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Evaluation of Injection Machine Performance Using Overall Equipment Effectiveness (Oee): A Case Study in A Footwear Manufacturing Plant

Magdalena Setyowati[1], Nyoman Sri Widari[2*], Desrina Yusi Irawati[3]

[1,2,3]Universitas Katolik Darma Cendika, Jl. Dr. Ir. H. Soekarno No.201, Surabaya, 60117, Indonesia.

ABSTRACT: Injection molding machines play a crucial role in achieving production targets at PT XYZ, a footwear manufacturing company located in East Java, Indonesia. However, operational inefficiencies have contributed to decreased machine effectiveness and overall productivity. This study aims to evaluate the performance of Injection Machine 7 by applying the Overall Equipment Effectiveness (OEE) method as a key performance indicator. OEE is measured through three main components: availability, performance, and quality, using operational data collected between June 2023 and October 2024. The results show that the average OEE value of Injection Machine 7 is 81.64%, which is below the world-class benchmark of 85% established by the Japanese Institute of Plant Maintenance (JIPM). The analysis indicates that relatively low performance and quality rates are the primary factors contributing to the reduced level of machine effectiveness. To identify the root causes of these issues, a cause-and-effect (fishbone) diagram based on the 4M framework (Man, Machine, Material, and Method) was employed. The findings reveal that human and machine factors are the dominant contributors to the observed inefficiencies. Key issues include operator negligence, inadequate adherence to maintenance procedures, machine breakdowns, and improper machine parameter settings. Based on these findings, several improvement strategies are proposed, including strengthening operator training programs, implementing more rigorous preventive maintenance practices, and conducting periodic machine calibration. The implementation of these corrective actions is expected to enhance machine effectiveness, improve production efficiency, and support sustainable manufacturing performance.

KEYWORDS: Overall Equipment Effectiveness, Injection molding machine, Manufacturing productivity, Preventive maintenance, Root cause analysis.

1. INTRODUCTION

The footwear manufacturing industry has experienced rapid growth in recent years, driven by increasing global demand for sports and fashion footwear products. This industry is characterized by intense competition, rapid product innovation cycles, and increasingly stringent quality standards. Under these conditions, companies are required not only to produce footwear that meets high standards of comfort and quality but also to maintain operational efficiency and consistent product quality on a sustainable basis [1]. PT XYZ, a footwear manufacturing company located in East Java, operates in a highly competitive and productivity-driven industrial environment. Consequently, improving production efficiency has become a critical strategy for maintaining the company's competitiveness.

One of the key factors influencing production efficiency is the effectiveness of production machinery. Machine performance directly affects production output, product quality, operational costs, and delivery reliability. In modern manufacturing practices, machine performance measurement no longer focuses solely on production volume but also considers machine availability, operational speed, and product quality simultaneously. By integrating these components, OEE provides a holistic perspective on production losses within manufacturing systems [2]. OEE evaluates machine performance through three main components: availability, performance, and quality, which together provide a comprehensive measure of equipment productivity [3]. By combining these three indicators, OEE allows companies to identify production losses and evaluate the operational efficiency of manufacturing equipment [4].

Machine effectiveness is particularly critical in industries that require high precision, such as footwear manufacturing. Inadequate maintenance practices can lead to reduced machine performance, increased downtime, and declining product quality. Maintenance activities are designed to preserve and restore equipment conditions so that machines can continue operating optimally according to their intended functions [5]. Total Productive Maintenance (TPM) is widely implemented in manufacturing industries as an approach to improve machine reliability and productivity. The implementation of TPM practices can reduce equipment failures and improve overall production efficiency [7]. Previous studies have demonstrated that the OEE method is effective in identifying major sources of production losses, including breakdown losses, setup and adjustment losses, reduced speed losses, and defect losses [8]. However, many previous studies primarily focus on calculating OEE values and classifying the six big losses without conducting an in-depth root cause analysis or integrating the findings into a systematic maintenance improvement framework [6]. Recent studies emphasize the importance of developing more comprehensive measurement frameworks to evaluate machine effectiveness in manufacturing systems using OEE indicators [9].

Furthermore, empirical research on OEE implementation has predominantly been conducted in automotive, metal processing, and other process-based industries. Studies specifically examining the application of OEE in the footwear manufacturing sector remain relatively limited. This gap is significant because footwear production processes, particularly in the injection stage for component formation, involve distinct technical characteristics and complex process parameters that differ from those of other manufacturing industries. Therefore, a more contextualized approach to evaluating machine performance is required for this sector [10].

In the footwear production process at PT XYZ, injection machines play a vital role in forming shoe components. Injection Machine 7, in particular, contributes significantly to achieving the company's production targets. However, operational observations indicate a decline in machine performance, as evidenced by increasing downtime, inconsistent product quality, and suboptimal production capacity utilization. These conditions highlight the need for a systematic evaluation of machine effectiveness to determine its actual performance level and to identify the factors affecting its operational efficiency.

Based on this background, this study aims to analyze the effectiveness of Injection Machine 7 at PT XYZ using the OEE method, identify the dominant factors contributing to production losses, and formulate improvement recommendations based on the principles of Total Productive Maintenance (TPM). This research is expected to provide both theoretical and practical contributions. Theoretically, it enriches the existing literature on the implementation of OEE in the footwear manufacturing industry. Practically, it offers data-driven recommendations to improve machine performance, reduce downtime, and enhance overall production quality.

2. RESEARCH METHODOLOGY

This research was conducted at PT XYZ, a footwear manufacturing company located in East Java, Indonesia. The object of the study was Injection Machine 7, which is used in the production process of shoe components. This machine was selected as the focus of the study because it is classified as a critical machine due to its significant contribution to achieving the company's daily production targets. The study aims to evaluate the effectiveness of the machine using a quantitative approach based on the OEE method.

The research employed a quantitative descriptive–analytical design. This approach was chosen to systematically measure and analyze machine performance using OEE indicators based on historical operational data. The data used in this study were secondary data obtained from machine operational records during the period June 2023 to October 2024. These data included planned production time, downtime, operating time, actual production output, ideal production output, and the number of defective products.

The research process began with a field study, which involved direct observation of the operational conditions of Injection Machine 7, the production workflow, and the patterns of machine disturbances. This observation aimed to obtain contextual insight into the injection process and to identify potential sources of production losses. Subsequently, a literature review was conducted to establish the theoretical foundation of the study, covering machine effectiveness, the OEE framework, the concept of the six big losses, and the principles of TPM.

Data collection was carried out through documentation of production reports and maintenance records provided by the company. The collected data were then validated to ensure consistency, completeness, and reliability prior to further analysis. The data analysis involved calculating the three main components of OEE [11]:

- Availability represents the proportion of actual operating time relative to the planned production time. Operating time is obtained by subtracting downtime from the planned production time.
- Performance measures the relationship between the actual production output and the ideal production capacity during the operating time. It is calculated by multiplying the number of units produced by the ideal cycle time and dividing the result by the operating time.
- Quality indicates the proportion of good products relative to the total number of units produced.

The OEE value is obtained by multiplying these three components:

$$OEE = (Availability \times Performance \times Quality).$$

The resulting OEE values were analyzed descriptively to identify trends in machine effectiveness during the observation period. These results were then compared with the international benchmark established by the Japanese Institute of Plant Maintenance (JIPM), which defines a world-class OEE value of 85% [12], [13]. Previous studies also use this benchmark to evaluate the effectiveness of manufacturing equipment in industrial environments [14].

To identify the factors contributing to low OEE performance, a root cause analysis was conducted using a cause-and-effect (fishbone) diagram based on the 4M framework, consisting of man, machine, material, and method [15]. This analysis aimed to systematically categorize the sources of problems and determine the dominant factors contributing to production losses. Based on the findings of this analysis, improvement recommendations were formulated to enhance machine effectiveness, reduce downtime, and optimize productivity as part of the implementation strategy for TPM within the company.

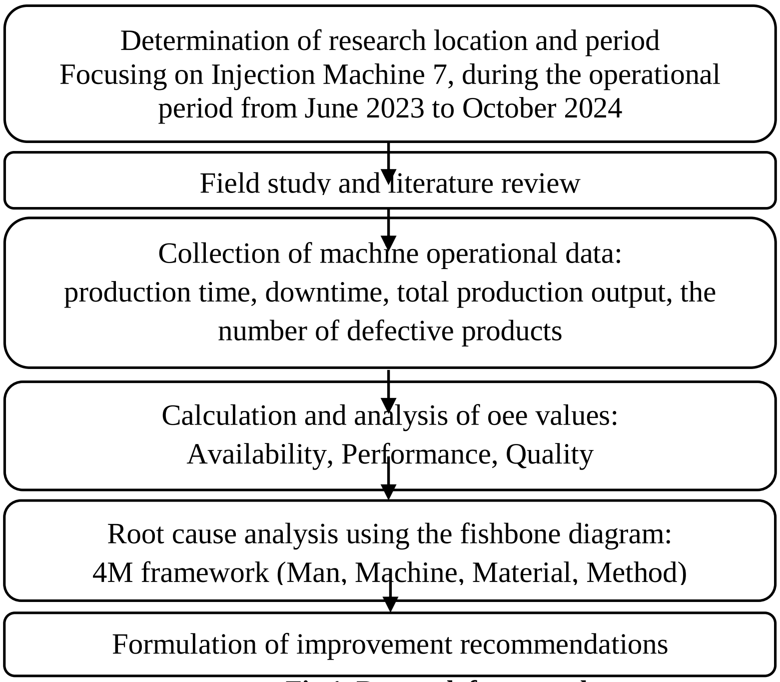

Fig 1. Research framework

3. RESULTS AND DISCUSSION

This study focuses on analyzing the effectiveness of Injection Machine 7 using the OEE method. The implementation process began with the collection of historical production data, followed by data processing to calculate the OEE components (availability, performance, and quality), and concluded with a root cause analysis using a cause-and-effect diagram.

3.1 Data Collection

Production data for the period June–October 2024 indicate that the total production target was 192,547 pairs, while the actual output reached 169,104 pairs, with 4,199 pairs classified as rejected products. These data served as the primary basis for calculating the performance and quality components of OEE. The detailed production data are presented in Table 1.

Table 1. Production Data for Injection Machine 7

Month	Target production (Pairs)	Actual output	Product reject
June	41327	39059	963
July	42389	39920	903
August	40698	29780	686
September	32146	28204	711
October	35987	32141	936
Total	192547	169104	4119

Based on production time data shown in Table 2, the machine operating time was set at 34,560 minutes per month, calculated from a 24-hour daily operation schedule with six working days per week. Over the five-month observation period, the total machine operating time reached 172,800 minutes. The setup time was scheduled for 20 minutes per week, resulting in a total of 400 minutes during the five-month period. In addition, routine preventive maintenance was carried out every Thursday during the morning shift for 30 minutes, resulting in a total planned maintenance duration of 600 minutes. The total breakdown time (unplanned downtime) recorded during the study period was 8,009 minutes. These data were used to calculate the three main components of OEE: availability, performance, and quality.

Table 2. Production Data for Injection Machine 7

Month	Machine operating time	Set up time	Preventive maintenance	Breakdown time
June	34560	80	120	2000
July	34560	80	120	2687
August	34560	80	120	1076
September	34560	80	120	826
October	34560	80	120	1420
Total	172800	400	600	8009

3.2 OEE Calculation

Availability was calculated as the ratio between actual operating time and planned production time after deducting planned downtime. Planned downtime consisted of setup time and preventive maintenance, whereas unplanned downtime represented machine breakdowns. The calculation results show that the average availability of Injection Machine 7 during the five-month period was 94.7%. This value exceeds the international benchmark of 90%, indicating excellent machine availability. These results suggest that the machine was generally capable of operating according to the planned production schedule. The detailed availability calculations are presented in Table 3.

Table 3. Availability Calculation Data for Injection Machine 7

Month	Machine operating time	Planned downtime	Unplanned downtime	Availability
June	34560	200	2000	93.60%
July	34560	200	2687	91.60%
August	34560	200	1076	96.30%
September	34560	200	826	97.00%
October	34560	200	1420	95.30%
Average	34560	200	1602	94.70%

Performance was calculated by comparing the actual production output with the ideal production output based on the standard cycle time. The calculation process included determining the operating load time (operating time minus planned downtime), the effective machine time (operating time minus unplanned downtime), and the ideal cycle time, which was obtained from the ratio of effective time to actual production output. The analysis shows that the average performance value during the study period was 88.5%, which is still below the ideal benchmark of 95%. This finding indicates that the machine was not operating at its optimal production speed. Although the machine was available for production, the actual production rate remained lower than the ideal capacity that could potentially be achieved. The detailed calculations for pre-performance and performance are presented in Tables 4 and 5.

Table 4. Pre-performance Calculation Data for Injection Machine 7

Month	Machine operating load time	Machine effective time	Ideal cycle time
June	34360	32560	0.8
July	34360	31873	0.8
August	34360	33484	1.1
September	34360	33734	1.2
October	34360	33140	1.0
Average	34360	32958	1.0

Table 5. Performance Calculation Data for Injection Machine 7

Month	Output actual	Effective machine time	Ideal cycle time	Performance
June	39059	32560	0.8	94.70%
July	39920	31873	0.8	87.60%
August	29780	33484	1.1	97.80%
September	28204	33734	1.2	75.40%
October	32141	33140	1.0	87.30%
Average	32511	32958	1.0	88.50%

The quality rate was calculated as the ratio of good products to total production output. The results indicate an average quality rate of 97.3%, which is slightly below the ideal benchmark of 99%. Although the quality level can still be considered relatively good, the difference from the benchmark suggests that improvements are still possible, particularly in reducing the number of rejected products. The detailed quality calculations are presented in Table 6.

Table 6. Quality Value Data for Injection Machine 7

Month	Output actual	Reject	Quality
June	39059	963	97.40%
July	33373	903	97.20%
August	29780	686	97.60%
September	28204	711	97.40%
October	32141	936	96.40%
Average	32511	840	97.30%

The OEE value was obtained by multiplying the three components: availability, performance, and quality. Based on the calculations, the results were availability= 94.7%, performance= 88.5%, and quality= 97.3%, resulting in an average OEE value of 81.64%. Although the availability component exceeded the benchmark, the performance and quality values remained below their respective standards, causing the overall OEE value to fall short of the 85% benchmark recommended by the JIPM. This result indicates that the effectiveness of Injection Machine 7 has not yet reached an optimal level and that significant production losses still occur, particularly in the performance component. The complete OEE calculation results are shown in Table 7.

Table 7. OEE Calculation Data

Month	Availability	Performance	Quality	OEE
June	93.60%	94.70%	97.50%	86.42%
July	91.60%	87.60%	97.20%	77.99%
August	96.30%	97.80%	97.60%	91.92%
September	97.00%	75.40%	97.40%	71.24%
October	95.30%	87.30%	96.90%	80.62%
Average	94.70%	88.50%	97.30%	81.64%
Standard	90%	95%	99%	85%

3.3 Root Cause Analysis

When one component of OEE has a relatively low value, it directly affects the overall OEE level. Based on the results of the analysis, performance was identified as the dominant factor contributing to the lower OEE value. To determine the underlying causes, a root cause analysis was conducted using a cause-and-effect (fishbone) diagram based on the 4M framework: Man, Machine, Material, and Method.

The analysis revealed several key contributing factors. First, the relatively old age of the machine and delayed maintenance activities increased the frequency of breakdowns. Component wear, hydraulic system disturbances, and irregularities in the heating system reduced the machine's operating capacity and prolonged repair times.

Second, material-related issues were identified. In some cases, discrepancies between material specifications and machine parameters slowed down the injection process and reduced performance. In addition, raw materials with high moisture content or contamination increased the likelihood of defective products and higher rejection rates.

Third, method-related factors were observed. Production procedures were not fully standardized, setup times were relatively long, and process adjustments were not consistently documented. These conditions resulted in unnecessary time losses and reduced production efficiency. The results of the fishbone analysis are presented in Figure 2.

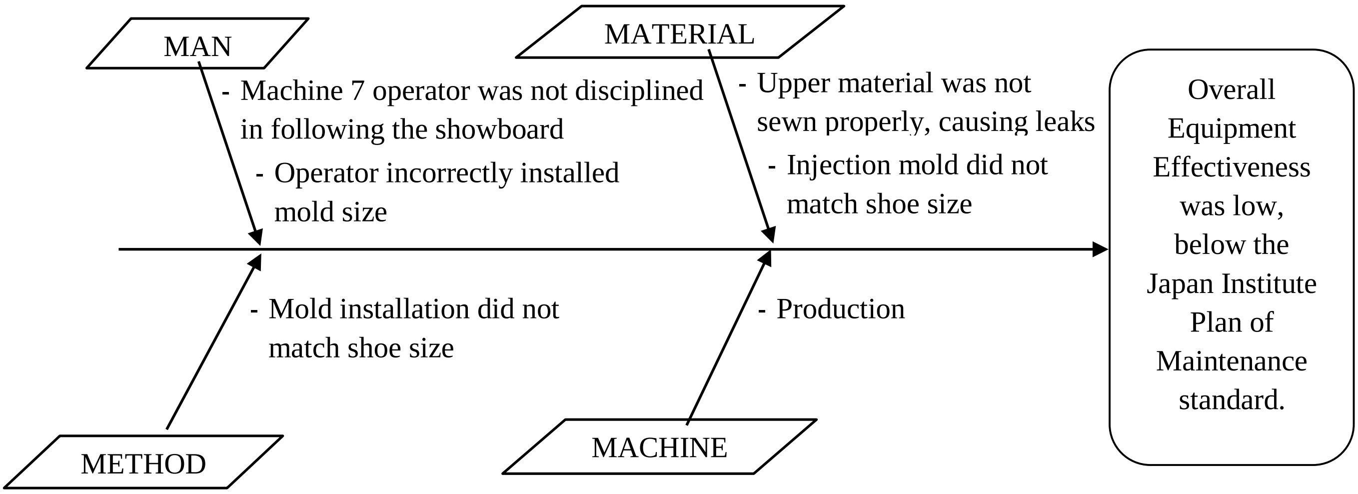

Fig 2. Fishbone diagram of OEE value

Overall, the study shows that the average OEE value of Injection Machine 7 during the June-October 2024 period was 81.64%, which is below the international benchmark of 85% recommended by JIPM. Therefore, the machine's effectiveness can be categorized as moderate and has not yet reached world-class performance.

Although the availability component (94.7%) demonstrates excellent performance and exceeds the minimum standard of 90%, the performance (88.5%) and quality (97.3%) components remain below the ideal standards of 95% and 99%, respectively. This indicates that the main issue lies not in machine availability but in production speed efficiency and product quality consistency.

From an analytical perspective, the high availability value suggests that the production scheduling system and preventive maintenance practices are relatively effective in maintaining machine operating time. However, the lower performance value indicates the presence of speed losses or minor stoppages that are not fully recorded as downtime but still reduce actual output relative to the machine's ideal capacity. These losses are commonly associated with inconsistent process parameters, fluctuations in material quality, and variations in operator skill levels during the injection process.

The quality component, which reached 97.3%, indicates that the rejection rate is relatively controlled. However, there is still room for improvement to achieve the 99% benchmark. Defective products in injection processes are generally caused by inaccurate heating temperatures, unstable injection pressure, or variations in material characteristics. Additionally, human factors and operational methods also influence the consistency of product quality. The fishbone analysis further confirms that the combined influence of man, machine, material, and method simultaneously contributes to the overall reduction in machine effectiveness.

From a managerial perspective, these findings emphasize that improving OEE cannot rely solely on reducing downtime. Instead, it requires an integrated strategy that simultaneously enhances production performance and product quality. The implementation of TPM principles, particularly the autonomous maintenance and focused improvement pillars, becomes crucial for reducing speed losses and defect losses. Through a structured continuous improvement approach, the company has the potential to increase its OEE value beyond the 85% benchmark, thereby improving productivity, cost efficiency, and long-term industrial competitiveness.

Nevertheless, this study has several limitations. The research scope was limited to a single machine, the observation period was relatively short, and the study did not include a direct evaluation of the implementation of improvement strategies or their economic impact. Therefore, future research is recommended to expand the scope of analysis to multiple machines or production lines, apply inferential statistical approaches to examine relationships among variables, and conduct implementation-based studies to measure the effectiveness of improvement strategies in increasing OEE performance over time.

4. CONCLUSION

Based on the analysis using the OEE method, the average OEE value of Injection Machine 7 was 81.64% during the period from June 2023 to October 2024. This value is still below the ideal standard of 85% established by the JIPM, indicating that the effectiveness of the machine has not yet reached the optimal level. Although the availability component has exceeded the recommended standard, the performance and quality components remain below the established benchmark, making them the primary factors contributing to the suboptimal OEE value. The root cause analysis using the 4M approach (Man, Machine, Method, and Material) shows that the dominant factors affecting machine effectiveness originate from the man aspect, such as operator negligence and lack of discipline, and the machine aspect, including machine breakdowns and suboptimal machine settings. Therefore, integrated improvement efforts are required through the implementation of TPM principles to enhance machine performance and achieve the expected effectiveness standards. This study has several limitations, including the scope being limited to only one machine, a relatively short observation period, and the absence of direct evaluation of improvement implementation as well as economic impact analysis.

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