Improving Printing Machine Effectiveness Using OEE and SMED: A Case Study at PT Kreasi Permata Sinergi

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Abstract. This study aims to improve the effectiveness of a printing machine at PT Kreasi Permata Sinergi by applying the Overall Equipment Effectiveness (OEE) and Single Minute Exchange of Die (SMED) methods. OEE is used to evaluate machine performance based on availability, performance efficiency, and quality rate. When the OEE value falls below the world-class standard (≥85%), a Six Big Losses analysis is conducted to identify the dominant sources of inefficiency. The study utilizes historical operational data collected from December 2024 to March 2025 on the Atexco Model X Plus printing machine. The results indicate that the average OEE value is below the benchmark, with setup and adjustment identified as the largest contributors to performance losses. To address this issue, improvement strategies are proposed through the implementation of SMED by separating internal and external setup activities. The proposed approach is expected to reduce setup time, enhance machine effectiveness, and minimize production delays.

1 Introduction

The industrial sector is experiencing rapid development, resulting in increasingly intense competition among companies. In the textile printing industry, this condition compels companies to deliver superior product quality and service to customers [1]. To remain competitive in the digital textile printing sector, companies must continuously improve efficiency, productivity, and quality across all operational aspects [2]. Optimal machine performance plays a critical role in achieving these objectives, as higher equipment effectiveness directly contributes to increased productivity and profitability [3].

However, suboptimal machine performance can significantly reduce production capacity, particularly when frequent machine constraints and breakdowns occur. Well-performing machines enhance productivity, support on-time order fulfillment, and strengthen a company's competitive position [4]. PT Kreasi Permata Sinergi, a premium-quality sublimation digital textile printing company operating under a Make-to-Order (MTO) system, is currently facing a decline in production capacity accompanied by frequent machine interruptions. Company records indicate delivery delays in 83 out of 175 orders in December 2024, 118 out of 220 orders in January 2025, and 50 out of 205 orders in

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February 2025. These conditions have forced the company to implement overtime work and risk financial losses, highlighting the urgency of identifying the factors contributing to reduced machine performance and production capacity.

Total Productive Maintenance (TPM) is a widely recognized approach for addressing equipment-related performance issues. TPM emphasizes the involvement of all organizational elements to improve overall equipment effectiveness through systematic maintenance, operator skill development, loss reduction, and continuous improvement [5]. A key performance indicator within TPM is Overall Equipment Effectiveness (OEE), which evaluates machine performance based on availability, performance efficiency, and quality rate. Furthermore, the Six Big Losses framework enables the identification of dominant sources of inefficiency that negatively impact machine effectiveness.

Despite the extensive application of OEE and Six Big Losses in manufacturing industries, many studies primarily focus on performance evaluation without translating the identified losses into structured and practical improvement actions, particularly in digital textile printing operations. In addition, limited research integrates OEE-based loss analysis with the Single Minute Exchange of Die (SMED) method to specifically address setup and adjustment losses, which are critical in Make-to-Order production environments characterized by frequent job changes.

Therefore, this study aims to improve the effectiveness of printing machines at PT Kreasi Permata Sinergi by applying the Overall Equipment Effectiveness (OEE) method to evaluate machine performance and identify the largest losses using the Six Big Losses framework. Subsequently, the Single Minute Exchange of Die (SMED) method is employed to formulate improvement proposals focused on reducing setup and adjustment time. The proposed approach is expected to enhance machine effectiveness, reduce production delays, and support more efficient operations in digital textile printing systems.

2   Methodology

The research stages consist of several sequential steps. Data were collected from December 2024 to March 2025, including production output and defect data, printing machine performance data, and cycle time data. The collected data were then processed using the Overall Equipment Effectiveness (OEE) method, which is widely applied within the Total Productive Maintenance (TPM) framework to evaluate how effectively machines support production processes. OEE is calculated based on three main components: Availability Ratio (AR), Performance Efficiency (PE), and Rate of Quality Product (ROQP) [5]. Each component is analyzed to determine the overall OEE value and to identify performance losses that affect machine effectiveness.

2.1   Data Collection

The research data were collected during the period from December 2024 to March 2025. The data include production output and defect data of the printing machine, printing machine performance data, and printing machine cycle time data.

2.2   Overall Equipment Effectiveness (OEE) Data Processing

Overall Equipment Effectiveness (OEE) is a widely used method within Total Productive Maintenance (TPM) to evaluate how effectively machines or equipment support production processes. OEE consists of three main components: Availability Ratio (AR), Performance Efficiency (PE), and Rate of Quality Product (ROQP) [5]. This section describes the calculation methods used to determine the OEE value.

a. Availability Ratio (AR)

AR indicates the extent to which a machine operates effectively based on the available production time [6], calculated using the formula:

$$AR = \frac{Operation\ Time}{Loading\ Time} \times 100\% \tag{1}$$

b. Performance Efficiency (PE)

PE reflects how effectively a machine produces output relative to its ideal performance [6], calculated using the formula:

$$PE = \frac{Total\ Production \times Ideal\ Cycle\ Time}{Operation\ Time} \times 100\% \tag{2}$$

c. Rate of Quality Product (ROQP)

ROQP represents the machine's ability to produce quality products [6], calculated using the formula:

$$ROPQ = \frac{Total\ Production - Total\ Reject}{Total\ Production} \times 100\% \tag{3}$$

d. Overall Equipment Effectiveness (OEE)

These three factors must be calculated sequentially and then analyzed based on the obtained values. The results of the analysis indicate whether the machine performance is effective or not, and are calculated using the following formula:

$$OEE = AR \times PE \times ROPQ \tag{4}$$

2.3   OEE Value Analysis

The analysis is conducted based on the OEE values obtained from the previous calculations. The OEE value represents the level of machine effectiveness. By analyzing this value and its components, the factors contributing to machine inefficiency can be identified, particularly those associated with the lowest-performing components.

2.4 Six Big Losses Data Processing

Six Big Losses data processing is conducted when the calculated OEE value indicates ineffective machine performance and requires further analysis. The Six Big Losses are classified into three main categories: downtime losses, speed losses, and quality losses. The following section describes the six major losses grouped into these categories [5].

2.4.1 Downtime Losses

Downtime losses refer to a reduction in available operating time caused by wasted time, resulting in the machine not operating according to the planned production schedule, as well as the occurrence of unplanned activities during the production process. Downtime losses are classified into two types of losses, namely:

a. Equipment Failure Losses (EFL)
   EFL these losses occur when machine or equipment failures lead to the interruption of production activities and are calculated using the following equation:

   $$EFL = \frac{Total\ Failure\ \&\ Repair}{Total\ Loading\ Time}\ x\ 100\% \tag{5}$$

b. Setup and Adjustment Losses (SAL)
   SAL refer to the time required for installation, setup, and adjustment of machine parameters to achieve the desired specifications when a machine or equipment is initially operated and are calculated using the following formula:

   $$SAL = \frac{Setup\ and\ Adjustment}{Total\ Loading\ Time}\ x\ 100\% \tag{6}$$

2.4.2 Speed Losses

Speed losses occur due to a decrease in machine speed or operational performance below the normal operating level and are classified into two types [2]:

a. Idle and Minor Stoppage Losses (IMSL)
   IMSL refer to losses that occur when the machine stops temporarily and does not produce any product or output [2], and are calculated using the following formula:

   $$IMSL = \frac{(Production\ Targets - Total\ Production)\ x\ Ideal\ Cycle\ Time}{Loading\ Time}\ x\ 100\% \tag{7}$$

b. Reduced Speed Losses (RSL)
   RSL refer to losses that occur due to a decrease in machine speed, resulting in the machine being unable to operate at its optimal performance level [2], and are calculated using the following formula:

   $$RSL = \frac{(Actual\ CT - Ideal\ CT)\ x\ Total\ Production}{Total\ Loading\ Time}\ x\ 100\% \tag{8}$$

2.4.3 Quality Losses

Quality losses refer to losses arising from production outputs that fail to meet the specified quality standards. These losses are categorized into two types [2]:

a. Process Defect Losses (PDL)

PDL These losses arise when defective products are generated, leading to additional rework costs and are calculated using the following equation:

$$PDL = \frac{Ideal\ CT\ x\ Total\ Reject}{Total\ Loading\ Time}\ x\ 100\% \tag{9}$$

b. Reduced Yield Losses (RYL)

RYL It refers to losses that occur during the production process until stable production conditions are achieved and are calculated using the following formula:

$$RYL = \frac{Total\ Reduced\ x\ Total\ Reject}{Total\ Loading\ Time}\ x\ 100\% \tag{10}$$

2.5 Six Big Losses Value Analysis

The loss analysis is conducted based on the Six Big Losses categories, which include equipment failure losses, setup and adjustment losses, idling and minor stoppage losses, reduced speed losses, process defect losses, and reduced yield losses. The magnitude of each loss category is then compared to identify the dominant sources of inefficiency, thereby determining the priority areas for improvement.

2.6 Proposed Improvements

The improvement proposals are developed based on the previous analysis by prioritizing the largest types of losses. The formulation of the improvements is supported by the SMED method, which distinguishes setup activities into internal and external setups. Through the implementation of this method, setup processing time and product changeover time are expected to be reduced.

3 Results And Discussion

The collected data were analyzed through two stages, namely the calculation of Overall Equipment Effectiveness (OEE) and the calculation of Six Big Losses. Subsequently, the analysis results were used as the basis for formulating improvement proposals using the Single Minute Exchange of Die (SMED) method.

3.1 Overall Equipment Effectiveness (OEE)

The calculation of Overall Equipment Effectiveness (OEE) involves three main parameters, namely the availability ratio (AR), performance efficiency (PE), and rate of quality product (ROQP). After the OEE values were calculated for each working day during the period from December 2024 to March 2025, the calculation results are presented in the Table 1.

Table 1. Results of OEE Value Calculation

Month	AR (%)	PE (%)	ROQP (%)	OEE (%)
December	88.00	86.08	98.37	74.42
January	88.29	82.43	98.08	71.32

Month				
February	86.99	84.71	98.20	72.38
March	86.96	82.11	97.83	69.86
Average	**87.56**	**83.83**	**98.12**	**71.99**

3.2 OEE Value Analysis

The results of data processing indicate that the Overall Equipment Effectiveness (OEE) value of the printing machine during the period from December 2024 to March 2025 ranged from 69.860% to 74.420%, with an average of 71.996%, which is still below the international standard of 85%. This low OEE value is mainly influenced by the availability ratio and performance efficiency. The low availability ratio is caused by prolonged setup and adjustment activities (design changes, planned downtime, test printing, and printhead cleaning) as well as failure and repair activities (printhead errors, paper jams, and system errors). Meanwhile, the low performance efficiency is triggered by a reduction in machine speed, resulting in the actual cycle time being higher than the ideal cycle time. In addition, the rate of quality product also decreased due to printing defects caused by clogged printheads and operator errors in design settings. These factors indicate that the machine has not yet been operating optimally and requires further evaluation and improvement.

3.3 Six Big Losses

The Six Big Losses calculation includes six main types of losses, namely equipment failure losses, setup and adjustment losses, idle and minor stoppage losses, reduced speed losses, process defect losses, and reduced yield losses. A summary of the Six Big Losses calculation results for the period from December 2024 to March 2025 is presented in the Table 2.

Table 2. Results of Six Big Losses Calculation

Month	EFL (%)	SAL (%)	IMSL (%)	RSL (%)	PDL (%)	RYL (%)
December	13.04	7.86	1.35	14.97	1.46	0.00
January	0.30	7.78	4.29	26.44	1.38	0.00
February	0.41	8.38	6.06	24.47	1.35	0.00
March	4.74	8.68	2.69	23.52	1.54	0.00
Average	**4.62**	**8.17**	**3.60**	**22.35**	**1.43**	**0.00**

3.4 Six Big Losses Value Analysis

The Six Big Losses analysis for the period from December 2024 to March 2025 shows that the largest loss occurred in reduced speed losses, with an average of 24.780%, followed by setup and adjustment losses at 12.140%. These two categories are the primary contributors to the low machine effectiveness. In addition, the average values of equipment failure losses, idle and minor stoppage losses, process defect losses, and reduced yield losses were recorded at 4.469%, 3.466%, 1.383%, and 0%, respectively. The high reduced speed losses are caused by the gap between the actual cycle time and the ideal cycle time, as well as

scheduled downtime, while the high setup and adjustment losses are influenced by the lengthy machine changeover and adjustment processes. Therefore, the low OEE value is mainly attributed to the significant losses in reduced speed and setup and adjustment, indicating that the printing machine has not yet achieved the international OEE standard of 85%.

3.5   Analysis of the Relationship Between OEE Values and Six Big Losses

An analysis of the relationship between the OEE values and the Six Big Losses was conducted to examine the correlation between the two. The relationship between the OEE values and the Six Big Losses is illustrated in Figure 1.
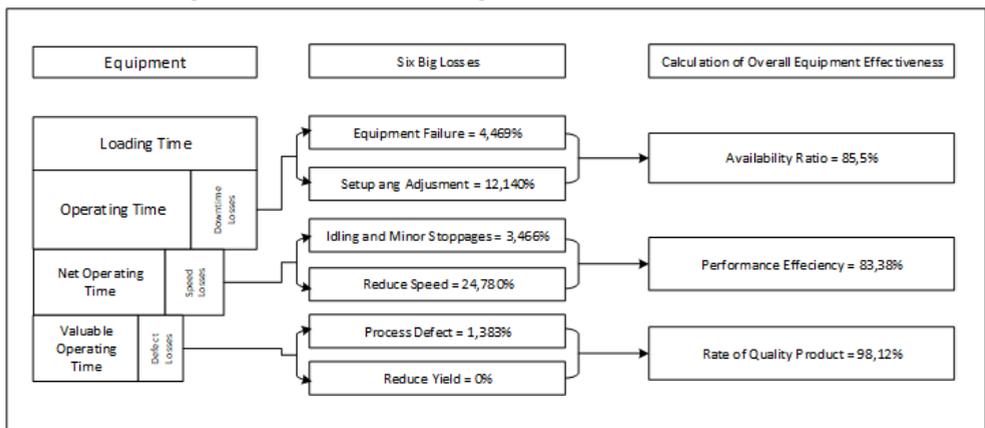

Fig 1. The Relationship Between OEE Values and Six Big Losses

3.6   Proposed Improvements

Based on the results of the Six Big Losses calculation, it is found that, in addition to issues related to reduced speed losses, the company also needs to evaluate setup and adjustment activities. The method used to propose improvements is the Single Minute Exchange of Die (SMED). The proposed improvements for setup and adjustment activities on the printing machine presented in Table 3.

Table 3. Proposed Improvements for Setup and Adjustment Activities

Num	Set-up Activity	Activity Improvement	Before		After	
			Activity Types	Time (min)	Activity Types	Time (min)
1	Preparing print-ready files and configuring color profiles	Previously, this activity was time-consuming as it was carried out during machine idle time. It is now performed on the computer while the machine continues printing jobs.	Internal	5	External	5
2	Removing the remaining paper roll, loading a new roll, and setting the paper tension	Roll replacement remains an idle-time activity but has been improved using visual guides, automatic cutting aids, and ergonomic roll positioning.	Internal	4	Internal	4

#	Activity	Improvement				
3	Cleaning the print head with cleaning fluid and ensuring no dried ink remains	Operators are provided with a nozzle cleaner kit and a streamlined cleaning SOP.	Internal	3	Internal	3
4	Adjusting the paper position on the rollers to ensure straight alignment and proper print margins	Visual alignment markers are added at the paper entry area.	Internal	2.5	Internal	2.5
5	Printing a nozzle test to ensure uniform spray and no clogging	Printing nozzle tests using automatic presets to reduce manual trial-and-error.	Internal	1	Internal	1
6	Refilling ink tanks before machine idle time.	Ink refilling is performed while the machine is printing the previous job, using automatic level indicators.	Internal	2.5	Internal	2.5
7	Adjusting the dryer temperature to match the printing speed and ink characteristics.	Using temperature presets based on paper type to avoid repeated manual adjustments.	Internal	1.5	Internal	1.5
8	Printing an initial sample to check alignment and color accuracy.	Using a standard print test template to enable direct printing without reconfiguring settings.	Internal	2	Internal	2
9	Providing spare paper rolls near the machine before the job starts.	Spare rolls are pre-staged near the machine using a staging system.	Internal	1.5	External	1.5
10	Recording process parameters (speed, temperature, ink) for reference in subsequent jobs.	Forms are automated with checklists to avoid repetitive manual entries.	Internal	1.5	External	1.5
11	Inter-shift and operator communication regarding jobs, settings, and machine conditions.	Coordination is carried out while the machine is operating or during routine shift handovers.	Internal	1	External	1
Total	Internal			25.5		16.5
	External			0		9

The results of implementing the SMED method in the printing machine setup activities show a reduction in the average setup time from 25.5 minutes to 16.5 minutes, representing a time saving of 35.29%. This improvement was achieved by converting several internal activities into external ones, such as design file preparation, ICC profile configuration, documentation of previous jobs, arrangement of backup paper rolls, and coordination among operators. Internal activities that could not be converted, including paper roll replacement, printhead cleaning, alignment calibration, and temperature setting, were improved through the use of supporting tools, visual guidelines, automatic presets, and visual-based standard operating procedures (SOPs). These changes successfully reduced waiting time, minimized operator variability, and enhanced the effectiveness of the setup process.

3.7   Simulation of Proposed Improvement Results

Based on the proposed improvements, an increase in the Overall Equipment Effectiveness (OEE) value is projected compared to the initial condition of the printing machine operation process. After the implementation of the improvements, setup and adjustment time decreased by 2,767 minutes, from 7,845 minutes to 5,078 minutes. This reduction directly increased the available time for the production process, as indicated by an increase in operation time of 2,767 minutes, from 55,677 minutes to 58,444 minutes. This occurred because operation time is directly affected by setup and adjustment time; therefore, a reduction in setup activities automatically increases operation time by the same amount. A

comparison of OEE values before and after the implementation of the proposed improvements is illustrated in Figure 2.
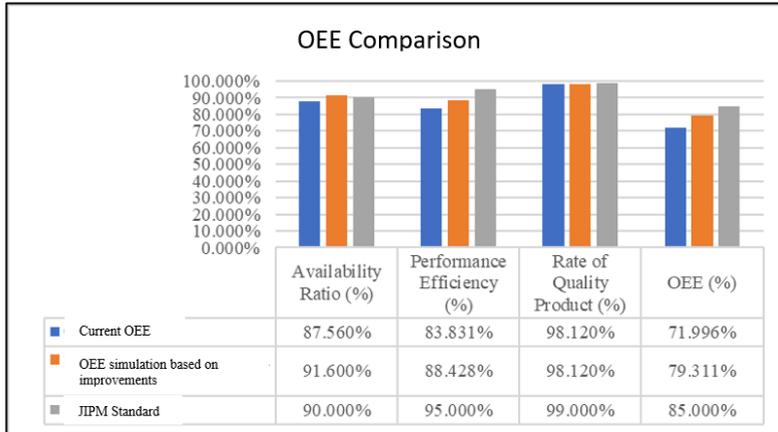

Fig 2. Comparison of OEE Values Before and After Improvement

An increase in Overall Equipment Effectiveness (OEE) has a positive impact on company productivity, including increased production capacity, a higher number of products produced per day, and a reduction in overtime hours. Ultimately, this condition contributes to an improvement in the company's margin or overall profitability.

4   Conclusion

The average OEE value of the printing machine during the period from December 2024 to March 2025 was 71.996%, which is below the international benchmark of 85%. The largest contributors to performance losses were reduced speed losses (24.780%) and setup and adjustment losses (12.140%). Following the implementation of the Single Minute Exchange of Die (SMED) method, setup time was reduced by 2,767 minutes, equivalent to a 35.29% reduction (from 7,845 to 5,078 minutes). Consequently, operating time increased from 55,677 to 58,444 minutes. This improvement led to an increase in the average OEE value by 7.315%, from 71.996% to 79.311%, demonstrating that machine effectiveness can be significantly improved through systematic setup time reduction.

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