PREVENTIVE MAINTENANCE IMPLEMENTATION AND ITS EFFECT ON MAINTENANCE AREA OUTCOMES: A CASE STUDY OF LAKE MAINTENANCE IN PUTRAJAYA CENTRAL WETLAND

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2024

Faculty of Mechanical Technology and Engineering

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

Faculty of Mechanical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: PREVENTIVE MAINTENANCE IMPLEMENTATION AND ITS EFFECT ON MAINTENANCE AREA OUTCOMES: A CASE STUDY OF LAKE MAINTENANCE IN PUTRAJAYA CENTRAL WETLAND

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

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Date : 10/1/2024

DEDICATION

I dedicate this report to my beloved parents, Mohd Jamain Bin Yusof and Suhaila Binti Zainuddin, for their unwavering support, endless love, and constant encouragement throughout my educational journey. Their strength has been a guiding light, propelling me forward in my pursuit of knowledge.

I would also like to express my sincere gratitude to Miss Nur Atiqah Nabila Binti Hazman, Manager of *Pusat Penyelenggaraan Tasik, Putrajaya*, for her invaluable assistance in making this project a reality. Her guidance and support were instrumental in overcoming challenges and achieving success.

To my sisters, friends, and classmates, thank you for the shared words of advice and encouragement. Your friendship and belief in me fueled my determination to persevere and reach this milestone.

Lastly, my deepest appreciation goes to Almighty God for the strength, clarity of mind, and protective hand that have guided me throughout my life. Without Your blessings and provision of good health, this achievement would not have been possible.

ABSTRACT

The proposed research aims to investigate the implementation of preventive maintenance and its impact on maintenance outcomes in the lake maintenance areas of *Pusat Penyelenggaraan Tasik Putrajaya*. The study will utilize a case study approach, selecting specific areas for in-depth analysis. These areas will represent diverse types and sizes, exhibiting varying maintenance history and conditions. The research has three objectives which is to determine the frequency and types of preventive and corrective maintenance activities conducted in the *Pusat Penyelenggaraan Tasik Putrajaya* areas. Secondly, to develop a more organized and efficient preventive maintenance schedule for the *Pusat Penyelenggaraan Tasik Putrajaya* areas and lastly to enhance the quality of preventive maintenance practices in the Flamingo Pond area. Data will be collected on the historical maintenance of the lake areas, including the type and frequency of repairs, alongside information on preventive maintenance activities such as inspections, cleaning, and regular maintenance. The findings from the case studies will be analyzed to inform the implementation of preventive maintenance measures and identify their impact on maintenance outcomes. The findings of this study will be valuable for various stakeholders involved in lake maintenance, including workers, policymakers, and decision-makers. The research will provide evidence-based recommendations for optimizing both preventive and corrective maintenance practices, ultimately leading to improved maintenance outcomes through the effective implementation of preventive measures.

ABSTRAK

Penyelidikan yang dicadangkan bertujuan untuk menyiasat pelaksanaan penyelenggaraan pencegahan dan kesannya terhadap hasil penyelenggaraan di kawasan Pusat Penyelenggaraan Tasik Putrajaya. Kajian ini akan menggunakan pendekatan kajian kes, memilih kawasan khusus untuk analisis mendalam. Kawasan ini akan mewakili pelbagai jenis dan saiz, mempamerkan sejarah dan keadaan penyelenggaraan yang berbeza-beza. Penyelidikan ini mempunyai tiga objektif iaitu untuk menentukan kekerapan dan jenis aktiviti penyelenggaraan pencegahan dan pembetulan yang dijalankan di kawasan Pusat Penyelenggaraan Tasik Putrajaya. Kedua, untuk membangunkan jadual penyelenggaraan pencegahan yang lebih teratur dan cekap bagi kawasan Pusat Penyelenggaraan Tasik Putrajaya dan akhir sekali untuk meningkatkan kualiti amalan penyelenggaraan pencegahan di kawasan Kolam Flamingo. Data akan dikumpul mengenai sejarah penyelenggaraan kawasan tasik, termasuk jenis dan kekerapan pembaikan, di samping maklumat mengenai aktiviti penyelenggaraan pencegahan seperti pemeriksaan, pembersihan dan penyelenggaraan tetap. Penemuan daripada kajian kes akan dianalisis untuk memaklumkan pelaksanaan langkah penyelenggaraan pencegahan dan mengenal pasti kesannya terhadap hasil penyelenggaraan. Penemuan kajian ini akan berguna untuk pelbagai pihak berkepentingan yang terlibat dalam penyelenggaraan tasik, termasuk pekerja, pembuat dasar, dan pembuat keputusan. Penyelidikan akan memberikan cadangan berasaskan bukti untuk mengoptimumkan kedua-dua amalan penyelenggaraan pencegahan dan pembetulan, yang akhirnya membawa kepada hasil penyelenggaraan yang lebih baik melalui pelaksanaan langkah pencegahan yang berkesan.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

Firstly, I must express my heartfelt gratitude to my beloved parents for their unwavering love and unwavering support throughout my life. This journey would not have been possible without their constant presence and belief in me. I also want to extend my deepest appreciation to Allah SWT, the Almighty, my Creator and Sustainer. All the blessings and experiences I have received since the beginning of my life are testaments to your infinite grace. Thank you, Ya Allah, for guiding me toward this accomplishment.

My sincere gratitude goes to University Teknikal Malaysia Melaka (UTeM) for providing the invaluable platform and resources that allowed me to pursue my dream and reach this moment. Special thanks also to my esteemed supervisor, Ts. Ahmad Nizam Bin Jamaludin, and co-supervisor, Miss Nur Atiqah Nabila Binti Hazman, your guidance, insightful ideas, unwavering support, and constant encouragement were instrumental in navigating the challenges and triumphs of my final year project. I could not have achieved this without your invaluable mentorship.

This project is dedicated to my dear family, especially my mother, Mrs. Suhaila Binti Zainuddin, and my father, Mr. Mohd Jamain Bin Yusof. Your foresight, sacrifices and unwavering belief in my education have paved the way for this success. This victory is for you both. To all my cherished friends, thank you for your unwavering encouragement and kind words throughout this journey. Your friendship fueled my determination and pushed me forward.

Finally, I express my deepest gratitude to everyone who, directly or indirectly, contributed to this research. Your recommendations, advice, and assistance, both big and small, have been invaluable to me. Thank you for being a part of this incredible journey.

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LIST OF SYMBOLS AND ABBREVIATIONS

CMMS	-	Computerized Maintenance Management System
NCR	-	Non-Comformance Report
MTBF	-	Mean Time between Failures
MTTR	-	Mean Time to Repair
PM	-	Preventive Maintenance
CM	-	Corrective Maintenance
CBM	-	Condition Based Maintenance
WIP	-	Work-in-Process
HRA	-	Human Reliability Analysis
HEA	-	Human Error Analysis
RCFA	-	Root Cause Failure Analysis
RCM	-	Reliability Centered Analysis
FMEA	-	Failure Mode Effect Analysis
FMECA	-	Failure Modes, Effect and Critically Analysis
FTA	-	Failure Tree Analysis
N	-	Number of failures
H	-	Total hours of working time
C	-	Corrective Maintenance downtime
TCM	-	Total Corrective Maintenance actions
PD	-	Planned Downtime
PO(t)	-	Plant Operating time
PP(t)	-	Planned Production time
UD	-	Unplanned Downtime
OEE	-	Overall Equipment Effectiveness
EAM	-	Enterprise Asset Management
KPIs	-	Key Performance Indicators
RCA	-	Root Cause Analysis

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CHAPTER 1

INTRODUCTION

1.1 Background

This chapter provides a proper management of maintenance offers that companies significant potential for improving corrective maintenance, preventive maintenance and profitability for cost maintenance. Additionally, ineffective energy management is also addressed lead to energy waste. Preventive maintenance is the logical way to eliminate problems and save money. Research in maintenance management in the *Pusat Penyelenggaraan Tasik Putrajaya* has focused on preventive maintenance and corrective maintenance even the schedule maintenance. It's considered to be a big problem in that company. High-quality solutions must be produced while following the highest standards of quality, which requires balancing maintenance performance, risks, and costs. This study proposes a decision model that could assist in a comparative evaluation of preventive and corrective maintenance problems. Therefore, the main target for this project is to validate the effectiveness of using Root Cause Analysis (RCA) to manage schedule the preventive maintenance and corrective maintenance in their management. Based on the problem statement and research question, this chapter elaborates on the goals and objectives of the research, provides a more thorough description of the methodology and discusses the scope of the project.

1.2 Problem Statement

Observations at the research site reveal critical shortcomings in both preventive and corrective maintenance practices. Addressing these issues is crucial for efficient operation and cost reduction. The most common concern at *Pusat Penyelenggaraan Tasik Putrajaya* is ignoring the maintenance deadline. This results in poor planning and scheduling leading to frequently missed deadlines for preventive and corrective maintenance. The reliance on a reactive approach, giving precedence to problem-solving rather than proactive prevention, results in elevated equipment breakdowns, increased maintenance expenditures, and potential environmental hazards. Neglecting the preventive maintenance schedule allows minor issues to escalate into costly repairs and equipment failures.

Furthermore, the lack of a comprehensive preventive maintenance plan poses a significant challenge. The organization responsible for the lake maintenance area might view preventive maintenance as a dispensable expense, especially when facing budgetary constraints. This often leads to prioritizing corrective maintenance, initially perceived as more cost-effective. However, this shortsighted approach frequently leads to higher overall costs due to unforeseen breakdowns and the necessity for major repairs.

In conclusion, higher maintenance expenses are caused by the consequences of missing deadlines and not having an appropriate preventative maintenance schedule. Regular equipment failures increase costs by requiring component replacements or repairs. This reactive strategy means that maintenance expenses frequently exceed budgetary constraints. As a result, taking proactive steps to spot problems early on can significantly reduce equipment failures and keep repair costs within acceptable limits.

1.3 Research Objective

The objectives of this research:

1) To determine the frequency and types of preventive and corrective maintenance activities conducted in the *Pusat Penyelenggaraan Tasik Putrajaya* areas.
2) To develop a more organized and efficient preventive maintenance schedule for the *Pusat Penyelenggaraan Tasik Putrajaya* areas.
3) To enhance the quality of preventive maintenance practices in the Flamingo Pond areas.

1.4 Scope of Research

This initiative's major goal is to enhance Pusat Penyelenggaraan Tasik Putrajaya's preventive maintenance practices, with an emphasis on the Flamingo Pond and its surroundings. The main goal is to increase the pump system's efficiency, which is an important part that has difficulties in this place. Firstly, the project aims to reduce operational costs throughout the entire lake management zone. Secondly, it aims to create a maintenance schedule that is optimized for Flamingo Pond and the surrounding area. By achieving these goals, the project aims to ensure equipment longevity, lower operating costs, and improve the efficiency of maintenance efforts.

1.5 Significant of Study

Efficient preventive maintenance practices have been shown to significantly decrease the need for corrective maintenance. The objective of this study is to establish a structured corrective maintenance system for the lake maintenance area, ultimately leading to a decrease in equipment maintenance costs. Additionally, this research has the potential to enhance employee awareness in the area regarding the advantages and efficacy of incorporating Root Cause Analysis (RCA) within an organizational framework. Moreover, RCA can serve as a valuable tool for companies without a Computerized Maintenance Management System (CMMS) to enhance both corrective and preventive maintenance practices (CM and PM). Ultimately, this research project can offer the lake maintenance center valuable insights and strategies to minimize Non-Conformance Report (NCR) occurrences during process audits.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter, which delves into the basis of the research, provides an in-depth knowledge of the case study by means of a careful examination of relevant research obtained from reputable experts in the subject. Each relevant piece of information has been carefully selected and combined, mainly from books, academic publications, scholarly papers, and related sources of knowledge. This project concludes with a brief review of the body of research on maintenance, including asset optimization, management methods, planning and scheduling, Root Cause Analysis (RCA), and the changing function of computerized maintenance management systems (CMMS). This chapter, by thoroughly analyzing and combining these many viewpoints, establishes the foundation for a thorough investigation, ready to develop current understanding and provide insightful understandings of the particular.

2.2 Maintenance

Maintenance refers to a comprehensive range of technical and administrative measures, which encompass monitoring and control procedures. These actions are aimed at preserving an entity in a predetermined state or under certain conditions. Dependability data, such as Availability, Reliability, Maintainability, and Security, are significant factors that enable the entity to execute the necessary function (Rabie Hamidane et al., 2018). The maintenance process is an essential activity aimed at preserving the integrity of facilities, machines, or equipment. This process entails crucial adjustments or replacements that are indispensable in attaining optimal production conditions as projected beforehand. With proper maintenance, all the facilities and machines possessed by the organization can be operated in accordance with the predetermined schedule. Maintenance can be defined as a series of activities that aim to restore the component or machine to a condition in which it can execute its assigned function. Maintenance is a fundamental process that involves repairing faulty components, maintaining the pristine condition of machines and equipment, and proactively averting potential malfunctions. This is important for reducing production losses and mitigating downtime, which is crucial for optimal productivity. By doing so, it is possible to minimize production losses and mitigate downtime, which is essential for optimal productivity (Fajri, 2017). The maintenance of a system typically entails a range of activities, including repairing, maintaining, serving, testing, and measuring failure, in order to prevent any possible disruptions that could hinder the manufacturing process (Poór & Basl, 2019).

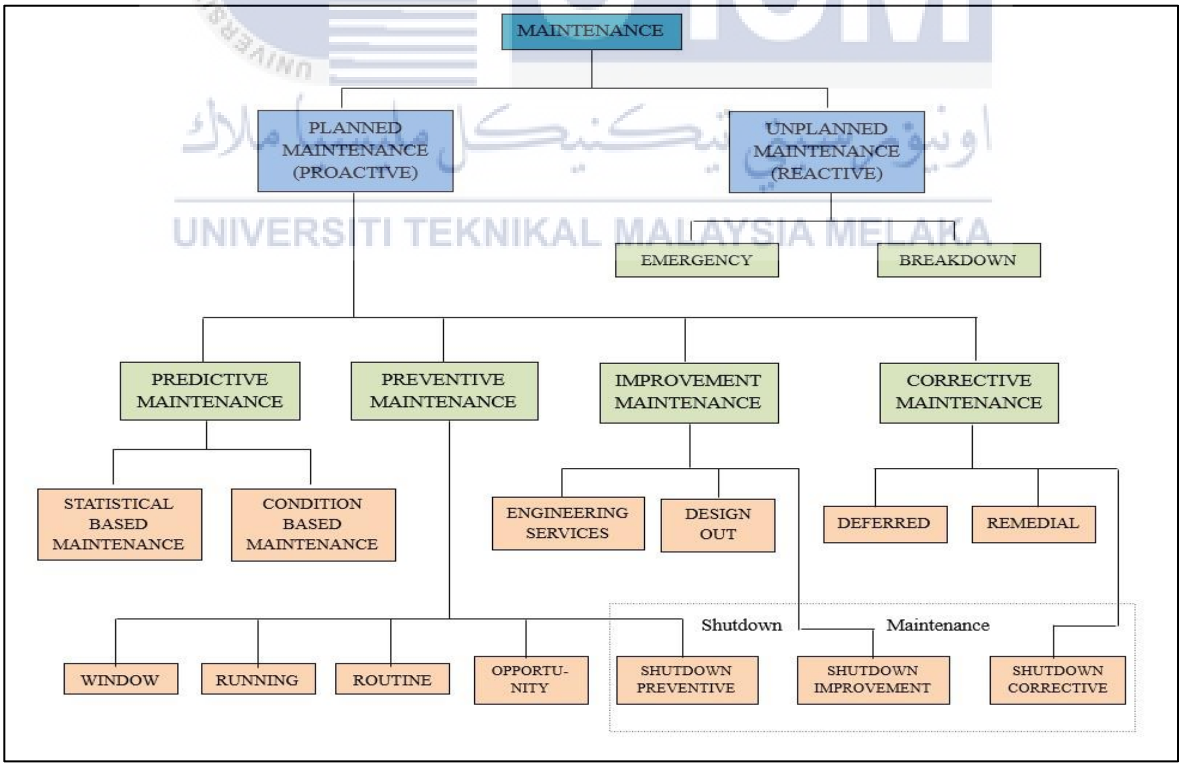


Figure 2.1 Types of machinery maintenance (Poór & Basl, 2019).

2.3 Framework of Maintenance Strategies

Maintenance encompasses two primary streams, namely corrective maintenance, which is sometimes referred to as breakdown maintenance, and preventive maintenance. Corrective maintenance is focused on restoring equipment that has ceased functioning, while preventive maintenance is carried out in advance of a potential failure to avert the occurrence of such an event. Consequently, maintenance strategies are primarily targeted at factors that are linked to equipment failure in plants (Ndlovu & Telukdarie, 2017). These factors include ensuring the reliability of components and systems to sustain operations, utilizing equipment prognostics to predict time-based failure occurrences by analyzing failure data and system characteristics, conducting systems diagnostics to classify failures and determine the necessary remedial actions to prevent lengthy downtime of equipment or components, and employing the concept of configurability or redundancy by managing subsystem configurations based on their failure severity in the overall system, thereby prioritizing equipment maintenance (Ndlovu & Telukdarie, 2017).

Effective plant management can lead to considerable cost savings and improved productivity of the facility. The expense of plant upkeep is consistently evaluated as a liability by upper-level management. However, a more optimistic outlook would be to regard maintenance efforts as a source of profit for an organization (Lawrence Kau, 2016). Estimating optimal maintenance policies for distinct failure modes poses a formidable challenge. To estimate optimum maintenance policies for various failure modes, one must possess a comprehensive understanding of various factors, such as safety concerns, environmental issues, Mean Time Between Failures (MTBF), and Mean Time to Repair (MTTR) for each machine component. Implementation of a range of maintenance measures can lead to improved machinery availability and reliability (Lawrence Kau, 2016).

Table 2.1 Maintenance Strategy Alternatives (Ndlovu & Telukdarie, 2017).

Maintenance Strategy	**Description**
Preventive Maintenance	Maintain equipment at periodic intervals to reduce the possibility of failure given the historic behaviour
Corrective Maintenance	The equipment is restored to a functional state or replaced after it has failed to operate.
Condition Based Maintenance	Maintenance done on equipment based on the historic data measured and monitored
Predictive Maintenance	Predicting risks of components failure in an equipment, given the historical behaviour of the equipment or system

2.4 Preventive Maintenance

Preventive maintenance is an essential maintenance undertaking that is regularly executed at predetermined intervals with the aim of identifying and addressing potential machine or component failure triggers (Fajri, 2017). Preventive maintenance is carried out at specified intervals to avoid the necessity of corrective maintenance. This is done through actions like cleaning parts, lubrication, and replacing worn-out components. An effective preventive maintenance program is unnoticeable. The preventive maintenance program aids in the prevention of environmental harm, personal injuries, production losses in quality and quantity, excessive maintenance expenses, and the deterioration of physical assets (Asokkumar & Parameswaran, 2003). On the other hand, preventive maintenance (PM) is a critical maintenance approach commonly used in manufacturing settings to systematize production processes and enhance equipment effectiveness. PM is typically associated with predetermined schedules based on fixed time intervals such as daily, weekly, monthly, or other designated intervals. The utilization of performance intervals facilitates the execution of preventive tasks as necessary. In general, when implementing PM, maintenance tasks are strategically planned and scheduled based on equipment needs and historical failure data (Basri et al., 2012).

The PM role is crucial in ensuring that the maintenance schedule is effectively integrated with the production schedule, resulting in a more efficient and effective manufacturing system. Hence, it is imperative to integrate production planning and PM activities in a cohesive manner, to prevent failures that necessitate re-planning (Basri et al., 2012). Implementing preventive maintenance can result in a decrease in equipment or process failure, leading to effective cost management of the machinery. Preventive maintenance can be an effective measure to manage the costs associated with machinery by reducing equipment or process failure. This can also lead to an increase in the life cycle of both the components and the machine, while minimizing the instances of downtime (Fajri, 2017).

2.5 Corrective Maintenance

The approach of corrective maintenance involves the replacement of a part only when it stops functioning, which is a traditional method for facility maintenance and still prevalent in modern times. Corrective maintenance (CM) is considered the most ancient variant of maintenance. The maintenance function's entire responsibility is delegated to the maintenance department, which includes a team of highly skilled professionals who are always prepared to take command whenever a maintenance issue arises during production (Magano Molefe, 2020). As failures inevitably occur, it is imperative for organizations to have corrective maintenance processes in place as an emergency plan to address unanticipated failures. Unfortunately, this approach results in facility downtime, decreased customer satisfaction, and lacks flexibility in terms of time and cost (Hao et al., 2010).

Corrective maintenance also known as breakdown maintenance, involves repairing malfunctioning equipment to restore its proper functioning. The corrective maintenance approach is often perceived unfavorably due to its substantial cost implications, extended downtime, labor-intensive nature, challenges in fault identification, complex installations, and requirement for overtime work. The correlation between maintenance and expenses is not limited to the procurement of equipment and services, but also extends to the time required for repairing equipment that is essential to the production process. As a result, this has an effect on the amount of production that is lost due to the inactivity of a particular equipment or component of the plant/system (Ndlovu & Telukdarie, 2017). Numerous corrective maintenance approaches can be implemented to reduce the impact of equipment malfunction. The application of various methodologies can be effective in minimizing the impact of equipment malfunction (Tabikh & Khattab, 2011) as Figure 2.3 shows the corrective maintenance cycle.

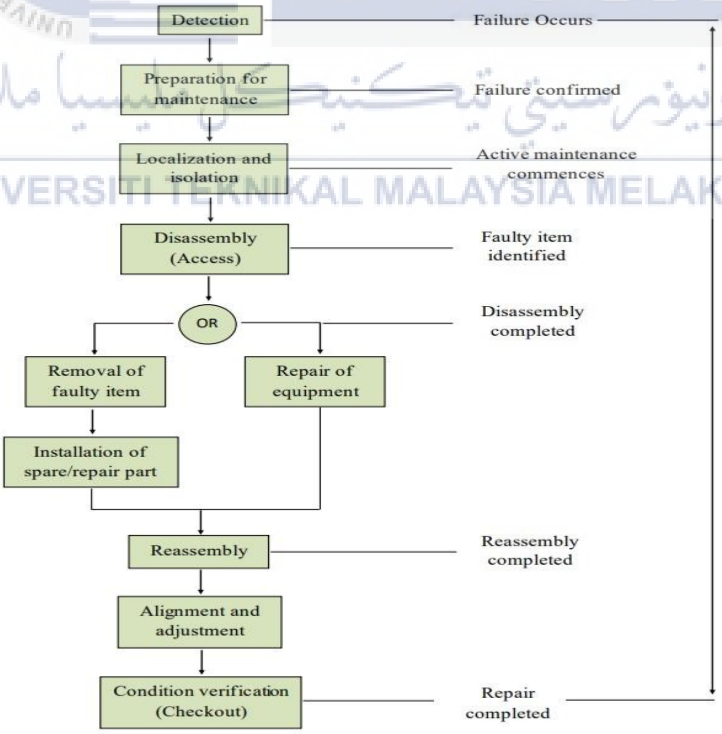


Figure 2.2 Corrective maintenance cycle (Tabikh & Khattab, 2011).

2.6 Condition Based Maintenance (CBM)

The practice of condition-based maintenance involves the evaluation of equipment condition and the monitoring of its performance patterns over time. The method's primary emphasis lies in tracking and detecting potential problem areas that may result in equipment failure or malfunction in advance. As a result, it curtails the unpredictability of maintenance activities based on the condition of the equipment (Ndlovu & Telukdarie, 2017). The primary objective of Condition Based Maintenance (CBM) is to provide maintenance recommendations by leveraging information acquired through the process of condition monitoring (Teixeira et al., 2020). Condition-based maintenance (CBM) has proven to be effective in assisting facility managers in identifying irregularity at an early stage, thus reducing the impact of operational disruptions. Condition-based maintenance (CBM) can significantly reduce maintenance expenses by avoiding costly failures such as collateral damage. Several notable companies across various industries, such as manufacturing, process, paper, and power generation, have made a shift from time-based preventive maintenance to adopting CBM protocols (Hao et al., 2010).

The main components of condition monitoring are routine equipment inspections performed with a combination of basic tools and advanced instruments as well as human sensory capacities. Condition monitoring is the process of analyzing and interpreting signals from transducers and sensors installed on operational machinery. It typically uses sensors placed outside of the machine, frequently away from the machine components that are being monitored, to monitor the health and condition of the machine. Using established techniques, the information provided by the sensor output is analyzed, and the evaluated output is interpreted, in order to determine the necessary course of action (Suresh Babu & Das, 2013).

2.7 Pros and Cons PM, CM and CBM

Table 2.2 Pros and Cons of PM, CM, and CBM (Hao et al., 2010).

PREVENTIVE MAINTENANCE	CORRECTIVE MAINTENANCE	CONDITION BASE MAINTENANCE
Fix it routinely before it breaks	Run to failure	Don't fix it if it is not going to break
+ Maintenance is controlled + Stored parts and cost can be controlled +Unexpected failures should be reduced	+ Facility is not over maintained + No initial invesment +Low costs	+Unexpected failures ar reduced + Parts and maintenance is do when it's needed +Facility life is extended
- Facilities are maintained where there is no fault - Unscheduled breakdowns cannot be avoided	- High risk pf secondary failure - Unscheduled and possibly long downtime	-High operation cost -Additional skill required

Notes: "+" : pros and "-": cons

2.8 Predictive Maintenance

In an organization, predictive maintenance aids in anticipating failure prior to an occurrence of catastrophic failure by collecting data through condition monitoring which facilitates planning of necessary equipment-related tasks to avert unexpected failures. This technique facilitates the planning of necessary equipment-related tasks to avert unexpected failures (Lawrence Kau, 2016). The practice of predictive maintenance involves the comparison of the trend in measured physical parameters with pre-established engineering limits. The primary objective of this exercise is the timely detection, analysis, and resolution of potential issues before they culminate in system failure. In order to achieve this goal, it is imperative that the engineering limits are established at a sufficiently low level such that routine monitoring can detect any anomalies before extensive damage has occurred. It is important to note that the effectiveness of predictive maintenance relies on the identification and resolution of the underlying issue causing the problem (Ali Jezzini et al., 2013). Predictive maintenance is a well-established concept that is widely recognized today. Within the maintenance field, it is commonly understood that relying only on reactive maintenance or implementing a preventive maintenance plan is insufficient (Poór & Basl, 2019).

2.9 Preventive Maintenance Planning and Scheduling

Scheduling preventive maintenance (PM) poses a formidable challenge in the realm of printed-circuit manufacturing, owing to the intricate nature of flexible printed circuit fabrication and systems, the interrelatedness of PM tasks, and the need to strike a harmonious balance between Work-in-Process (WIP) and demand/throughput requirements (Ab-Samat et al., 2012). Maintenance scheduling is a procedural approach that involves matching jobs with resources and allocating specific time slots for execution in a structured manner. The scheduling process comprises three stages, and the division is based on the time horizon of planning and implementation. These stages are: (1) Long-term or master scheduling, which spans across a period of 3 months to 1 year; (2) Weekly scheduling, which involves maintenance work for a single week; and (3) Daily scheduling, which encompasses work that must be completed daily (Hidayatullah et al., 2022). To achieve world-class standards, it is imperative that planning and scheduling be executed with great attention to detail. The assessment of the planning and scheduling of both regular and shutdown maintenance operations should be based on the following four distinct categories (Asokkumar & Parameswaran, 2003):

1. Planned and scheduled.
2. Planned but not scheduled maintenance.
3. Scheduled but not planned maintenance.
4. Break-in-work.

2.10 Maintenance Management

The comprehension of maintenance terminology comprises the identification of maintenance as a multifaceted process that encompasses the efficient management, careful administration, and skilled execution of technical activities aimed at conserving or restoring equipment to its essential state. The introduction emphasizes the crucial stipulations of ensuring safe and high-quality maintenance (Pacaiova & Glatz, 2015). Maintenance management embodies a proactive approach to preserving the quality, lifespan, and value of assets, and should be recognized as a crucial business function that provides ample opportunities to optimize cost, risk, and productivity considerations within organizations (Hasmi et al., 2014). Property management necessitates a strong desire to offer top-notch services to clients, as it is a key factor in retaining their loyalty (Oluwatobi et al., 2019). Maintenance management should possess knowledge not only of the principles of system management, but also of the tools and sources for making strategic decisions and conducting maintenance activities based on analytical approaches and methods. These include (Pacaiova & Glatz, 2015):

1. Root Cause Failure Analysis (RCFA)
2. Failure Modes and Effects Analysis (RCM/FMEA/FMECA –Criticality Analysis)
3. Fault Tree Analysis (FTA)
4. Human Error / Reliability Analysis (HEA/HRA)

There exists a necessity for a structured framework that could effectively direct maintenance organizations towards ensuring that each initiated and executed maintenance task adheres to a consistent, systematic, and comprehensive approach (Oluwatobi et al., 2019).

2.11 Root Cause Failure Analysis (RCFA)

Root Cause Failure Analysis (RCFA) is a widely used approach to identify the underlying cause of equipment failure. Its foremost aim is to reduce costs, Mean Time To Failure (MTTF) and Mean Down Time (MDT) for the organization. Successful implementation of RCFA can lead to significant cost savings or even the complete elimination of a failure. By investigating the failure, it is possible to prevent future failures by eliminating the root cause responsible for the initial failure (Lawrence Kau, 2016). RCFA is focused on identifying and eliminating the physical, human, and latent system roots that can result in equipment failure. The ultimate goal is to minimize the probability of occurrence of a failure by targeting corrective measures at the root cause. It is important to note that RCFA is a reactive approach to problem detection and resolution, as it involves analysis after an event has already occurred (Lawrence Kau, 2016).

2.12 Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a widely employed method for determining failures in complex systems. It is acknowledged as a highly effective approach for investigating the root causes of intricate system breakdowns. With the capability to analyze components, environmental conditions, and human factors that may contribute to system failure, FTA proves to be highly efficient in evaluating the reliability and security of complex systems. Utilizing a logical diagram to scrutinize various factors contributing to system failure, FTA facilitates prompt and accurate fault diagnosis and troubleshooting to identify potential causes of system failure. (Lawrence Kau, 2016). Fault trees play a crucial role in elucidating the sequence of events, encompassing both routine and abnormal occurrences, leading to the identification of a fault at the component level or an undesired event that warrants further investigation (Torell et al., 2017). The primary objective is to diagnose the worst event and pinpoint the direct consequences of failure until the failure mechanism is identified. The worst event is defined as the top event (Lawrence Kau, 2016). The output of FTA is the probability of the occurrence of the top-level failure. The following steps are required when conducting FTA (Lawrence Kau, 2016):

1. Identification of top-level failure
2. Development fault tree
3. Analysing fault tree

2.13 Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance (RCM) stands as a holistic engineering methodology striving to guarantee the ongoing operability of machinery and equipment. This strategic approach pursues diverse objectives, encompassing cost reduction, the improvement of asset reliability, and the heightened awareness within the organization concerning potential risks of malfunctions (Martins et al., 2020). This is accomplished by creating a maintenance strategy that systematically incorporates availability, reliability, quality, and safety principles. Essentially, the goal of RCM is to pinpoint and implement maintenance practices that efficiently sustain system functionality while staying within acceptable cost constraints. It's worth noting that RCM may not be advantageous if the expenses related to preventive maintenance surpass those linked to operational losses and repairs, unless such maintenance is obligatory due to regulatory, safety, or environmental requirements (Lawrence Kau, 2016).

The reliability analysis needs to be used to identify the times to failure behaviour of each component. The Reliability Centered Maintenance (RCM) methodology is widely acknowledged as the preeminent process for safeguarding the operational effectiveness of industrial production (Lawrence Kau, 2016).

Table 2.3 Essentials of RCM activities (Lawrence Kau, 2016).

	Activity	Scope
1	Maintenance team training / role definition	Selecting the appropriate maintenance personnel, designating them to a particular role, and providing them with adequate instruction to effectively execute their responsibilities.
2	Component identification	In order to comprehensively examine the sector, it is imperative to identify and classify all equipment, along with their respective sets, subsets, and components.
3	Function classification	The categorization of each component's role involves identifying an essential function that serves as the primary objective of the component installation. In addition, the necessary auxiliary functions are required to support the primary objective of the component installation.
4	Failure classification	Classify failures as hidden failures and apparent failures.
5	Failure analysis	To conduct an analysis on the behaviour of the time to failure of a component throughout its lifespan is warranted.
6	Component classification	Functional failures of the components can be Three groups can be used to classify these components: critical components, economically important components, and other components.omponents, and non-critical components.
7	Maintenance strategy classification	The selection of the optimal maintenance approach, whether it be corrective, preventive, or predictive, is of utmost importance.
8	Maintenance planning	The activities need to be organized into smaller maintenance packages for easier scheduling
9	Stock planning	To ascertain the quantity of inventory needed to meet the desired level of service, a determination must be made.
10	Indicators monitoring	This task involves developing and monitoring performance indicators for the maintenance process.

2.14 Failure Mode Effect Analysis (FMEA)

In the manufacturing sector, machinery or systems may encounter malfunctions stemming from various factors, including machine-related issues, materials, measurements, manpower, methods, and environmental conditions. To minimize the impact of such failures on product defect costs and operational risks in manufacturing processes, leading production and manufacturing companies have implemented methods for predicting failures. Numerous industrial firms and research institutions have dedicated significant resources to analyze failure modes and their repercussions on manufacturing and production systems (Elbadawi et al., 2018). Failure Mode and Effects Analysis (FMEA) is an effective approach for prioritizing failure modes, prescribing corrective measures to prevent catastrophic failures, and ultimately enhancing the quality of manufacturing and production processes. FMEA aims to comprehend the criticalities and dependencies of different system types, while also enabling the evaluation of process manipulation options to achieve an enhanced level of system reliability (Elbadawi et al., 2018).

2.15 Failure Modes, Effect and Criticality Analysis (FMECA)

Failure Modes, Effects, and Criticality Analysis (FMECA) stands out as a method to improve product reliability. This approach involves a comprehensive examination of potential failure modes within a system, along with the associated equipment throughout its design, manufacturing, and usage stages. During this analytical scrutiny, each cause and effect of failure modes undergoes careful evaluation, enabling the detection of potential vulnerabilities. Subsequent to this identification, recommendations for improvement are put forth. FMECA technology is commonly applied in both reliability and supportability analyses linked to equipment development. (Lawrence Kau, 2016). The FMECA methodology signifies an advanced evolution of the FMEA, focusing on evaluating potential risks associated with all failure modes. Its primary aim is to devise maintenance protocols that can systematically eliminate sources of failure while also mitigating the potentially severe and detrimental consequences of such failures. Ultimately, the core objective of FMECA is to implement measures that significantly reduce the likelihood of failures occurring in the process (Elbadawi et al., 2018).

2.16 Reliability based Predictive and Preventive Maintenance

To evaluate the reliability of equipment or machinery, it must be operational and capable of fulfilling its designated function. When machinery or equipment has proven its functionality without any malfunctions during a specified time frame, its availability can be confirmed at 100%. However, reliability involves predicting that the machinery or equipment will continue to function over a predetermined period, and this can be quantified using statistical measures such as Mean Time Between Failure (MTBF) or Mean Time to Repair (MTTR) (Tshabuse, 2015). After an instance of system breakdown, failure, or maintenance, its availability will inevitably be diminished. The evaluation of a system, product, or process performance can be ascertained by analyzing its reliability. This analysis must consider the system configuration, component reliability, safety factors, and component age or deterioration, as all of these factors are potential causal elements that may affect the reliability of the system (Tshabuse, 2015).The reasonable selection and effective scheduling of predective and preventive maintenance is crucial for optimizing reliability, reducing production downtime, and minimizing maintenance requirements. Systems that possess multiple components exhibiting distinct reliabilities and prescribed maintenance intervals and schedules may give rise to a "combinatorial explosion" when their maintenance prerequisites appear uninterrupted owing to their self-governing potential failures (Tshabuse, 2015). The Mean Time Between Failures (MTBF) and Mean Time to Repair

(MTTR) of manufacturing equipment play a crucial role in quantitative methods for analyzing the performance, continuous improvement, and design of production systems. To assess MTBF and MTTR in a manufacturing environment, it is vital to quantify the stochastic events related to the system's uptime and downtime. These measurements can be aggregated to calculate estimates for both MTBF and MTTR (Alavian et al., 2021).

2.17 Mean Time Between Failures (MTBF)

The metric referred to as Mean Time Between Failures bears resemblance to the anticipated duration between two or more system or component failures during operation, as predicted by average. MTBF serves as a fundamental gauge for system reliability, usually indicated in units of hours (Magano Molefe, 2020). The higher the MTBF number is, the higher the reliability of the product (Torell et al., 2017). MTBF is the mean time between failures (in hours) (Minteh et al., 2019).It is expressed as:

$$\text{MTBF} = \frac{H}{N} \text{ (hour)} \quad \ldots\ldots (1)$$

MTBF represents the meantime between failures, N is the number of failures in a given period, and H is the total hours of working time (Magano Molefe, 2020). Figure 2.3 shows Bathtub curve to ilustrate constant rate of failure.

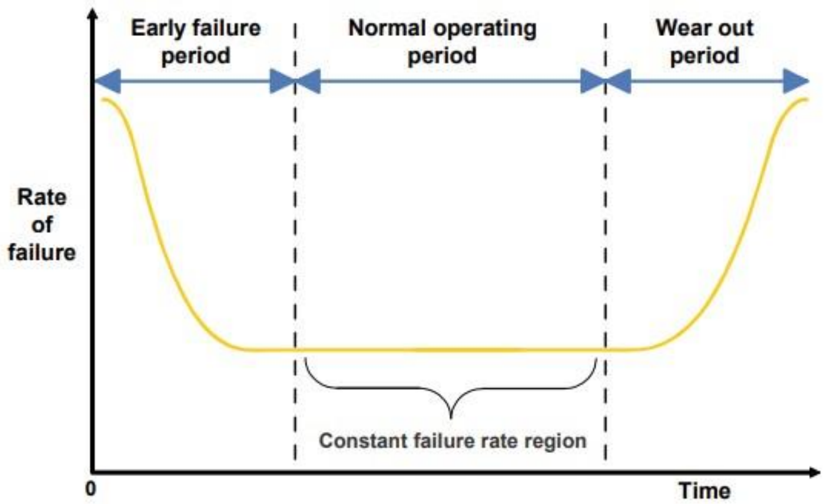


Figure 2.3 Bathtub curve to ilustrate constant rate of failure (Torell et al., 2017).

2.18 Mean Time to Repair (MTTR)

The metric of MTTR, an arithmetic means of the speed at which system repairs are conducted, is a more readily comprehensible representation than probability values. It signifies the mean amount of time needed to restore an inoperative component or device(Museka & Dissertation, 2012). This is the average time required to troubleshoot and repair failed components and return them to normal functional state. It is a maintainability parameter, and it is used to calculate the mechanical availability of a machine (Minteh et al., 2019). MTTR is a maintainability parameter that is required to calculate the availability of the system. It is expressed as the following (Magano Molefe, 2020):

$$\text{MTTR} = \frac{C}{TCM} \text{ (hour)} \quad \text{.......} \quad (2)$$

MTTR is the meantime to repair (in hours); C is the corrective maintenance (CM) downtime, and TCM is the total CM actions (same the number of failures) (Magano Molefe, 2020).

2.19 Cost-based Planning

Cost-based planning necessitates a comprehensive examination of the primary expenses and benefits that companies may face as a result of preventive maintenance. This type of planning entails a thorough evaluation of recommendations and their associated costs, as well as the economic benefits that may be realized upon implementation of such recommendations. As illustrated in Figure 2.4, the costs associated with maintenance in preventive maintenance (PM) planning are established considering factors like down time cost, asset redundancy, and reliability features. The techniques utilized in this planning process are influenced by maintenance factors that affect the efficacy of preventive maintenance planning (Magano Molefe, 2020).

When building a maintenance plan, it is imperative to take into account the condition of each component as well as the potential impact of failure on overall system reliability. The highest priority for maintenance should be assigned to the component that has the greatest impact on system reliability, while the component that contributes the most to improving system reliability should be given precedence for maintenance. In instances where workforce or maintenance budget constraints exist, the maintenance of a component whose failure has little or no effect on system reliability may be postponed (Magano Molefe, 2020).

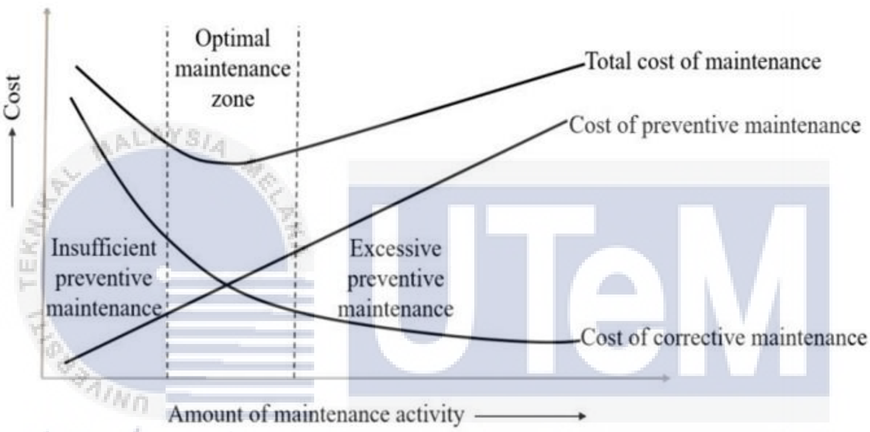


Figure 2.4 Total of maintenance cost (Le et al., 2018)

2.20 Down Time

Downtime is defined as the temporal duration during which a particular equipment or machine is rendered inoperative or incapable of functioning. This phenomenon is typically attributed to technical malfunctions, machine reconfigurations, maintenance procedures, as well as inadequate raw materials, manpower, and power supply. The cumulative downtime experienced negatively affects the overall production capacity and efficiency (Ekanayake et al., 2018). Downtime refers to any occurrence that halts planned production for a certain period. There exist various categories of downtime, namely: Planned downtime (PD), which is the duration of misplaced operating time resulting from intended events where the plant's operation is not maintained, such as breaks, scheduled maintenance, and holidays. Plant operating time (PO(t)) denotes the total duration that the plant is available for operation. Planned Production time (PP(t)) serves as the standard against which unplanned downtime occurrences are gauged. Unplanned Downtime (UD) quantifies the loss of scheduled production time caused by unforeseen events, adversely affecting Overall Equipment Effectiveness (OEE). Operator errors, mechanical issues, and insufficient oversight stand out as prominent causes of unplanned downtime. The total duration of unplanned downtime is calculated by summing the durations of individual events, each leading to operational shutdowns (Hidayatullah et al., 2022).

2.21 Overall Equipment Effectiveness (OEE)

The Key Performance Indicator (KPI), known as Overall Equipment Effectiveness (OEE) was initially conceptualized and introduced by Nakajima. The Overall Equipment Effectiveness (OEE) Key Performance Indicator (KPI) was developed by Nakajima to gauge the efficiency of manufacturing equipment in the context of Total Productive Maintenance (TPM)(Corrales et al., 2020). After defects in equipment have been identified, OEE has become an important catalyst for improvement attempts. In the end, OEE gives management the ability to recover unused capacity, lower production losses, and determine whether more capital investments are necessary. It is noteworthy that elevated OEE values lead to greater cost savings, which can be attributed to the equipment's improved efficiency (Prakash et al., 2019). The OEE methodology is a collection of metrics that have been compiled from state guidelines for equipment manufacturing and are integrated within a measuring system. This system facilitates the improvement of equipment quality and minimization of ownership costs by production and operating teams (Magano Molefe, 2020).

2.22 Computerized Maintenance Management System (CMMS)

The Computerized Maintenance Management System (CMMS), also referred to as Enterprise Asset Management (EAM), plays a pivotal role as a software application streamlining maintenance management. Its functionalities encompass the coordination of complex processes, including supply chain management and maintenance operations. As a computerized tool, the CMMS enables organizations to digitally store their maintenance data (Kimuel Kier Mercado Rosita & Michael Nayat Young, 2020). In this situation, using CMMS proves to be very helpful. It provides work order administrators with the option to designate specific things from the system's comprehensive database of all available resources in order to complete the task at hand (Lawrence Kau, 2016).

Additionally, the software affords users the ability to monitor and input all necessary equipment details. This facilitates the identification of work priorities when a work order is generated. Comprehensive information pertaining to the equipment is incorporated, including but not limited to visual, manufacturing, operational, and maintenance data (Lawrence Kau, 2016). In addition, this maintenance tool provides prompt response to work orders for any breakdowns in a firm's operational processes. By generating elaborate work order schedules and precise inventory forecasts, the CMMS also serves as a maintenance management software that offers immediate insights into the status of an organization's maintenance needs. Ultimately, its implementation results in improved maintenance reliability and performance (Kimuel Kier Mercado Rosita & Michael Nayat Young, 2020). The Computerized Maintenance Management System (CMMS) plays a significant role in the budgeting process by facilitating easy storage and retrieval of different crafts. Moreover, it enables the generation of comprehensive reports and graphs across various fields, including equipment, cost centers, projects, labor, inventory, reason for outage parts, and parts usage (Lawrence Kau, 2016). Therefore, the utilization of CMMS software facilitates the reduction of equipment downtime, diminution of maintenance expenses, promotion of extended lifespan of manufacturing machinery, and ultimately augmentation of productivity in a manufacturing plant (Kimuel Kier Mercado Rosita & Michael Nayat Young, 2020).

2.22.1 CMMS Function

A computerized maintenance management system (CMMS) provides a plethora of maintenance functionalities and operations, which extend beyond software systems and encompass facilities, manufacturing, utilities, fleet, hospitals, and other sectors. These systems, equipment, and assets are prone to repairs and require maintenance or change. Figure 2.5, illustrates various types and functions of CMMS. Given the advancements in technology and the growing complexities, many companies and organizations are transitioning to CMMS, replacing manual methods for tracking and organizing information related to maintenance or change operations. CMMS packages are suitable for any organization or company that carries out maintenance on equipment, assets or systems, including software systems. While some CMMS products are geared towards specific industry sectors, such as vehicle or healthcare maintenance, others aim to be more general (Alshokry et al., 2021).

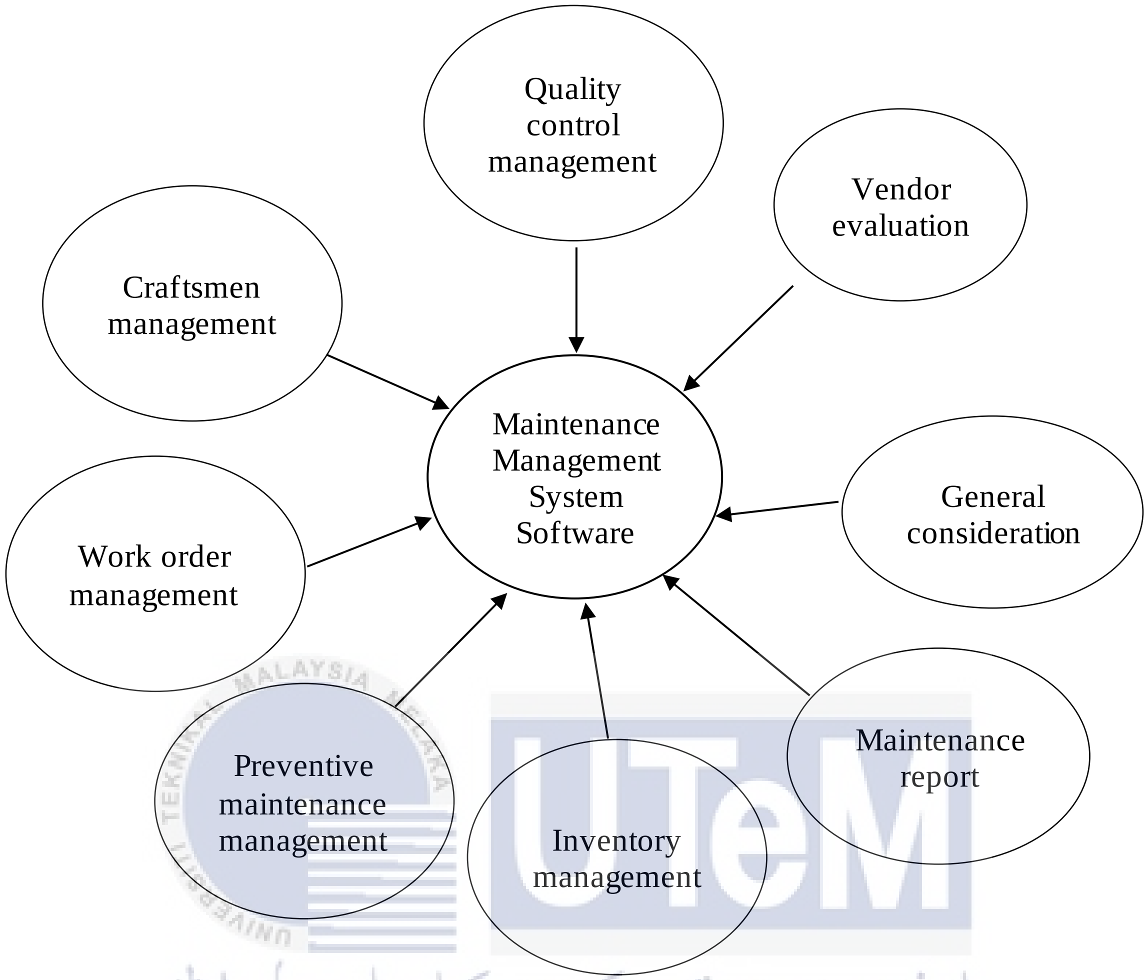


Figure 2.5 Function of Computerized Maintenance Management System (Alshokry et al., 2021).

2.23 Identifying Maintenance Needs

The initiation of maintenance procedures is activated upon the issuance of a work order. The integration of a novel work order into the CMMS is subject to variation among mining sites, contingent upon the workflow of a given enterprise. In the case of one mining site that was interviewed, virtually all maintenace staff possessed the requisite ability to generate a work order and incorporate it into the system. On the contrary, at all other surveyed sites, a designated team member had to verify and validate employee-generated work order requests before incorporating them into the CMMS, while in a specific mining site that was interviewed, most maintenance personnel had the required skills to produce and integrate a work order into the system (Robatto Simard et al., 2023). Automated work order creation can also be initiated by the system in certain cases based on triggers established by the general superintendent. In some instances, the system can delegate the creation of work orders via automation. This creation process is dependent on fixed triggers established by the general superintendent, which are based on the maintenance plan in place. The triggers frequently monitor an equipment's total engine hours and will append a PM work order to the system if a certain threshold is exceeded. However, several Key Performance Indicators (KPIs) can serve as triggers (Robatto Simard et al., 2023).

Automated work order creation is particularly advantageous for recurrent maintenance tasks, such as those related to PM. Conversely, work orders can also be created manually. Manual work order creation typically occurs after a PM inspection by the mechanic or following equipment usage by the operator. It is important to note that the active work order creation procedure at the mine must be respected, regardless of the method employed to create work orders. Nevertheless, the creation step is crucial in minimizing equipment downtime and is therefore strictly regulated. Proper documentation and explication of work orders can only be achieved by adhering to particular standards, which in turn enhances the efficacy of maintenance planning and scheduling. The prioritization of work orders is a crucial standard among them. Preeminent among such standards is the prioritization of work orders (Robatto Simard et al., 2023).

2.24 Maintenance Execution

The implementation of a scheduling calendar by the general maintenance supervisor plays a crucial role in the allocation of workers to their respective work orders. The assignment of workers relies on various factors, including equipment criticality, manpower availability, worker specialization, current mining operations state, and other pertinent elements. Nonetheless, it is the schedule that serves as the foundation for all decision-making activities undertaken by the supervisor. One of the participants in the study posited that the general maintenance supervisor oversees worker assignments because they possess knowledge of workers' strengths and weaknesses, which enables optimal placement of the workforce. On the other hand, another participant noted that the supervisor collaborates with the maintenance planner and superintendent in the assignment process to enhance coordination among the maintenance teams (Robatto Simard et al., 2023).

Upon the completion of the work orders, it is imperative that they undergo validation and closure by the general supervisors. It is worth noting that the process of closing work orders varies across maintenance sites. The general supervisor in their respective maintenance sites can directly update the status of the work orders to "Closed" in the CMMS. Other members of the work force can merely confirm the validation of the maintenance job. Nevertheless, irrespective of the implementation, the work order closing procedure denotes the conclusion of the maintenance process. Subsequently, the scheduling calendar developed during the current week will serve as the basis for maintenance jobs in the following week, and maintenance planning will organize maintenance for the week thereafter (Robatto Simard et al., 2023).

2.25 Diagnosis Vibration Problem of Pumping

Vibration monitoring is a well-established technique that can be used to effectively determine the physical movements of a machine or structure caused by issues such as imbalance, improper mounting, or misalignment. The process involves attaching a transducer, also known as a sensor, to record its vibration levels. Specialized equipment is then used to analyze the sensor's output, allowing for the identification of the specific nature of the vibration problem and its precise source (Suresh Babu & Das, 2013). Vibrations may occur while many types of equipment or facilities are operating; if these vibrations reach a certain level, the equipment's lifespan may be shortened. Furthermore, the noise produced by these vibrations may have an impact on people's health (Marius & Minescu, 2015). The machine's condition can be determined by analyzing the vibration that was generated. Specifically, problems can be identified in their early stages by monitoring changes in the vibration signature brought on by modifications in the machine state (Siano & Panza, 2018). Identifying the sources of high vibration is the aim of the analysis. The first step in resolving any structural weakness causing resonance issues is understanding the dynamic characteristics (natural frequencies & damping) of the pumping system. Every defective component has exciting frequencies that are unique to the pump system. To easily relate each exciting frequency and high vibration level to its source, it is crucial to define all the exciting frequencies for the rotors, bearings, couplings, gears, and so forth at the beginning of vibration analysis in addition to modal analysis (Abdel-Rahman & El-Shaikh, 2009).

2.26 Ishikawa Diagram

The Ishikawa diagram, sometimes referred to as the causes and effects diagram or fishbone diagram, is a classic quality management tool because it facilitates visualization. The technique of Ishikawa diagramming has been used to analyze issues and pinpoint possible root causes. For instance, during brainstorming, this diagram could be made. The 5 Why technique is frequently used to identify the main cause of an issue once the Ishikawa diagram has been produced and the possible and main causes have been identified. But since a false identification decreases time and resources, it is crucial to actually determine the cause of the problem. This can be difficult because there are a lot of cause issues with it, and brainstorming can lead to subjectivity. It was determined that in order to get over the limitations of the Ishikawa diagram, it is useful to provide a numerical approach of analyzing the problem's causes of occurrence. This method will help to identify, arrange, and graphically display the problem's potential causes by using the following methods (PACANA & SIWIEC, 2020) :

1) Evaluating the significance and impact of the problem's possible causes.
2) Identifying the reason that has the biggest impact on the problem's occurrence in a measurable (numerical) method.
3) considering the personal viewpoints of the decision-makers.

An Ishikawa diagram was created during the problem assessment's initial stages. This graphical diagram is also known as the cause-effect diagram. The analyzed problem was highlighted (linear indication) in the diagram's main section. The possible causes of the issue were then determined through brainstorming and categorized according to the fundamental Ishikawa categories (5M+E), which are: man, measure, method, material, machine, environment, and management. These categories and reasons were mentioned jointly since the method and material categories pointed to similar causes. Intermediate causes were observed in relation to the potential causes (PACANA & SIWIEC, 2020).

2.27 Summary

In summary, preventive maintenance is a proactive, planned method that aims to reduce downtime, prevent breakdowns, and effectively manage expenses. Corrective maintenance, on the other hand, addresses unforeseen malfunctions but has drawbacks like costly downtime and prolonged downtime. Reducing maintenance costs and improving operating efficiency are two benefits of condition-based maintenance, which uses condition monitoring to predict future problems. Integrating these maintenance techniques can lead to optimal facility management and ensure equipment availability and reliability. To effectively manage equipment reliability and minimize downtime, the crucial strategies involve predictive maintenance and preventive maintenance planning. Predictive maintenance entails gathering information through condition monitoring to anticipate malfunctions and address underlying issues. In the context of printed-circuit manufacturing, preventive maintenance planning necessitates meticulous scheduling of designated time slots and a careful balance between available resources and task requirements to ensure optimal equipment reliability and minimize downtime. The objective of maintenance management is to efficiently oversee and execute technical tasks to maximize cost-effectiveness, mitigate risks, and enhance production.

Root Cause Failure Analysis (RCFA) is an effective technique that aids in the identification of underlying failure causes. Fault Tree Analysis (FTA) is a process that investigates the different causes that lead to system failure, in contrast. Reliability Centered Maintenance (RCM) is a comprehensive approach that integrates maintenance practices with multiple considerations to ensure sustained equipment functionality. Failure Mode Effect Analysis (FMEA) and Failure Modes, Effect and Criticality Analysis (FMECA) prioritize failure modes and propose corrective measures to enhance reliability and quality in manufacturing processes. These methods and frameworks collectively contribute to effective maintenance activities and improved system performance. In industrial settings, reliability-based predictive and preventive maintenance is essential for optimizing equipment performance and minimizing downtime. MTBF and MTTR are statistical measures that can be implemented to assess the reliability of equipment by measuring the expected duration between failures and the average time required for repair.

Cost-based planning involves assessing the costs and benefits associated with preventive maintenance, taking into account factors like downtime expenses and asset redundancy. Prioritizing system components based on their impact on reliability is crucial in maintenance planning, where downtime refers to the period when machinery or equipment is non-operational, causing a halt in production. Downtime can result from technical malfunctions, maintenance procedures, insufficient resources, and unplanned events. In cost-based planning, the classification of downtime into planned or unplanned is essential. Planned downtime, such as breaks, maintenance, and holidays, can be anticipated, while unplanned downtime, caused by factors like operator errors or mechanical problems, is unpredictable. Cumulative downtime adversely affects Overall Equipment Effectiveness (OEE), diminishing overall production capacity and efficiency. To maximize productivity, minimizing both planned and unplanned downtime is crucial.

A widely used metric for analyzing equipment efficiency and driving improvement efforts is Overall Equipment Effectiveness (OEE). Through OEE, organizations can pinpoint equipment deficiencies, reclaim latent capacity, reduce production losses, and assess the necessity for capital investments. By implementing reliability-based maintenance strategies and leveraging OEE, manufacturing performance can be improved, and costs can be minimized. A Computerized Maintenance Management System (CMMS), also known as Enterprise Asset Management (EAM), is a software application designed to streamline maintenance management by coordinating processes such as supply chain management. It enables organizations to digitally archive maintenance data and offers features for work order administration, inventory management, and equipment tracking. CMMS software generates work order schedules, monitors equipment details, and facilitates prompt responses to breakdowns. It also aids in budgeting by storing and retrieving various crafts and generating comprehensive reports and graphs. The implementation of CMMS leads to reduced equipment downtime, lower maintenance expenses, extended machinery lifespan, and improved productivity.

Maintenance needs are identified through work order initiation, which can be initiated manually or automatically based on triggers set in the system. The creation of work orders is crucial for minimizing downtime, and adherence to specific standards enhances maintenance planning and scheduling. Maintenance execution involves the allocation of workers based on factors such as equipment criticality and manpower availability, with the scheduling calendar serving as a foundational tool. Upon completion of work orders, they are required to undergo a validation and closure process, which is subject to variation across maintenance sites. The termination of work orders, regardless of the chosen technique, is a clear indication that the maintenance process has been concluded. The scheduling calendar generated for the current week serves as the foundation for scheduling maintenance jobs in the ensuing week, and maintenance planning is conducted for the subsequent week. This methodical approach guarantees systematic maintenance tasks and supports the maintenance of a well-organized maintenance schedule.

Vibration monitoring is a critical and well-established technique used to evaluate the physical movements of machines or structures, identifying issues such as imbalance, misalignment, or improper mounting. The process entails attaching a transducer to record vibrations, and specialized equipment is employed to analyze the output, pinpoint specific problems, and identify their sources. When vibrations exceed a certain level, the lifespan of the equipment can be compromised, and the associated noise may have adverse effects on human health. By analyzing the generated vibrations, the machine's condition can be determined, enabling the early identification of potential issues. The key goal is to locate and address sources of high vibration, with the initial step involving an understanding of the dynamic characteristics of the system. Defective components possess unique exciting frequencies, making it crucial to define these frequencies for rotors, bearings, couplings, and gears during vibration analysis. This comprehensive approach facilitates a targeted resolution of structural weaknesses causing resonance problems in pumping systems.

The Ishikawa diagram, or fishbone diagram, is a vital tool in quality management for visualizing and analyzing problems to pinpoint potential root causes. To enhance accuracy, a proposed numerical approach involves evaluating the significance and impact of potential causes, identifying the most impactful cause quantitatively, and incorporating decision-makers' perspectives. The process begins with creating an Ishikawa diagram during the initial stages of problem assessment, categorizing possible causes under fundamental Ishikawa categories (5M+E). These categories, encompassing aspects like man, measure, method, material, machine, environment, and management, collectively help identify intermediate causes related to potential root causes, addressing limitations of subjective brainstorming.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter 3, propose a methodological structure on analysis to performed preventive maintenance schedule in the area Flamingo Pond. The structure is developed through a thought process for designing a systematic preventive maintenance schedule for the assets and equipment at the lake maintenance area. This chapter focuses and analyses the master plan of preventive maintenance schedule and corrective maintenance damage report to solve the problem that occur in the lake maintenance area.

3.2 Research Strategy

Data accumulation is an important aspect of the research procedure. The flow of research can be visually depicted in Figure 3.1. The preliminary stage of the exploration process requires identifying a particular dilemma in the field of concern. This is then followed by converting the problem into a research issue through establishing a research objective and creating research inquiries or conjectures. The third step involves data collection through various available means. After the information is gathered, the fourth stage of the examination process involves dissecting it, and the last stage is to report the discoveries of the examination.

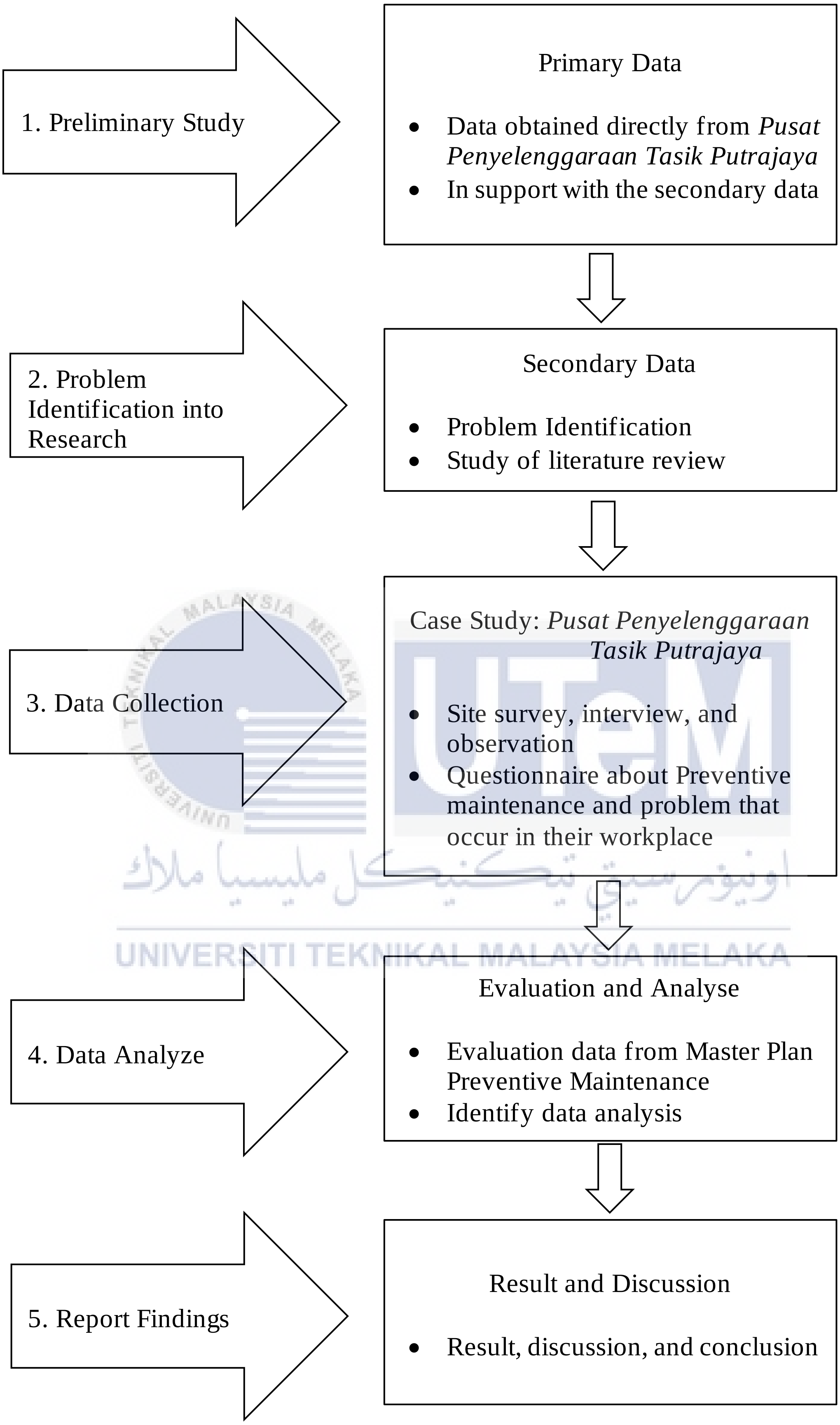


Figure 3.1 The systematic flow of research

From Figure 3.1, secondary sources (such as journals, articles, and books) in the research area of preventative maintenance were used to form a literature review. The literature review served as the basis of an idea generation phase after the identification of numerous breakdown equipment and corrective list at the lake mainteance area. The information obtained from the literature review assisted in translating identified issues into research problems and questions, leading to the formulation of the research objectives. The research objectives served as a guide to the execution of the entire study. Additionally, the researcher comprehensively reviewed literature in the areas of maintenance (such as maintenance strategies, maintenance planning, the system state), and different techniques used for maintenance improvements were researched to develop a thorough knowledge of the strategic role of maintenance.

3.3 Flow Chart

In this section, the stage of the overall process of carrying out research will be discussed in detail. The flow chart and an explanation of the research technique are included in this section. These steps can serve as a guide for the researcher to follow to begin and continue the research efficiently up until the research goals are achieved. The following is a step that was taken to address the issues that were found during this research. In addition to being useful, the flowchart promotes focus and clarity. It gives a visual picture of the whole research process, enables to see the whole thing while carefully attending to every little detail. This ongoing awareness keeps from becoming overwhelmed by the scope of the job, enable to approach each work with assurance and accuracy.

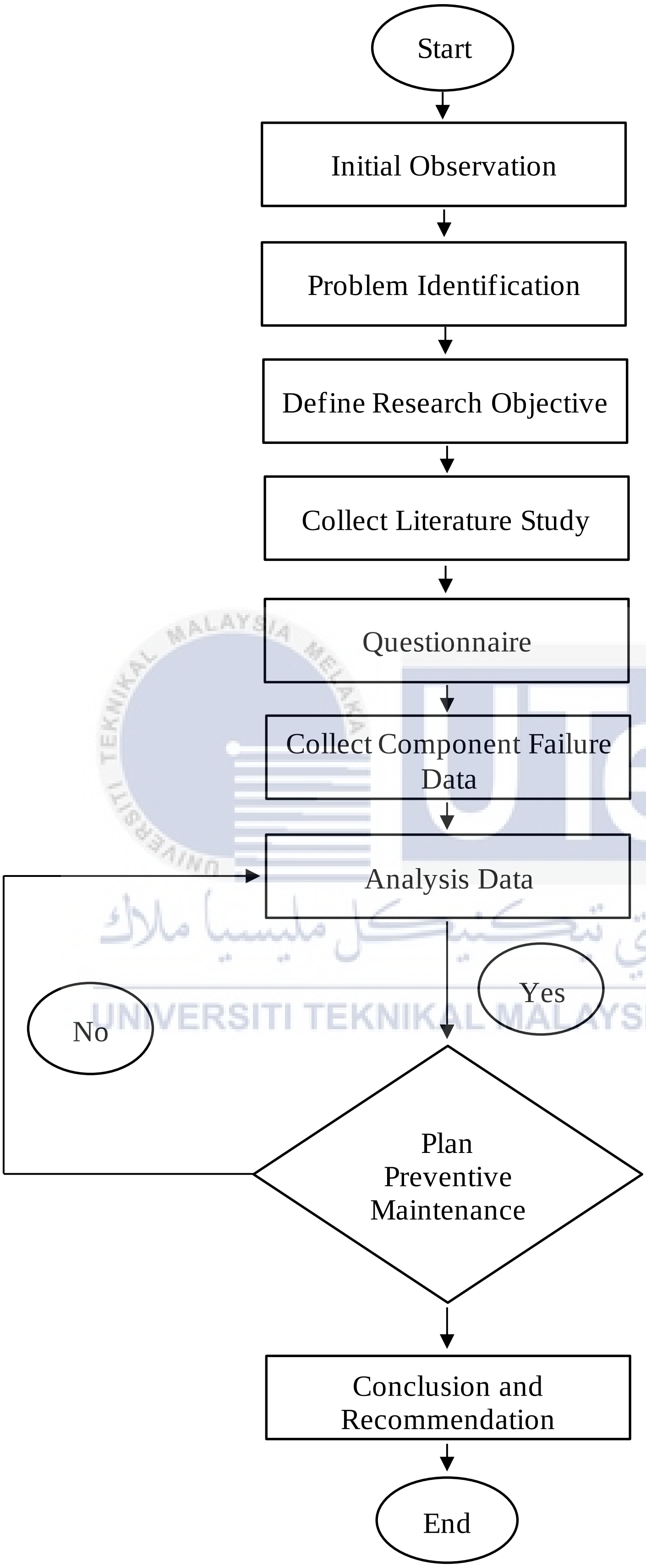


Figure 3.2 Flow Chart

3.4 Gantt Chart PSM 1

Figure 3.3 Gantt Chart for PSM 1

A detailed 14-week study project exploring the impact of preventative maintenance on Pusat Penyelenggaraan Tasik Putrajaya is outlined in the Gantt Chart in Figure 3.3. The method focuses its attention on scheduling tasks and deadlines and is presented in a systematic series of chapters, each of which fulfills a crucial function. The first several weeks establish the structure, as Chapter 1 explores the background of the research and provides a clear definition of the problem statement, goals, parameters, and importance of the study. After that, Chapter 2 leads students on a thorough literary tour while thoroughly examining the body of knowledge that exists on the topic. With this base, Chapter 3 carefully describes the research technique, including the important procedures of visiting the site to evaluate problem area, creating, and distributing questionnaires, carefully collecting data, and then carefully analyzing it. Then, Chapter 4 is a turning point as it presents the initial results and provides an overview of the new understandings. The following weeks are wisely devoted to completing the dissertation, keeping an accurate logbook, creating powerful presentations, and submitting the dissertation in its final form. In addition to acting as a roadmap, the image emphasizes how important coordinated work is to achieving maximum efficiency. Key dates and milestones are clearly marked, which guarantees the project's smooth development toward its objective. In the end, this study hopes to provide insightful information about the field of facility management techniques. It does this by using a targeted case study methodology that promotes preventive maintenance to bring light on methods for maximizing building performance, reducing downtime, and eventually increasing cost-efficiencies. The meticulous planning and rigorous methodology reflected in the Gantt chart are testaments to the project's potential to generate impactful findings and contribute meaningfully to the field of maintenance management.

3.5 Gantt Chart PSM 2

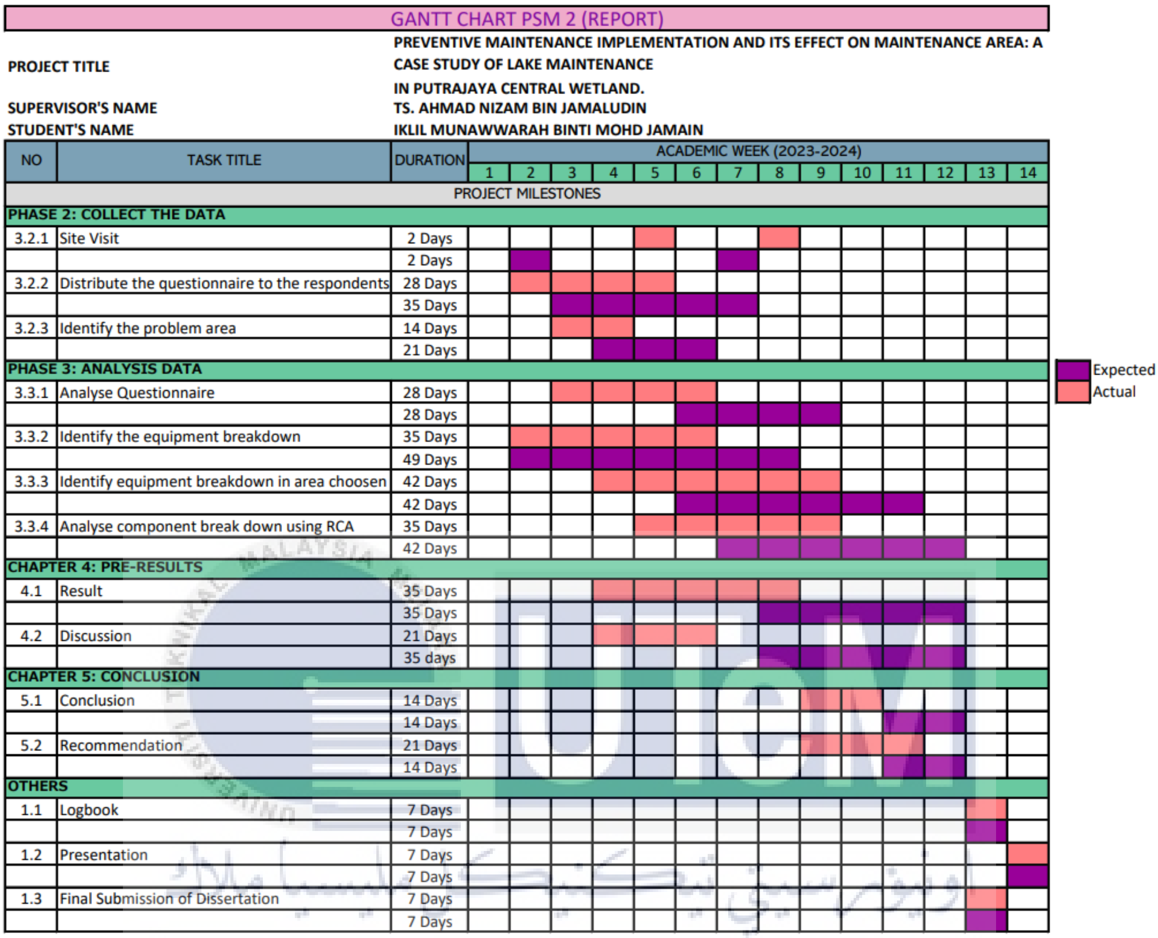


Figure 3.4 Gantt Chart for PSM 2

The detailed Gantt chart shown in Figure 3.4 shows a meticulously planned 14-week project schedule centered around the topic of preventive maintenance implementation and its effect on maintenance area. The project is organized into five carefully planned stages, each of which is essential to the overall success of the project. Over the course of several weeks, the project's third phase becomes more focused on the detailed examination of the data that has been gathered. This entails a thorough Root Cause Analysis (RCA) of component breakdown, identification of equipment breakdown within the designated maintenance region, and rigorous review of questionnaire replies. Through the assignment of distinct time intervals to each aspect of this analytical stage, the project seeks to elucidate crucial perspectives on equipment malfunctions, maintenance procedures, and their fundamental causes. This strategic method provides an in-depth understanding of the effects of preventative maintenance and establishes a basis for strong findings and useful suggestions in the next project stages. The Gantt chart's activity division promotes efficient time management by matching project milestones and deadlines.

3.6 Initial Observed

Observation will be carried out at *Pusat Penyelenggaraan Tasik Putrajaya*. It also covers the maintenance area at the Wetland, Putrajaya and has three section areas to maintenance of equipment and asset, which is mechanical, electrical, and civil. *Pusat Penyelenggaraan Tasik Putrajaya* has many assets and equipment from mechanical systems. The problem that occurs with this workplace was the corrective maintenane and their cost for that area is high. To ensure that lake management performance is not affected, engineers are responsible for organizing maintenance schedules systematically. Unfortunately, the lake maintenance management centre has not adequately managed their maintenance activities and caused a lack of a good plan for preventive maintenance and their employe was ignore the deadlines for corrective and preventive maintenance.

3.7 Problem Identification

For this research, interviews and conduct observations were done at the lake maintenance area. From the result, the Flamingo Pond area within the Wetland is experiencing maintenance challenges. The current system of maintenance pump is ineffective, resulting in excessive silt accumulation, reduced water depth, compromised water quality, and plant and animal species, which negatively impact the native biodiversity. The objective of the research is to identify the causes of these maintenance problems and propose the implementation of preventive maintenance schedule so these solutions can enhance the ecological health and functionality of system mechanical in Flamingo Pond and the Wetland. The Flamingo Pond region and its surroundings will be the focus of the investigation. In the end, it seeks to identify the variables influencing the high incidence of corrective maintenance.

3.8 Literature Study

The relevance of this stage is with the collection of appropriate theoretical materials that are related to the research such as books, journals, articles, and other publications, that will support the analysis presented for Chapter 4. The most essential and helpful research from the field of literature is about maintenance management, preventive maintenance, corrective maintenance, predictive maintenance, planning and scheduling maintenance, maintenance cost and the Root Cause Analysis (RCA).

3.9 Data Collection

The process of gathering data is an essential part of systematic research, which involves the systematic collection of precise observations or measurements. The data that will be collected to solve problems that occur at the place of research, Flamingo Pond area beginning from January 2023 and continuing until November 2023, which is determine selected equipment, collect the required data from maintenance department and perform knowledge sharing and interview with person in charge at the *Pusat Penyelenggaraan Tasik Putrajaya*.

3.9.1 Questionnaire Design

A questionnaire consists of a list of questions to be presented to interview respondents together with detailed instructions on which questions to ask and in what order. Survey research and experimental design are two of the many study domains that use questionnaires. A questionnaire offers a consistent way to record responses and an organized method for conducting interviews, making it simple to gather data from research study participants and streamline data processing. A research questionnaire is comprised of a series of questions or cues designed to extract information from participants. Typically, such questionnaires incorporate a mix of closed- and open-ended questions. During the survey conducted at the lake maintenance facility, participants were provided with unstructured questionnaires, placing a specific focus on qualitative data collection. These questionnaires were intentionally crafted with a straightforward framework and minimal branching questions to facilitate the collection of more precise and in-depth information from the participants. The simplicity of the questionnaire design aimed to make it easier to gather detailed insights from the participants.

The research gained from the insightful opinions of *Pusat Penyelenggaraan Tasik Putrajaya* staff members. The study used a structured format of open-ended questions that were carefully prepared by the workplace itself, as opposed to using random questions. Valuable qualitative data was obtained from this focused approach, enabling a thorough examination of the particular problem in the lake region. This approach placed a higher priority on gathering detailed viewpoints and comprehending the real-life experiences of those who were directly involved than typical surveys, which frequently give preference to quantitative data. Overall, this survey was an invaluable instrument for compiling specific data and a range of perspectives, which helped to develop a precise and thorough analysis of the issue at hand.

3.10 Data Analysis

The results of the data processing will be subjected to a thorough examination once the data collection and processing phases have been concluded. Pareto charts will be scrutinized to identify critical components, and a maintenance schedule proposal will be executed after analysis of the data.

To manage the grouping, examination, understanding, and presentation of numerical data, statistical methods is mathematical techniques and solutions that can be utilized. As previously indicated, the information for this study was acquired using inquiries and data collection.

Subsequently, a statistical methodology shall be employed to systematize and scrutinize the amassed information. Typically, descriptive statistics, which portray the attributes of specific data and showcase the data in the form of tables or graphs for illustrative purposes, shall precede statistical analysis in this course.

3.10.1 Pareto Analysis

A Pareto chart is a data analysis instrument utilized to discern the primary factors responsible for the occurrence of failures. The downtime analysis using the Pareto principle. Analysis indicates that approximately 20% of the downtime factors contribute 80% of total downtime. The goal of the Pareto chart is to identify the issue currently taking up the most significant amount of time and effort. The Pareto chart illustrates which of our issues should be tackled first to reduce the number of instances of failure and enhance our operations. First, we will address the problematic goods that appear most frequently, then move on to the second-highest defective item, and so on.

The Pareto chart, a graphical representation of data as shown in Figure 3.5, comprises a line graph that visually represents the cumulative percentage along the right vertical axis. This cumulative percentage is determined by computing the sum of a specific cause's percentage against the total of all causes. The primary objective of this distribution is the classification of maintenance interventions based on their frequency, followed by the prioritization of these interventions. The process of constructing a Pareto diagram involves a series of steps which include the collection of interventions per type of failure, the classification of these groups in an ascending order, determination of the total number of interventions or time spent in accordance with the type of diagram under analysis, computation of the percentage per group, which is represented by the intervention number divided by the total time spent and finally, the creation of a graph to generate a Pareto curve.

A horizontal bar graph for every bar stands for a component that affects the result. The longer ones represent the largest contributors, and their lengths are carefully scaled. This is the point at which the chart begins to reveal its secrets: the few but powerful bars on the left together represent 80% of the findings. This visual clarity acts as a beacon, directing our attention to these high-leverage aspects through analysis. By concentrating on these crucial few, we may maximize the use of our resources, get the most significant outcomes, and finally turn data analysis into something that is both strategically useful and insightful.

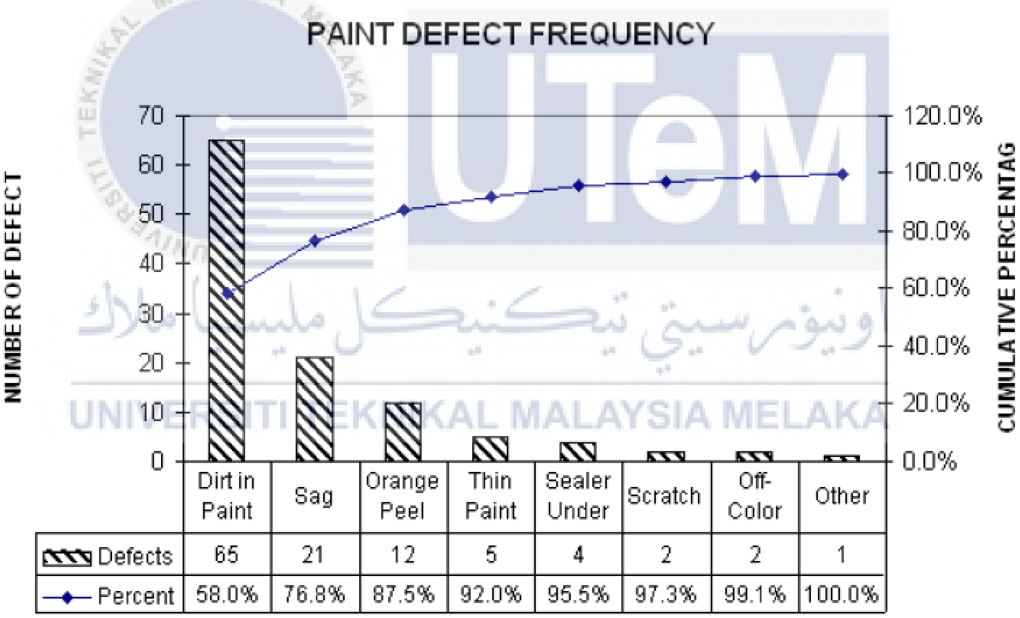


Figure 3.5 The Example of Pareto Chart

3.10.2 Root Cause Analysis

In handling projects, root cause analysis, or RCA, is crucial to understanding and solving complicated problems. Using RCA in the framework of the final project offers a methodical and organized way to investigate the root causes of any difficulties or failures that may arise. Utilizing RCA allows these projects to move beyond addressing immediate symptoms and instead identify the underlying sources of those problems. By tackling these root causes, they pave the way for lasting improvements and secure project success. This paper will examine the process, information gathered, and results of the Root Cause Analysis that was carried out using the Fishbone Diagram and the 5 Whys technique. It will also highlight the important function that this analysis plays in the framework for problem-solving that our project uses.

This analysis identified several important root causes. The Fishbone Diagram's visual aid made it easier to classify the various elements people, places, machines, and processes that contribute to the problems that were found. The impact analysis showed the direct relationship between resolving these primary reasons and the project's overall performance, showing how important it is to do so. As such, the report's conclusion includes a comprehensive implementation plan along with several well-founded suggestions for addressing the core issues that were found. We aim to strengthen the project against future obstacles and guarantee its smooth improvement towards a successful finish by providing an outline for combining these solutions. With the Fishbone Diagram added, Root Cause Analysis becomes a crucial instrument for analyzing project problems and more importantly opening the door to strategic problem-solving and long-term project excellence.

3.10.3 Fishbone Diagram

The Ishikawa or Cause-and-Effect Diagram, sometimes referred to as the Fishbone Diagram, is a potent diagram used in Root Cause Analysis that helps organize and methodically identify potential reasons that may be contributing to a certain issue. The Fishbone Diagram was important to improving the scope and depth of our study in our senior year project. Its unique structure, which has been designed after the skeletal system of a fish, makes it possible to categorize contributing elements into important branches like people, equipment, processes, environments, and materials. Through a complete graphic mapping of these aspects, the Fishbone Diagram facilitates a more nuanced and efficient problem-solving process by offering a full perspective of the likely reasons impacting the observed issues.

Application of the Fishbone Diagram required collaboration to recognize and organize the probable causes of the problems that faced with. Sub-branches within each branch of the diagram provided more information about particular elements within the main categories each branch represented in relation to the problem. This method able to investigate the complex nature of the problems and make sure that no probable cause was missed according to our careful methodology. The graphic aid facilitated team discussions and brainstorming sessions, promoting a shared understanding of the numerous interdependencies within the project. When coupled with the 5 Whys method, the Fishbone Diagram provided a comprehensive perspective for identifying the causes of observed problems along with their symptoms.

Beyond its role as a visual aid, the Fishbone Diagram significantly influenced and became an integral part of our problem-solving methodology. The graphic served as a guide for our Root Cause Analysis efforts by categorizing and grouping potential causes, aiding in the identification of essential areas for improvement and issue prioritization. The Fishbone

Diagram's graphical design enhanced communication, allowing stakeholders to quickly grasp the complexity of the problems. In summary, the Fishbone Diagram emerged as a valuable tool for Root Cause Analysis, contributing to the clarification of problems and offering focused, practical solutions. Its integration serves as an example of how analytical techniques and visual tools collaborate to address complex problems within the context of an analysis.

3.11 Summary

Chapter 3 presents a methodological framework for scrutinizing and executing a preemptive maintenance program in the Flamingo Pond vicinity. The approach adopted for this research entails a structured methodology starting with the identification of the problem and its translation into research queries. Secondary sources are utilized for conducting a literature review on preventive maintenance, maintenance strategies, and techniques. Preliminary observations at the lake maintenance center indicate issues pertaining to corrective maintenance and the absence of a well-crafted plan for preventive maintenance.

Subsequently, interviews and observations are conducted to identify maintenance problems in the Flamingo Pond area encompassing difficulties with the maintenance pump system leading to sediment accumulation, decreased water depth, and compromised water quality. The research objectives aim to propose a preventive maintenance schedule to improve the ecological well-being and functionality of the area. The literature review concentrates on pertinent subjects, namely maintenance management, preventive maintenance, and maintenance cost. The process of data collection encompasses the acquisition of meticulous observations and measurements, involving equipment data from the maintenance department and interviews with the individual in charge. To gather qualitative data, a questionnaire is constructed, and the analytical process entails the utilization of Pareto charts and statistical methodologies.

The outcomes will serve as the cornerstone for the development of a maintenance schedule proposal. The utilization of a data analysis tool is imperative in the identification of primary factors contributing to failures. This tool serves to prioritize issues by identifying those that require immediate attention, thereby reducing downtime and improving operations. The Pareto Chart, a visual representation of the cumulative percentage of causes, highlights the most frequent and significant issues. To generate a Pareto Curve, the construction process involves the collection and classification of interventions, computation of their percentages, and the creation of a graph.

Within the field of project management, Root Cause Analysis (RCA) is essential for understanding and addressing complicated problems. The Fishbone Diagram helped define relevant factors, and the combined study using these methods highlighted important root causes. The impact analysis highlighted how resolving these main problems directly affects the project's overall performance. Root Cause Analysis emerges as an indispensable tool for strategic problem-solving and sustained project excellence.

The Fishbone Diagram, also referred to as the Ishikawa or Cause-and-Effect Diagram turned out to be a useful tool for the Root Cause Analysis portion of our senior year project. This impactful visual aid enhanced the scope and depth of our research by providing a systematic and structured approach to identify potential causes for the observed problems. The distinctive fishbone-like structure allowed for the categorization of contributing factors into key branches, including people, tools, environments, processes, and materials. When utilized in conjunction with the 5 Whys technique, the Fishbone Diagram facilitated a comprehensive examination of the intricate structure of the challenges. The sub-branches within each category ensured that no potential cause was overlooked, and the graphical representation encouraged team members to develop a shared understanding of the issues. The Fishbone Diagram's unique structure and collaborative use with other analytical methods proved to be a valuable asset in thoroughly exploring and addressing the complexities of the problems at hand.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter, which focuses on the analysis and interpretation of the results acquired, is the culmination of the study done for this final year project. This chapter seeks to determine significant findings and conclusions that offer a thorough knowledge of the research objectives by means of a thorough analysis of the collected data and a careful inspection of the project site procedures.

The important results will be clearly and briefly stated in this section. A variety of graphical aids, such as tables, figures, and graphs, will be utilized to enhance understanding and simplify analysis. Every outcome will go through a thorough process of analysis and interpretation, making connections with the goals of the research and having a significant conversation with the body of knowledge already available in the field.

This section will include an analysis of the data on the plan preventive and corrective maintenance of Flamingo Pond, as well as an analysis of the surveys that were carried out. Included in this area will also be the results and discussion of the data collected. The objectives of this section are to provide a solid scientific reason for the facts that were obtained and to discover the findings of the inquiry that was presented earlier.

4.2 Data Collection

Gathering accurate and comprehensive data is crucial for effective preventive and corrective maintenance (PM and CM) programs. This data provides insights into equipment performance, helps predict potential failures, and enables informed decisions about maintenance activities. Here are the methods used for data collection in problems that occurs at *Pusat Penyeleggaraan Tasik Putrajaya* for PM and CM programs. All of these facts are required at the beginning of the research process in order to determine the source of the problem and locate a solution to it.

4.3 Data Analysis

This investigation provides a thorough perspective on the difficulties involved in failure mitigation by exploring the careful use of open-ended questionnaires as a useful data analysis tool. 30% of *Pusat Penyelenggaraan Tasik Putrajaya* staff, which includes staff managers, engineers, and human resource specialists, supplied the replies that form the basis of this inquiry. Important insights can be gained from the examination of open-ended replies from important stakeholders in order to address existing issues and strengthen the organization against prospective

A major problem in the *Pusat Penyelenggaraan Tasik Putrajaya* areas is shown on Figure 4.1 by the survey data gathered through questionnaires is high maintenance downtime and machine lifespan, which raises the cost of breakdown maintenance. Two significant causes of this are an irregular maintenance schedule and a deficient preventive maintenance system. In the case of this workplace, a weak preventive maintenance system means machines are likely nearing the end of their useful life or operating near capacity, increasing the susceptibility to failures. Moreover, deficiencies in planned and preventative maintenance procedures are probably connected to an excessive dependence on corrective maintenance. This implies that regular corrective actions lead to more downtime overall. In the end, the profitability of the company may suffer from the frequency of issues in the *Pusat Penyelenggaraan Tasik Putrajaya* area.

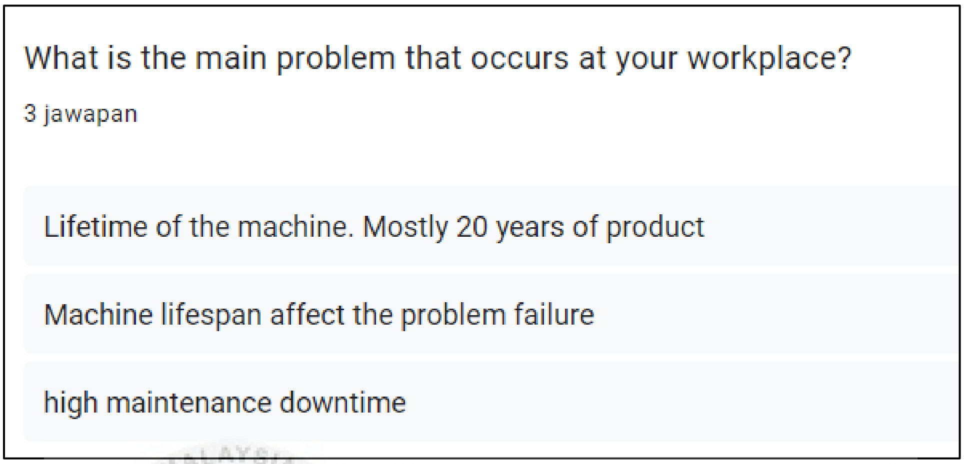


Figure 4.1 Main problem that occurs at workplace

Important information gleaned by examining answers to issues such as "How many times in the last six months have employees participated in skills development training related to maintenance procedures?" on Figure 4.2 shows that all respondents said they received training once or twice in 6 months. Based on Figure 4.3, irregular or insufficient training appears as a potential contributor to this issue through skills deficiencies. However, the persistence of downtime despite regular training programs warrants a scrutinized evaluation of their efficacy and value. The data set reveals that they have a lack of knowledge and skill training in operating equipment that needs to be maintained. In addition, downtime events will last for a longer period when they are handled by technicians who have special expertise in maintenance especially in mechanical equipment. Because of this association, it is important to invest in technical training programs to improve the knowledge of the workforce responsible for maintenance. The data collected from the survey also shows a worrying pattern in terms of adherence to scheduled actions for maintenance.

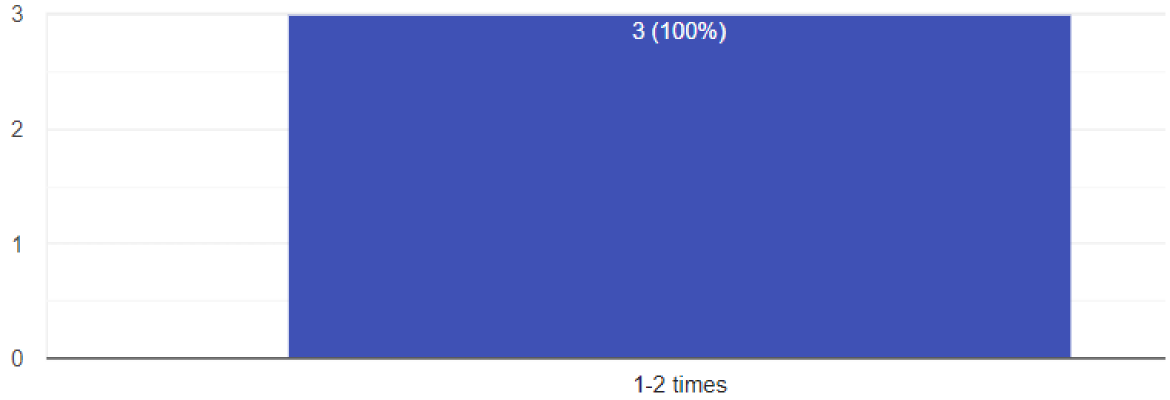


Figure 4.2 Answers from 3 respondent for question How many times in the last six months have employees participated in skills development training

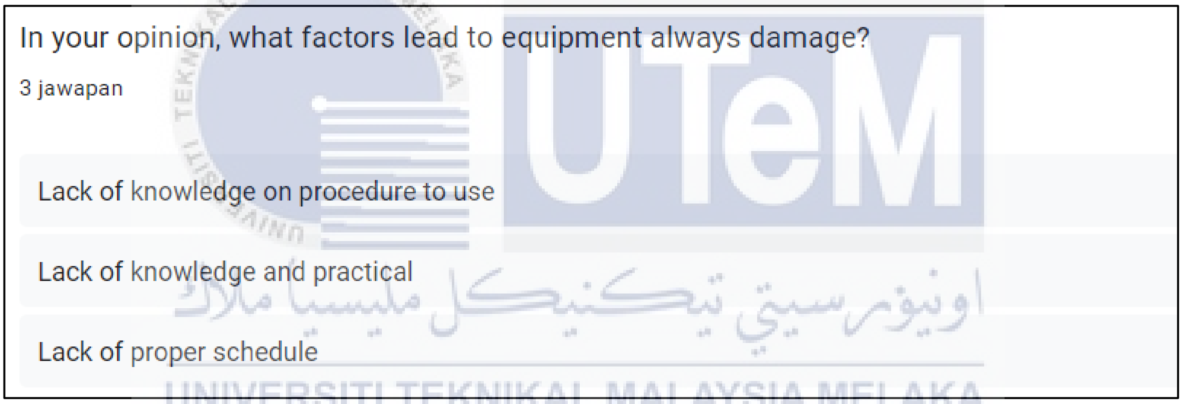


Figure 4.3 Answers from 3 respondent for factors lead to equipment always damage in the workplace

Figure 4.4 shows that respondents answered using root cause analysis (RCA) to reshape the maintenance management system and refine the preventive maintenance schedule. RCA functions as a strong investigator, investigating behind the obvious symptoms to identify potential causes of equipment malfunctions. Through a methodical review of maintenance records, analysis of failure patterns, and consideration of operational aspects, root cause analysis (RCA) can reveal critical weaknesses in the system. Preventive maintenance schedule surgically tailored based on RCA insights. Inspections can be prioritized for vulnerable components, maintenance tasks optimized to address specific failure modes, and training programs targeted at areas where human error surfaces. This method leading to a substantial reduction in downtime, a decrease in costly corrective repairs, and ultimately, a healthier more productive equipment lifespan.

Have you ever considered what changes could be made to your workplace's maintenance management system to make it more effective?

3 jawapan

Root cause analysis

Do root cause analysis

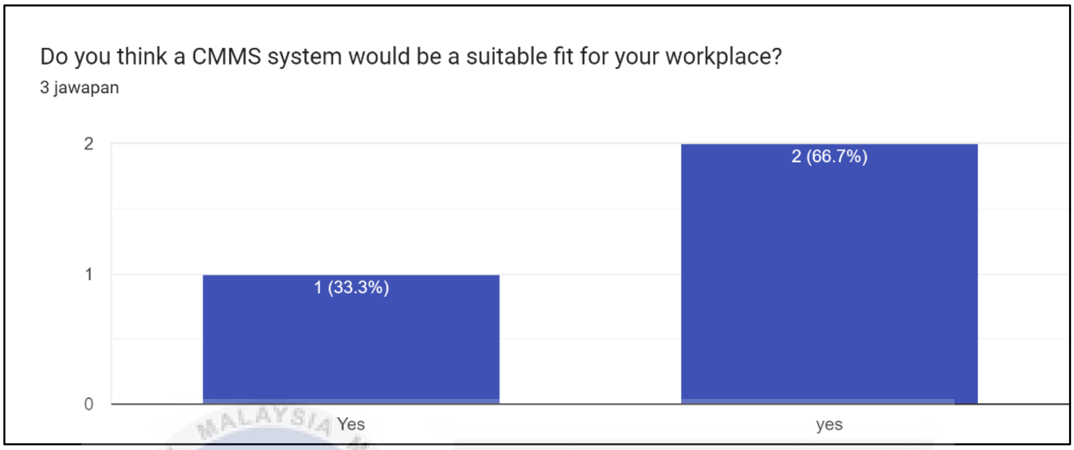
Improve preventive maintenance schedule

Figure 4.4 Method for made changes maintenance management system

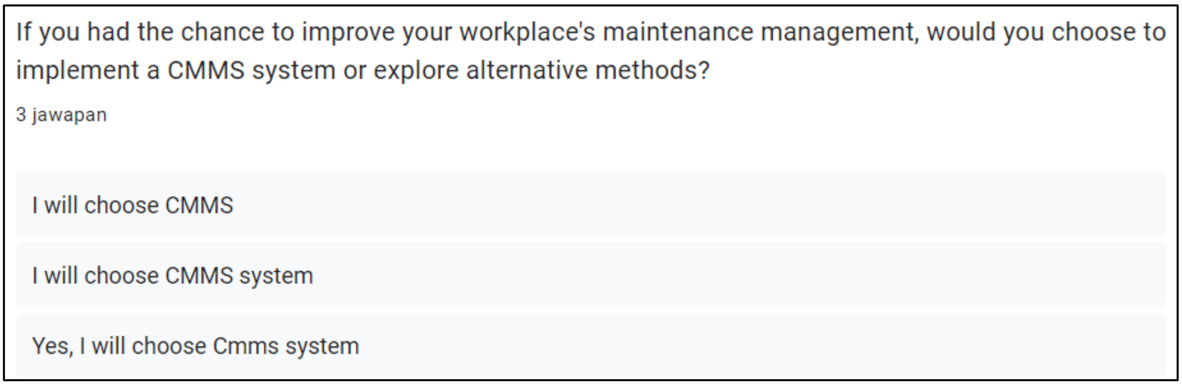
Developing a new maintenance plan incorporating routine inspections, predictive analytics, and preventive maintenance exemplifies a proactive approach as a result of respondent responses on Figure 4.5. This approach is designed to proactively identify and resolve potential issues before they escalate. The objective of implementing such a framework is to optimize equipment performance, extend the lifespan of components, and prevent unscheduled downtimes. Computerized Maintenance Management Systems (CMMS) play a crucial role in improving organizational efficiency and reducing operational disruptions by facilitating the proactive scheduling of preventive maintenance. Leveraging this advanced technology allows companies to move away from reactive maintenance strategies, thereby reducing the risk of unplanned downtime, costly repairs, and unscheduled breakdowns.

By means of the systematic scheduling of standard maintenance chores, CMMS enables companies to attend to any problems prior to their escalation, therefore increasing the life of equipment and enhancing overall asset performance.

Figure 4.5 Answers for question is a CMMS system suitable for their workplace



Based on Figure 4.6 shows that there is acceptance in the workplace to move forward with the Computerized Maintenance Management System (CMMS) installation. Acknowledging the possible advantages in optimizing maintenance protocols, augmenting effectiveness, and reducing unavailability, the resolution to implement CMMS signifies our dedication to ongoing enhancement and updating our operating procedures. Projected to have a significant impact on preventative maintenance procedures, resource optimization, and consequently, increased workplace efficiency, this strategic initiative anticipates the effective implementation of the CMMS system into the workplace. The benefits of improved maintenance management are expected to be realized through the cooperation of all stakeholders.


If you had the chance to improve your workplace's maintenance management, would you choose to implement a CMMS system or explore alternative methods?

3 jawapan

I will choose CMMS

I will choose CMMS system

Yes, I will choose Cmms system

Figure 4.6 The respondent's answers for implement a CMMS system to improve maintenance management

The *Pusat Penyelenggaraan Tasik Putrajaya* main problem has been found to be a high maintenance downtime and a lower machine lifespan, which raises the cost of breakdown maintenance. An irregular maintenance schedule and a weak preventive maintenance system are the two main causes of this. The workplace's inadequate preventative maintenance program highlights possible issues, such as machinery that is functioning at maximum capacity and approaching the end of its useful life, which increases the likelihood of failures. The problem is made worst by an over-reliance on corrective maintenance, which could hurt the company's profits and cause further downtime.

Survey data analysis in Figure 4.2 shows that the company are not regularly trained in maintenance methods, which may lead to skill problems and eventually, ongoing problems with downtime of the equipment. While technical training programs are essential for increasing labor knowledge, Figure 4.3 shows a concerning pattern of scheduled maintenance tasks not being followed. This emphasizes how crucial it is to assess the worth and efficacy of current training programs and fill in the knowledge gaps regarding the operation and maintenance of equipment.

As shown in Figure 4.4, respondents' understanding of the importance of root cause analysis (RCA) offers a chance to improve preventive maintenance schedules and reorganize the maintenance management system. RCA is a powerful investigative tool that can be used to identify serious systemic problems by examining operational and failure patterns. *Pusat Penyelenggaraan Tasik Putrajaya* may reduce responsibilities, prioritize inspections, and implement targeted training programs by customizing preventive maintenance plans based on root cause analysis (RCA) insights. This leads to decreased downtime, reduced corrective repairs, and a more productive equipment lifespan.

Figure 4.5 suggests creating a new maintenance plan with preventive maintenance, predictive analytics, and routine inspections in response to the issues found. The objectives of this proactive strategy are to increase equipment efficiency, improve equipment life, and avoid unplanned downtime. As seen in Figure 4.6, implementing Computerized Maintenance Management Systems (CMMS) becomes apparent as an effective way to improve organizational effectiveness. It will be expected that the implementation of CMMS will promote workplace productivity, optimize maintenance procedures, and better utilize assets, all of which will demonstrate a stakeholder's commitment to continuous improvement and collaboration.

4.3.1 Identification Location of Total Breakdown in Lake Maintenance

The lifeblood of our community, the Lake Maintenance Area ecosystem thrives due to diligent maintenance efforts. However, recent equipment breakdowns threaten the lake's well-being and operational efficiency. This report presents a comprehensive analysis of total equipment breakdowns within the Lake Maintenance Area, identifying the types, frequency, and potential consequences. Analyzing failure reports, maintenance records, and on site inspections uncovers critical insights to guide future maintenance strategies and safeguard the lake's health.

In the table 4.1 shows that the total of frequency of breakdown that happen in Lake Maintenance Area. These breakdown was taken from January 2023 and continue until November 2023. The purpose for this table is to determining which location is must to focus and requires additional investigation, the information presented in the figure serves as a core piece of information.

Table 4.1 The Frequency of Breakdown for *Pusat Penyelenggaraan Tasik Putrajaya* from January until November 2023

Location	Frequency of Breakdown	Downtime (Hours)	MTTR (Hours)
LMC	65	2148	33.0462
TBMF	46	2856	62.0870
LAKE VALLEY	12	1512	126
WETLAND	14	4368	312
FLAMINGO POND	12	5040	420

4.3.2 Pareto Analysis for Type of Location in Lake Maintenance Area

Often referred to as the 80/20 rule, Pareto Analysis posits that roughly 80% of the effects (often negative) stem from just 20% of the causes. By applying this principle, the problems was identified and focus for disproportionate disruption and allowing to focus efforts where they matter most. Below in Figure 4.7 shows the Pareto chart from the data Mean Time To Repair of breakdown at Lake Maintenance Area of Putrajaya.

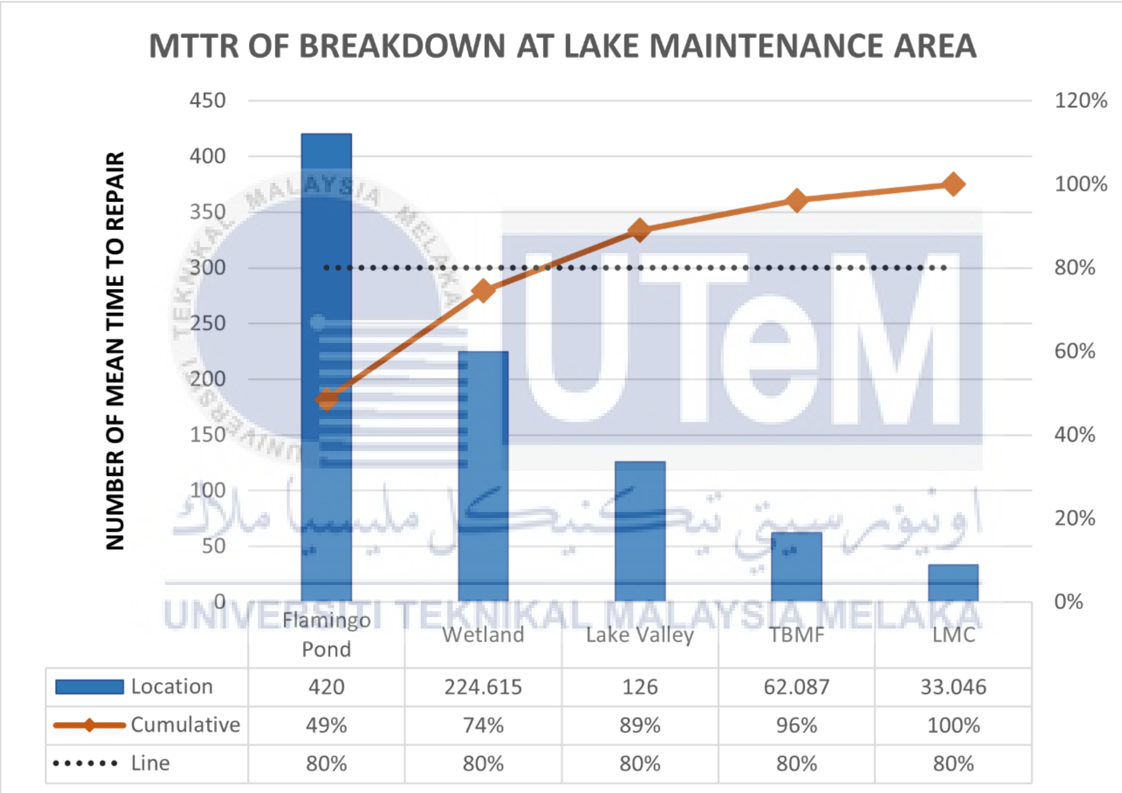


Figure 4.7 Pareto Chart for MTTR of Breakdown at Lake Maintenance Area in January until November 2023

The table shows the number of breakdowns at five different locations within the Lake Maintenance Area, along with the Mean Time to Repair (MTTR) for each location. The data is presented for the months January to November 2023. Figure 4.7 shows that Flamingo Pond has the most critical problem that occur in the Lake Maintenance Area. Flamingo pond need 420 or 49% of the total hours of mean time to repair the breakdown at Lake Maintenance Area. For Wetland, 224.615 or 26% of the MTTR shows a long repair challenges compared to Lake Valley, having 126 or 15% to repair of total breakdown. Due to its high number of equipment issues requiring repair and ongoing monitoring, Flamingo Pond will be prioritized for attention in this project. Furthermore, the maintenance schedule for Flamingo Pond will be closely evaluated and adjusted as needed.

4.3.3 Identification Equipment Breakdown in Flamingo Pond

The next step is to pinpoint the specific equipment within Flamingo Pond causing the most frequent breakdowns and contributing significantly to downtime. This analysis will follow the identification of critical breakdown equipment across the entire Lake Maintenance Area, including Flamingo Pond. Table 4.2 presented below, details the Mean Time to Repair (MTTR) for each piece of equipment in Flamingo Pond from January to November 2023. This data will allow us to identify the problematic equipment requiring prioritization for repair and maintenance.

Table 4.2 The Frequency of Breakdown at Flamingo Pond per month

Equipment	Frequency of Failure	Downtime (Hours)	MTTR (Hours)
Fresh Water Pump	1	504	504
Cascading Submersible Pump	1	504	504
Re-circulation Pump	1	336	336
Toveko Sand Filter	3	168	56
Compressor	4	12	3
Water Tank	2	24	12
Wash Water Pump	1	24	24
Dosing Pump	2	336	168
Gate Valve	6	48	8
Foutain	5	336	67.2
Ventilation Fan	2	24	12

Applying Pareto analysis to the MTTR data in Table 4.2 reveals that 20% of the equipment in Flamingo Pond is responsible for a staggering 80% of downtime, allowing us to strategically prioritize resources towards these critical assets. However, further examination of Table 4.2 reveals that while most equipment experiences infrequent failures but experienced long duration of downtime such as Fresh water pump, Cascading Submersible Pump and Re-circulation Pump.

4.3.4 Pareto Analysis for Equipment in Lake Maintenance Area

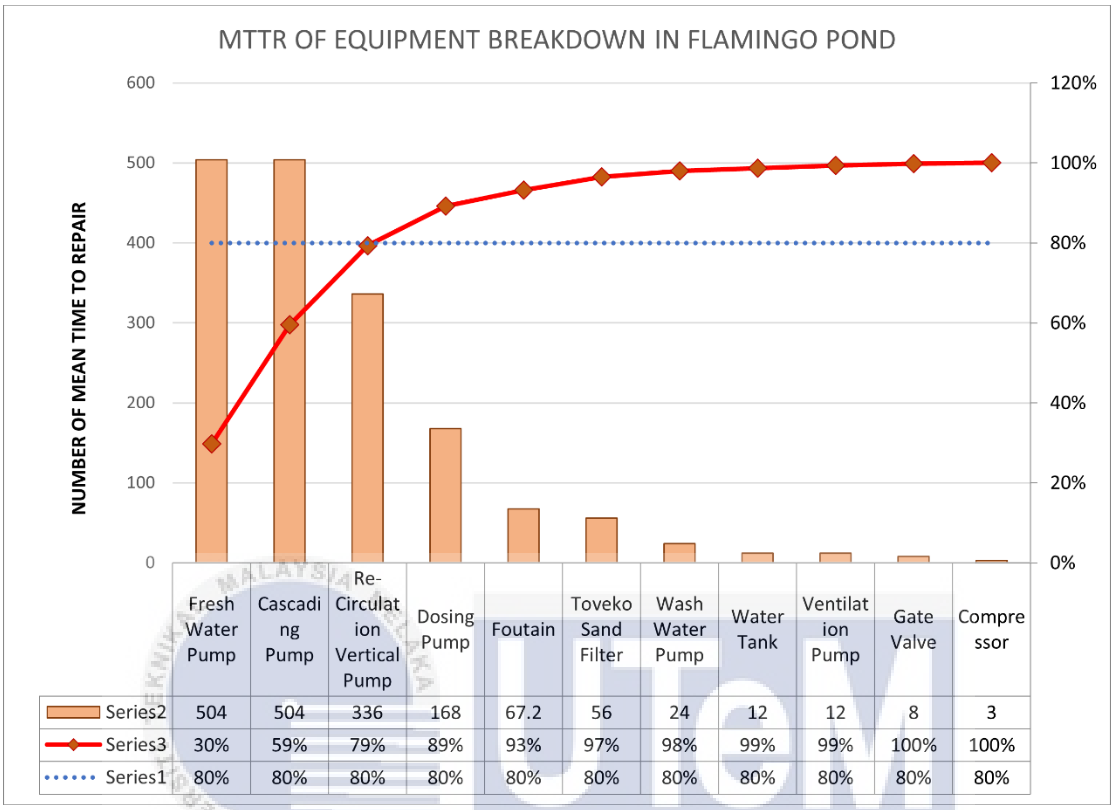


Figure 4.8 Pareto Chart for MTTR Equipment Breakdown at Flamingo Pond in January until November 2023

Applying Pareto analysis allows for the clear identification of the critical few equipment items contributing the majority of downtime at Flamingo Pond. The Pareto chart, based on Figure 4.8, reveals that equipment Fresh Water pump and Cascading Submersible pump are responsible for 504 or 30% of total downtime. This highlights the importance of focusing maintenance efforts on these specific assets. Looking closer, it can be seen that Re-circulation Vertical pump falls within the "vital few" category. These critical items, despite representing only 20% of the total equipment, contribute significantly to downtime at Flamingo Pond, with Dosing Pump causing 10% of downtime. This underscores the need for targeted interventions such as increase monitoring, preventative maintenance, or replacements to address these problematic equipment items.

MTTR tend to be longer for a few equipment in Flamingo Pond. This suggests that long repair times like complex repairs or lack of spare parts or training skill could be contributing to extended downtime. If the downtime continues for a longer period than it did in the past, it will result in the losses that the company has earned becoming even more significant. Therefore, implementing strategies to improve repair efficiency for this equipment group, such as improved training, spare parts optimization, or organized schedule maintenance, could also yield significant improvements in overall operational efficiency.

4.3.5 Root Cause Analysis

In many different industries, root cause analysis is a vital technique for problem-solving and continuous improvement that improves systems, processes, and overall organizational performance. Fundamentally, Root Cause Analysis encourages a proactive and useful analysis of occurrences or issues, going beyond simple symptom management. The goal of root cause analysis (RCA) is to identify the fundamental causes of problems by removing the layers of superficial concerns. Organizations can implement focused solutions through this methodological inquiry that address urgent concerns and avoid similar difficulties from happening in the future.

In the context of this final year project, the application of Root Cause Analysis will be examined as a critical component in understanding and addressing challenges within reducing the downtime that has occurred in the Flamingo pond area. This project aims to showcase the effectiveness of RCA in identifying the root causes of issues encountered during analysis the problem that happen in lake maintenance area. From the Pareto Analysis to address high downtime and associated equipment breakdown costs, Root Cause Analysis

(RCA) was conducted on the Fresh water pump, Cascading pump and Re-circulation vertical pump. This systematic approach identified the underlying issues causing equipment failures, paving the way for targeted solutions and improved operational efficiency.

4.3.6 Fresh Water Pump

Figure 4.9 Failures that occur in Fresh Water Pump

According Figure 4.9, Fresh Water pump are essential components in water supply systems, ensuring efficient and reliable delivery of clean water for various applications in Flamingo pond. The consistent and reliable operation of Fresh water pumps is essential for numerous applications, yet the occurrence of recurrent failures poses a significant challenge, warranting a thorough investigation into the root causes to enhance the efficiency and longevity of these vital systems. Fresh water pump is to transport clean water from a source to a desired location.

4.3.6.1 Fishbone Diagram and RCA for Fresh Water Pump

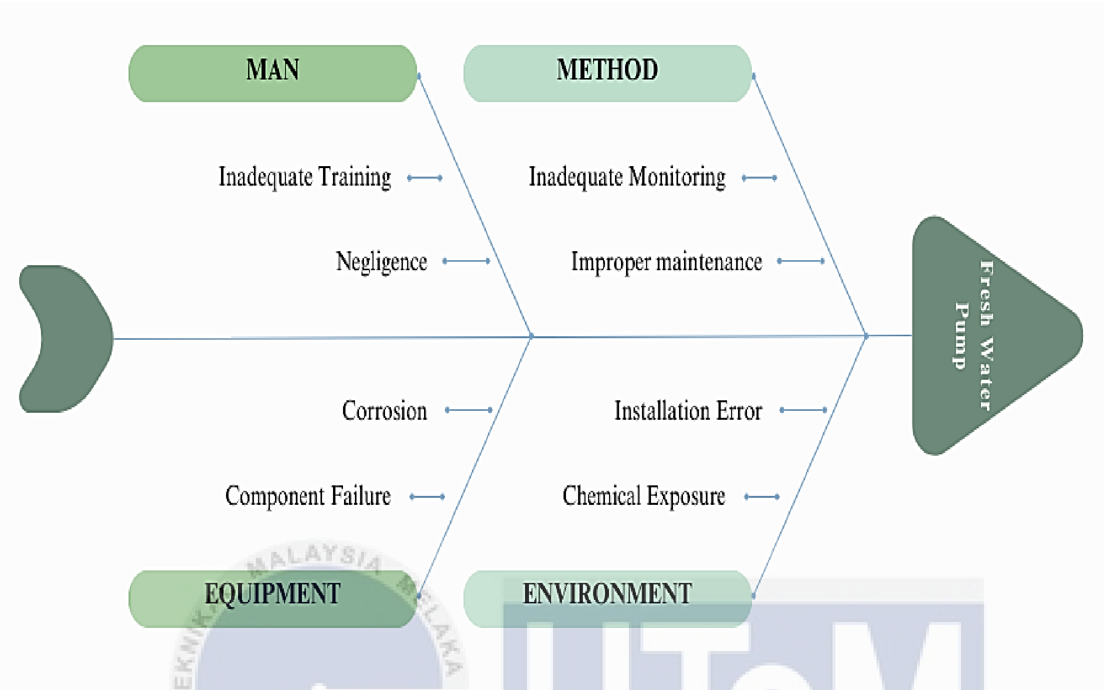


Figure 4.10 Fishbone Diagram for Fresh Water Pump

According to the results of the investigation Figure 4.10, Fresh water pumps are one of the causes of high MTTR. After further investigation, several related factors were identified. These factors include the quality of the men employed, the condition of the equipment, maintenance methods and environmental impact. Identifying the underlying cause requires a thorough understanding of these symptoms.

Table 4.3 RCA and changes improvement for Fresh Water Pump

Major Cause	Root Cause	Changes of Improvement (Recommendation)
Man: 1) Inadequate Training 2) Negligence	1) Inability to identify and address early warning signs can allow minor issues to escalate into major breakdowns. 2) Skipped maintenance schedules can lead to component failure, reduced efficiency and potential safety hazards.	1) Ensure operators receive thorough training on pump operation, maintenance and troubleshooting, covering both theoretical knowledge and practical hands-on experience. 2) Monitor operator performance, compliance with procedures, and maintenance schedules to identify and address potential issues early on.
Method: 1) Inadequate Monitoring 2) Improper maintenance	1) Does not monitor pressure, flow rate, temperature, vibration, and noise level. 2) Clogged filters impede flow, reduce efficiency, and strain the pump.	1) Implement automated monitoring systems if possible and train operators to recognize and report anomalies. 2) Perform routine inspections of the entire system, encompassing pipes and valves, to pinpoint potential sources of contamination that may contribute to filter clogging.
Equipment: 1) Corrosion 2) Component Failure	1) Contaminants like chlorides, sulfates, or nitrates can significantly increase the corrosivity of the water. 2) Motor Malfunction.	1) Choose material resistant and clean the pump regularly to prevent corrosion buildup. 2) Watch for worn bearings, seals, and impellers, and address motor issues like overheating or electrical faults.
Environment: 1) Installation Errors 2) Chemical Exposure	1) Unstable foundations cause excessive vibration. 2) Abrasive particles can wear down impellers and seals, reducing efficiency and causing leaks.	1) Update maintenance schedules to address seasonal changes and potential hazards. 2) Use dust filters or enclosure protection.

The initial branch of the RCA Fishbone diagram presented in Table 4.3 for Fresh Water pump breakdowns focuses on the "Man" or people aspect. Inadequate training stands out as a significant cause, resulting in an inability to recognize and address early warning signs, allowing minor issues to escalate. To tackle this issue, comprehensive training programs covering theoretical knowledge and practical hands-on experience in pump operation, maintenance, and troubleshooting are crucial. Additionally, addressing negligence, such as skipped maintenance schedules, can be mitigated by monitoring operator performance, compliance with procedures, and maintenance schedules, enabling organizations to identify and address potential issues early on.

In the Method category, it is identified that inadequate monitoring is a cause of Fresh Water pump breakdowns, mainly due to the omission of critical parameters such as pressure, flow rate, temperature, vibration, and noise level during operation. To address this issue, the recommended improvement involves the implementation of automated monitoring systems wherever possible. Additionally, operators should be trained to recognize and promptly report anomalies to ensure proactive maintenance. Another significant contributor is improper maintenance, with clogged filters impeding flow, reducing efficiency, and straining the pump. To counteract this, changes should focus on conducting regular inspections of the entire system, including pipes and valves. This proactive approach aids in identifying potential sources of contamination that could lead to filter clogging, thereby enhancing overall maintenance practices and preventing avoidable pump malfunctions.

In the Equipment branch, corrosion emerges as a major cause, with contaminants increasing water corrosivity. Choosing resistant materials and regular cleaning to prevent corrosion buildup are crucial. Component failure, particularly motor malfunction, is identified as another key issue, emphasizing the importance of monitoring for worn bearings, seals, and impellers, as well as addressing motor issues like overheating or electrical faults.

Environmental factors impacting Fresh Water pump breakdowns include significant contributions from installation errors, particularly through unstable foundations causing excessive vibration. Addressing this issue involves updating maintenance schedules to accommodate seasonal changes and potential hazards, ensuring the stability of the pump foundation. Another environmental challenge arises from chemical exposure, where abrasive particles can wear down impellers and seals, diminishing efficiency and causing leaks. The recommended changes include the implementation of dust filters or enclosure protection to shield the pump components from harmful chemicals, ultimately safeguarding the pump's longevity and performance.

In conclusion, the RCA Fishbone diagram offers a systematic understanding of the myriad factors contributing to Fresh Water pump breakdowns. Analyzing the problems in terms of people, methods, environment, and equipment has led to the identification of key challenges and proposed targeted improvements. Enhancing monitoring processes and addressing maintenance issues, such as filter clogging, can significantly enhance the operational efficiency of the pump system. By adopting these changes and improvements, organizations can establish a comprehensive strategy to minimize Fresh Water pump breakdowns.

4.3.7 Cascading Submersible Pump

Figure 4.11 Failures that occur in Cascading Submersible Pump

According to Figure 4.11, the Cascading Submersible pump in Flamingo Pond experienced a failure due to a non-functioning motor pump, attributed to damage. Additionally, the pump area was filled with moisture and rust. From the Figure 4.11, the action must take to fix the pump to work normally because Cascading pumps can be more expensive than single-stage pumps due to their more complex design.

4.3.7.1 Fishbone diagram and RCA for Cascading Submersible Pump

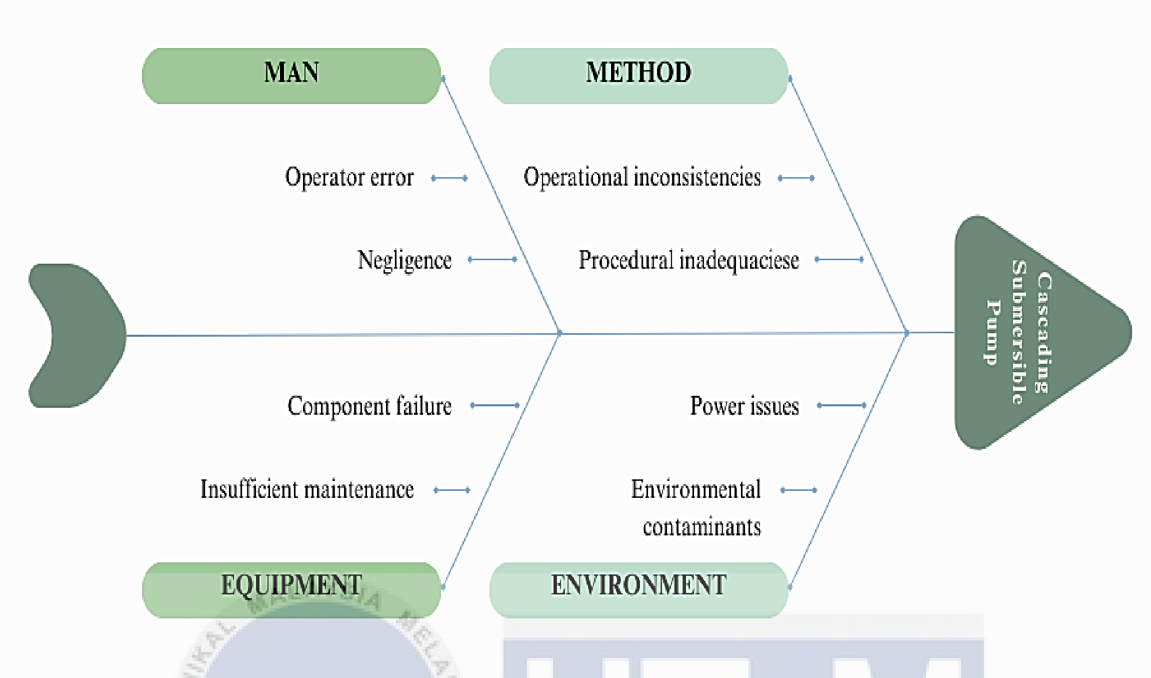


Figure 4.12 Fishbone diagram for Cascading Submersible Pump

According to the results in the Fishbone diagram Figure 4.12, analyzing the connections and interactions between various causes on the diagram makes it easier to identify the most likely root causes and prioritize them for further investigation. This process helps identify the true causes of problems and implement solutions to prevent them from recurring.

Major Cause	Root Cause	Changes of Improvement (Recommendation)
Man: 1) Operator Error 2) Negligence	1) Inadequate training in operation and maintenance and improper valve manipulation 2) Skipping or postponing preventive maintenance.	1) Implement comprehensive training programs for cover operation, maintenance, troubleshooting, and safety procedures 2) Develop clear checklists and guidelines for operation, maintenance, and emergency response. Conduct regular audits and provide feedback to improve compliance.
Method: 1) Operational inconsistencies 2) Procedural inadequacies	1) Failure to follow recommended operating parameters and inappropriate schedule for servicing and component replacements. 2) Insufficient lubrication schedules for specific operating conditions	1) Install real-time data monitoring and analysis tools to track key parameters like pressure, flow rate, temperature, and vibration 2) Implement preventive maintenance tasks like lubrication, cleaning, and component replacements before failures occur.
Equipment: 1) Component failure 2) Insufficient maintenance	1) Worn-out bearings, seals, impellers, or motor components due to age or use. 2) Failure to replace worn components before failure.	1) Implement a proactive inspection program to identify potential issues early. Check for wear and tear, leaks, corrosion, and electrical faults. 2) Utilize proper lubrication techniques, cleaning methods, and replacement parts. Invest in training for maintenance personnel to ensure quality workmanship.
Environment: 1) Power issues 2) Environmental contaminants	1) Frequent power outages leading to abrupt shutdowns and water hammer. 2) Abrasive dust or sand accumulation clogging impellers and seals.	1) Uninterruptible power supplies or backup generators can prevent disruptions and water hammer due to power outages. 2) Use dust filters, protective enclosures, and corrosion-resistant materials to mitigate the impact of contaminants and external elements.

Table 4.4 RCA and changes improvement for Cascading Submersible Pump

In the “Man” or people category based on Table 4.4, operator errors stand out as a major contributor to Cascading pump breakdowns, primarily stemming from inadequate training in both operation and maintenance, coupled with improper valve manipulation. To rectify this issue, a critical improvement involves the implementation of comprehensive training programs covering the entirety of pump operation, maintenance, troubleshooting, and safety procedures. This holistic training approach ensures that operators acquire both theoretical knowledge and practical hands-on experience. Additionally, the development of detailed checklists for startup, operation, and shutdown procedures is recommended of pump operation. These changes aim to enhance operator competency, reduce the likelihood of errors, and ultimately contribute to the reliability and efficiency of the Cascading pump system.

The second branch, "Method" delves into operational aspects contributing to pump breakdowns. Operational inconsistencies, such as failure to follow recommended parameters and inappropriate servicing schedules, are identified as root causes. Installing real-time data monitoring and analysis tools to track key parameters, like pressure, flow rate, temperature, and vibration, is recommended to enhance operational efficiency. Procedural inadequacies, such as insufficient lubrication schedules, can be addressed through the implementation of preventive maintenance tasks, ensuring lubrication, cleaning, and component replacements are performed before failures occur.

Within the “Equipment” category, component failure emerges as a major cause of Cascading Submersible pump breakdowns, attributed to worn-out bearings, seals, impellers, or motor components resulting from age or extended use. To address this issue, a crucial improvement involves the implementation of a proactive inspection program aimed at identifying potential issues at an early stage. This includes thorough checks for wear and tear, leaks, corrosion, and electrical faults. Simultaneously, insufficient maintenance, particularly the failure to replace worn components before actual failure occurs, poses a significant risk. To mitigate this, recommended changes involve adopting proper lubrication techniques, implementing effective cleaning methods, and using high-quality replacement parts. Furthermore, investing in training for maintenance personnel becomes essential to ensure a high standard of workmanship, ultimately contributing to the prevention of component failures and prolonging the overall lifespan of the Cascading pump system.

Within the “Environment” category, two significant causes contribute to Cascading pump breakdowns. The first cause is power issues, particularly frequent power outages leading to abrupt shutdowns and the potential for water hammer. The root cause lies in the instability of the power supply. To address this, recommended improvements involve the implementation of uninterruptible power supplies or backup generators, which can effectively prevent disruptions and mitigate the risk of water hammer during power outages. The second major cause is environmental contaminants, with abrasive dust or sand accumulation posing a threat to pump components, particularly impellers and seals. The root cause is the lack of protective measures against external elements. To counteract this, changes should focus on utilizing dust filters, protective enclosures, and corrosion-resistant materials to mitigate the impact of contaminants and external elements, thereby enhancing the resilience of the Cascading pump system against environmental challenges.

In conclusion, the RCA Fishbone diagram provides a comprehensive understanding of cascading submersible pump breakdowns, highlighting the interplay of factors across people, methods, environment, and equipment. By addressing operator errors, enhancing operational methods, mitigating environmental challenges, and ensuring proper equipment maintenance, organizations can develop a holistic strategy to minimize pump breakdowns. This approach not only increases the reliability and efficiency of submersible pumps but also contributes to reduced downtime and maintenance costs over the long term.

4.3.8 Re-circulation Vertical Pump

Figure 4.13 Failures that occur in Re-circulation Vertical Pump

Re-circulation is a specialized type of pump designed to move fluids within a closed-loop system. A malfunctioning pump can lead to increased energy consumption due to reduced efficiency and potentially damage other components due to improper fluid circulation. From Figure 4.13, it can be observed that the pump area has been filled with water as a result of damage that has caused corrosion in the area. Root cause investigation is conducted to identify the problem and find ways to fix it.

4.3.8.1 Fishbone Diagram and RCA for Re-circulation Vertical Pump

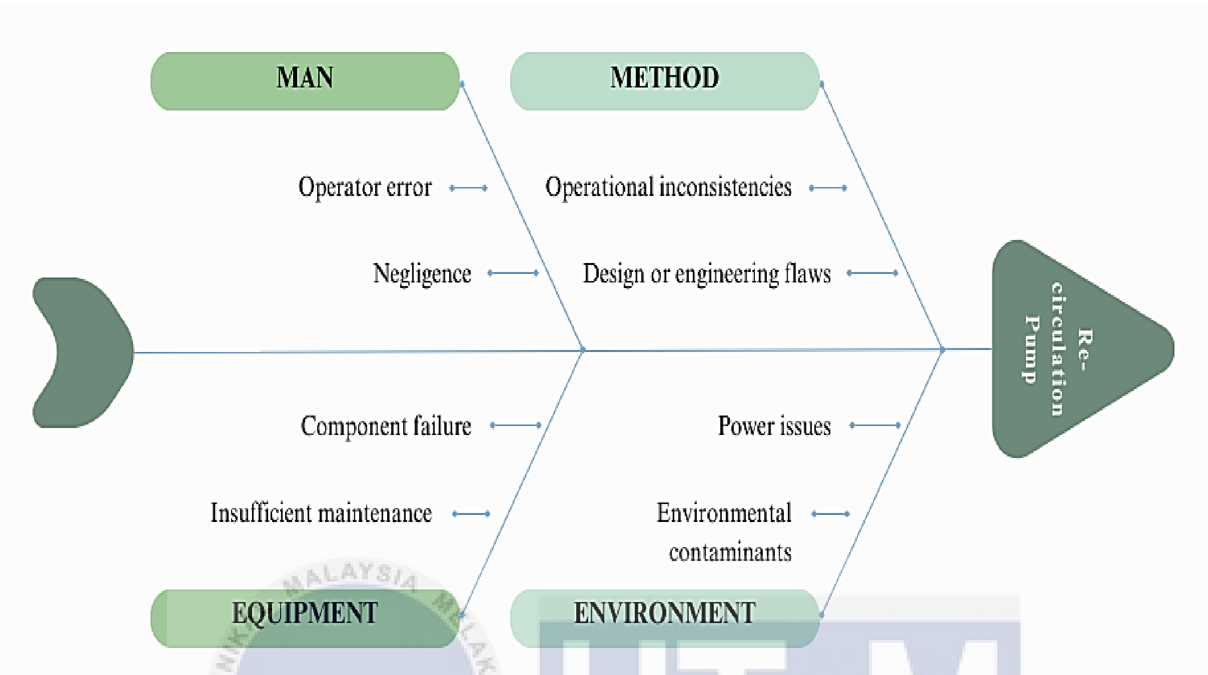


Figure 4.14 Fishbone diagram for Re-circulation Vertical pump

From the Fishbone diagram Figure 4.14, the problem was identified of the root cause of failure for equipment Re-circulation Vertical pump for ongoing improvement the asset to be good working. Depending on the breakdown complexity, repairs or replacements can be costly, impacting budgets and operational schedules. This problem need to take action to address the equipment breakdown issue and reduce costs.

Table 4.5 RCA and changes improvement for Re-circulation Pump

Major Cause	Root Cause	Changes of Improvement (Recommendation)
Man: 1) Operator Error 2) Negligence	1) Ignoring pump limitations or exceeding flow and head requirements. 2) Skipping or postponing preventive maintenance schedules.	1) Develop checklists for startup, operation, and shutdown. 2) Enforce preventive maintenance schedules with accountability measures.
Method: 1) Operational inconsistencies 2) Design or engineering flaws	1) Inadequate monitoring of key parameters like temperature, vibration or cavitation. 2) Lack of automated monitoring or alarm systems for critical parameters	1) Standardize procedures and checklists for different operating scenarios. 2) Implement additional sensors and monitoring systems for critical parameters.
Equipment: 1) Component failure 2) Insufficient maintenance	1) Worn-out bearings, seals, impellers, or motor components due to age or use. 2) Failure to inspect for wear and tear, leaks, or cavitation damage.	1) Monitor operating conditions and identify potential stress factors. 2) Improve access for easier inspection and maintenance tasks.
Environment: 1) Power issues 2) Environmental contaminants	1) Voltage fluctuations impacting pump speed and performance. 2) Corrosive elements in the re-circulated fluid degrading pump components.	1) Invest in surge protectors and voltage regulators for stable power supply. 2) Implement enclosures or shielding to protect the pump from external elements.

The first branch of the RCA Fishbone Diagram on Table 4.5 focuses on the "Man" or people aspect of the Re-circulation Vertical pump breakdown. The major causes identified include operator error, such as ignoring pump limitations or exceeding flow and head requirements and negligence in adhering to preventive maintenance schedules. To address these issues, changes and improvements should involve the development of comprehensive checklists for startup, operation and shutdown procedures, as well as enforcing preventive maintenance schedules with accountability measures.

The second branch, "Method" highlights operational inconsistencies as a major cause of pump breakdown. Inadequate monitoring of key parameters like temperature, vibration, or cavitation is identified as a root cause. To improve this, standardizing procedures and checklists for different operating scenarios is recommended. Additionally, addressing design or engineering flaws by implementing additional sensors and monitoring systems for critical parameters is crucial to prevent breakdowns caused by operational inconsistencies.

The third branch, "Equipment" delves into the physical components of the pump. Component failure, including worn-out bearings, seals, impellers, or motor components due to age or use, is identified as a major cause. To mitigate this, continuous monitoring of operating conditions and identifying potential stress factors is essential. Additionally, insufficient maintenance, such as failure to inspect for wear and tear, leaks, or cavitation damage, can be addressed by improving access for easier inspection and maintenance tasks. Overall, a holistic approach that combines changes in procedures, monitoring systems, environmental protections, and equipment maintenance is necessary to minimize re-circulation vertical pump breakdowns.

The fourth branch, "Environment" considers external factors affecting pump performance. Power issues, such as voltage fluctuations, are identified as a major cause impacting pump speed and performance. To counter this, investing in surge protectors and voltage regulators for stable power supply is recommended. Moreover, addressing environmental contaminants, such as corrosive elements in the re-circulated fluid, involves implementing enclosures or shielding to protect the pump from external elements.

In conclusion, this comprehensive strategy recognizes that a variety of variables frequently contribute to pump malfunctions, and solutions must also be comprehensive. Through the implementation of the recommended modifications to people, methods, environment, and equipment, companies can develop a robust plan to reduce the likelihood of Re-circulation Vertical pump failures. To ensure the long-term dependability and effectiveness of these crucial elements, it is important to promote a culture of responsibility, adherence to best practices, and ongoing development. By taking these steps, companies can improve pump performance, address problems early on, and ultimately lower maintenance costs and downtime related to pump failures.

4.4 Plan Preventive Maintenance

The peacefulness of Putrajaya's Flamingo Pond depends on how well technology and the natural world interact. It is advised that the pond's Cascading Submersible pumps, Re-circulation pump, and Freshwater pump undergo a carefully designed preventative maintenance program. These are crucial components that generate the pond's cascading waters and maintain its delicate equilibrium. This approach designates certain duties to every part, going above and beyond routine inspections. Examples of these duties include impeller inspections and motor vibration monitoring. The objective is to protect the dependability of the pumps, extend their lifespan, and maintain the tranquil atmosphere of the pond for future generations by stepping up the frequency of these checks and implementing a methodical methodology. This preventive strategy protects the delicate environment in the water, minimizing interruption and downtime and enabling the beautiful flamingos to continue their graceful.

4.4.1 Preventive Maintenance Checklist

My goal for this topic is to create a thorough preventative maintenance checklist that is centered on organizing and maximizing maintenance tasks for different kinds of equipment pump and their systems. The aim is to create a systematic structure that guarantees the proactive and routine maintenance of essential parts, reducing the likelihood of unforeseen malfunctions, enhancing operational effectiveness, and prolonging the life of equipment. The knowledge that efficient preventative maintenance is essential in a variety of industries to improve dependability, decrease downtime, and eventually result in cost savings is what drives this initiative. The checklist intends to give an organized method that can be customized to the unique requirements of diverse systems by methodically organizing and carrying out maintenance chores.

Table 4.6 Improvement checklist maintenance schedule for Fresh Water Pump

No	Description	Freq	Done	Pass / Fail		Remarks
				(P)	(F)	
Fresh Water Pump						
a	Check for any visible leaks, corrosion, or damage to the pump and associated components	M				New Plan
b	Check and tighten all screws, bolts, and connections	M				Original Plan
c	Vacuuming eliminates accumulated sediment, dirt, and other debris	6M				Original Plan
d	Check oil levels in the motor and gearbox if applicable	M				New Plan
e	Check the motor and cable termination	M				Original Plan
f	Check and adjust pump and motor alignment if necessary	3M				New Plan
g	Repainting tank if necessary	M				Original Plan
h	Check oil level (lubrication oil)	3M				Original Plan (Change 6 month to 3 month)
i	Check valve condition	3M				Original Plan (Change 6 month to 3 month)
j	Clean the valve components and inspect them for wear or damage	3M				New Plan
k	Check and cleaning impellers and filters (note any physical damage or excessive wear)	M				New Plan
l	Inspect seals and gaskets and replace seals and gaskets as needed	3M				New Plan
m	Conduct vibration analysis to identify any abnormal levels of vibration	6M				New Plan

From Table 4.6, a number of significant improvements have been made in the ongoing effort to optimize the Fresh Water pump maintenance schedule in order to ensure the pump lifespan and successful operation. The first set of improvements is on a comprehensive examination of the pump and related parts, providing a monthly schedule for examining obvious leaks, corrosion, or damage. This proactive strategy makes it possible to detect possible problems early on and stop small problems from developing into significant problems. In addition, regular maintenance such as cleaning the impellers and valve components, checking the oil levels in the motor and gearbox, and maintaining clear flow pathways and effective filtration all help to avoid wear and pressure. The maintenance schedule now more closely correlates with the Fresh Water Pump dynamic operational demands due to the increased frequency of these jobs.

A change in the frequency of crucial component maintenance is another important improvement. From a 6 month frequency to a more regular 3 month schedule, inspections of seals and gaskets, oil levels, valve condition, and alignment of the pump and motor have all been changed. This modification signifies a calculated shift in focus towards a proactive and preventative maintenance methodology. Through regular inspections and adjustments, the maintenance team can prevent operating disruptions by identifying and resolving potential issues before they arise. By paying more attention to these crucial components, unplanned malfunctions can be prevented, enhancing the overall dependability and performance of the Fresh Water pump.

Moreover, one significant improvement to the maintenance plan is the addition of a biannual vibration analysis work. Every six months, vibration analysis should be carried out to enable early identification of abnormal vibration levels, which may be a sign of underlying problems. This innovative diagnostic technique guarantees that any new issues impacting the stability or alignment of the pump are quickly resolved. The team may better control potential hazards and maximize the performance of the pump by taking control of this task and gaining useful information about the pump's condition by adding it into the maintenance routine. In conclusion, these enhancements support the Fresh Water Pump preventive maintenance approach by highlighting routine inspections, early problem detection, and focused interventions to preserve the pump dependability and increase its operating life.

Table 4.7 Improvement checklist maintenance schedule for Cascading Submersible pump

No	Description	Freq	Done	Pass / Fail (P)	Pass / Fail (F)	Remarks
Cascading Submersible Pump						
a	Test run for 2 nos of submersible pump	6M				Original Plan
b	Change oil or coolant (Inspect oil or coolant for evidence of Cascading)	6M				Original Plan
c	Check condition and operation of upper and lower shaft seals	6M				Original Plan
d	Check Impeller (note any physical damage or excessive wear)	6M				Original Plan
e	Check condition and operation leakage and bearing sensors (if equipped)	3M				Original Plan (Change 6 month to 3 month)
f	Drain oil from oil housing and replace with new oil	3M				Original Plan (Change 6 month to 3 month)
g	Check for worn or loose impeller or propeller	6M				Original Plan
h	Check impeller wear rings (rotating & stationary)	6M				Original Plan
i	Clean the pump and remove any debris or sediment	3M				Original Plan (Change 6 month to 3 month)
j	Test the pump: Put the pump back into the well and test it to make sure it is running properly	6M				Original Plan
k	Remove and replace the valve from the system and disassemble it.	6M				Original Plan
l	Clean the valve components and inspect them for wear or damage	3M				Original Plan (Change 6 month to 3 month)
m	Replace any damaged or worn parts and reassembled	3M				Original Plan (Change 6 month to 3 month)
n	Conduct vibration analysis to identify abnormal levels of vibration.	6M				New Plan

The Cascading Submersible pump maintenance schedule at Table 4.7 has undergone a number of improvements in an effort to achieve both extended equipment life and operational excellence. These enhancements represent an important move toward a proactive and preventative maintenance approach, focusing essential components that have a major impact on the performance of the pump. One significant improvement is the increased frequency of jobs, which include checking valve components for wear or damage, removing oil from the oil housing, cleaning the pump to remove dirt and monitoring the state and functionality of leakage and bearing sensors. These duties, which were previously scheduled every six months, are now completed every three months, demonstrating a commitment to more regular and in-depth inspections.

The Cascading Submersible pump dynamic operating demands led to a purposeful modification to the maintenance schedule for important parts, with the goal of preventing potential problems before they increase. Maintenance workers can reduce the possibility of malfunctions by inspecting the leakage and bearing sensors more often. This allows them to quickly resolve any variations in the pump performance. In a similar vein, regular cleaning and oil changes help to reduce wear and tear and guarantee that the pump runs as efficiently as possible. This change in maintenance intervals is essential to promoting a proactive maintenance culture and recognizes the significance of these parts in the overall reliability of the pump.

In addition, the biannual vibration analysis assignment emphasizes the dedication to improved diagnostics. Every six months, vibration analysis is performed to offer a thorough evaluation of the structural stability and operational health of the pump. By doing this preventive measure, maintenance workers can spot unusual vibration levels, which may be the first signs of hidden problems. The team may obtain significant insights into the status of the pump by incorporating vibration analysis into their routine maintenance. This enables them to avoid potential dangers and enhance the performance of the pump. In conclusion, these enhancements to the Cascading Submersible Pump maintenance schedule demonstrate a deliberate move toward proactive inspections, increased regularity of important duties, and the integration of sophisticated diagnostics, all of which enhance the pump's dependability and operational longevity.

Table 4.8 Improvement checklist maintenance schedule for Re-circulation pump

No	Description	Freq	Done	Pass / Fail (P)	Pass / Fail (F)	Remarks
Re-circulation Pump						
a	Ensure control panel is clean and dry,free from rags and empty chemical bags	3M				Original Plan (Change 6 month to 3 month)
b	Check for leaks around pump seals and connections.	3M				New Plan
c	Check pump set and associated equipment are in working condition	3M				Original Plan
d	Check and clean the nozzles if necessary	3M				Original Plan
e	Check the floating structure position , re-balance if necessary	3M				Original Plan
f	Check pump running phase	3M				Original Plan
g	Conduct vibration analysis to identify abnormal levels of vibration	6M				New Plan
h	Check pump cable tension	M				Original Plan
i	Inspect seals and gaskets and replace if necessary	M				New Plan
j	Check and clean HDPE pipe suction if necessary	M				Original Plan
k	Check the timer sequence	M				Original Plan
l	Switch off power supply to the board and check for loose connections and sparks.	M				Original Plan
m	Check and adjust pump and motor alignment if necessary.	M				New Plan
n	Check the motor terminal of the pump	M				Original Plan

Significant improvements have been made to the Re-circulation Pump maintenance schedule at Table 4.8 in an ongoing attempt to ensure either its longevity and operational efficiency. Increasing the frequency of jobs that are critical to the dependability of the pump is a significant improvement. The first important change is the modification of the maintenance schedule to guarantee that the control panel is dry and clean. This task was previously scheduled every six months, however it is currently performed every three months. By doing this preventive action, possible problems that could arise from the buildup of rags, dirt, or chemical bags in the control panel are avoided, and the electrical systems of the pump remain clean of challenges that might hinder performance.

Checking for leaks around pump seals and connections more frequently is another important improvement. Changes from a 6-month to a 3-month frequency allow the maintenance crew to quickly detect and fix possible fluid leak problems. This modification is in line with the objective of safeguarding the integrity of the system and avoiding damage to pump components. Furthermore, a proactive attitude to maintenance is reinforced by the increased frequency of jobs like monitoring and modifying pump and motor alignment and examining seals and gaskets, both of which are planned on a monthly basis. By preventing wear and tear, these actions help to improve the Re-circulation Pump overall reliability.

Another notable addition to the maintenance plan is the incorporation of biannual vibration analysis work. Vibration analysis, an advanced diagnostic method allowing for the early identification of abnormal vibration levels suggesting underlying difficulties, should be conducted every six months. This preventive action ensures the structural integrity of the pump and the alignment of crucial parts. By integrating vibration analysis into the maintenance routine, the team can address potential risks and maximize performance, gaining insights into the pump's condition. In conclusion, these improvements contribute to a more thorough and methodical approach to Re-circulation Pump maintenance, emphasizing early problem detection and preventive actions to maintain the pump's reliability and prolong its working life.

4.5 Expected Result for Mean Time to Repair (MTTR) Before and After Recommendation to Implement New Maintenance Schedule

When assessing the effectiveness and dependability of maintenance procedures, Mean Time to Repair (MTTR) is a critical measure that provides information on how long it takes to get equipment working again following a malfunction. The anticipated outcomes of introducing a new maintenance schedule for the Fresh water pump, Cascading pump, and Re-circulation pump are covered in detail in this article. The major goal is to evaluate the expected changes in Mean Time to Repair before and recommendation after implement the new maintenance schedules are put into effect. Examining the MTTR will allow us to gauge how well the new maintenance procedures are working to reduce downtime and improve each pump's overall reliability. A comparison table will also be provided, including a thorough summary of the expected improvements in repair times for each of the three types of pumps. This will enable a more in-depth assessment of the effects of the revised maintenance schedules.

Table 4.9 Comparison of MTTR

No	Pump Type	Current MTTR (hours)	Expected Improvement MTTR (hours)
1	Fresh Water Pump	504	Decrease (100.8)
2	Cascading Submersible Pump	504	Decrease (100.8)
3	Re-circulation Pump	336	Decrease (67.2)

The Mean Time to Repair (MTTR) for equipment breakdown at the Flamingo Pond is projected to be affected by the propose of a new preventive maintenance action, as shown in the comparison Table 4.9. The three types of pumps that are taken into consideration are the Cascading Pump, Recirculation Pump, and Fresh Water Pump. The MTTR values for each type of pump prior to the new schedule's adoption are shown in the second column. For the MTTR of the Fresh Water Pump and Cascading Pump is 504 hours, and Re-circulation Pump is marginally lower at 336 hours. These preliminary numbers are used as a starting point to evaluate how well the suggested modifications to the maintenance schedule work.

The expected MTTR results following of the new implementation preventative maintenance schedule are displayed in the third column. It is projected that the MTTR would significantly drop for all pump types, as a result of the proactive and methodical approach that the updated maintenance standards have brought. The magnitude of the anticipated improvements in repair times is indicated by the expected improvement highlighted in the fourth column. This projected results paint a symphony of success is an expected 80% reduction in Mean Time to Repair (MTTR) for all pumps. This translates to fewer disruptions, lower maintenance costs, and a thriving ecosystem in Flamingo pond will be happen.

The anticipated improvements in MTTR signify the potential benefits of the new preventive maintenance schedule, including enhanced operational resilience, minimized disruptions, and improved efficiency in addressing breakdowns. This table comparison provides a clear overview of the positive impact after recommendation to implement new preventive maintenance schedule.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The primary focus of this final year project was to evaluate and enhance maintenance practices within Flamingo Pond, with a specific emphasis on the Fresh Water Pump, Cascading Submersible Pump, and Re-circulation Pump. The initial objective involved determining the frequency and types of preventive and corrective maintenance activities carried out in the Pusat Penyelenggaraan Tasik Putrajaya areas. Through a comprehensive analysis of maintenance records and personnel interviews, this objective provided a baseline understanding of the maintenance needs. The project applied Root Cause Analysis (RCA) to develop guided preventive maintenance plans that were more effective. Additionally, the monthly inspection schedule for each pump was adjusted to include vibration analysis and thorough component checks, demonstrating an intentional effort to identify potential issues early and prevent unscheduled breakdowns.

The second goal was accomplished with great success, showing a major step toward the development of more effective maintenance processes with the introduction of new preventive maintenance plans and activities for every pump. Significant adjustments to the Fresh Water Pump, Cascading Submersible Pump, and Recirculation Pump maintenance schedules shown an efficient and methodical approach, including more frequent inspections, advanced diagnostic tools, and additional responsibilities for better systematic maintenance. This commitment to improving maintenance procedures is consistent with the third project goal, which focuses on increasing the requirements for preventative maintenance by carefully reviewing and modifying each pump's maintenance plan.

A critical aspect of the project involves assessing the impact of these modifications on repair times, measured by Mean Time to Repair (MTTR) before and after implementing the new preventive maintenance schedules. The anticipated significant improvements in repair times across all pump types underscore how the modified schedules have effectively reduced downtime and enhanced the overall operating robustness of the Flamingo Pond pumps. The expected 80% improvement rate highlights the success of the new preventative maintenance strategy in promptly and effectively addressing equipment issues.

In conclusion, this project not only demonstrates the successful assessment and optimization of maintenance schedules for the *Pusat Penyelenggaraan Tasik Putrajaya* pump systems but also establishes a valuable framework for the methodical planning and execution of preventive maintenance programs in the future. The careful examination and modifications made to each pump's maintenance plan reflect a dedication to raising the standard of preventative maintenance, with the potential to significantly improve equipment durability, dependability, and sustainability in the *Pusat Penyelenggaraan Tasik Putrajaya* and serve as a guide for future maintenance programs in similar environments.

5.2 Recommendations

Given the current challenges posed by an increase in corrective maintenance and the identified weaknesses in the existing preventive maintenance system, to ensure the successful execution of this project, the strong recommendation is to utilize a Computerized Maintenance Management System (CMMS). While acknowledging that the initial investment in a CMMS system may be perceived as expensive, its effectiveness in transforming preventive maintenance practices cannot be overstated. The CMMS system serves as a digital hub, providing a centralized platform to streamline and orchestrate maintenance activities. This digital solution enables a seamless transition from a reactive to a proactive maintenance approach, enhancing the overall reliability and performance of the equipment in *Pusat Penyelenggaraan Tasik Putrajaya*.

Beyond the cost, there are other advantages to CMMS system installation. The asset availability and productivity are greatly increased by the CMMS through the optimization of maintenance schedules and the reduction of unscheduled outages. This increase in efficiency results in lower expenses for routine maintenance, emergency repairs, and downtime. By prioritizing preventive maintenance tasks, the system makes sure that important parts are regularly inspected and maintained, which averts possible malfunctions before they happen. This proactive approach reduces the need for expensive corrective actions, which makes maintenance less costly and sustainable. The CMMS system ensures that essential spare parts are readily available when needed, eliminating the risk of downtime due to part shortages. This enhanced spare parts management not only contributes to improved asset reliability but also supports a more cost-conscious inventory management approach, aligning with the overall goal of operational efficiency.

In conclusion, though a CMMS system may appear like a big initial spending, the long-term advantages greatly exceed the expenses. The system promotes operational excellence by establishing *Pusat Penyelenggaraan Tasik Putrajaya* for sustainable and effective maintenance practices. For the purpose of minimizing the need for corrective maintenance, minimizing the amount of downtime, and guaranteeing the continued dependability of vital equipment, the innovative effect of CMMS on spare parts management, preventative maintenance, and overall operational efficiency is important. The project's major objective is to improve the Flamingo Pond preventative maintenance quality in order to provide the groundwork for long-term sustainability and optimal asset performance. The integration of a CMMS system is in line with this objective.

5.3 Project Potential

In terms of future plans for additional maintenance equipment at Pusat Penyelenggaraan Tasik Putrajaya, the results of this final year project in analyzing and enhancing maintenance practices within the Flamingo Pond, with a particular focus on the Fresh Water Pump, Cascading Submersible Pump and Re-circulation Pump, holds huge potential. With advanced tasks like vibration analysis and thorough component checks, the recently developed preventive maintenance schedules which are guided by Root Cause Analysis (RCA) offer an effective basis for ongoing maintenance improvement. With an emphasis on more frequent inspections, advanced diagnostic tools, and extra assignments to improve systematic maintenance, the meticulous and exact approach taken in changing maintenance schedules shows an ongoing commitment to efficiency. This commitment provides the stage for an ongoing, proactive approach to equipment maintenance.

Furthermore, Mean Time to Repair (MTTR), which measures the expected effect on repair times, is a useful parameter for further analysis. The potential for higher operational reliability and lower corrective maintenance costs is shown by the anticipated 80% improvement rate in downtime reduction. In addition to the direct advantages for Flamingo Pond, the knowledge acquired from this project can act as a template for other comparable settings, directing future maintenance plans toward enhanced equipment longevity, dependability, and sustainability. This project's methodical planning and execution set the stage for a proactive, data-driven approach to maintenance, providing a model for company's looking to improve their asset management procedures going forward.

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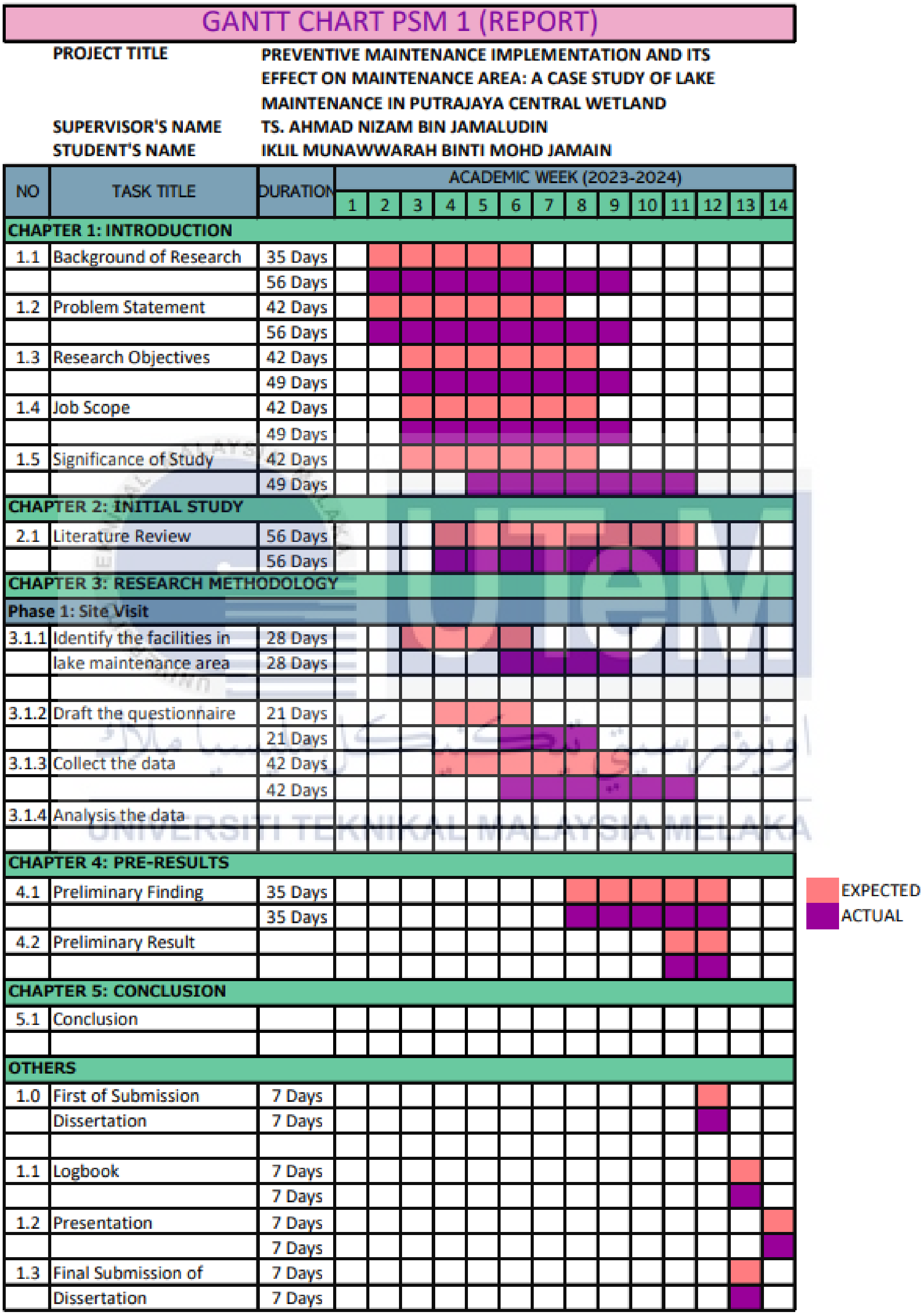
APPENDICES

APPENDIX A Gantt Chart PSM 1



APPENDIX B Gantt Chart PSM 2

GANTT CHART PSM 2 (REPORT)

PROJECT TITLE: PREVENTIVE MAINTENANCE IMPLEMENTATION AND ITS EFFECT ON MAINTENANCE AREA: A CASE STUDY OF LAKE MAINTENANCE IN PUTRAJAYA CENTRAL WETLAND.

SUPERVISOR'S NAME: TS. AHMAD NIZAM BIN JAMALUDIN

STUDENT'S NAME: IKLIL MUNAWWARAH BINTI MOHD JAMAIN

NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
PROJECT MILESTONES																
PHASE 2: COLLECT THE DATA																
3.2.1	Site Visit	2 Days														
		2 Days														
3.2.2	Distribute the questionnaire to the respondents	28 Days														
		35 Days														
3.2.3	Identify the problem area	14 Days														
		21 Days														
PHASE 3: ANALYSIS DATA																
3.3.1	Analyse Questionnaire	28 Days														
		28 Days														
3.3.2	Identify the equipment breakdown	35 Days														
		49 Days														
3.3.3	Identify equipment breakdown in area choosen	42 Days														
		42 Days														
3.3.4	Analyse component break down using RCA	35 Days														
		42 Days														
CHAPTER 4: PRE-RESULTS																
4.1	Result	35 Days														
		35 Days														
4.2	Discussion	21 Days														
		35 days														
CHAPTER 5: CONCLUSION																
5.1	Conclusion	14 Days														
		14 Days														
5.2	Recommendation	21 Days														
		14 Days														
OTHERS																
1.1	Logbook	7 Days														
		7 Days														
1.2	Presentation	7 Days														
		7 Days														
1.3	Final Submission of Dissertation	7 Days														
		7 Days														

Expected
Actual

APPENDIX C Result of Questionnaire from responden at Department in *Pusat Penyelenggaraan Tasik Putrajaya*

Borang Soal Selidik untuk mengurangkan masalah kegagalan aset penyelenggaraan di Pusat Penyelenggaraan Tasik Putrajaya

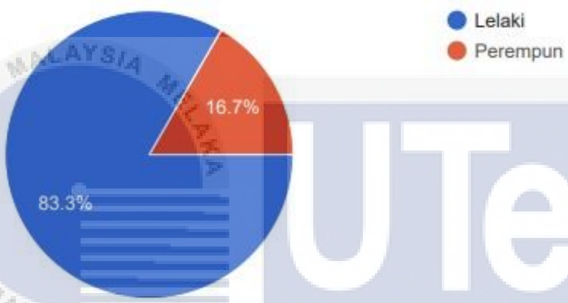
6 jawapan

Siarkan analitis

Jantina

Salin

6 jawapan

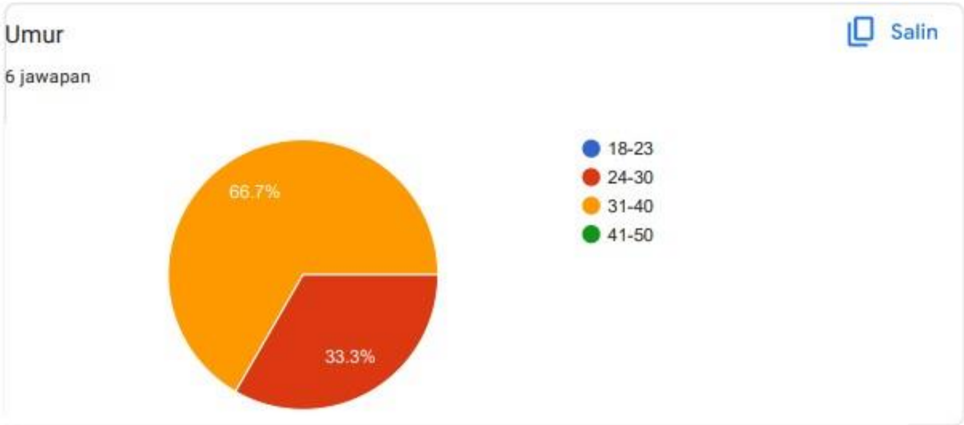


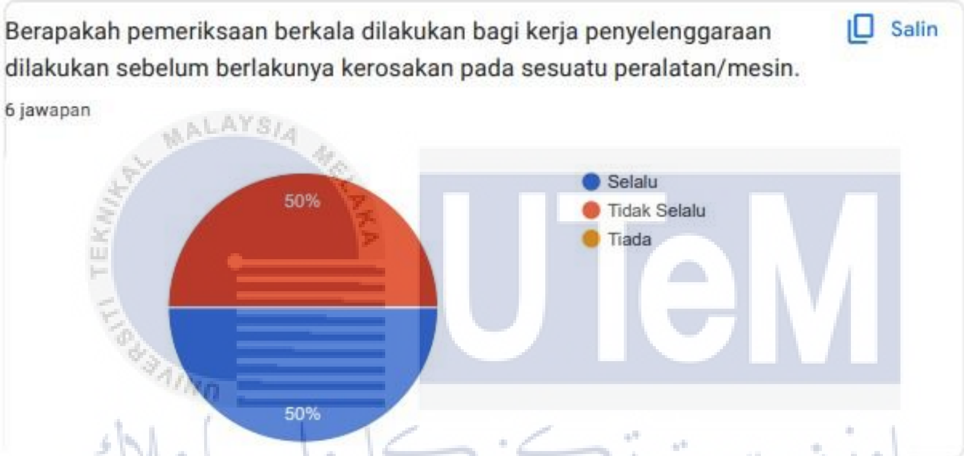
Kaum

Salin

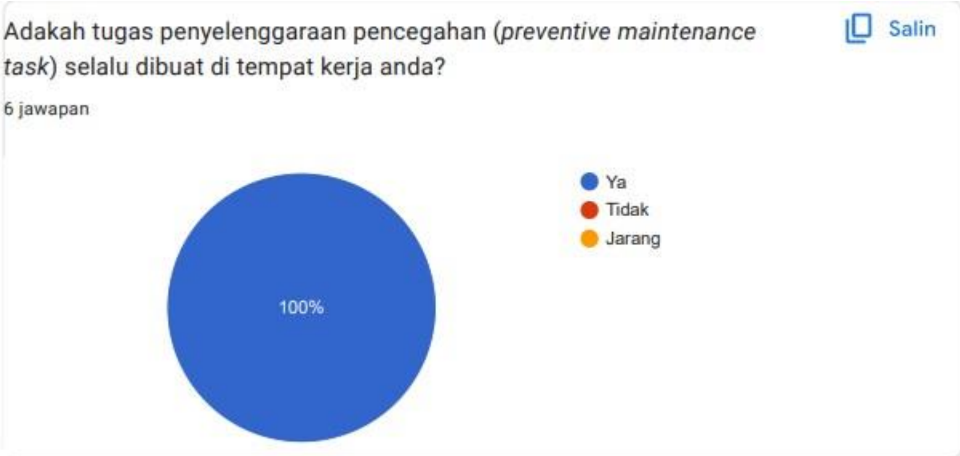
6 jawapan

APPENDIX D Result from Collecting Data of Questionnaire





APPENDIX E Result from Collecting data of Questionnaire



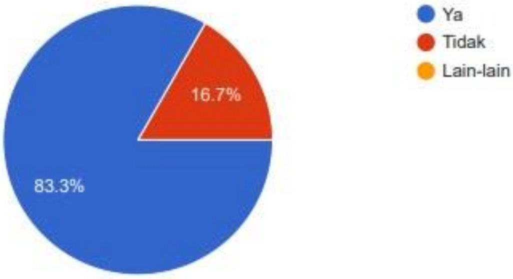
APPENDIX F   Result from collecting data of Questionnaire

APPENDIX G Result from collecting data of Questionnaire

Adakah anda ingin membuat perubahan terhadap sistem pengurusan penyelenggaraan di tempat kerja anda supaya menjadi lebih bagus?

Salin

6 jawapan



Apakah jenis work order untuk permintaan penyelenggaraan yang terdapat di tempat kerja anda?

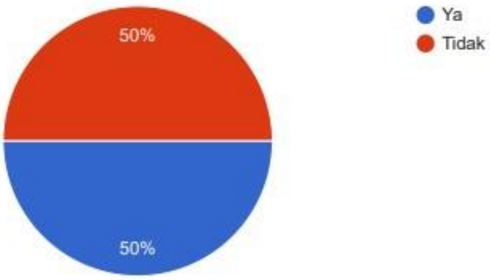
Salin

6 jawapan

Adakah anda tahu tentang Sistem pengurusan penyelenggaraan berkomputer (CMMS)?

Salin

6 jawapan

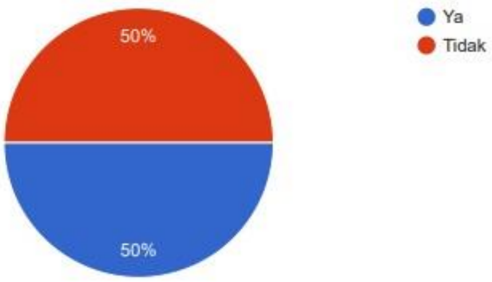


APPENDIX H Result from collecting data of Questionnaire

Adakah anda tahu tentang kebaikan Sistem pengurusan penyelenggaraan berkomputer (CMMS) ini untuk meningkatkan produktiviti dan prestasi peralatan?

Salin

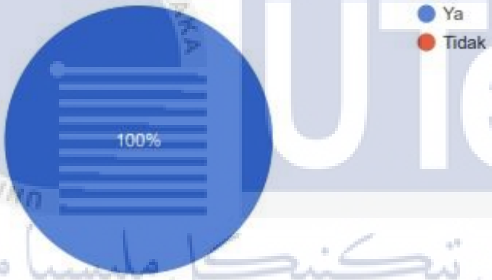
6 jawapan



Jika diberi peluang, adakah anda mahu Sistem pengurusan berkomputer (CMMS) ini digunakan di tempat kerja anda?

Salin

6 jawapan



APPENDIX I Result from Data Analysis Questionnaire 1-Person

Does your workplace experience a lot of downtime for maintenance? *

Yes

What types of maintenance activities typically cause the most downtime at your workplace? * *(example: replacement / upgrade / maintenance*)

Replacement and Upgrading

What is the main problem that occurs at your workplace? *

Lifetime of the machine. Mostly 20 years of product

In your opinion, what factors lead to equipment always damage? *

Lack of knowledge on procedure to use

APPENDIX J Result from Data Analysis Questionnaire 1-Person

Would implementing a new preventive and corrective plan be considered necessary in your current workplace? *

Yes

How many training events or programs focusing on skills development were conducted for maintenance employees within the past 6 months? *

1-2 times

Do you see any opportunities to enhance your workplace's maintenance management system? *

Yes

Have you ever considered what changes could be made to your workplace's maintenance management system to make it more effective? *

Root cause analysis

Do you think a CMMS system would be a suitable fit for your workplace? *

yes

If you had the chance to improve your workplace's maintenance management, would you choose to implement a CMMS system or explore alternative methods? *

I will choose CMMS

APPENDIX K Result from Data Analysis Questionnaire 2-Person

Does your workplace experience a lot of downtime for maintenance? *

yes

What types of maintenance activities typically cause the most downtime at your workplace? *
(example: replacement / upgrade / maintenance)

replacement & upgrade

What is the main problem that occurs at your workplace? *

Machine lifespan affect the problem failure

In your opinion, what factors lead to equipment always damage? *

Lack of knowledge and practical

APPENDIX L Result from Data Analysis Questionnaire 2-Person

Would implementing a new preventive and corrective plan be considered necessary in your current workplace? *

Yes

How many training events or programs focusing on skills development were conducted for maintenance employees within the past 6 months? *

1-2 times

Do you see any opportunities to enhance your workplace's maintenance management system? *

Yes

Have you ever considered what changes could be made to your workplace's maintenance management system to make it more effective? *

Do root cause analysis

Do you think a CMMS system would be a suitable fit for your workplace? *

Yes

If you had the chance to improve your workplace's maintenance management, would you choose to implement a CMMS system or explore alternative methods? *

I will choose CMMS system

APPENDIX M Result from Data Analysis Questionnaire 3-Person

Does your workplace experience a lot of downtime for maintenance? *

Yes

What types of maintenance activities typically cause the most downtime at your workplace? *
(example: replacement / upgrade / maintenance)

maintenance

What is the main problem that occurs at your workplace? *

high maintenance downtime

In your opinion, what factors lead to equipment always damage? *

Lack of proper schedule

APPENDIX N Result from Data Analysis Questionnaire 3-Person

Would implementing a new preventive and corrective plan be considered necessary in your current workplace? *

Yes

How many training events or programs focusing on skills development were conducted for maintenance employees within the past 6 months? *

1-2 times

Do you see any opportunities to enhance your workplace's maintenance management system? *

Yes

Have you ever considered what changes could be made to your workplace's maintenance management system to make it more effective? *

Improve preventive maintenance schedule

Do you think a CMMS system would be a suitable fit for your workplace? *

yes

If you had the chance to improve your workplace's maintenance management, would you choose to implement a CMMS system or explore alternative methods? *

Yes, I will choose Cmms system

PSM 2

by Hazim Aiman

Submission date: 11-Jan-2024 08:17AM (UTC+0000)
Submission ID: 2269290307
File name: CHECK_TURNITIN_IKLIL.pdf (1.54M)
Word count: 21325
Character count: 128125