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| RESEARCH ARTICLE

OEE Improvement by Increasing Maintenance System Efficiency Through DigiPM and DigiBox

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| ABSTRACT
PT Andromeda is experiencing a decline in market share compared to its local competitors, with a steady decrease in operating margin of 1-2% annually. To address this, the company initiated efforts to strengthen its business fundamentals and competitiveness in 2022. Within the Supply Chain, various activities are involved, from procuring raw materials to delivering finished goods to customers. To address these challenges, the proposed solutions are DigiPM and DigiBox which aim to establish a seamless connection between spare parts inventory management and preventive maintenance activities. Improving OEE is crucial for enhancing productivity and reducing downtime in manufacturing systems. This study examines the limitations of the existing maintenance system, highlighting three primary issues: inefficient spare part management, lack of clear inventory information, and insufficient knowledge sharing. To address these issues, a digital platform integrating maintenance activities with spare parts inventory is proposed. Through the application of CRT Analysis, the 8 waste of lean, and AHP under the framework of PDCA, DigiPM and DigiBox are developed as solutions, with DigiPM facilitating digital maintenance and DigiBox managing spare parts inventory. Post-implementation, OEE increases by around 4% from 2022, with significant reductions in breakdowns and minor stoppages. Repair and maintenance costs also show significant savings of 4 billion IDR. Maintenance digitalization provides data-driven insights, facilitates communication, enables report analysis, and prevents similar problems, serving as a learning system for technicians.

| KEYWORDS

Maintenance, Digitalization, Spare Part, Inventory, CRT Analysis, 8 Waste Lean

| ARTICLE INFORMATION

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1. Introduction

During pre-Covid-19 period, Indonesia, the fourth-most populous country in the world, has experienced an average annual GDP growth rate of 5%. As per observation from (Juhro & Iyke, 2020) the economic growth in Indonesia is driven by consumption around 60%. On top of that, the worldwide Beauty & Personal Care market is expected to reach USD 483 million in 2020 and placing Indonesia as the top 5 countries with its growth in Asia (Senn-Kalb, 2020).

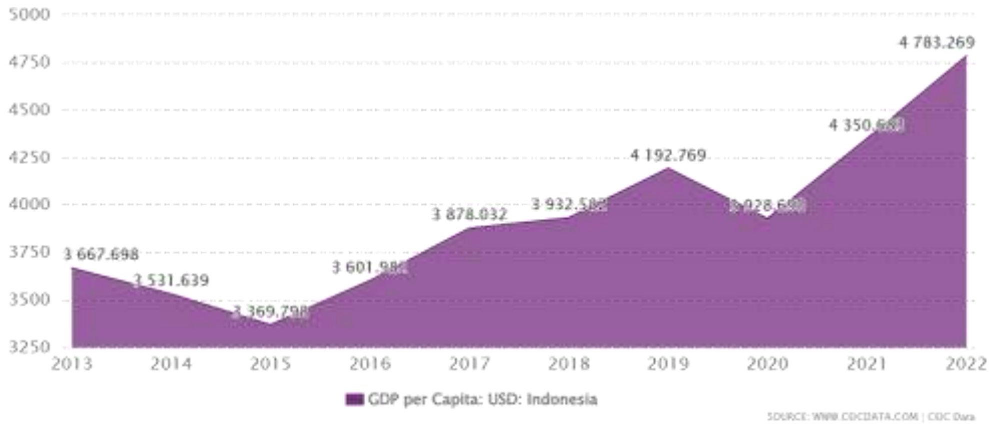

Figure 1. GDP Indonesia from 2013-2022

However, PT. Andromeda is facing a downtrend in the market share compared to its local competitors (Internal source, 2021). Their operating margin slowly decreases 1-2% in each year (Annual Report, 2022). Hence, in 2022, PT Andromeda tried to strengthen the business fundamentals and the competitiveness as a solid foundation for long-term growth. The company implemented five strategic priorities, namely: 1) To strengthen and unlock the full potential of the core brands; 2) To expand and enrich the portfolio to the premium and value segments; 3) To build an execution powerhouse to strengthen leadership in the main channels; 4) To implement E-Everything in all business lines; and 5) To remain at the forefront of sustainable business development.

During the implementation of E-Everything, the company transformed the business process from upstream to downstream by eliminating complexity, integrating operations, and leveraging data, insights, and technology to create a better- greater customer experience. Simplified operational tasks will transform the efficiency and effectiveness of processes that streamline Customer Development, Supply Chain and Finance, as well as create added value for customers and partners.

In the Supply Chain, there were a lot of activities, from procuring raw materials, processing it into finished goods, then delivering them to customer. The processing of finished goods will be done in the factory which includes many complexities . The machine healthiness should be maintained and reviewed regularly. PT Andromeda already initiated the use of the Andromeda Manufacturing System which could be enhancing operational efficiency and optimizing the performance.

Figure 2. Dashboard Report of Operational Production PT. Andromeda

The importance and integral nature of the maintenance function as a fundamental component of the Andromeda Manufacturing System cannot be underestimated. Its proper execution is a prerequisite for driving on-time delivery, first-time quality, and cost competitiveness across all sourcing units. The overall objective of maintenance is to maximize equipment reliability while minimizing costs. Maintenance cost, consisting of spare parts, maintenance labor, and third-party services as defined by standard plant accounting procedures, typically represent a significant portion of the total operating expenditure in Andromeda factories.

Efficient management of spare parts plays a crucial role in achieving an optimal balance between two seemingly contradictory objectives. On the one hand, there is a vision to have 100% availability of spare parts, enabling immediate delivery to breakdown locations and facilitating repairs on the first attempt. On the other hand, there is a vision to maintain the lowest possible levels of spare parts in stock. In the pursuit of enhancing operational efficiency and optimizing performance within the Andromeda

Manufacturing System, several key objectives arise in relation to spare part management. These objectives encompass reducing cycle-time by mitigating lead times, transportation times, and repair and return times; enhancing the kitting and delivery processes; enhancing inventory accuracy; minimizing inventory levels and the associated carrying costs; augmenting the service level of the storeroom; and ultimately improving overall profitability.

By focusing on the reduction of cycle-time, PT. Andromeda aims to streamline and expedite the various stages involved in the spare parts management process. This includes minimizing lead times, which refers to the time required to acquire or replenish spare parts from suppliers, as well as reducing transportation times, which involve the transit duration from the supplier to the designated storeroom or maintenance facility. Additionally, the objective is to diminish repair and return times, which pertain to the time taken to restore and return spare parts to operational readiness following repairs or maintenance activities.

Improving the kitting and delivery processes entails optimizing the organization and packaging of spare parts to facilitate their efficient and timely delivery to the designated maintenance locations. This optimization ensures that the necessary spare parts are readily available when needed, thus minimizing delays and downtime associated with maintenance operations.

Another objective is to increase inventory accuracy, which involves implementing robust inventory management systems and practices that ensure the precise tracking and recording of spare parts within the storeroom. Accurate inventory records enable efficient stock control, timely replenishment, and effective demand forecasting, consequently minimizing the risk of stockouts or excessive inventory levels.

To achieve cost optimization, the reduction of inventory levels and associated carrying costs is crucial. By maintaining optimal inventory levels, Andromeda aims to strike a balance between ensuring spare parts availability and minimizing the financial burden of carrying excess inventory. This is achieved through meticulous inventory planning, forecasting, and demand analysis, thereby preventing overstocking or understocking situations. Moreover, enhancing the service level of the storeroom is a vital objective. This involves optimizing the processes, systems, and personnel responsible for managing and dispensing spare parts. By ensuring prompt and accurate order fulfillment, efficient stock retrieval, and responsive customer service, Andromeda seeks to enhance the overall satisfaction of maintenance teams and minimize disruptions caused by delayed or inaccurate spare parts provision. Ultimately, the overarching objective of pursuing these various goals in spare part management is to improve profitability. By streamlining processes, reducing costs, increasing efficiency, and minimizing downtime, Andromeda aims to enhance its financial performance and achieve sustainable profitability in the context of spare part management.

Preventive Maintenance plays a pivotal role within the Andromeda Production System, as it is essential for ensuring the overall health and functionality of machines. To accomplish this, the implementation of a robust maintenance system is imperative, which should be seamlessly integrated with the entire operational framework. PT. Andromeda has adopted SAP as its enterprise resource planning (ERP) system. However, the maintenance schedule is currently manually managed, relying on administrative clerks to handle the task. Furthermore, the recording of spare part inventory is also done manually, giving rise to potential discrepancies during stocktaking processes. In an effort to digitize the maintenance operations, an initial system has been developed, known as DigiPM 1.0. This application automates the scheduling of maintenance activities and assigns them directly to technicians. Nevertheless, there remains a lack of integration with the warehouse system, leading to discrepancies in tracking the utilization or return of spare parts. Additionally, the availability of parts for maintenance activities is not readily accessible through the application, potentially causing conflicts during the preparation of spare parts. To address these challenges, the proposed solutions are DigiPM 2.0 and DigiBox, which aim to establish a seamless connection between spare parts inventory management and preventive maintenance activities. By implementing these applications, the need for manual clerical work can be minimized, while ensuring the accuracy of stock records. Therefore, the issues previously mentioned serve as the foundation for the research conducted in this final project as the OEE Improvement by Increasing Preventive Maintenance Compliance and Robust Maintenance System Through DigiPM and DigiBox.

2. Literature Review

2.1 PDCA Framework

According to Song & Fischer (2020), PDCA (plan-do-check-act) is a control framework facilitating iterative process improvement in manufacturing and beyond. PDCA is based on scientific approaches which related to hypothesis, experiment, and evaluation. It is stated that the analyst should take action based on the conclusions of the evaluation (Zohuri & McDaniel, 2021). The PDCA cycle and scientific method employ iterative methodology to validate hypotheses, yielding progressive knowledge enhancement. Fig x shows multiple iterations of PDCA cycle are repeated to achieve optimal problem resolution and operational excellence (Moen & Norman, 2009). Zohuri & McDaniel (2021) explain how to use PDCA by recognizing an opportunity and plan a change as part of Plan Stage. Continue with testing the change and carrying out a small-scale study which included as Do Stage. Then, for the Check Stage, do the test review, analyze the results, and identify the learning outcomes. At the last stage of Act, the action is taken based on the learning outcomes. If the change does not work, go through the cycle again with a different plan. However, if it is successful, incorporate the solutions into the wider changes. The learning outcomes can be used to plan new improvements and start a new cycle.

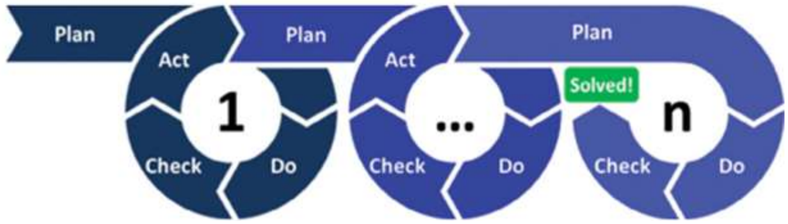

Figure 3. Multiple PDCA Iteration Process Illustration (Moen & Norman, 2009)

2.2 Current Reality Tree

Gaspar et al. (2019) stated that Goldratt developed a set of Thinking Processes tools to put TOC-TP on practice, including logic trees like the Current Reality Tree (CRT), which defines central problems in systems (Resende & Amaral, 2015). The CRT is a methodological tool for systematic problem-solving and decision-making (Umble & Umble, 2015), involving steps such as identifying Undesirable Effects (UDEs), arranging them in cause-and-effect relationships, analyzing root causes, developing and testing solutions, and reviewing results to update the CRT. This rigorous and visual method helps address root causes rather than symptoms, enhancing the likelihood of effective and sustainable solutions.

2.3 The 8 Waste of Lean

Lean philosophy defines waste as any activity or process that does not add value to the end product or service. It identifies eight primary sources of waste that hinder organizational efficiency. These include: (1) Defects, resulting from errors or rework; (2) Overproduction, producing more than demand; (3) Waiting, idle time due to equipment downtime or lack of materials; (4) Non-Utilized Talent, underutilization of employees' skills; (5) Transportation, unnecessary movement of materials; (6) Inventory, excess materials or finished goods; (7) Motion, unnecessary movement of people or equipment; and (8) Overprocessing, using excessive resources or unnecessary steps (McCarty et al., 2004).

2.4 Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a widely recognized key performance indicator providing a holistic assessment of production machine performance. OEE integrates six significant manufacturing losses through a tripartite framework, encompassing availability (unplanned stoppages and setup times), performance rate (operational inefficiencies and speed reductions), and quality rate (output conformity to standards), thereby providing a holistic evaluation of manufacturing machine effectiveness (Thiede, 2023). However, PT. Andromeda has a different approach to calculating the OEE where the calculation will refer to the Manufacturing Performance losses and Process Driven losses. It reflects how effectively the Loading Time is being used to produce Good Volume (Agarwal et al., 2015). The structure of OEE on the PT. Andromeda will be supported based on top-down and bottom-up approach which the Manufacturing Performance Losses and Process Driven Losses are measured during production planning that shown in Fig 4. Furthermore, Each of the losses can be defined according to losses that happen in every situation, as described in Fig 5. (Agarwal et al., 2015).

Figure 4. OEE Calculation (Agarwal et al., 2015)

Figure 5. Losses in OEE Calculation (Agarwal et al., 2015)

2.5 Maintenance Management System

All the activities of the management that determine the maintenance objectives or priorities (defined as targets assigned and accepted by the management and maintenance department), strategies (defined as a management method in order to achieve maintenance objectives), and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, and several improving methods including economical aspects in the organization (Ben-Daya et al., 2016). Controlling the maintenance activities in any facility requires an effective organization. Also required is an accurate, comprehensive, easily accessible database of relevant information. Some maintenance organizations still manage their operations with a manual system or with no system at all. In all but the smallest of maintenance operations, manual systems break down under the burden of the vast amount of information generated and required by maintenance (William W. Cato and R. Keith Mobley, 2002). For this reason, the digital system is now being recognized as a powerful tool for maintenance to store, retrieve, calculate, organize, and present vast amounts of data efficiently and accurately.

2.6 Digital System Transformation

Digital transformation is a process that aims to enhance a system by triggering significant changes to its workflows through combinations of information, computing, communication, and connectivity technologies (Vial, 2019). As stated by Maretto et al. (2023), the digital transformation will enable the manufacturer to retrieve and analysis of data in real time and, above all, allow to connect machines and elements of the physical world, that can now communicate with each other; moreover, these technologies are being increasingly used to support humans, from strategic decision-making to assembly activities. Hence, the factory is able to increase their productivity and, at the same time, increase their responsiveness and adaptation ability to both demand and productive mix.

2.7 Maintenance Digitalization

Combining business-as-usual (BAU), at this point, is maintenance activity, and the digital ecosystem results in new collaborative organizational networks which resulting fully integrated and collaborative manufacturing system to achieve customer satisfying needs (Suuronen et. al., 2022). Furthermore, by having digital maintenance allows the operations to be transformed into data-driven evidence-based practices that make it possible to track the sources of product faults, analyze production efficiency and identify bottle necks, and predict future resource requirements (Lu et al., 2020). On the other hand, as the complexity of the machines increases to fulfil the market demand that needs more unique products, the digital platform can be used for the sharing information platform so that information can be shared more efficiently. User information is also very valuable. Better understanding the user makes it more likely that a company can apply its development resources correctly and better people development (Eisenmann et al., 2006).

2.7 Conceptual Framework

This study conducts an in-depth investigation into the prevailing inefficiencies and opportunities for improvement within the manufacturing performances in PT Andromeda. The research identifies key areas of concern, including excessive spare parts inventory, unnecessary clerical processing, prolonged machine repair times, non-value-added motion and underutilization of personnel. By implementing Current Reality Tree (CRT) and Swimlane methodologies, the analysis is performed to understand the underlying causes and interrelationships. The findings inform the development of alternative solution proposals designed to optimize manufacturing performance, answer research questions and provide scalable applications for implementation in other factories.

Figure 6. Conceptual Framework

3. Methodology

The research project explores several research questions which require a step-by-step approach. The various sources from literature review, group discussions, and historical records will be used to analyze the business issue, define problems, alternative solutions, and performance evaluation. The method that will be used is a combination of qualitative and quantitative methods to study the manufacturing performance, maintenance system, and spare parts inventory. The data collection for this thesis report will use several resources which: the primary data sourced from the group discussion, interview, and historical data of OEE Performance, Maintenance Records, and Spare Part Spendings from PT. Andromeda, while the secondary data was derived from annual report and literature review. The research methodology uses a mixed methods approach, which combining both quantitative and qualitative research methodologies. Quantitative data is collected from recorded company data, while qualitative data is gathered from group discussions and interviews that will be subjected to be used to find the root cause.

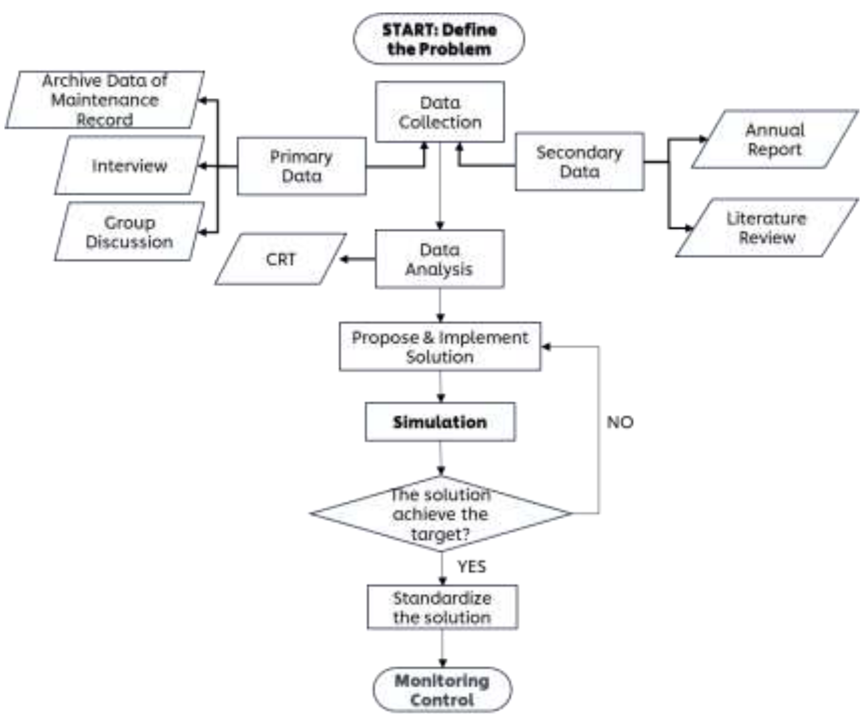

Figure 7. Research Methodology

The quantitative data will be collected from recorded data on the factory OEE performance, maintenance activities records, and spare parts spendings. This data will shows the previous trends and performance on the OEE performance and spare parts usage. The qualitative data will be collected using the following approaches:

1. Group Discussion
   Group sessions are arranged to gather the current issues, define the root cause, and brainstorm the solution according to the issues and root causes.
2. Interview
   A structured written interview questionnaire was conducted to the key stakeholders including Maintenance Manager, Assistant Maintenance Manager, Maintenance Supervisor, Technician, Maintenance Planner, Admin Maintenance, Assistant Continuous Improvement Manager, and HR Manager. The interview protocol was conceptualized to get insights into current problems and potential solutions from each division.

During the initial phase, the research will extensively explore the analysis of the business process. This analysis will involve identifying the various business processes and gaining a comprehensive understanding of the vision, mission, and objectives of the organization. Moving on, the research will proceed to define the problem by gathering relevant information pertaining to breakdown issues, plant maintenance records, and spare parts spendings. Subsequently, the flow process will be thoroughly comprehended based on the data provided and group discussion.
Moving on to the second stage, the research will delve into a comprehensive analysis of the issues present in the current work methods using Current Reality Tree and Swimlane Diagram. Lastly, this stage aims to prioritize the most significant factors that require attention and resolution. The objective is to devise and experiment with potential enhancements that will result in a process that is both more streamlined and more productive. Furthermore, the selected solutions are put to the test on a small scale through piloting and testing, ultimately leading to necessary adjustments and refinements based on the outcomes of the pilot phase.
Once process improvements have been implemented, the final stage is dedicated to establishing measures that will uphold these improvements in the long run and prevent any regression back to previous practices. In the final stage, the Key Performance Indicators (KPI) will be thoroughly evaluated after the implementation of the improvement, along with a careful examination of the business case. Moving on to the final stage, it is crucial to ensure the effectiveness of the action plan and make necessary preparations for expanding the project, considering it as a benchmark for future endeavors.

4. Results and Discussion

4.1 Analysis

Interpreting the Response

In the "Plan" phase, identifying the problem, reviewing the historical data, and understanding the business process through group interviews are conducted. Subsequently, the analysis is carried out in the "Do" phase. To analyze the issue, a swimlane diagram is created, and CRT analysis is conducted to understand the current business process, what the current issue is, and what solution can be designed. The purpose of this phase is to have a clear understanding of what the problem is. The answer to the prepared questions is collected and interpreted based on the group of similarity. The group of respondents who are answering the questions is shown in Table 1. Each response is coded with a unique code for ease of reference and the source of the statement. The coding format follows the pattern [X,YY,ZZ] with the following information:

X: The method of getting the information,
YY: The resource where data comes from, which can be the document's name or the initials of responders,
ZZ: The series of the event.

Based on the interviews, the codes can be grouped to align with the categories of the 8 wastes of lean manufacturing. The list of categories can be found in the table below.

Tabel 1. Interpreted and Grouped Respondent Answer (Author, 2025)

No	8 Waste	Findings	ML	SW	DM	FM	DS	OS	DO	FS	SS	RR
1	Over Production	Not Applicable										
2	Excess Inventory	No clear spare part list			I,DM,05 I,DM,06	I,FM,05 I,FM,06						
3	Defects	Not Applicable										
4	**Over Processing**	Back and forth to find spare part	I,ML,05	I,SW,05 I,SW,06			I,DS,05		I,DO,4			
5	Waiting	No real time spare part information's availibility			I,DM,07			I,OS,4				
6	**Motion**	Unclear spare part location	I,ML,06		I,DM,08 I,DM,09			I,OS,5				
7	Transportation	Not Applicable										
8	**Underutilized Employee**	No knowledge management information for technician								I,FS,4 I,FS,5 I,FS,6	I,SS,4	

CRT Analysis

The Current Reality Tree (CRT) analysis is conducted to identify the root cause of the problem by determining the Undesirable Effects (UDEs) and arranging them in a cause-and-effect relationship, as illustrated in Figure 8. In the CRT diagram, blue boxes represent UDEs, highlighting gaps in the current maintenance system, while white boxes indicate possible causes underlying these gaps, based on interview responses. Additionally, yellow boxes denote potential root causes that emerge from this analysis.

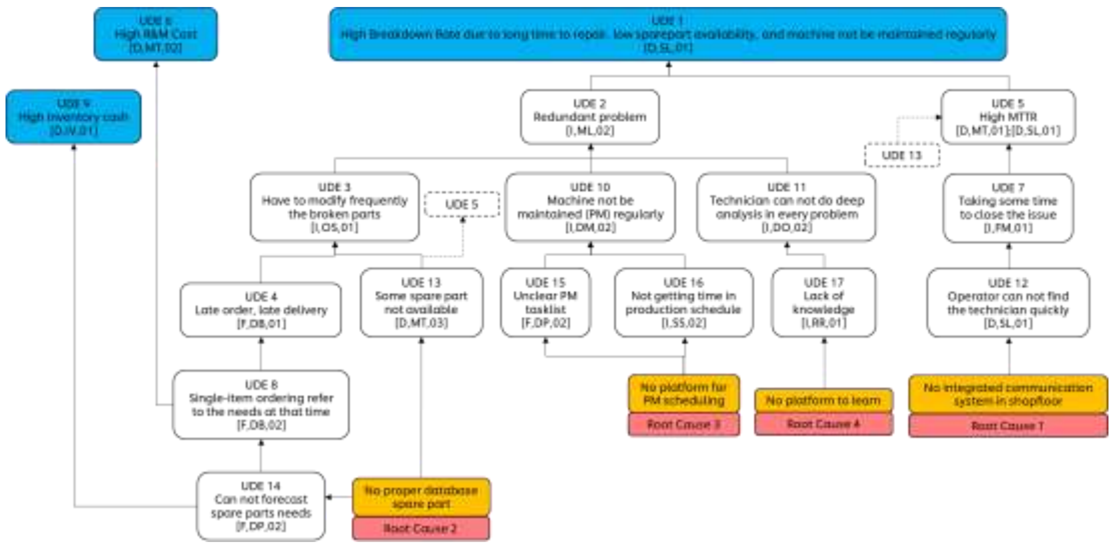

Figure 8. CRT Diagram (Author, 2025)

The business issue identified was "The Lack of Maintenance System," which caused low OEE performance due to frequent breakdowns and high costs from excessive inventory and spare part usage. Recurring machine problems were linked to poor discipline in AM/PM activities and long mean time to repair (MTTR). Contributing factors included modifying worn parts due to delayed spare part orders, lack of a monitoring system for safety stock, and the absence of a proper spare part database affecting demand forecasting. Preventive maintenance was not conducted regularly due to unclear task lists, no scheduled time in production plans, and the absence of an automated scheduling system. Operator limitations in analyzing problems were caused by knowledge gaps and lack of flexible learning platforms. Delays in resolving breakdowns were also due to the absence of an integrated communication system on the shop floor. Interview responses helped build a causal structure linking the lack of a digital maintenance system to unhealthy machine behavior and poor OEE performance. The lack of an integrated learning and communication system further burdened staff, while missing databases and auto-scheduling tools led to repeated maintenance issues, highlighting the need for a more integrated maintenance management approach.

Eight Waste of Lean

The concept of waste, as defined by McCarthy et al. (2004), refers to any activity or process that does not contribute to meeting customer requirements or adding value to the production process. Waste can manifest in various forms, including overproduction, excess inventory, defects, overprocessing, waiting, motion, transportation, and underutilized employee talent. The presence of these wastes can lead to significant inefficiencies, resulting in reduced OEE and increased breakdown rates, ultimately affecting productivity and profitability. In the context of this project, the eight wastes of Lean principles were studied in detail through a series of interviews and discussions with relevant stakeholders. The results of this analysis are presented in Table 2, offering a comprehensive understanding of the prevailing wastes and potential avenues for improvement.

Table 2. The 8 Waste of Lean Approach (Author, 2025)

No	8 Waste	Description	Activity
1	Over Production	Producing more than required by the subsequent process.	Not Applicable
2	Excess Inventory	Maintaining surplus supplies beyond what is necessary for production.	Inventory discrepancies due to inadequate parts cataloging.
3	Defects	Product or service aspects that fail to meet requirements, necessitating inspection, repair, or rework.	Not Applicable

No	8 Waste	Description	Activity
4	Over Processing	Non-value-added activities that are unnecessary or redundant.	Inefficient parts retrieval processes resulting from inadequate location tracking.
5	Waiting	Idle time spent waiting for events or actions, including human, machine, or material downtime.	Real-time spare part information is unavailable, hindering efficient inventory management.
6	Motion	Unnecessary movement of people or information that doesn't add value.	Ambiguous storage location identification.
7	Transportation	Movement of parts and materials within a facility that doesn't contribute to value creation.	Not Applicable
8	Underutilized Employee	Failure to leverage employees' mental, creative, innovative, and physical abilities to their full potential.	The absence of a knowledge management system for technicians results in lost productivity and expertise. information for technician

Swimlane Analysis

The swimlane process chart is an advanced flowcharting technique, featuring multiple lanes representing various stakeholders or employees. This diagram illustrates process phases and corresponding timeframes along the top and bottom axes, respectively. Its structured format effectively communicates complex processes, complementing traditional flowcharts. Notably, swimlane diagrams adhere to standardized conventions and are integrated into software tools like MS Visio (Shibayama et al., 2017). The current process issues faced by PT. Andromeda is depicted in Fig. 9.

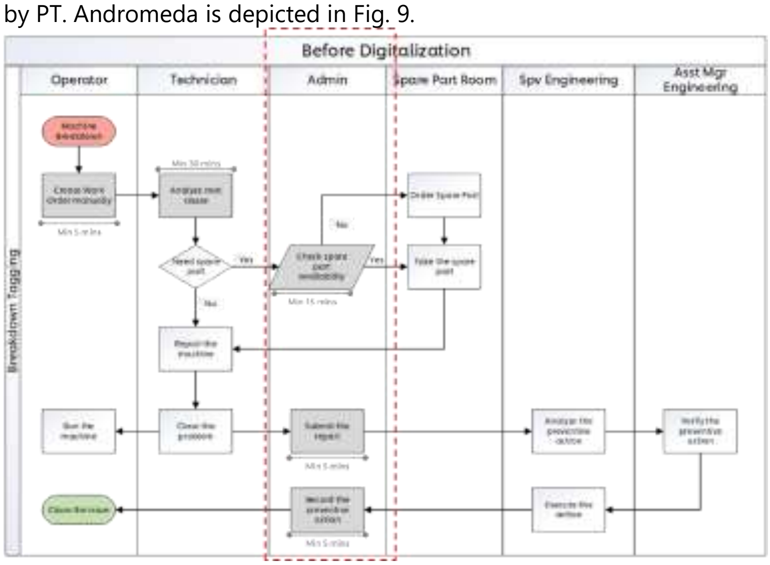

Figure 9. Swimlane Chart of the Current Process When Problems Arise

By detailing the process, it can be seen in each function as below:

- During the problem happened in the line, the operator will create a work order manually to describe the problem and explain the phenomenon briefly. After creating the work order, the operator will wait until the technician comes, which typically takes around 5 minutes for them to be notified. This waiting period constitutes a form of waste in terms of waiting time.
- The technician encounters two forms of waste: motion waste and underutilization of employee skills. They require a significant amount of time, typically a minimum of 30 minutes, to analyze the problem before solving the issues, which leads to underutilization of their skills and time. On the other hand, the operator will check the spare part availability by either checking directly with the warehouse or asking the administration, which takes around 15 minutes to complete.
- Both administrators, supervisors, and assistant managers contribute to machine repairment, albeit not directly. They assist the organization by managing reports, reviewing, and analyzing the root cause to find the right preventive measures to avoid

future machine downtime. However, these activities are often filled with redundancies and non-value-added tasks, which lead to waste in the form of overprocessing.

- The spare part room encounters a specific type of waste, namely excess inventory. This waste is a result of the lack of integration between maintenance activities and the stock of spare parts. Additionally, since there is no spare part database, each spare part cannot be grouped for similar machines, which further exacerbates the issue.

4.2 Solution and Proposed Implementation Plan

Alternative Solution

As part of the interview process, some respondents were presented with proposed solutions, including systems, tools, technologies, and best practices, to address the challenges they faced during machine repair.

Table 3. Interpreted Solutions Derived from the Interview (Author, 2025)

utions	ML	SW	DM	FM	DS	OS	DO	FS	SS	RR
Excess Inventory										
An integrated system that captures all spare parts for PM and regular parts replacement, ensuring seamless tracking and				I,FM,06						
Overprocessing										
Enhanced tools that automatically record transactions, reducing manual errors and increasing efficiency.		I,SW,06								
A mobile app for technicians to find the correct spare parts during replacement, streamlining the process and minimizing errors.					I,DS,05					
Waiting										
A communication system that tracks technician positions and escalates issues if there's no response within a specified timeframe, ensuring prompt issue resolution.										I,RR,05
Motion										
A platform providing real-time information on spare part locations and current status, enabling efficient inventory management.			I,DM,09							
l Employees										
An integrated system storing machine troubleshooting information and previous resolutions, serving as a foundation for future AI-generated solutions and continuous improvement.								I,FS,07		

Most of the respondents suggested developing a digital platform that can integrate the maintenance activity with spare parts inventory, which includes an automatic spare part transaction system, a communication system on the shop floor that also has tracking capabilities, and a knowledge management system. Hence, the author was exploring alternative solutions that can address the issues raised by the respondents. There were several options considered, including Virtusee as a standalone app that has been built for other companies in Indonesia, DigiPM and DigiBox as apps that have been locally developed by the factory team, and DMS (Digital Maintenance System), which has been developed by the Global team.

AHP (Analytical Hierarchical Process)

Given three proposed solutions for the maintenance system, the following features are deemed essential: Preventive Maintenance, Breakdown Maintenance, Abnormality Maintenance, Machine Ledger, Interface to ERP System, Budgeting and Costing, Spare Part Inventory, Knowledge Management, and Integration with Other Apps. These features collectively aim to enhance maintenance scheduling, issue tracking, spare part management, budgeting, and knowledge sharing while ensuring seamless integration with existing systems. Based on the study of the given alternatives, the selection of alternatives was conducted using the Analytical Hierarchy Process (AHP) method. As mentioned by (Kayum et al., 2025), AHP serves as the basis for pair-wise comparison procedures, enabling multi-criteria decision-making (MCDM) through a structured approach. This involves constructing a hierarchical framework of criteria, conducting pair-wise comparisons, and assigning weights to each node, which allows for effective ranking and rating of alternatives. The design step of the Analytical Hierarchy Process (AHP) involves constructing a hierarchical decision model, where the top level represents the overarching objective of the decision-making process. This model employs a hierarchical structure, where indicators at the top level serve as criteria that are then divided into more specific sub-criteria. To facilitate pairwise comparisons, a comparison matrix is created, wherein each pair of criteria or sub-criteria elements is evaluated based on their relative importance. This evaluation utilizes a 9-point scale, as proposed by Saaty (1980), which ranges from 1 (indicating equal contribution) to 9 (indicating a significantly higher contribution of one indicator over another). The detailed scale is presented in Table 4, outlining a structured approach for assessing the relative importance of each criterion.

Table 4. 9-point system (Saaty, 1980)

Comparative Importance	Definitions	Descriptions
1	Equal importance	Two indicators equally influence the parent's decision
3	Weak importance	One factor is moderately influential over the other

Comparative Importance	Definitions	Descriptions
5	Essential or strong importance	One factor is strongly favored over the other
7	Demonstrated importance	One decision factor has a significant influence over another
9	Absolute importance	Evidence favoring one decision factor over the other is the highest order of affirmation
2,4,6,8	Intermediate	When compromise is needed, values between two adjacent judgments are used
Reciprocals	If A_i is the judgmental value when i is compared with j, then A_j has the reciprocal value when compared to A_i	A reasonable assumption

The pairwise comparison matrix shown in Table 5. is a widely used multi-criteria decision-making method aiming to derive relative priorities in multi-level hierarchic structures and to allocate weights to these elements quantitatively. Following the comparative importance and the definition stated by (Dandapat & Panda, 2017) score 1 signifies equal importance, score 3 denotes weak preference, scores 5 and 7 represent strong preference, while score 9 indicates the highest preference. Even numbers (i.e., 2, 4, 6, and 8) are used when a concession is required between the odd numbers.

Table 5. Criteria Priority for Apps Development using the AHP method (Author, 2025)

	PM01	PM02	PM03	Machine Ledger	Interface to SAP	R&M Cost	Spare Part Inventory	Knowledge Management	Integration with other Apps
PM01	1	5	5	1	1	3	3	7	2
PM02	1/5	1	1	1/3	1/2	1	1/3	4	2
PM03	1/5	1	1	1/3	1/2	1/2	1/3	4	2
Machine Ledger	1	3	3	1	1/7	1/7	1/7	5	1
Interface to SAP	1	2	2	7	1	1	1/5	1	1
R&M Cost	1/3	1	2	7	1	1	1	4	4
Spare Part Inventory	1/3	3	3	7	5	1	1	7	4
Knowledge Management	1/7	1/4	1/4	1/5	1	1/4	1/7	1	1
Integration with other Apps	1/2	1/2	1/2	1	1	1/4	1/4	1	1

By determining the priority and calculating the weight of each criterion, it becomes evident that preventive maintenance, budgeting and costing, and spare part inventory emerge as the major criteria that need to be considered. For the application to be effectively utilized in the factory, it is essential that these requirements are fulfilled. Furthermore, the general structure of the Digital Maintenance System to be developed has also been analyzed, as illustrated in Fig 10, providing a comprehensive foundation for the system's design and development.

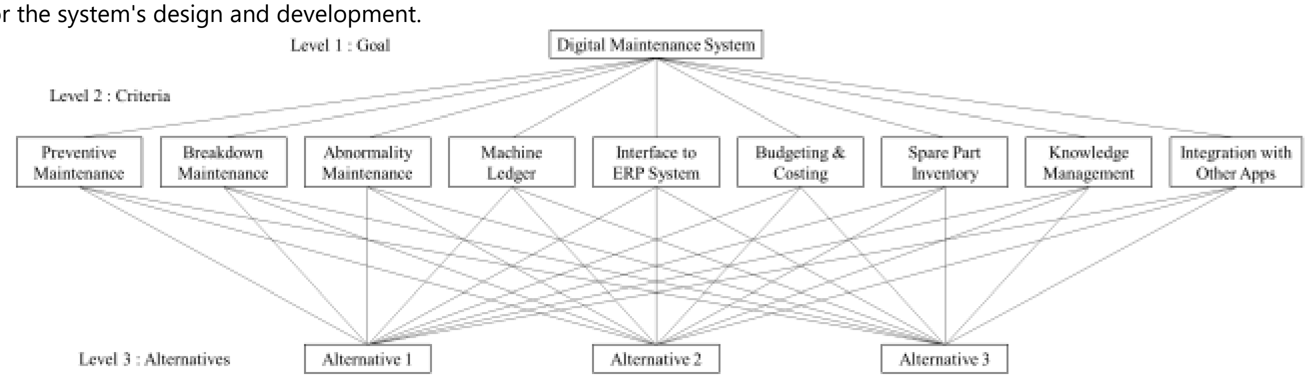

Figure 10. The general structure of the Analytical Hierarchy Process (AHP) for multi-criteria decision making (MCDM) (Author, 2025)

The hierarchical structure of the digital maintenance system that was proposed previously was assessed under the AHP for MCDM that shown in Fig. 10. According to Fig. 10, the goal of decision making problem is presented at the top level of the hierarchical structure, followed by the criteria for ranking the alternatives at the second level and the alternatives themselves at the third level.

Proposed Solution Implementation Plan

Based on the alternatives evaluated and the analysis conducted using the Analytical Hierarchy Process (AHP), DigiPM and DigiBox emerge as the most suitable solutions. DigiPM will serve as the digital maintenance system, facilitating activities such as preventive, breakdown, and abnormality maintenance through its platform. Operators and technicians will interact with the system, while their superiors can monitor and review their work. Additionally, DigiPM enables the creation of schedules for preventive maintenance and maintains a record of activities as a machine ledger. By capturing all relevant information, the system is also equipped with a knowledge management feature, allowing technicians to access resolution instructions and share their insights if not previously documented. As the solution evolves, the app is poised to incorporate AI-generated solutions in the future, further enhancing its capabilities. Furthermore, for inventory management specifically, DigiBox will serve as a digital platform for spare part management. This application not only provides a comprehensive spare part inventory but also interfaces with the ERP system, enabling DigiPM to generate budgeting and costing reports. Consequently, DigiPM and DigiBox collectively fulfill most of the requirements for a digital maintenance solution. However, one limitation is that both applications currently lack integration with other apps that are already in use within the factory, highlighting an area for future development. As shown in Fig 11, the applications have a seamless data flow between them, ensuring effective communication and support among each application. The data exchange starts with the master data shared between SAP and DigiPM, where each application has its own distinct data sources. Specifically, DigiPM provides detailed information on the spare parts required for each machine, including specifications and requirements, while SAP shares the price information for each part, enabling accurate cost calculations. When a work order is created in DigiPM, it is interfaced with SAP if any spare parts are utilized, enabling SAP to initiate stock replenishment promptly. This integration applies to predictive, breakdown, and abnormality maintenance scenarios, allowing stakeholders to track repair and maintenance costs on a daily basis and make informed decisions.

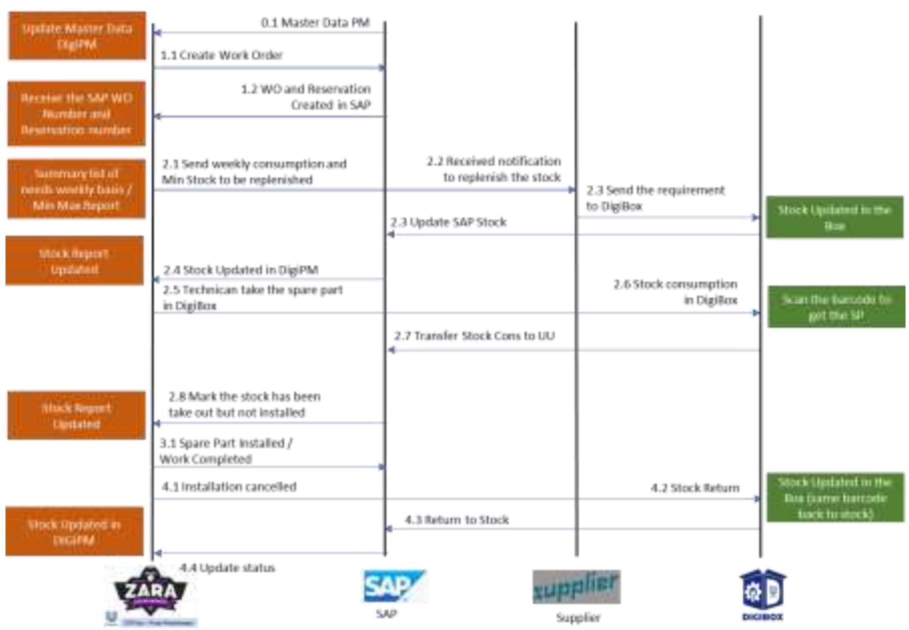

Figure 11. Data Process Flow after Application Establishment (Internal Source, 2024)

Furthermore, DigiBox receives updates on stock replenishment, which is reflected in its dashboard monitoring, providing real-time visibility into inventory levels. With safety stock levels and delivery timelines already configured in DigiBox, the application can perform advanced spare part forecasting to prevent inventory excess and minimize stockouts. Additionally, DigiBox automatically notifies suppliers when spare part levels fall below the safety stock threshold, and they can then send the necessary parts to the warehouse. This streamlined process helps reduce MTTR and minimizes the need for modification work on broken parts, ultimately improving operational efficiency and productivity.

4.3 Justification of Implementation Plan

Designing Solution for Root Causes

The applications were developed to fulfill the requirements and address the root cause of the issue. The application was developed as both mobile apps and web-based platforms, enabling effective utilization by operators, technicians, and administrators to support their respective tasks and responsibilities. DigiPM provides a comprehensive solution that serves as a digital platform for all maintenance-related activities. This application offers detailed machine information, encompassing specifics such as spare part details, replacement schedules, maintenance activities, execution reports, and budgeting and costing for spare parts. Through its mobile app version, technicians receive direct notifications within the app, and all scheduled activities are conveniently listed. Upon completion of each activity, operators can check off tasks within the app, ensuring accurate tracking. Moreover, other stakeholders can monitor the progress of maintenance activities in real-time through this app, enhancing transparency and collaboration. DigiBox provides an additional solution related to spare parts inventory management, featuring a spare part room equipped with an RFID system. This feature enables seamless spare part replenishment and withdrawal, resulting in high stock accuracy. Furthermore, the implementation of DigiBox facilitates the adoption of Vendor Managed Inventory (VMI), which enhances agility in managing spare part stock inventory. This application also extends to suppliers, allowing them to directly review the part stock inventory at Andromeda and prepare parts for dispatch once the safety stock level is reached. By providing real-time visibility into inventory levels, DigiBox enables suppliers to respond promptly to inventory needs, thereby improving the OEE from factory.

Improvement Results

The implementation of DigiPM and DigiBox can be visualized and reviewed through the swimlane diagram presented in Fig 12. These applications effectively address and mitigate various forms of waste that previously existed in the maintenance process, including excess inventory, over-processing, waiting, motion, and underutilization of employees. By streamlining processes and improving efficiency, DigiPM and DigiBox enable the organization to eliminate unnecessary waste, thereby enhancing overall productivity and operational performance.

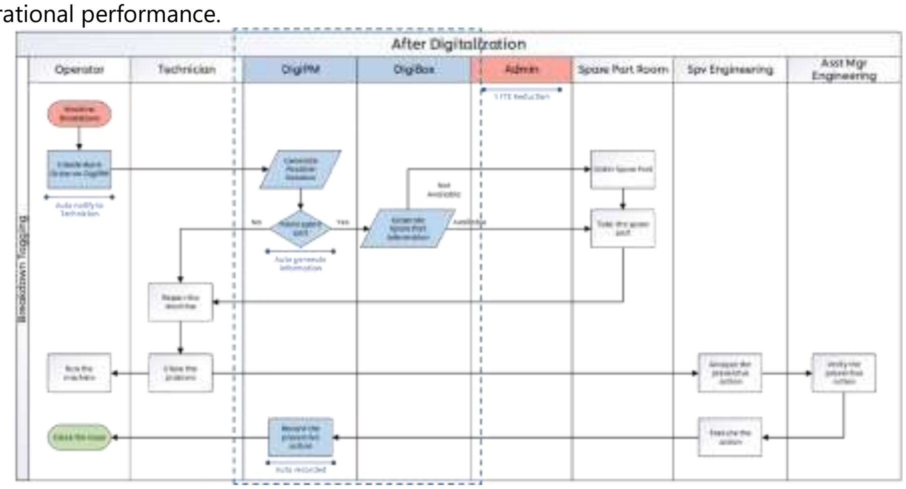

Figure 12. Swimlane Diagram Post to Improvement Implementation

It is evident that excess inventory has been effectively eliminated through the utilization of DigiBox, which maintains optimal safety stock levels and leverages Vendor Managed Inventory (VMI) to ensure the consistent availability of spare parts. Additionally, a notable reduction in over-processing is observed as DigiPM and DigiBox automate previously manual processes, thereby streamlining operations. Furthermore, these applications serve as a communication platform for the shop floor team, facilitating seamless connectivity between operators and technicians. In instances where technicians are unresponsive, an escalation matrix ensures that issues are promptly escalated to superiors for timely resolution. The implementation of a new spare part room equipped with RFID technology has also led to a reduction in unnecessary motion, as technicians can easily locate parts. Lastly, DigiPM features a comprehensive learning management system that acts as a centralized knowledge hub for machine troubleshooting, empowering technicians to work more efficiently and effectively. This integrated suite of features ultimately results in higher productivity and enhanced operational performance.

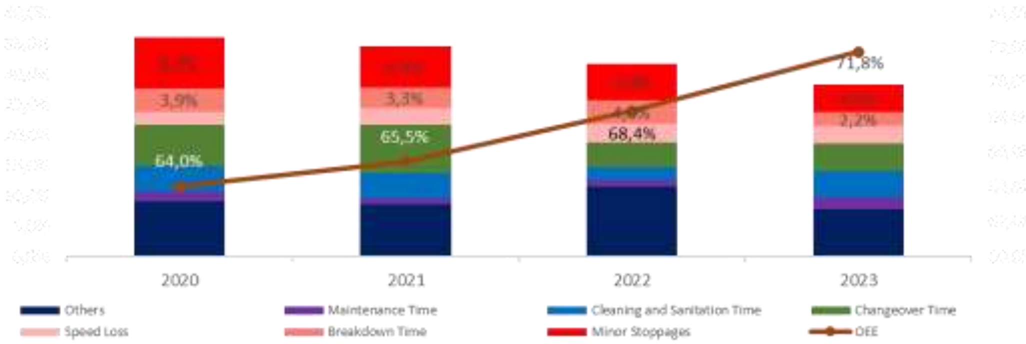

Figure 13. OEE Performance 2020-2023

As shown in Fig 13, the Overall Equipment Effectiveness (OEE) will increase by around 4% from 2022, and there is a notable reduction in breakdowns and minor stoppages. This improvement indicates that the digital maintenance system is having a positive impact on production performance. Furthermore, as shown in Fig 14, the repair and maintenance costs show significant savings that exceed expectations, with a reduction of 4 billion IDR from 2022. This considerable cost reduction highlights the effectiveness of the digital maintenance system in enhancing operational efficiency and minimizing expenses.

Figure 14. Repair & Maintenance Cost 2020-2023

Implementation Plan

Table 6 provides a detailed timeline for the implementation plan of the digital maintenance system, encompassing the initial brainstorming phase, followed by application development, and culminating in the successful handover of the application.

Table 6. Implementation Timeline (Author, 2025)

Task	Person In Charge	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Assess workflow of spare part ordering and maintenance activities	Maintenance Planner and Expert Engineering	—	—						
Brainstorming for the improvement plan	Maintenance Planner and Application Vendor	—	—						
Contract agreement	Procurement and Spare Part Supplier			—	—	—			
Application and program development	Maintenance Planner and Application Vendor		—	—	—	—	—		
Project cascading and deployment	Engineering Manager						—	—	
Implementation of new DigiPM and DigiBox								—	—

5. Conclusion

The current OEE performance was below 70% due to a high breakdown rate resulting from prolonged repair times, low spare part availability, and inadequate regular maintenance of machines. Several forms of waste were observed, including excess inventory, over-processing, waiting, motion, and underutilization of employees, ultimately leading to suboptimal machine condition and low performance. The low OEE performance was attributed to unstable machine productivity stemming from the absence of a robust maintenance system. This lack of a structured maintenance system resulted in the absence of a clear spare part list, activity task list, and machine troubleshooting record, thereby hindering effective machine maintenance. OEE can be improved by implementing a robust maintenance system, and the introduction of a digital platform can effectively guide the team in enhancing OEE. Specifically, DigiPM and DigiBox can serve as viable solutions to increase OEE by reducing NVAA and developing technician capabilities. As a result, OEE increased by 4% to reach 72% by the end of 2023. The implementation of the digital maintenance system yielded significant benefits, including a cost savings of 4 billion IDR and a reduction of over 10% in inventory cash. Moreover, maintenance digitalization provided data-driven evidence-based insights, facilitated communication through a dedicated platform, enabled report analysis, prevented the recurrence of similar problems, and served as a learning system for technicians.

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