G-Tech : Jurnal Teknologi Terapan
Vol. 9, No. 4, October 2025, p. 2030-2041
E-ISSN: 2623-064X | P-ISSN: 2580-8737

Effectiveness Analysis Using Overall Equipment Effectiveness (OEE) and Failure Modes And Effect Analysis (FMEA) Methods at PT. XYZ

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Article Information

Article History

Received : September 11, 2025
Revised : October 07, 2025
Published : October 20, 2025

***Keywords*:**

OEE;
FMEA;
Six Big Losses.

ABSTRACT

PT. XYZ is a manufacturing company engaged in the production of NPK fertilizer. During its production process, the company frequently encounters machine downtime issues that significantly affect overall production effectiveness. This study aims to evaluate machine performance effectiveness using the Overall Equipment Effectiveness (OEE) method by assessing three key components: Availability, Performance, and Quality, as well as to identify the dominant sources of failure through Failure Mode and Effect Analysis (FMEA). Data were analyzed using Microsoft Excel through descriptive and comparative approaches to calculate the average OEE value, identify the contribution of the Six Big Losses, and determine the Risk Priority Number (RPN) in FMEA. The results show that the average OEE value was 83%, consisting of Availability 76%, Performance 110%, and Quality 99.8%, which remains below the Japan Institute of Plant Maintenance (JIPM) standard of 85%. The largest loss factor originated from idling and minor stoppages, contributing 38.2% of total production losses. FMEA analysis identified the most critical failure mode in the gearbox/fluid coupling of the conveyor, with the highest RPN value of 448.3, caused by mechanical wear and insufficient periodic inspections. Based on these findings, it is recommended to implement a scheduled preventive maintenance program, ensure the availability of critical spare parts, and enhance operator competence in machine operation and monitoring to improve the overall production system effectiveness.

INTRODUCTION

The industry can be divided into two major categories, namely the manufacturing industry and the service industry(Vázquez et al., 2022). The manufacturing industry produces physical products that can be stored as inventory, while the service industry produces *intangible and non-storeable* outputs(Pressbooks (Atlanticoer-Relatlantique), 2021). In recent years, the development of the manufacturing industry has shown a very competitive dynamic(World Manufacturing Foundation, 2024). The increasingly fierce competition requires companies to produce products that are not only superior in terms of quality, but also offered at competitive prices according to consumer needs and expectations(Valdez-de la Rosa et al., 2020). Thus, companies need to consistently pay attention *to the aspects of quality*, performance, and *availability* in each stage of the production process(Markatos & Mousavi, 2023).

However, in reality, the effectiveness of a production process is often only measured by the degree of machine breakdown or failure(Febianti et al., 2022). This approach does not fully reflect the real conditions in the field, as there are still other factors that also affect the level of production effectiveness. Some of them include the non-achievement of production targets that have been set by management, as well as incompatibility between the products produced with technical specifications and customer needs(Mirzaei & others, 2021).

PT XYZ, as one of the NPK fertilizer manufacturing companies, faces similar challenges. In its operational activities, problems are often found in the form of high machine downtime, decreased product quality, and delays in meeting production targets. These problems cause a decrease in the effectiveness of the production system and hinder the achievement of overall company performance. Therefore, a comprehensive, measurable, and structured evaluation of the production system is needed to identify the root cause of the problem and determine the appropriate remedial steps.

The *Overall Equipment Effectiveness* (OEE) method is used as a measuring tool to assess the effectiveness of a production system, OEE provides a comprehensive overview of machine availability, performance, and production quality(Prasetio & Oktora, 2024). However, to find out the main causes of low effectiveness and potential failures in the production system, the OEE method needs to be combined with FMEA analysis(Wardhani et al., 2025). FMEA helps identify potential failure risks in the production process and prioritize repairs based on severity, likelihood of occurrence, and detection capability(Menčík, 2016).

To strengthen the results of the identification of the cause of the problem found through FMEA, the Fishbone diagram (Ishikawa diagram) is also used as a visual aid in analyzing the root cause analysis of a production problem(Kusuma et al., 2024). This diagram groups causal sources based on general categories such as man, machine, method, material, measurement, and environment. The combination of OEE, FMEA, and Fishbone Diagram allows for a thorough evaluation, from effectiveness measurement, failure risk assessment, to specific root cause identification(Guste & others, 2024). With this integrated approach, companies can formulate data-driven and measurable improvement strategies to continuously improve the effectiveness of production equipment. The purpose of this study is to evaluate the effectiveness of machine performance at PT XYZ using the OEE method, as well as identify the main causes of the decrease in effectiveness through the FMEA method as the basis for planning strategies to improve the performance of the production system.

RESEARCH METHODS

This study uses a combination of Overall Equipment Effectiveness (OEE) and Failure Mode and Effect Analysis (FMEA) methods to evaluate the effectiveness of production machinery at PT XYZ. The data used included the ideal time of the plant 3 system, production volume, percentage of defective products, history of machine availability, unexpected downtime (due to disruption and maintenance), and scheduled downtime such as preventive maintenance activities. Data was collected during the period August 2024 to May 2025 through direct observation on the production floor, interviews with operators and maintenance staff, as well as documentation of production reports and engine log sheets. Validation is carried out by the source triangulation method, which is comparing the results of observations, interviews, and documents to ensure the accuracy and consistency of the data.

Furthermore, the data was analyzed using Microsoft Excel with a descriptive and comparative approach. The analysis stage includes calculating Availability, Performance, and Quality values to obtain OEE values and comparing them with the Japan Institute of Plant Maintenance (JIPM) standard of 85%. The analysis continued with the identification of Six Big Losses to determine the dominant factors causing the decrease in effectiveness, as well as the application of FMEA to calculate the Risk Priority Number (RPN) based on the level of severity, occurrence, and detection as the basis for prioritizing engine improvement and performance.

Overall Equiqment Effectiveness (OEE)

OEE is an indicator to assess the total performance of *equipment*, which reflects the extent to which the equipment is able to function according to its intended use(Ng Corrales et al., 2020). This approach is considered an important component of the maintenance system and has been widely implemented by large companies in Japan. Efforts to increase the value of OEE can be done by improving aspects of system time availability, performance of a system (Performance), and quality of production results (Quality) (Rabiatussyifa et al., 2022).

The calculation of the OEE value is carried out through three main ratios which are formulated as follows:

Overall Equiqment Effectiveness = *Availability* x *Performance* x *Quality rate* x 100% (1)

Tabel 1. Ideal value on OEE

OEE Factor	Processed OEE
Availability	90%
Performance	95%
Quality	99%
Overall Oquipment Effectiveness (OEE)	85%

Source : (Rabiatussyifa et al., 2022)

The aspects that make up OEE are as follows:

a. *Availability*

is the ratio of the time available for the operational activities of the current machine compared to the predetermined time(Wahid, 2020)

$$\boldsymbol{Availability} = \frac{\boldsymbol{Loading\ time - Downtime}}{\boldsymbol{Loading\ time}} \boldsymbol{x100\%} \quad (2)$$

Loading time is obtained from the total available time (availability) per day or per month after deducting planned downtime. Meanwhile, operation time is the difference between loading time and machine shutdown time (non-operation). Mathematically, the calculation can be written as follows:

- *Loading time = Working hours – Planned downtime* (3)
- *Downtime = Breakdown time + Setup and adjustment* (4)
- *Operation = Loading time – Downtime production – Downtime maintenance – Setup and adjustment* (5)

b. *Performance Efficiency*

This comparison is used to describe the actual production output, which is calculated by multiplying the ideal cycle time and then dividing it by the operating time. (Hafiz & Martianis, 2019)

$$\boldsymbol{Performance\ Efficiencey} = \frac{\boldsymbol{Processed\ amount\ x\ Ideal\ Cycle\ Time}}{\boldsymbol{Operation\ time}} \boldsymbol{x100\%} \quad (6)$$

c. *Quality Ratio*

This comparison shows the level of machine ability to produce products that are in accordance with quality standards. (Prasetyo et al., 2022)

$$\boldsymbol{Rate\ of\ Quality\ Product} = \frac{\boldsymbol{Processed\ amount\ x\ Defect\ Amount}}{\boldsymbol{Processed\ amount}} \boldsymbol{x100\%} \quad (7)$$

Six Big Losses

The definition of six big losses can be explained as follows:

Tabel 2. Table of Definitions of Six Big Losses

Six Big Losses	Description
Breakdown	These losses arise due to failure or damage to equipment, which has an impact on lost production time as well as a decrease in the amount of output.
Setup and adjustment	Losses due to congestion arise when there is a change in the work system, for example the replacement of products and equipment.
Reduced speed loss	This disadvantage relates to the actual operating speed conditions that do not reach the ideal operating speed level.
Idling and minor stoppage loss	This loss is related to minor stoppages, which are when the production process is stopped due to a temporary disruption or when the machine is completely out of operation.
Process defect loss	Lost time occurs due to product defects and rework processes, while financial losses arise due to a decrease in the quality of production results. In addition, there is also a loss of time spent repairing defective products to the standard, which is triggered by the suboptimal performance of production equipment.
Reduced yield loss	Material loss is related to the mismatch in the number of material inputs as well as the decrease in product yields that meet high quality standards.

Source : (Author, 2018)

$$Equipment\ Failure = \frac{Total\ Breakdown\ Time}{Loading\ Time} x100\% \tag{8}$$

$$Setup\ and\ Adjustment\ Loss = \frac{Total\ setup\ and\ Adjustment}{Loading\ Time} x100\% \tag{9}$$

$$Idling\ and\ Minor\ Stoppage = \frac{Non\ Productive\ time}{Loading\ Time} x100\% \tag{10}$$

$$Reduce\ Speed\ Loss = \frac{Operational\ time - (Ideal\ cycle\ time\ x\ Processed\ amount)}{Loading\ Time} x100\% \tag{11}$$

$$Process\ Defect\ Loss = \frac{Ideal\ Cycle\ time\ x\ Total\ defect\ amount}{Loading\ Time} x100\% \tag{12}$$

$$Reduce\ Yield\ Loss = \frac{Ideal\ Cycle\ time\ x\ Yield}{Loading\ Time} x100\% \tag{13}$$

Failure Mode and Effect Analysis (FMEA)

A structured method with the aim of recognizing and anticipating potential failures in a system. (Sartor & Cescon, 2019). RPN is used to assess the highest level of failure risk by combining three main aspects, namely severity, occurrence, and detection. The larger RPN value indicates the lower the reliability of a system component, with the calculation shown in the following formula (Akula et al., 2022)

$$\text{RPN} = \text{Severity x Occurance x Detection} \tag{14}$$

RESULTS AND DISCUSSION

Data Collection

This study utilizes data related to the production system at plant 3, in the form of secondary data from production defect reports and interview results. The data analyzed covers the period from August 2024 to May 2025, including information on downtime, production output, and reprocessed products. The results of data collection are presented as follows:

a. Data Downtime of production system plant 3

Tabel 3. Data Downtime of production system plant 3

Section	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	Mei-25
Feeding	35	110	180	50	675	255		185	110	150
Granulation	145	150	385	345	180	90	795	170	130	495
Drying	1725	215		35	685	1465	1359	1105	780	3435
Cooling	25	2460	180	740		65	25	235		250
Screening Process						115	45	370		
Screening Final									395	
Final Product		255					85		780	530

Source : Company Data Aug 24 – Mei 25

b. Production Results Data Production system plant 3

Tabel 4. Production Results Data Production system plant 3

Month	Target Amount/Month (Kg)	Production Quantity/Month (Kg)	Target Achievement (%)
Aug-24	17.670.000	19.235.800	108,86%
Sept-24	17.100.000	18.076.150	105,71%
Oct-24	17.670.000	17.817.800	100,84%
Nov-24	17.100.000	15.573.800	91,07%
Dec-24	17.670.000	17.526.700	99,19%
Jan-25	17.670.000	16.326.650	92,40%
Feb-25	15.960.000	15.609.000	97,80%
Mar-25	17.670.000	14.643.900	82,87%
Apr-25	17.100.000	13.448.450	78,65%
Mei-25	17.670.000	14.245.000	80,62%

Source : Company Data Aug 24 – Mei 25

c. Data product reprocess plant 3

Tabel 5. Data product reprocess plant 3

Month	Production Quantity/Month (Kg)	Number of Reprocessed Products (kg)
Aug-24	19.235.800	-
Sept-24	18.076.150	-
Oct-24	17.817.800	-
Nov-24	15.573.800	-
Dec-24	17.526.700	-
Jan-25	16.326.650	-
Feb-25	15.609.000	80.000
Mar-25	14.643.900	55.000
Apr-25	13.448.450	-
Mei-25	14.245.000	180.000

Source : Company Data Aug 24 – Mei 25

The collected quantitative data is used in the OEE analysis, with the assessment based on three main ratios, namely availability, performance efficiency, and quality rate. Furthermore, qualitative data was used in the FMEA analysis with assessments based on the aspects of severity, occurrence, and detection, which was then continued in the calculation of the Risk Priority Number (RPN).

Data Processing

The processing stages in the production system of plant 3 include the calculation of the OEE value, the analysis of the six main types of losses, the preparation of a Fishbone diagram to identify the factors causing material losses while facilitating the implementation of FMEA, the calculation of SOD and RPN through the FMEA method, and the preparation of improvement recommendations.

OEE Plant 3 Calculation

The stages of calculating the OEE value in plant 3 are carried out in the following order:

a. *Availability Calculation*

Example calculation in August 2024:

Loading time = 744 - 93 = 651

Down time = 91,17 + 46,5 = 137,67

Operation time = 651 – 46,5 = 604,5

Availability = (651-137,67) / 651 = 78,85%

The following is the calculation data for the availability of plant 3.

Tabel 6. Data Calculation of *Availability* plant 3

Month	Loading Time (Minute)	Total Downtime (Minute)	Operation Time (Minute)	Availability (%)
Aug-24	651	137,67	604,50	78,85%
Sept-24	630	162,23	585,00	74,25%
Oct-24	651	148,05	604,50	77,26%
Nov-24	630	139,25	585,00	77,90%
Dec-24	651	157,33	604,50	75,83%
Jan-25	651	117,08	604,50	82,01%
Feb-25	588	127,57	546,00	78,30%
Mar-25	651	156,42	604,50	75,97%
Apr-25	630	188,67	585,00	70,05%
Mei-25	651	194,42	604,50	70,14%
Mean				76%

Based on the table above, the results of the calculation of availability each month show a variation in value. The highest percentage was recorded in January 2025 at 82.01%, while the lowest percentage occurred in April 2025 with a value of 70.05%. The average overall availability was obtained at 76%, which is still below the OEE ideal standard for availability which is 90.00%.

b. *Performance Efficiency Calculation*

Example of calculation for August 2024:

Performance Efficiency = (19.236 x 0,04) / 604,50 = 127%

The following is the calculation data for the performance efficiency of plant 3.

Tabel 7. Data Calculation of *Performance Efficiency* plant 3

Month	Production Quantity/Month (Ton)	*Ideal Cycle Time* (Jam / Ton)	*Operating Time*	*Performance Efficiency* (%)
Aug-24	19.236	0,04	604,50	127%
Sept-24	18.076	0,04	585,00	124%
Oct-24	17.818	0,04	604,50	118%
Nov-24	15.574	0,04	585,00	106%
Dec-24	17.527	0,04	604,50	116%
Jan-25	16.327	0,04	604,50	108%
Feb-25	15.609	0,04	546,00	114%
Mar-25	14.644	0,04	604,50	97%
Apr-25	13.448	0,04	585,00	92%
Mei-25	14.245	0,04	604,50	94%
Mean				110%

The Performance Efficiency calculation in the table above shows results that vary every month. The highest percentage was recorded in August 2024 at 127%, while the lowest percentage occurred in April 2025 with a value of 92%. From the average calculation, the performance efficiency reaches 110%, this figure has exceeded the OEE ideal standard for performance efficiency, which is 95.00%.

c. *Quality Ratio Calculation*

Example calculation in August 2024:

Quality Ratio= (19.236 – 0) / 19.236 = 100%

The following is the calculation data for the Quality Rate of plant 3.

Tabel 8. Data Calculation of Quality Rate plant 3

Month	Production Quantity/Month (Ton)	Number of Production Reproses (Tons)	Quality Ratio
Aug-24	19.236	0	100,0%
Sept-24	18.076	0	100,0%
Oct-24	17.818	0	100,0%
Nov-24	15.574	0	100,0%
Dec-24	17.527	0	100,0%
Jan-25	16.327	0	100,0%
Feb-25	15.609	80	99,5%
Mar-25	14.644	55	99,6%
Apr-25	13.448	0	100,0%
Mei-25	14.245	180	98,7%
Mean			99,8%

Based on the table above, the calculation of the rate of quality each month shows the variation in results. The highest score of 100% was obtained in August, to January, and April, while the lowest score was recorded in May with a percentage of 98.7%. The average calculated quality level reached 99.8%, and this figure has exceeded the OEE ideal standard for quality rate which is 99.00%.

d. Calculation of OEE values

By obtaining information about the availability, performance efficiency, and quality level at plant 3, the OEE value can be calculated to assess the effectiveness of the production system through the following formula:

OEE = 78,85% x 127% x 100% = 100,4%

The following is presented the accumulated data from the results of the OEE calculation in plant 3:

Tabel 9. Accumulated data of OEE plant 3 results

Month	Availability (%)	*Performance Efficiency* (%)	Quality Ratio (%)	OEE (%)
Aug-24	78,85%	127%	100,0%	100,4%
Sept-24	74,25%	124%	100,0%	91,8%
Oct-24	77,26%	118%	100,0%	91,1%
Nov-24	77,90%	106%	100,0%	83,0%
Dec-24	75,83%	116%	100,0%	87,9%
Jan-25	82,01%	108%	100,0%	88,6%
Feb-25	78,30%	114%	99,5%	89,1%
Mar-25	75,97%	97%	99,6%	73,3%
Apr-25	70,05%	92%	100,0%	64,4%
Mei-25	70,14%	94%	98,7%	65,3%
Mean	76%	110%	99,8%	83%

The calculation results show that the highest percentage of OEE was recorded at 100.4% in August 2024, while the lowest value occurred in May 2025 with a percentage of 65.3%. Overall, the OEE value is still below the standard of 85%, which indicates that production is in the reasonable category but still needs improvement.

Calculation of the Value *of the Six Big Losses*

Through the comparison between the value of OEE plant 3 and the ideal OEE standard, it can be seen that the company needs to take improvement steps to improve the OEE of the machine. In connection with that, six big losses were calculated, the results of which are presented in the following table:

Tabel 10. Six Big Losses *Accumulated Data*

Six Big Losses	Presentase (%)	Kumulatif Presentase (%)
Equipment Failure (Breakdown Loss)	16,7	16,7
Setup and Adjustment Loss	7,1	23,89
Idling and Minor Stoppage	38,2	62,12
Reduce Speed Loss	-9,0	53,14
Process Defect Loss	0,2	53,33
Reduce Yield Loss	4,5	57,80

Based on the table above, an average percentage of six main types of losses over a 10-month period is obtained. From these results, five main factors that affect engine performance were identified, which include Breakdown losses, Setup and adjustment, Reduced yield losses, Idling and minor stoppages losses, and Defect losses. The highest percentage came from Idling and minor stoppages at 38.2%, while the lowest was Reduce Speed Loss with a value of -9.0%. Thus, for the Breakdown losses and Idling and minor stoppages categories, more intensive maintenance is needed on the production system of plant 3, as well as the control of raw materials to remain in accordance with standards so that the products produced meet the company's expectations. As a follow-up step, a fishbone diagram was created to explain in more detail the factors that cause material loss.

Fishbone Diagram

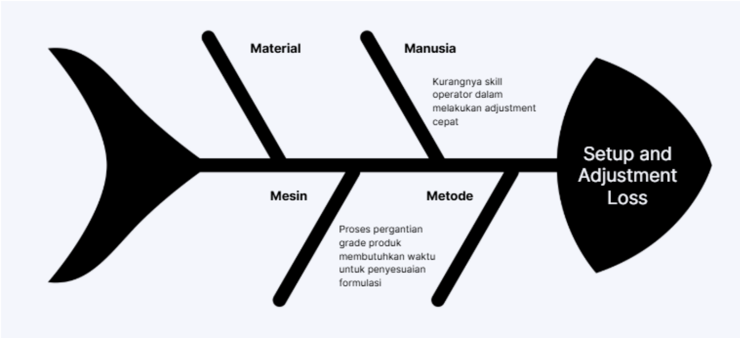

Figure 1. Fishbone diagram *idling and minor stoppage*

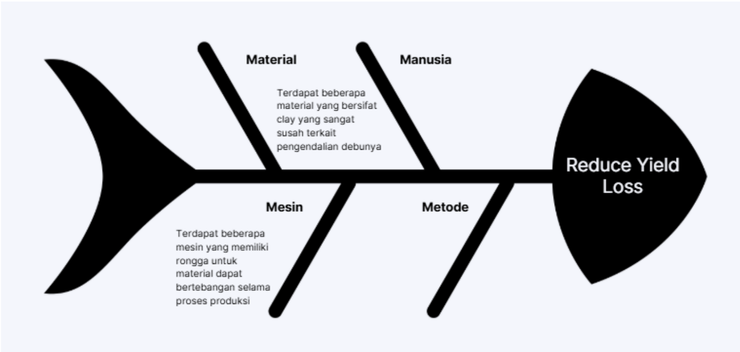

Figure 2. Fishbone diagram *setup and adjustment loss*

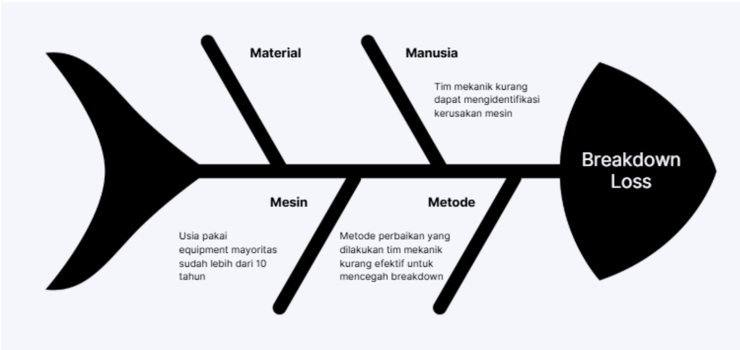

Figure 3. Fishbone diagram *reduce yield loss*

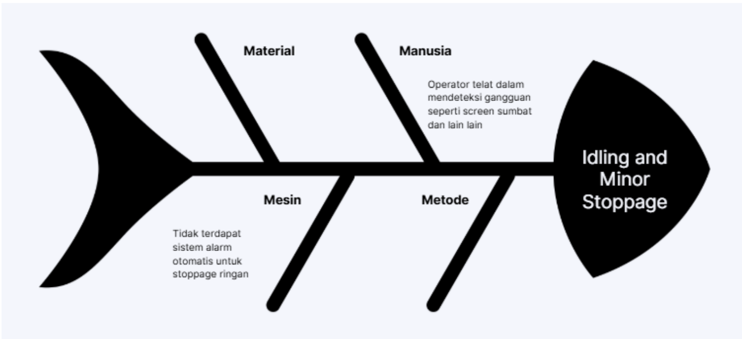

Figure 4. Fishbone diagram *breakdown loss*

Analisis FMEA

FMEA consists of several components collected through field studies and interviews, with the following data results:

1. Breakdown Losses : Losses incurred due to damage or failure of production machines so that the process stops completely. This condition leads to reduced operating time and production capacity.
2. Setup and Adjustment Losses : Losses that arise when the machine stops for setup, equipment replacement, or adjustment due to changes in products or production process specifications.
3. Reduced Speed Losses : The loss that occurs when the machine runs at an actual speed is lower than the ideal speed that has been set, so that the production output is not maximized.
4. Idling and Minor Stoppage Losses : Losses caused by the shutdown of the machine for a short period of time, such as stuck, stuttering, or repeated minor interruptions that reduce production effectiveness.
5. Process Defect Losses : Losses that arise due to defective products or production results that do not meet quality standards so that they must be repaired (reworked) or discarded.
6. Reduced Yield Losses : Losses occur in the early stages of the production process (start-up) when the machine produces products that do not meet quality standards until the machine reaches stable operating conditions.

No	Types of Losses	Severity	Occurance	Detection	Risk Priority Number
1.	Equipment Failure (Breakdown Loss)	8,2	7,1	7,7	448,3
2.	Setup and Adjustment Loss	7,8	6,6	7,8	401,5
3.	Idling and Minor Stoppage	7,4	7,3	7,7	416,0
4.	Reduce Speed Loss	7,6	7,5	7,2	410,4
5.	Process Defect Loss	7,6	7,5	6,9	393,3
6.	Reduce Yield Loss	7,2	6,9	7,5	372,6

From the table above, there is a type of loss with the highest RPN value in the type of *loss Equipment Failure (Breakdown Loss).* With an RPN value of 448.3, while the lowest RPN value is in the Reduce Yield Loss type with an RPN value of 372.6.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of calculation and analysis, it can be seen that the average value *of Overall Equipment Effectiveness* (OEE) at plant 3 PT. XYZ is 83%, still below the JIPM standard of 85%. The factor with the largest contribution to the low OEE value comes from *the Idling and Minor Stoppage Loss* with a percentage of 38.2%.

The results of the FMEA analysis show that the critical failure mode is found in the type of *Equipment failure loss (Breakdown Loss)* with the highest RPN value of 448.3%, which indicates the need for priority action on these components. In addition, human factors, methods, and materials also affect the occurrence of machine downtime and the failure to achieve production targets. Thus, the production system of PT. XYZ still has great opportunities to improve through the implementation of proper maintenance strategies, strict supervision, and improvements to the factors that cause production losses.

Suggestion

To increase the effectiveness of the production system at PT XYZ, it is necessary to implement regular preventive maintenance, especially on critical components such as gearboxes and conveyors to minimize engine damage. This effort needs to be supported by improving operator competence through technical training and work supervision so that the risk of human error can be reduced. In addition, companies need to conduct regular evaluations of the OEE value each production period to monitor effectiveness and immediately take corrective actions if there is a decline in performance. The provision of spare parts for components with a high risk of damage is also important to reduce downtime, as well as adjustments to work procedures (SOPs) to better suit actual operational conditions and still pay attention to work safety aspects.

ACKNOWLEDGEMENTS

The author expresses sincere gratitude to Allah Subhanahu wa Ta'ala for His endless blessings and guidance that have enabled the completion of this final project. Deep appreciation is also extended to the beloved parents for their constant prayers, support, and unconditional love, as well as to the dearest girlfriend for the encouragement, care, and motivation given throughout the preparation of this report. May all the kindness and support received be rewarded abundantly by Allah Subhanahu wa Ta'ala.

The author's gratitude is also addressed to PT. XYZ has given permission and support in this research process. The author thanks all employees of the production department who have played an active role in collecting data and providing the information needed during the research. With this support, research can be completed properly and is expected to provide benefits for improving the reliability of the production system at PT. XYZ.

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