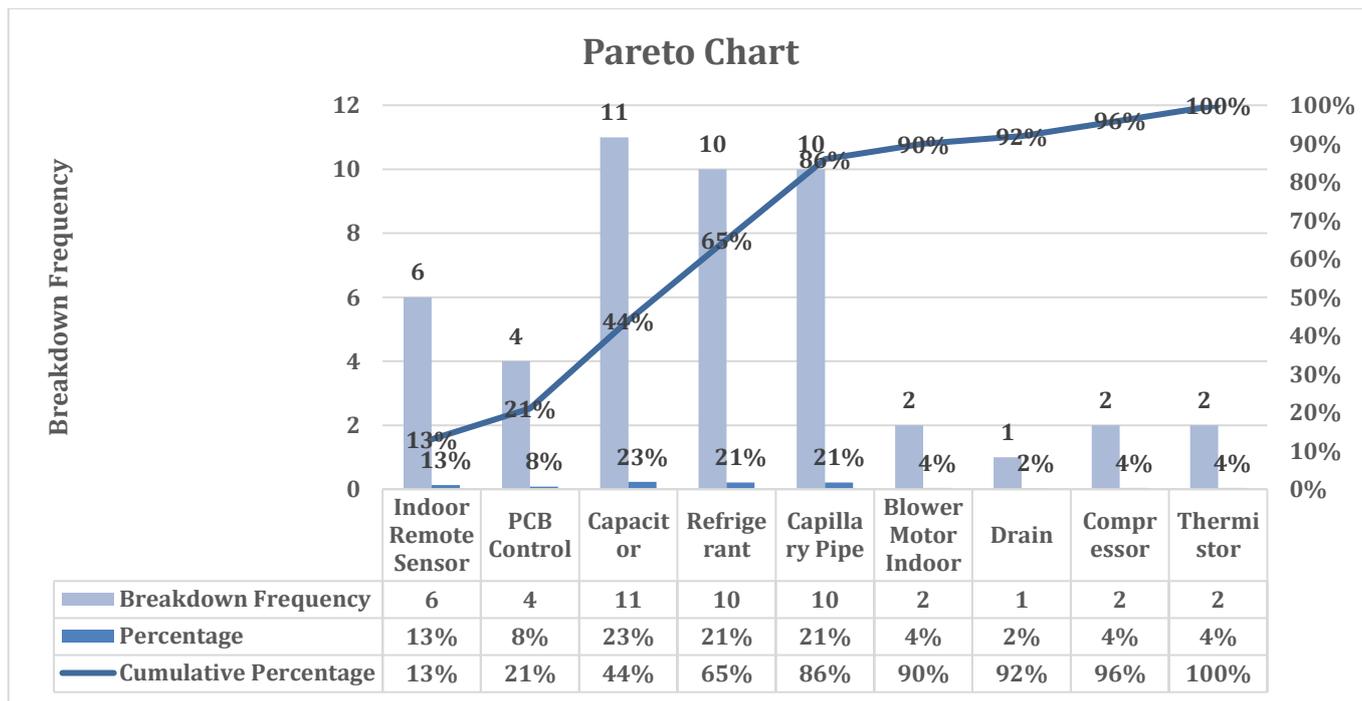
This section presents the results following the aforementioned methodology. The section is organized into nine parts.

### 4.1 Identification of breakdown

The first step is the identification process to prioritize problems by looking at the frequency of failures in the air conditioning components. This data is obtained through interviews with the respondents, namely Mr. Sumadi. Based on the identification results, 9 breakdown frequency significantly impacts the systems. The results of the identification of breakdown are shown in Table 1 and Figure 1.

**Table 1.** Data on The Frequency of Breakdown to Air Conditioning Components

No	Components	Breakdown Frequency	Cumulative	Percentage	Cumulative Percentage	Total Hours
1	Indoor Remote Sensor	6	6	13%	13%	6
2	PCB Control	4	10	8%	21%	40
3	Capacitor	11	21	23%	44%	11
4	Refrigerant	10	31	21%	65%	10
5	Capillary Pipes	10	41	21%	86%	20
6	Blower Motor Indoor	2	43	4%	90%	4
7	Drain	1	44	2%	92%	1.5
8	Compressor	2	46	4%	96%	4
9	Thermistor	2	48	4%	100%	2
<b>Total</b>		<b>48</b>		<b>100%</b>		



**Figure 1.** Pareto Chart

Based on the data and pareto diagrams above, these results will then be processed to determine critical components using FMEA calculations.

#### 4.2 System Selection and Information Gathering

In this study, the system of the air conditioner unit will be analyzed. Air conditioner is a device used to regulate or condition air quality, which includes air circulation, air humidity, air cleanliness, and purifying air (purification) so that temperature, humidity, and air circulation remain comfortable and under control. Information gathering serves to get a deeper picture and understanding of the system and how the system works. The workings of an air conditioning system are as follows:

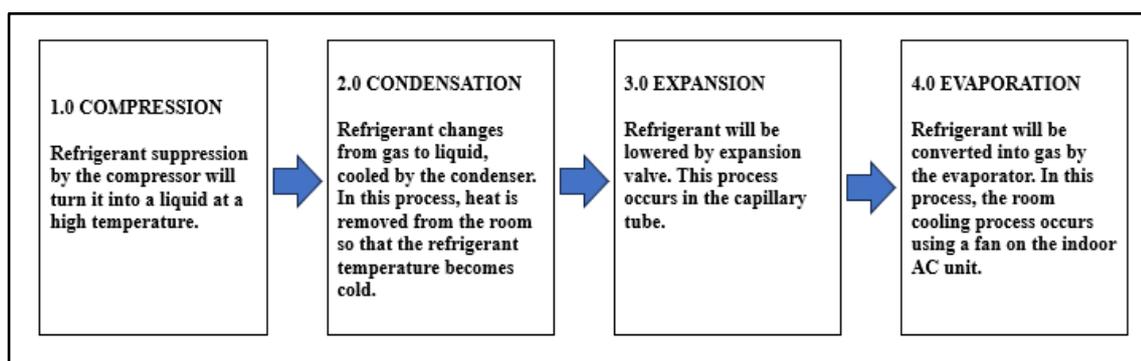
1. The compressor compresses refrigerant gas or vapor, which is at high temperature and high pressure, because it absorbs heat from the evaporator plus the heat generated during the exhaust step.
2. Refrigerant gas flows into the condenser, in the condenser the refrigerant gas is condensed into a liquid or a change in form (phase), namely refrigerant condensation.
3. Refrigerant liquid flows into the receiver to be filtered between refrigerant liquid and oil until the evaporator requires refrigerant to be evaporated.
4. The expansion valve lowers the pressure and temperature or temperature of the pressurized and high-temperature liquid refrigerant to low.
5. This cold condensed refrigerant gas flows into the evaporator. The refrigerant evaporates and absorbs heat from the outside air or foggy air so that the outside temperature will cool down.

#### 4.3 System Boundary Definition

Setting system boundaries is necessary so that there are boundaries, and the identified components are clear and do not overlap. Based on the results of interviews and observations that have been processed, it is known that the components that are often damaged in air conditioners are indoor remote sensors, PCB controls, capacitors, refrigerants, capillary pipes, indoor blower motors, drains, compressors, and thermistors.

#### 4.4 System Description and Functional Block Diagram

A system description is carried out to identify critical equipment components that have an influence on equipment performance. Existing information is used as the basis for making functional flow block diagrams to identify the system in detail. Functional flow block diagram is a diagram that illustrates the process of a complete system. This diagram helps to visualize a clear function structure. The FFBD of the air conditioner is shown in Figure 2.



**Figure 2.** Functional Flow Block Diagram (FFBD) Air Conditioner

#### 4.5 System Work Breakdown Structure (SWBS)

System work breakdown structure (SWBS) is a structure that describes a number of components, machines, process units, and subsystems that can cause failure in a working system. At this stage, a set of component lists will be described for each part of the subsystem function failure in a working system. This system consists of two main

components, namely diagrams and code of the subsystems that experience breakdown. The SWBS of air conditioner as shown in Table 2.

**Table 2.** System Work Breakdown Structure (SWBS)

System	Code	Sub System	Code	Component
Air Conditioner	A	Indoor Unit	A.1	Indoor Remote Sensor
			A.2	PCB Control Sensor
			A.3	Indoor Capacitors
			A.4	Refrigerant
			A.5	Blower Motor Indoor
			A.6	Thermistors
	B	Outdoor Unit	B.1	Outdoor Capacitors
			B.2	Capillary Pipe
			B.3	Drain
			B.4	Compressor

#### 4.6 Description of System Functions and Functional Failure

System function is the performance expected by the system to operate. Functional failure is defined as the inability of a component or system to meet the expected performance standard based on data of system work breakdown structure. System functions and functional failure are shown in Table 3.

**Table 3.** System Functions and Functional Failure

Function Code	Function Description Code	Function Description	Functional Failure Code	Functional Failure
A	A.1	To set the air conditioner according to the buttons on the remote air conditioner	A.1.1	The sensor is not connected or connected to the remote
	A.2	To regulate and control the electrical system of the air conditioning unit	A.2.1	The fuse is totally off, and the PCB control sensor is flashing
	A.3	Serves to store electric charge temporarily and as a prime mover or starter of the compressor	A.3.1	The bulging capacitor body keeps the outdoor fan not moving and making noise.
	A.4	As a fluid to absorb heat from the air in the room, so the temperature in the room becomes cold	A.4.1	Refrigerant leaks and runs out
	A.5	To circulate air in the room so that air can circulate through the evaporator	A.5.1	There is no airflow from the indoor unit, the cable reel is broken making the blower motor spin weakly and can't even rotate
	A.6	As a room temperature change detector and automatic temperature control in the air conditioner	A.6.1	The outdoor unit turns on and off unstable, so the blinking timer light sends an error code signal
B	B.1	Serves to temporarily store electric charge and act as a prime mover or starter for outdoor fan motors	B.1.1	The bulging capacitor body keeps the outdoor fan not moving and making noise
	B.2	To reduce refrigerant pressure and regulate refrigerant flow to the evaporator to produce cold air	B.2.1	Leaking and clogged pipes because dirt or compressor oil rises into the pipeline and settles
	B.3	To dispose of condensed water from the indoor air conditioner to the nearest drainpipe or water shaft	B.3.1	The drain is clogged because it is clogged with mucus, making the condensation water flow imperfect
B	B.4	As a circulation center that pumps and distributes refrigerant to all parts of the air conditioner	B.4.1	When the air conditioner turned on, outdoor unit lose power and generate bad electricity. On outdoor units, vibrating condenser, and loud noise. In the indoors, air conditioner emits warm air

#### 4.7 Failure Mode and Effect Analysis (FMEA)

Based on data on system functions and functional failure, the functional failure of each component is known, and then an FMEA analysis is carried out. FMEA analysis was made based on the failure, the impact of the failure, and the causes of the failure that have occurred (historically) in the air conditioning facility at the Engineering Faculty, Mulawarman University. The failure function, the impact of the failure function, and the causes of the failure function were obtained through the results of interviews with the Air Conditioning Technician of the Engineering Faculty, namely Mr. Sumadi, who had processed the results of processing. The FMEA results are shown in Table 4.

**Table 4.** Failure Mode and Effect Analysis (FMEA)

No	Part	Function	Functional Failure	Failure Effect	S	Failure Cause	O	Detection	D	RPN
1	<b>Compressor</b>	As a circulation center that pumps and distributes refrigerant to all parts of the air conditioner	When the air conditioner is turned on, the outdoor condenser unit loses power and makes bad electricity. On the outdoor unit, the condenser vibrates and makes a loud noise. Inside the room, the air conditioner emits warm air	The circulation process is not smooth because it cannot pump refrigerant through the system so it cannot produce cold air	9	Over heating on the compressor, excessive electrical power, lack of compressor oil and a blockage in the flow	5	Unit disassembly	9	405
2	<b>Thermistors</b>	As a room temperature change detector and automatic temperature control in the air conditioner	The outdoor unit turns on and off unstable, so the blinking timer light sends an error code signal	Temperature regulation becomes problematic, and the air conditioner has difficulty to detecting changes in room temperature	7	Excessive component life and exposed to excessive electrical voltage	7	Unit disassembly	4	196
3	<b>Indoor Remote Sensor</b>	To set the air conditioner according to the buttons on the remote air conditioner	The sensor doesn't want to connect or connect to the remote	Air conditioner can not be turned on.	2	The sensor is exposed to water when sprayed on the evaporator and the service life of the components is exceeded	4	Visually	3	24
4	<b>Capacitors</b>	As the prime mover or starter of the compressor	The bulging capacitor body keeps the outdoor fan not moving and making noise	The air conditioner cannot be turned on for a long time and emits warm air	7	The capacitor voltage value does not match the air conditioner, the voltage is unstable, and the service life is exceeded	7	Unit disassembly	3	147

**Table 4.** Failure Mode and Effect Analysis (FMEA) (continued)

No	Part	Function	Functional Failure	Failure Effect	S	Failure Cause	O	Detection	D	RPN
5	<b>PCB (Printed Circuit Board) Control</b>	To manage and control the electrical system of the air conditioning unit	The fuse is totally off, and the PCB control sensor is blinking	The air conditioner can not turn on and can not switch on and off automatically because the sensor is not connected	8	Electrical instability and damage to the IC program	5	Unit disassembly	8	320
6	<b>Pipa Kapiler</b>	To reduce refrigerant pressure and regulate refrigerant flow to the evaporator to produce cold air	The pipe is clogged and leaks	A clogged capillary pipe cannot drain the refrigerant properly so that the amount of refrigerant that enters the evaporator becomes small and frost appears	6	Blockage of dirt or compressor oil that rises into the pipeline and settles	9	Unit disassembly	4	216
7	<b>Blower Motor Indoor</b>	To circulate air in the room so that air can circulate through the evaporator	There is no airflow from the indoor unit, the cable reel is broken making the blower motor spin weakly and can't even rotate	Heat exchange is obstructed. In the evaporator, an ice block occurs, and the refrigerant does not get enough heat to change form	5	Dead or weak capacitors, worn bearings and burnt blower motor windings.	4	Unit disassembly	9	180
8	<b>Drain</b>	To dispose of condensation water from the indoor air conditioner to the nearest water drainpipe / shaft	The drain is clogged	Unable to dispose of condensation water from the indoor air conditioner to the nearest Water drainpipe / shaft	5	There is no routine maintenance so that there is a blockage of mucus in the drain which makes the condensation water flow imperfect	4	Unit disassembly	4	80
9	<b>Refrigerant</b>	As a fluid that is used to absorb heat from the air in the room so that the	Refrigerant leaks and runs out	Cause the air conditioner can not cool the room	5	The pipe flaring is cracked, the installation pipe is corroded, refrigerant gas leaks occur in the	4	Unit disassembly	3	60

temperature inside becomes  
low or cold

evaporator or condenser  
component

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Based on Table 4, the results of the FMEA show that the highest to lowest RPN values are compressor components with an RPN value of 405, PCB control components with an RPN value of 320, capillary pipe components with an RPN value of 216, thermistor components with an RPN value of 196, blower motor components with an RPN value of 180, capacitor components with an RPN value of 147, drain components with an RPN value of 80, refrigerant components with an RPN value of 60 and remote indoor sensor components with an RPN value of 24. This value identified the order of criticality of a component. Researchers determine critical components based on the 5 highest RPN values, namely compressor, PCB control, capillary pipes, thermistors, and blower motors.

#### 4.8 Logic Tree Analysis (LTA)

Logic Tree Analysis (LTA) aims to prioritize each critical component failure mode and review the function and malfunction by answering the questions provided in the LTA. Filling in the LTA table was carried out by an air conditioner technician from the Engineering Faculty, Mulawarman University, namely Mr. Sumadi. The logic tree analysis is shown in Table 5.

**Table 5.** Logic Tree Analysis (LTA)

No	Components	Evident	Safety	Outage	Category
1	Compressors	Y	T	Y	C
2	PCB Control	Y	T	Y	B
3	Blower Motor	Y	T	Y	B
4	Thermistors	Y	T	Y	B
5	Capillary Pipe	Y	T	Y	B

Based on Table 5, the results of the LTA analysis show that damage to the air conditioner unit is an outage problem which can result in partial failure or total failure of the system and is an economic problem, namely a failure that causes losses to the company.

#### 4.9 Task Selection

Task selection is used to determine maintenance policies that are effectively implemented to minimize the possibility of failure occurring and to select tasks that are efficient in terms of maintenance costs. Failure modes are directly related to Time Directed (TD), Condition Directed (CD), and Failure Finding (FF). The task selection results are shown in Table 6.

**Table 6.** Task Selection RCM

Major Sub System	Spare Part	RPN	LTA Category	Failure Causes	Action Plan
Indoor Unit	PCB Control	320	B	Electrical instability and exceeding the mains voltage limit	CD
	Blower Motor Indoor	180	B	Dead or weak capacitors, worn bearings, and burnt blower motor windings	CD
	Thermistor	196	B	The age of the component is valuable and exposed to excess voltage	TD
Outdoor Unit	Compressor	405	C	Lack of compressor oil and a blockage in the flow	CD
	Capillary Pipes	216	B	Blockage of dirt or compressor oil that rises into the pipeline and settles	CD

Based on the results of the recapitulation of RCM task selection in Table 6, it is known that the right action plan for the malfunction of PCB control components, blower motors, capillary pipes, and compressors is Condition

Directed (CD). The form of action taken by the condition directed (CD) action plan is to detect damage by conducting visual inspections, checking tools, and checking existing data. If the symptoms of damage are detected, then repair or replacement of components is carried out. For thermistor components, use a time directed (TD) action plan. The form of action taken in time directed is to avoid component failure by focusing on component replacement activities that are carried out regularly.

## 5. Discussions

This section presents a discussion related to the results obtained. The section is organized into three parts.

### 5.1 Failure Mode and Effect Analysis (FMEA)

Based on historical data on damage to air conditioner components for the period January 2021 - July 2022, there are five components that have the most frequency of damage, namely compressor, PCB control, capillary pipes, thermistors, and blower motors. So, a Failure Mode and Effect Analysis (FMEA) analysis was carried out using a questionnaire based on the results of observations and interviews to identify the failure causes and failure effects of the five critical components, as well as calculating the Risk Priority Number (RPN) to determine the priority level of the failure of these components. Failure modes are identified by assigning a value or score to each failure mode based on severity, occurrence, and detection level.

The malfunction that occurs in the compressor is when the air conditioner is turned on, and the outdoor condenser unit loses power and makes bad electricity. On the outdoor unit, the condenser vibrates and makes a loud noise. Inside the room, the air conditioner emits warm air. This malfunction causes the compressor to be unable to pump refrigerant through the system, so it cannot produce cold temperatures for the room. This malfunction can occur due to overheating, excessive electrical power, lack of oil in the compressor, and a blockage in the system flow. Failure detection is done by dismantling the air conditioner device. Based on the results of the FMEA questionnaire, the compressor has a severity value of 9, occurrence of 5, and detection of 9 with a total RPN value of 405. Based on the RPN value, the compressor has the largest RPN value compared to the other components.

The malfunction that occurs on the control PCB is the fuse, or the fuse is totally dead, and the control PCB sensor flashes. This malfunction causes the air conditioner to not turn on and cannot switch on and off automatically because the sensor does not work. This malfunction can occur due to electrical instability, crossing the electric voltage limit, and damage to the program IC. A form of failure detection through disassembling the PCB control device. Based on the results of the FMEA questionnaire, the PCB control sensor has severity 8, occurrence 5, and detection 8 values with a total RPN value of 320.

The malfunctions that occur in capillary pipes are clogged pipes and leaks. This malfunction causes the capillary tube to become clogged, and the refrigerant cannot flow properly, so the amount of refrigerant that enters the evaporator becomes small, and frost appears. This malfunction can occur due to clogged dirt or compressor oil that rises into the pipeline and settles. Failure detection is done by dismantling the air conditioner device. Based on the results of the FMEA questionnaire, the capillary tube has a severity value of 6, occurrence of 9, and detection of 4 with a total RPN value of 216.

The malfunction in the thermistor is when the outdoor unit turns on and off unstable so that the LED flashes send an error code signal. This malfunction causes temperature regulation to be problematic and the air conditioner has difficulty adjusting the temperature output. This malfunction can occur because the component's service life is exceeded and exposed to excessive electrical voltage. Failure detection is done by dismantling the air conditioner device. Based on the results of the FMEA questionnaire, the thermistor has a severity value of 7, occurrence of 7, and detection of 4, with a total RPN value of 196.

The malfunction that occurs in the blower motor is that there is no airflow from the outdoor unit, the broken cable reel makes the blower motor spin weakly and cannot even rotate. This malfunction causes heat exchange to be blocked, ice blocks occur in the evaporator and the refrigerant (freon) does not get enough heat to change form. This malfunction can occur due to dead or weak capacitor components, worn bearings, and burned-out blower motors.

Failure detection is done by dismantling the air conditioner device. Based on the results of the FMEA questionnaire, the blower motor has a severity value of 5, occurrence of 4, and detection of 9 with a total RPN value of 180.

### 5.2 Logic Tree Analysis (LTA)

Compressors are included in category C. Category C is an economic problem, namely if a component failure causes economic problems for the company. Compressor component failure can cause high repair costs that can be detrimental to the company. PCB controls are included in category B. Category B is an outage problem, namely if a component failure causes all or part of the machine to stop, which can cause the electrical system and work process settings in the air conditioner to stop. Capillary pipes are included in category B. Category B is an outage problem, that is, if a component failure results in all or part of the machine stopping, i.e., a clogged capillary pipe cannot drain the refrigerant properly so that the amount of refrigerant entering the evaporator becomes small and frost appears. A thermistor is included in category B. Category B is an outage problem, namely, if a component failure causes all or part of the machine to stop, the temperature regulation process becomes problematic, and the air conditioner has difficulty detecting changes in room temperature. Blower motors are included in category B. Category B is an outage problem, namely if a component failure causes all or part of the engine to stop, namely, heat exchange is hampered. In the evaporator, an ice block occurs, and the refrigerant does not get enough heat to change form.

### 5.3 Task Selection

Based on the malfunction and the maintenance action's appropriateness, the thermistor component uses a time directed (TD) action plan. Time directed (TD) is an action aimed at direct prevention of the source of equipment damage based on time or component age. For compressor components, PCB control, capillary pipes and blower motors, use an action plan condition directed (CD). Condition directed (CD) is the act of detecting damage by performing a visual inspection, inspecting tools, and checking existing data. If signs of damage are found in the detection, repair or replacement of components is carried out.

Maintenance actions that can be taken for compressor components are periodic inspections of compressor components at least once a month. Inspections are carried out in the form of checking the outdoor air conditioner unit and cleaning it to avoid bushes, twigs, dirt, or other objects that can cover the outdoor unit. In addition, the action that needs to be taken for compressor maintenance is regularly checking the refrigerant capacity in the air conditioner. If the number of refrigerant decreases, it is certain that there is a leak. This also affects the performance of the compressor and makes the electricity bill large.

Maintenance actions that can be taken for PCB control components are conducting periodic inspections on PCB control components by routinely checking fuses or fuses using a multimeter tool. A multimeter is a measuring device used to determine the size of electrical voltage, resistance, and electric current. Failures due to program IC damage can be overcome by replacing the IC power component. Program IC in PCB control is a microcontroller that regulates the working system of the air conditioner unit.

Maintenance actions that can be taken for capillary pipe components are conducting periodic inspections to identify potential pipe dead ends and leaks due to dirt or compressor oil that rises into the pipeline and settles. This failure can be overcome by using the flushing technique. The flushing technique is a way to overcome the condition of the air conditioner that is clogged due to a pile of dirt and compressor oil in the pipe. Before performing the flushing technique, an inspection is carried out first using a manifold gauge. Inspection using a manifold gauge will show the condition of the clogged pipe based on the needle.

Maintenance actions that can be taken for thermistor components are direct prevention of the source of damage, such as replacing components based on their use time or the age of the component to avoid potential damage that can affect other components such as evaporators. The age of the thermistor component depends on its use and maintenance of the air conditioner unit.

Maintenance actions that can be taken for blower motor components are routine periodic inspections of components. Inspections are carried out in the form of inspection and cleaning. The inspection carried out involves checking the cleanliness of the motor blower engine, checking the cables (if there is damage, the cable must be connected immediately), checking the fan rotation, and checking the performance of the motor blower. The fan rotation check is carried out to check the strength of the rotation, if the rotation is weak and must be assisted by hand

so that it can spin fast, then the capacitor on the engine must be replaced. Cleaning is done by cleaning the blower motor and blower from dust, dirt, and rust those sticks. The machine must also be routinely lubricated so that it can rotate more optimally.

## 6. Conclusion

Based on the results of research and discussion using the RCM method and FMEA analysis, the following conclusions can be drawn:

1. Functional failures and the level of failure were obtained based on the RPN value of the FMEA questionnaire. The malfunction of the compressor component is that the compressor cannot turn on and the outdoor air conditioner unit buzzes and vibrates when turned on. The RPN value of the compressor component is 405. The malfunction of the PCB control component is that the fuse or fuse is completely dead, and the PCB control sensor is blinking. The RPN value of the PCB control component is 320. The malfunction of the blower motor component is that there is no air blowing from the outdoor unit, the broken cable reel makes the blower motor spin weakly or even unable to rotate. The malfunction of the thermistor component is that the outdoor unit turns on and off unstable so that the timer lights blink sending an error code signal. The RPN value of the thermistor component is 196. The malfunction of the capillary pipe component is that the capillary pipe is stuck and leaks. The RPN value of the capillary pipe component is 216.
2. Based on the Reliability Centered Maintenance (RCM) analysis results, a new task selection policy is obtained, namely the thermistor component using the Time Directed (TD) action plan. Time directed (TD) is an action that aims to take direct prevention of sources of equipment damage based on the time or life of the component. As for compressor components, PCB control, capillary pipes, and blower motors, using the Condition Directed (CD) action plan. Condition directed (CD) is an action that aims to detect damage by checking the tool. If the inspection finds symptoms of equipment damage, then proceed with repair or replacement of components.
  - Maintenance actions that can be carried out for compressor components are conducting periodic inspections on compressor components at least once a month. The inspection is carried out by checking and cleaning the outdoor air conditioner unit.
  - Maintenance measures that can be taken for PCB control components are periodic inspections using a multimeter tool.
  - Treatment measures that can be taken for capillary pipe components are periodic inspections and cleaning using flushing techniques.
  - Maintenance actions that can be taken for the thermistor components are direct prevention of the source of the damage, such as replacing components based on the time they are used or the age of the thermistor components.
  - Maintenance actions that can be carried out for the blower motor components are routine periodic inspections, namely checking cable connections and cleaning the blower motor and indoor blower machines.

This proposed maintenance program can be a reference for other institutions with similar cases of not having a maintenance program for air conditioner facilities.

### Acronym

- RCM : *Reliability Centered Maintenance*
- FMEA : *Failure Mode and Effect Analysis*
- RPN : *Risk Priority Number*

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