



DOI: <https://doi.org/10.38035/gjes.v4i2>
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Analisis dan Peningkatan Efektivitas Mesin Produksi Menggunakan Metode Overall Equipment Effectiveness (OEE) dan Failure Mode and Effects Analysis (FMEA) pada PT Alcotraindo Batam

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Abstract: In the manufacturing industry, machine effectiveness plays a crucial role in achieving production targets, maintaining product quality, and improving operational efficiency. PT Alcotraindo Batam, as a manufacturing company, relies heavily on production machines to support its operational activities. However, machine downtime, performance losses, and equipment failures can reduce productivity and hinder the achievement of production objectives. Therefore, this study aims to analyze the effectiveness of production machines using the Overall Equipment Effectiveness (OEE) method and identify critical failure factors using Failure Mode and Effects Analysis (FMEA). This research employed a quantitative descriptive approach using production data, machine downtime records, maintenance reports, and quality data collected over a six-month observation period. The OEE analysis showed that the average machine effectiveness value was 76.40%, which is below the world-class standard of 85%. The average Availability Rate, Performance Rate, and Quality Rate were 88.32%, 88.00%, and 98.30%, respectively. Furthermore, the Six Big Losses analysis revealed that Equipment Failure Losses were the largest contributor to productivity losses, accounting for 35.14% of total losses. The FMEA results indicated that conveyor motor overheating was the most critical failure mode, with the highest Risk Priority Number (RPN) value of 320, followed by sensor malfunction (245) and roller wear (210). Based on these findings, several improvement strategies are recommended, including strengthening preventive maintenance programs, conducting routine inspections of critical components, enhancing operator training, and improving machine monitoring systems. The integration of OEE and FMEA proved effective in identifying machine performance losses and determining improvement priorities. The implementation of these recommendations is expected to increase machine effectiveness, reduce downtime, and improve overall production productivity at PT Alcotraindo Batam.

Keyword: Overall Equipment Effectiveness (OEE), Failure Mode and Effects Analysis (FMEA), Machine Effectiveness, Productivity, Manufacturing Industry.

INTRODUCTION

The manufacturing industry is currently facing increasingly complex challenges due to intensified global competition, changing market demands, and the need to deliver high-quality products at efficient production costs. To maintain competitiveness, companies are required to optimize all available resources, particularly production machinery and equipment. Production machines are essential assets in manufacturing operations because they directly contribute to producing goods that meet predetermined quantity and quality targets. Therefore, machine effectiveness has become one of the key factors determining a company's ability to achieve optimal productivity.

Company productivity is influenced not only by machine capacity but also by the organization's ability to maintain machine availability, sustain operational speed according to established standards, and produce products that meet quality specifications. In practice, various issues such as machine breakdowns, extended setup times, unplanned production stoppages, reduced operating speeds, and high defect rates often result in decreased machine effectiveness. These conditions subsequently lead to increased operational costs, delayed order fulfillment, and lower customer satisfaction levels.

PT Alcotraindo Batam is a manufacturing company that relies heavily on machine-based production systems to conduct its operational activities. The company's ability to achieve production targets is significantly influenced by the performance of the machines used throughout the production process. Any disruption to production machinery can hinder operations, resulting in reduced output, increased idle time, and higher production costs. Therefore, a comprehensive evaluation of machine effectiveness is necessary to assess machine performance and identify the factors contributing to productivity losses.

One of the most widely used methods for measuring production machine effectiveness is Overall Equipment Effectiveness (OEE). OEE is a performance indicator developed within the concept of Total Productive Maintenance (TPM) to evaluate equipment effectiveness based on three key components: Availability Rate, Performance Rate, and Quality Rate. Availability Rate reflects the extent to which machines are available during planned production time. Performance Rate measures the machine's ability to produce output according to its designed capacity, while Quality Rate indicates the machine's capability to produce products that meet quality standards. A high OEE value signifies that a machine operates effectively with minimal production losses.

According to Nakajima (1988), a world-class OEE score is 85% or higher, consisting of 90% Availability, 95% Performance, and 99% Quality. However, many manufacturing companies still fail to achieve these benchmarks due to various forms of production losses known as the Six Big Losses, namely equipment failure losses, setup and adjustment losses, idling and minor stoppage losses, reduced speed losses, process defect losses, and reduced yield losses. These six categories of losses are recognized as the primary causes of declining machine effectiveness and reduced organizational productivity.

Numerous previous studies have demonstrated the effectiveness of OEE in measuring and evaluating machine performance across different industrial sectors. Research conducted by Muchiri and Pintelon (2008) found that OEE provides a comprehensive representation of actual machine conditions and serves as a valuable tool for continuous improvement decision-making. Similarly, Gupta and Vardhan (2016) reported that low OEE values in manufacturing companies are generally associated with excessive machine

downtime and poor operational performance, highlighting the need for corrective actions that address the root causes of production losses.

Although OEE is capable of measuring machine effectiveness, it has limitations in identifying the root causes of failures that contribute to reduced effectiveness. OEE only provides information regarding the magnitude of productivity losses without offering a detailed explanation of the underlying causes. Therefore, an additional method is required to identify, analyze, and prioritize potential failures occurring within production machinery.

One of the most widely applied methods for failure risk analysis is Failure Mode and Effects Analysis (FMEA). FMEA is a systematic approach used to identify potential failure modes, analyze their effects, determine their causes, and establish improvement priorities based on the Risk Priority Number (RPN). The RPN is calculated by multiplying three primary parameters: Severity (S), Occurrence (O), and Detection (D). The higher the RPN value, the greater the priority assigned to corrective actions for the corresponding failure mode.

The application of FMEA in manufacturing industries has proven effective in helping organizations prioritize improvement initiatives. Stamatis (2003) explained that FMEA functions not only as a risk identification tool but also as a preventive approach to reduce the likelihood of failures that may disrupt production processes. Furthermore, research conducted by Liu et al. (2013) demonstrated that the implementation of FMEA can enhance maintenance program effectiveness by identifying critical components with the highest failure risks.

The integration of OEE and FMEA has been widely adopted in previous studies because it provides a more comprehensive analytical framework. OEE is used to measure machine effectiveness and identify areas experiencing productivity losses, while FMEA is employed to determine the root causes of identified problems and prioritize improvement actions based on risk levels. Research conducted by Prabowo et al. (2021) in the manufacturing sector demonstrated that integrating OEE and FMEA significantly improved machine effectiveness through reduced downtime and enhanced maintenance systems. The findings indicated that the combined application of these methods offers greater benefits than using either method independently.

Based on previous studies, it can be concluded that measuring machine effectiveness using OEE and identifying failure risks through FMEA represent an appropriate approach to improving productivity and production efficiency. Nevertheless, each company possesses unique production characteristics, machinery types, failure patterns, and maintenance systems. Therefore, a specific study at PT Alcotraindo Batam is required to obtain an accurate understanding of the actual conditions within the company.

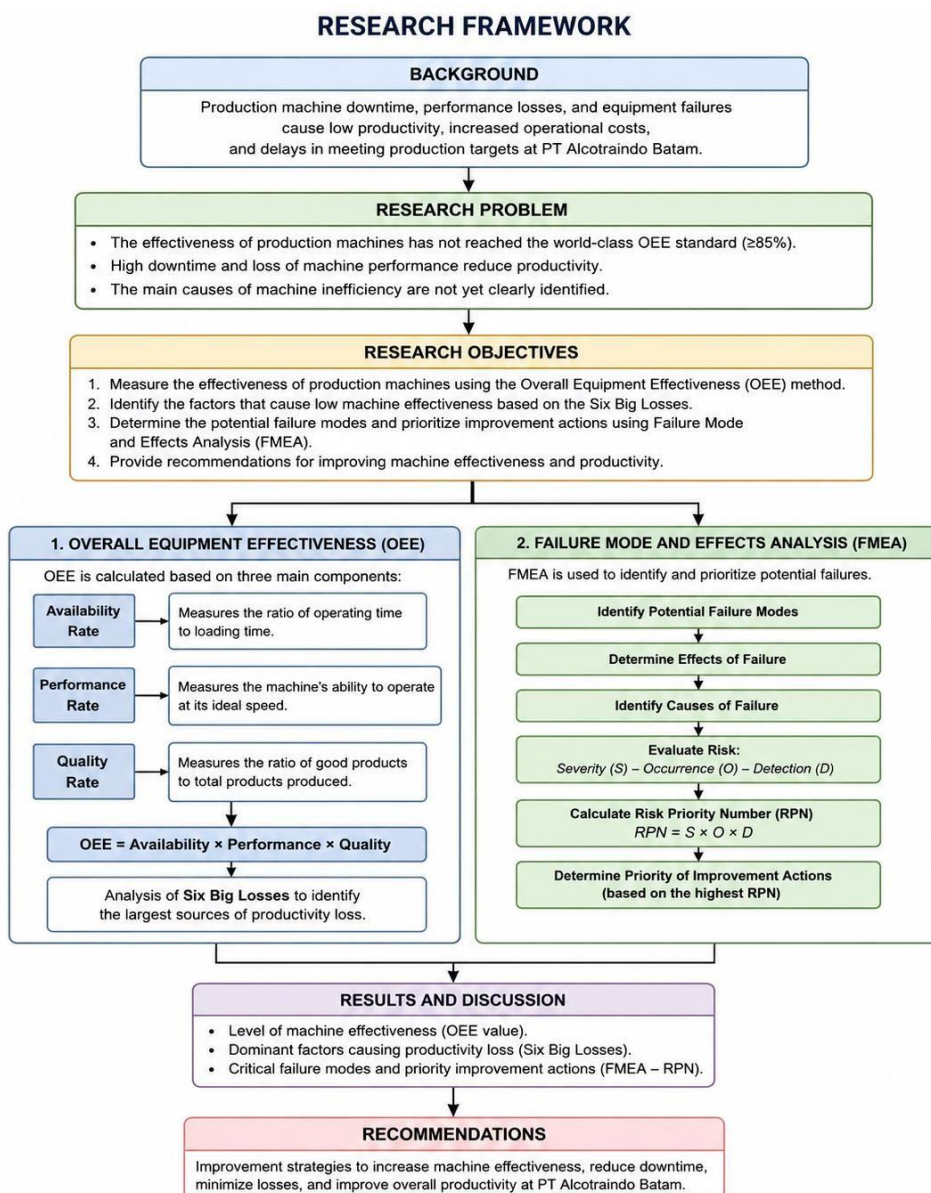
Accordingly, this study aims to analyze the effectiveness of production machines at PT Alcotraindo Batam using the Overall Equipment Effectiveness (OEE) method, identify the factors contributing to low machine effectiveness based on the Six Big Losses concept, and determine improvement priorities using Failure Mode and Effects Analysis (FMEA). The findings are expected to provide practical recommendations for enhancing machine effectiveness, reducing downtime, minimizing product defects, and supporting sustainable productivity improvement within the company. Furthermore, this study is expected to serve as a reference for future research related to measuring and improving machine performance in manufacturing industries

RESEARCH METHODS

Research Design

This study employed a quantitative descriptive approach to evaluate the effectiveness of production machines and identify the dominant factors causing performance losses at PT Alcotraindo Batam. The research integrated two analytical methods, namely Overall Equipment Effectiveness (OEE) and Failure Mode and Effects Analysis (FMEA). OEE was utilized to measure machine effectiveness through the dimensions of availability, performance, and quality, while FMEA was applied to identify potential failure modes, evaluate their impacts, and prioritize corrective actions based on risk levels.

The study was conducted on production machines that play a critical role in the manufacturing process. Data were collected through direct observation, interviews with production and maintenance personnel, and documentation of production records, machine downtime reports, maintenance reports, and quality control records. The collected data were analyzed systematically to determine the effectiveness level of production machines and formulate recommendations for improvement.



Overall Equipment Effectiveness (OEE)

The first stage of analysis involved measuring machine effectiveness using the Overall Equipment Effectiveness (OEE) method. OEE is a key performance indicator widely used in manufacturing industries to assess how effectively equipment is utilized during the production process. The OEE value is obtained from three main components: Availability Rate, Performance Rate, and Quality Rate.

Availability Rate measures the proportion of actual operating time compared to planned production time. This indicator reflects the extent to which machine downtime affects production activities. Availability Rate is calculated using the following formula:

$$\text{Availability Rate} = \frac{\text{Operating Time} \times 100\%}{\text{Loading Time}}$$

Performance Rate evaluates the machine's operating speed compared to its ideal operating speed. This component indicates losses caused by reduced operating speed or minor stoppages during production.

$$\text{Performance Rate} = \frac{\text{OperalIdeal Cycle Time} \times \text{Total Outputting Time} \times 100\%}{\text{Operating Time}}$$

Quality Rate measures the percentage of products that meet quality standards compared to the total products produced. This component identifies losses caused by product defects and rework activities.

The OEE value is calculated by multiplying the three components as follows:

$$\text{Quality Rate} = \frac{\text{Good Product} \times 100\%}{\text{Total Product}}$$

The resulting OEE value is then compared with the world-class standard of 85% to determine the effectiveness level of the production machine. Furthermore, the Six Big Losses concept is used to identify the dominant sources of productivity losses affecting machine performance.

Failure Mode and Effects Analysis (FMEA)

After obtaining the OEE results, the study proceeded with Failure Mode and Effects Analysis (FMEA) to identify potential machine failures contributing to low effectiveness levels. FMEA is a structured analytical technique used to evaluate possible failure modes, their causes, consequences, and priorities for improvement.

The implementation of FMEA consisted of several stages. First, potential failure modes were identified through machine maintenance records, downtime reports, observations, and interviews with operators and maintenance personnel. Second, each failure mode was assessed based on three criteria: Severity (S), Occurrence (O), and Detection (D).

Severity represents the seriousness of the impact caused by a failure on the production process. Occurrence indicates the frequency or probability of a failure occurring. Detection reflects the ability of existing control systems to identify failures before they affect production performance. Each criterion was rated on a scale of 1 to 10 according to standard FMEA guidelines.

Failure modes with the highest RPN values were categorized as critical issues requiring immediate corrective action. Based on the results, recommendations were developed to minimize machine failures and improve production effectiveness. These recommendations included preventive maintenance scheduling, operator training, standardization of operating procedures, replacement of critical machine components, and continuous machine performance monitoring.

Data Analysis Procedure

The data analysis process was carried out through several stages. First, production, downtime, quality, and maintenance data were collected and verified. Second, the Availability Rate, Performance Rate, and Quality Rate were calculated to determine the OEE value of the production machines. Third, the factors contributing to low machine effectiveness were identified using the Six Big Losses framework. Fourth, FMEA was conducted to determine the priority level of each identified failure mode through RPN calculations. Finally, improvement recommendations were formulated based on the critical failure modes identified through the FMEA analysis.

The integration of OEE and FMEA in this study provides a comprehensive approach to evaluating machine performance. OEE serves as a tool to measure equipment effectiveness, while FMEA helps identify root causes of performance losses and prioritize corrective actions. Consequently, the combined application of these methods is expected to support continuous improvement efforts and enhance production productivity at PT Alcotraindo Batam.

RESULTS AND DISCUSSION

Results

Overall Equipment Effectiveness (OEE) Analysis

Data were collected from one of the main production machines at PT Alcotraindo Batam during a six-month observation period (January–June 2026). The OEE calculation was conducted using the Availability Rate, Performance Rate, and Quality Rate indicators.

Table 1. OEE Calculation Results

	Availability (%)	Performance (%)	Quality (%)	OEE (%)
January	88.50	86.20	98.10	74.82
February	87.30	87.40	98.50	75.12
March	89.10	88.30	98.20	77.22
April	86.80	87.10	98.00	74.09
May	88.70	89.20	98.40	77.84
June	89.50	89.80	98.60	79.28

Source: Processed Research Data (2026)

The results indicate that the average OEE value of the production machine was **76.40%**, which is below the world-class benchmark of **85%**. The Quality Rate achieved the highest average value (98.30%), indicating that the machine consistently produced products meeting quality standards. However, the Availability and Performance Rates remained below the benchmark, suggesting that machine downtime and reduced operating speed significantly affected overall effectiveness.

Six Big Losses Analysis

To identify the dominant factors contributing to low OEE performance, the Six Big Losses analysis was conducted.

Table 2. Six Big Losses Contribution

	Time Loss (Minutes)	Percentage (%)
Equipment Failure Losses	3,250	35.14
Setup and Adjustment Losses	1,850	20.00
Idling and Minor Stoppages	1,620	17.51
Reduced Speed Losses	1,480	16.00
Process Defect Losses	670	7.24
Reduced Yield Losses	380	4.11
Total	9,250	100.00

Source: Processed Research Data (2026)

The analysis revealed that Equipment Failure Losses were the largest contributor to productivity losses, accounting for 35.14% of total losses. This was followed by Setup and Adjustment Losses (20.00%) and Idling and Minor Stoppages (17.51%). These findings indicate that machine breakdowns and setup activities were the primary causes of reduced machine effectiveness.

Failure Mode and Effects Analysis (FMEA)

Based on the Six Big Losses results, FMEA was performed to identify critical failure modes and determine corrective action priorities.

Table 3. FMEA Analysis Results

	Effect of Failure	S	O	D	RPN
Conveyor motor overheating	Production stoppage	8	8	5	320
Sensor malfunction	Incorrect machine operation	7	7	5	245
Roller wear	Reduced production speed	6	7	5	210
Loose electrical connection	Sudden machine shutdown	8	5	5	200
Delayed machine setup	Production delay	6	5	4	120

Source: Processed Research Data (2026)

The highest Risk Priority Number (RPN) was found in the conveyor motor overheating failure mode with an RPN value of 320, indicating that this issue should receive immediate corrective action. The second highest RPN was sensor malfunction (245), followed by roller wear (210).

Discussion

The results showed that the average OEE value of 76.40% is below the world-class standard of 85%, indicating that the production machine has not yet achieved optimal effectiveness. This finding is consistent with the study conducted by Gupta and Vardhan (2016), which reported that manufacturing companies often experience OEE values below world-class standards due to machine breakdowns and operational inefficiencies.

Among the three OEE components, Quality Rate achieved the highest average value (98.30%), indicating that product quality was generally maintained throughout the production process. This result aligns with previous studies that found quality-related losses tend to contribute less significantly to overall productivity losses compared to equipment-related issues. However, Availability Rate (88.32%) and Performance Rate (88.00%) remained below the benchmark, suggesting that machine downtime and reduced operational speed continue to affect productivity.

The Six Big Losses analysis identified Equipment Failure Losses as the largest contributor to production losses, accounting for 35.14% of total losses. This finding supports the research of Muchiri and Pintelon (2008), who emphasized that equipment failure is often the primary factor affecting OEE performance in manufacturing industries. Frequent machine breakdowns reduce available production time and increase maintenance costs, thereby lowering overall equipment effectiveness.

Furthermore, the FMEA results demonstrated that conveyor motor overheating represented the most critical failure mode, with the highest RPN value of 320. This indicates that the motor system is a critical component requiring immediate attention. Similar findings were reported by Stamatis (2003), who stated that equipment components with high RPN values should become the main focus of preventive maintenance programs because they have a significant impact on production continuity.

Sensor malfunction and roller wear were also identified as high-priority issues. Sensor failures can cause machine operation errors and unplanned stoppages, while worn rollers reduce machine performance and output speed. These findings indicate that preventive maintenance activities have not been fully optimized. Previous research by Liu et al. (2013) demonstrated that systematic maintenance scheduling and monitoring of critical machine components can significantly reduce machine failures and improve productivity.

Based on the findings, several improvement strategies are recommended. First, PT Alcotraindo Batam should strengthen its preventive maintenance program, particularly for conveyor motors, sensors, and roller components. Second, routine inspections and predictive maintenance techniques should be implemented to detect potential failures before they lead to machine breakdowns. Third, operator training programs should be enhanced to improve machine handling and troubleshooting capabilities. Finally, standardized machine setup procedures should be established to reduce setup and adjustment losses.

Overall, the integration of OEE and FMEA proved effective in identifying both the performance level and root causes of machine effectiveness losses. The results confirm previous studies suggesting that combining these methods provides a comprehensive framework for continuous improvement and productivity enhancement in manufacturing

industries. Through the implementation of the proposed corrective actions, PT Alcotraindo Batam is expected to improve machine effectiveness, reduce downtime, and move closer to achieving world-class manufacturing performance.

CONCLUSION

Based on the results of the study, it can be concluded that the effectiveness of the production machine at PT Alcotraindo Batam has not yet reached the world-class OEE standard of 85%, as indicated by the average OEE value of 76.40%. The analysis showed that the Quality Rate achieved a high performance level, while the Availability Rate and Performance Rate remained below the expected standard due to machine downtime and reduced operating speed. The Six Big Losses analysis identified Equipment Failure Losses as the dominant source of productivity loss, contributing 35.14% of total losses. Furthermore, the FMEA results revealed that conveyor motor overheating, sensor malfunction, and roller wear were the most critical failure modes based on their high Risk Priority Number (RPN) values. These findings indicate that machine-related failures significantly affect production effectiveness and require immediate corrective actions. Therefore, the implementation of preventive maintenance programs, periodic inspection of critical components, improvement of machine monitoring systems, and enhancement of operator competencies are recommended to reduce machine failures, improve equipment effectiveness, and increase overall production productivity at PT Alcotraindo Batam..

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