SITEKIN: Jurnal Sains, Teknologi dan Industri, Vol. 23, No. 1, December 2025, pp.23 - 34
ISSN 2407-0939 print/ISSN 2721-2041 online

Analysis of Packaging Machine at PT. DKJ Using Overall Equipment Effectiveness and Fault Tree Analysis

Muhammad Farich Maulana[1], Mohammad Jufriyanto[2]
[1.2.3] Department of Industrial Engineering, Faculty of Engineering, Muhammadiyah University of Gresik
Jl. Sumatra No. 101, Gn. Malang, Randuagung, Kec. Kebomas, Kab. Gresik, Jawa Timur 61121
Email: farichmln@gmail.com

ABSTRACT

This study evaluates the effectiveness of a Sodium Metabisulfite (SMBS) packaging machine at PT. DKJ using Overall Equipment Effectiveness (OEE) and Fault Tree Analysis (FTA). OEE was employed to assess machine performance through availability, performance, and quality indicators, while the Six Big Losses framework was used to identify major sources of productivity loss. Furthermore, FTA was applied to determine the root causes of dominant losses affecting machine effectiveness. The study utilized production data, direct observations, interviews, and company records collected from December 2024 to May 2025. The results indicate that the average OEE value of the packaging machine was 63.26%, significantly below the international benchmark of 85%, with low availability and performance as the primary contributors. Six Big Losses analysis revealed that breakdown losses and setup and adjustment losses were the most dominant factors. FTA identified component failure, inadequate preventive maintenance, operator-related errors, and complex setup procedures as the main root causes. This study proposes structured preventive maintenance, operator training, standardized operating procedures, and improved production–material coordination to enhance machine effectiveness and ensure sustainable production performance.

Keywords: *Overall Equipment Effectiveness, Six Big Losses, Fault Tree Analysis, Packaging Machine, Production Performance.*

Introduction

The chemical industry plays a crucial role in supporting national and global economic growth, as it is a vital supplier of raw materials for a wide range of everyday products. In response to technological advancement and increased industrial demand, chemical manufacturing companies are required to maintain high production performance standards and operational stability [1]. PT. DKJ is one of Indonesia's chemical manufacturing companies that produces a wide range of formulated chemical products, including Sodium Metabisulphite (SMBS), which is widely used in the food, pharmaceutical, cosmetic, and agricultural sectors [2].

As demand for chemical products increases, PT. DKJ must optimize its production line to remain competitive. The SMBS packaging machines have shown fluctuating effectiveness, potentially affecting the company's ability to meet targets and maintain product quality. Therefore, identifying and resolving the sources of production inefficiency is essential [3].

Table 1 Production Output of SMBS Packaging Machine

Year	Month	Production Target (Kg)	Actual Production (Kg)	Result (%)
2024	Dec	375,000	247,525	66%
2025	Jan	420,000	306,103	73%
2025	Feb	390,000	253,256	65%
2025	Mar	390,000	258,175	66%
2025	Apr	345,000	249,225	72%
2025	May	405,000	319,300	79%
Average		**390,000**	**277,212**	**71%**

Table 1 shows a significant contrast between the production target and the actual production achieved by the SMBS packaging machine [4]. The data shows that, on average, the machine only reached 71% of the planned production capacity, which indicates a considerable gap from the expected performance level. This result suggests that the production process is still not operating efficiently [5]. Similarly, a study was conducted on the UH-61 machine at PT. Petronika found that production shortfalls were primarily caused by frequent downtime events in the production facilities [6]

To achieve this, the study employs the Overall Equipment Effectiveness (OEE) method as a comprehensive approach to measure machine performance. Introduced by Seiichi Nakajima, OEE evaluates three main components of equipment effectiveness: availability, performance, and quality. By analyzing these indicators, companies can determine whether the equipment is operating close to its full potential. In addition, the application of the Six Big Losses framework allows for the classification of productivity losses [7][8].

This study also applies Fault Tree Analysis to examine how potential causes of machine breakdowns affect overall performance [9][10][11]. Using its logic-based structure with AND/OR gates, FTA helps trace failure sequences that lead to major downtime. When integrated with OEE and the Six Big Losses, it provides a comprehensive assessment of the SMBS packaging machine, enabling the identification of dominant failure modes and the development of targeted improvement strategies. For example, Suliantoro et al. (2017) applied OEE and FTA to a “reng machine”, finding that its effectiveness was only about 57.55%, far below the ideal benchmark of 85%, with downtime, speed losses, and defects identified as primary contributors to low performance.[4].

Research Methods

The methods used in this study are the Overall Equipment Effectiveness (OEE) and Fault Tree Analysis (FTA) methods to calculate and evaluate the performance of the packaging machine at PT. DKJ [12], [13], [14][15], [16], [17].

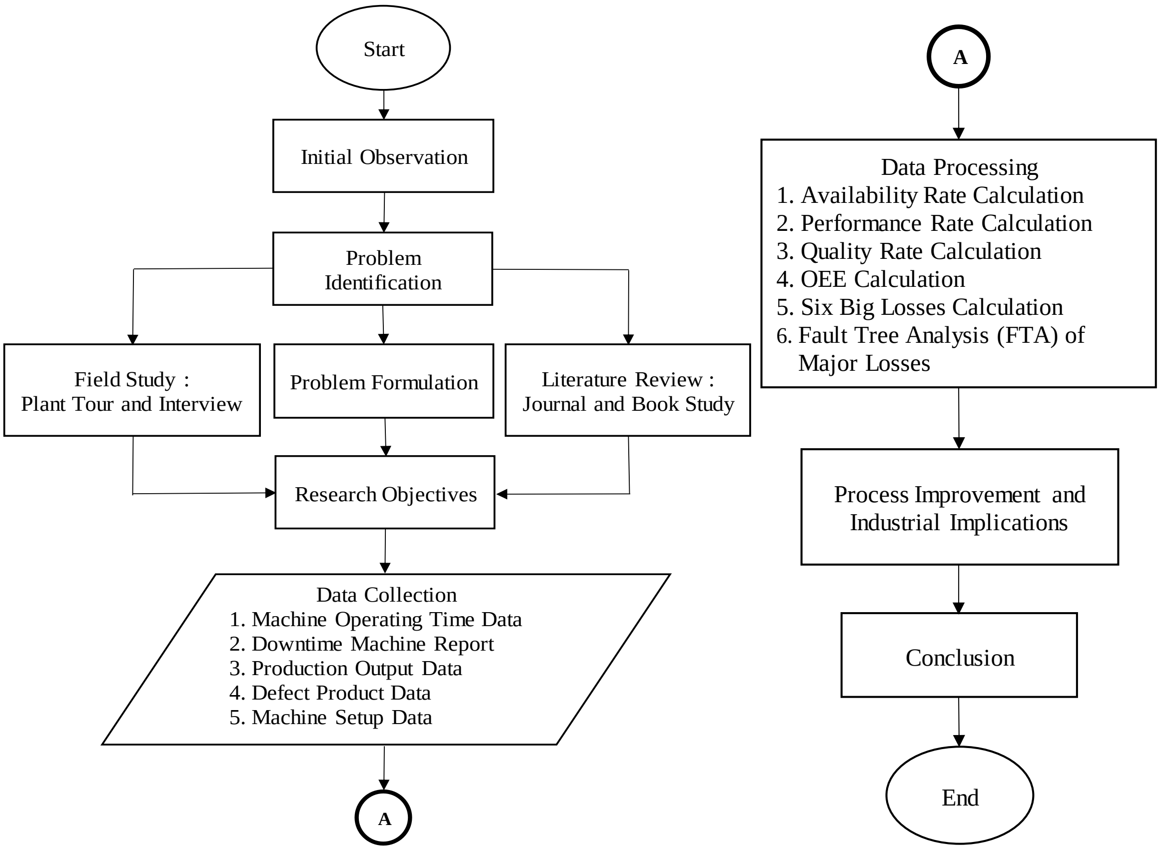


Figure 1 Research Methodology Flowchart of OEE - FTA

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a key indicator used to measure machine effectiveness through three aspects: availability, performance, and product quality [18], [19]. OEE also plays an important role in identifying the causes of production losses (Six Big Losses), making it a useful tool for formulating improvement strategies under the Total Productive Maintenance approach [20], [21], [22], [23]. The key factors influencing the OEE value consist of availability, performance, and quality, and the formula for calculating OEE is presented as follows [18], [24].

$$OEE = Availability\ x\ Performance\ x\ Quality \quad (1)$$

Table 2 OEE Calculation Value

No	Description	Value
1	Availability	>90%
2	Performance	>95%
3	Quality	>99%
4	OEE	>85%

1. Availability
   Availability is a measurement of how effectively a machine can produce product items according to the predetermined schedule [19][20], [21], [22], [23].
   $$Availability\ Rate = \frac{Operating\ Time}{Loading\ \ Time} x100\% \quad (2)$$
   Operating time is the result of planned production time minus downtime. Loading time is the result of planned production time minus planned downtime.
   $$Operating\ Time = Planned\ Production\ Time - Downtime \quad (3)$$
   $$Loading\ Time = Planned\ Production\ Time - Planned\ Downtime \quad (4)$$
2. Performance
   The performance rate indicates how closely the machine's actual production speed matches its designed maximum capacity. [9].
   $$Performance\ Rate = \frac{Output\ Product\ x\ Ideal\ Cycle\ Time}{Operating\ Time} x100\% \quad (5)$$
3. Quality
   The Quality Rate metric represents the proportion of products that pass quality standards relative to total production output. [10].
   $$Quality\ Rate = \frac{Output\ Product\ x\ Defect\ Product}{Total\ Amount} x100\% \quad (6)$$

Six Big Losses

Six Big Losses are six main sources of inefficiency in manufacturing, consisting of breakdowns, setup and adjustment, idling and minor stoppages, reduced speed, startup losses, and defects, all of which significantly reduce Overall Equipment Effectiveness [18], [24].

a. Breakdown Losses
   Losses arising from equipment failure happen when machinery malfunctions or gets damaged, forcing production to halt. [12].
   $$\boldsymbol{Breakdown\ Losses = \frac{Unplanned\ Downtime}{Loading\ Time} x100}\% \quad (7)$$
b. Setup and Adjustment Losses
   Setup and adjustment losses happen when production is delayed due to changes in tooling, equipment, or product setup, requiring system adjustments. [13].
   $$\boldsymbol{Setup\ and\ Adjusment\ Losses = \frac{Setup\ Time}{Loading\ Time} x100}\% \quad (8)$$
c. Idle and Minor Stoppages
   Losses arise when a machine operates slower than its designed speed or experiences stoppages that do not completely shut it down, but reduce its throughput. [14].
   $$\boldsymbol{Idle\ and\ Minor\ Stoppages = \frac{Non\ Productive\ Time}{Loading\ Time} x100}\% \quad (9)$$
d. Reduces Speed Losses
   Idling and minor stoppages are losses that occur when a machine runs without a load or experiences repeated short interruptions, preventing it from operating at a stable speed. This situation is often caused

by delays in material supply or the absence of operators, even though work-in-progress (WIP) is available. [15].

$$\textbf{Reduce Speed Losses} = \frac{\textbf{Operating Time} - \textbf{Actual Operating Time}}{\textbf{Loading Time}} \textbf{x100\%} \quad (10)$$

e. Product Defect Losses
Product defect losses happen when the machine produces items that do not meet the predetermined quality criteria, resulting in scrap or rework of those flawed products. [20], [21], [25].

$$\textbf{Product Defect Losses} = \frac{\textbf{Ideal Cycle Time x Defect Product}}{\textbf{Loading Time}} \textbf{x100\%} \quad (11)$$

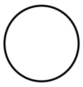
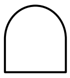
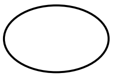
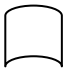
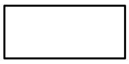
f. Reduce Yield losses
Reduced yield refers to losses that occur at the beginning of production, when the process has not yet reached a stable operating condition, and continue until the system achieves steady-state performance [22], [23], [26].

$$\textbf{Reduce Yield Losses} = \frac{\textbf{Ideal Cycle Time x Initial Setup Defect}}{\textbf{Loading Time}} \textbf{x100\%} \quad (12)$$

Fault Tree Analysis

Fault Tree Analysis (FTA) is a deductive method used to trace system failures by starting from a top event and breaking it down to basic failure events [7], [27]. It is applied to identify causal factors of product defects, often combining qualitative and quantitative assessments to pinpoint root causes [11], [28], [29]. Industrial safety and quality studies across Indonesian journals report that FTA supports management decisions by highlighting minimal cut sets and the most influential basic events [30], [31], [32].

Table 3 Fault Tree Analysis Symbol

Symbol	Meaning	Symbol	Meaning
	Basic Event: A simple fault initiation that doesn't need optimization.		AND Gate: Manual error due to all problem inputs.
	Event Conditioning: Indicate circumstances that different logic gates can be subject to		OR Gate: An error occurs due to one of the problem inputs
	Top Event: The main system failure or undesired event that is the focus of the fault tree analysis.		Intermediate Event: A fault that results from combinations of lower-level events and leads toward the top event.

Results and Discussion

Data Collection

Data collection was conducted at PT. DKJ from December 2024 to May 2025 and again in July 2025 through direct observation, interviews, and documentation review. The participants included production operators, production foremen, and production supervisors, providing insights from different operational levels to ensure a comprehensive understanding of the production process.

Table 4 Data Collection During December 2024 – May 2025

Year	Month	Days	Total Sift	Working Hours	Unplanned Downtime	Planned Downtime (Hours)	Downtime (Hours)	Ideal Cycle Time (Hours)	Operating Time (Hours)	Output Produksi (Kg)	Defect Product (Kg)
2024	Dec	25	3	8	73.41	95.83	169.24	0.001212	430.76	247,525	71.31
2025	Jan	28	3	8	96.78	107.33	204.11	0.001212	467.89	306,103	71.76
2025	Feb	26	3	8	144.62	99.67	244.29	0.001212	379.71	253,256	61.74
2025	Mar	26	3	8	144.43	99.67	244.10	0.001212	379.90	258,175	52.98
2025	Apr	23	3	8	135.43	88.17	223.60	0.001212	328.40	249,225	59.70
2025	May	27	3	8	58.04	103.5	161.54	0.001212	486.46	319,300	58.92

Table 4 presents the data collected during the observation period at PT. DKJ from December 2024 to May 2025, which serves as the primary basis for evaluating the performance conditions of the SMBS packaging machine.

Data Processing

The processing activities on the SMBS packaging machine will be evaluated by calculating Availability, Performance, Quality, Overall Equipment Effectiveness (OEE), and Six Big Losses. Furthermore, a Fault Tree Analysis (FTA) will be employed to identify the primary causal factors.

OEE Calculation Of SMBS Packaging Machine

The steps in calculating OEE on the SMBS packaging machine are as follows:

A. Availability rate calculation
   December calculation example:
   Loading time = 600 – 95,83 = 504,17
   Operating Time = 600 – 169,24 = 430,76

$$\text{Availability} = \frac{430{,}76}{504{,}17} x100\% = 85{,}44\%$$

The result of the availability rate will be shown in Table 5 below.

Table 5 Result of Availability Rate

Availability Rate				
Year	**Month**	**Loading Time (Hours)**	**Operation Time (Hours)**	**Rate (%)**
2024	Dec	504.17	430.76	85.44%
2025	Jan	564.67	467.89	82.86%
2025	Feb	524.33	379.71	72.42%
2025	Mar	524.33	379.90	72.45%
2025	Apr	463.83	328.40	70.80%
2025	May	544.50	486.46	89.34%
Average				**78.89%**

Table 5 above shows the calculation result that the average availability rate is 78,89%, indicating that the machine operates below the commonly recommended benchmark for the international standard of 90%.

B. Performance rate calculation
   December calculation example:

$$\text{Performance} = \frac{247.525\ x\ 0{,}001212}{430{,}76} x100\% = 69{,}65\%$$

The result of the performance rate will be shown in Table 6 below.

Table 6 Result Of Performance Rate

Performance Rate					
Year	**Month**	**Output Produksi (kg)**	**Ideal cycle time(Hours)**	**Operating Time (Hours)**	**Rate (%)**
2024	Dec	247,525	0.001212	430.76	69.65%
2025	Jan	306,103	0.001212	467.89	79.30%
2025	Feb	253,256	0.001212	379.71	80.85%
2025	Mar	258,175	0.001212	379.90	82.37%
2025	Apr	249,225	0.001212	328.40	91.99%
2025	May	319,300	0.001212	486.46	79.56%
Average					**80.62%**

Based on Table 6 above shows the calculation result that the average performance rate is 80.62%, indicating that the machine operates below the commonly recommended benchmark for the international standard of 95%.

C. Quality rate calculation
December calculation example :

$$\text{Quality} = \frac{247.525\ x\ 71{,}31}{247.525} x100\% \ = 99{,}971\%$$

The result of the quality rate will be shown in table 7 below.

Table 7 Result of Quality Rate

Quality Rate				
Year	**Month**	**Output Product (Kg)**	**Total Lost Unit(Kg)**	**Rate (%)**
2024	Dec	247,525	71.31	99.971%
2025	Jan	306,103	71.76	99.977%
2025	Feb	253,256	61.74	99.976%
2025	Mar	258,175	52.98	99.979%
2025	Apr	249,225	59.70	99.976%
2025	May	319,300	58.92	99.982%
		Average		**99.977%**

Based on Table 7 above, the average quality rate is 99.977%, indicating that the machine operates above the commonly recommended benchmark for the international standard of 99%.

D. Overall Equipment Effectiveness calculation
December calculation example:
OEE = $85{,}44\ x\ 69{,}65\ x\ 99{,}971$ = 59,493%

The result of the overall equipment effectiveness rate will be shown in Table 8.

Table 8 Result of Overall Equipment Effectiveness

Year	Month	Availability	Performance	Quality	OEE
2024	Dec	85.44%	69.65%	99.971%	59.493%
2025	Jan	82.86%	79.30%	99.977%	65.693%
2025	Feb	72.42%	80.85%	99.976%	58.532%
2025	Mar	72.45%	82.37%	99.979%	59.671%
2025	Apr	70.80%	91.99%	99.976%	65.114%
2025	May	89.34%	79.56%	99.982%	71.067%
Average		**78.89%**	**80.62%**	**99.977%**	**63.262%**

A prior study on the Burner Oil (UH-61) machine at a chemical manufacturing company reported an average OEE of 69.03%, mainly due to low availability rates. [21]. This figure, like the 63.262% OEE of the SMBS packaging machine in this study, is below the 85% benchmark for the international standard, highlighting that equipment performance in the chemical industry still needs improvement, especially in maintaining machine availability and reliability [24], [33], [34].

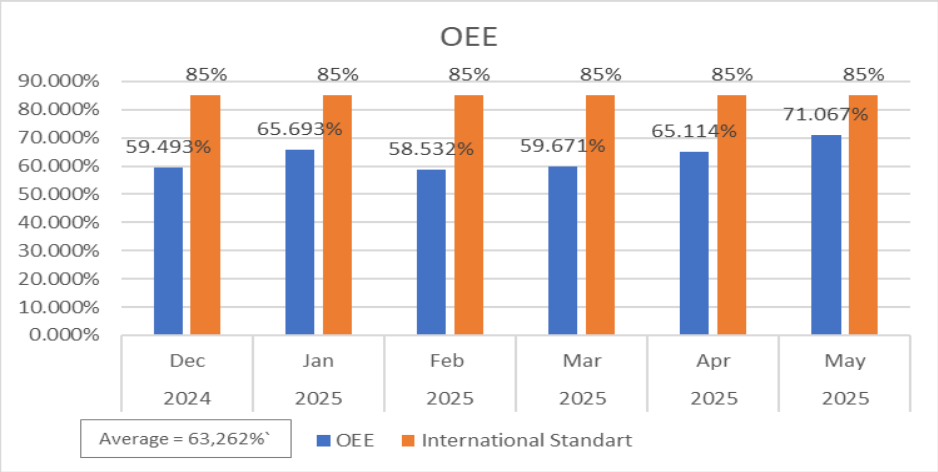


Figure 2 Bar Diagram of Overall Equipment Effectiveness

Figure 2 illustrates the bar diagram of Overall Equipment Effectiveness (OEE) compared with the international standard benchmark. The chart shows noticeable fluctuations in OEE values each month, with the highest value recorded in May 2025 and the lowest in March 2025. Meaning that the produced output consistently meets the required international standard [20], [21], [25], [35].

Six Big Losses

After evaluating the SMBS packaging machine's OEE results against the ideal standard, it is clear that the company needs to take corrective actions to boost the machine's efficiency. Therefore, it is necessary to calculate the six main losses based on the data shown in the following table below.

Table 9 Result of Six Big Losses

Year	Month	Breakdown Losses (%)	Setup and Adjusment (%)	Idle and Minor Stoppages (%)	Reduce Speed Losses (%)	Process Defect Losses (%)	Reduce Yield Losses (%)
2024	Dec	14.56%	16.40%	8.13%	25.93%	0.017%	0.004%
2025	Jan	17.14%	17.07%	7.59%	17.15%	0.015%	0.003%
2025	Feb	27.58%	15.02%	6.26%	13.87%	0.014%	0.003%
2025	Mar	27.55%	13.64%	6.16%	12.77%	0.012%	0.003%
2025	Apr	29.20%	14.71%	6.11%	5.67%	0.016%	0.004%
2025	May	10.66%	17.63%	7.84%	18.26%	0.013%	0.003%
Average		**21.11%**	**15.75%**	**7.01%**	**15.61%**	**0.015%**	**0.003%**

Table 9 shows that breakdown losses and setup and adjustment losses have the highest values compared to the other four types of losses. These two factors are the main contributors to reduced machine performance and production efficiency, while reduced speed losses, idle and minor stoppages, process defect losses, and reduced yield losses have relatively smaller impacts on the total production time losses.

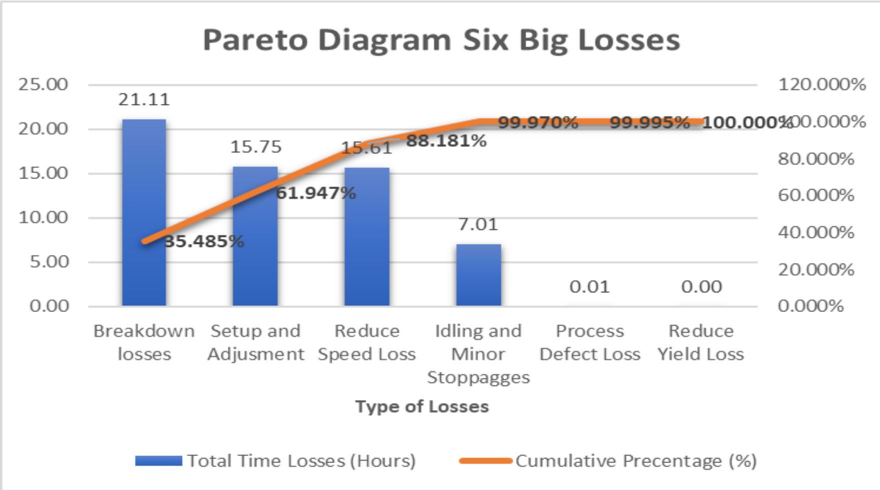


Figure 3 Pareto Diagram Six Big Losses

Figure 3 above reveals that breakdown losses, setup and adjustment are the most dominant contributors to the six big losses. These factors lead to the low OEE value on each machine. Therefore, the next stage is to perform a Fault Tree Analysis so that the root causes of these dominant losses can be systematically identified and prioritized, enabling the company to develop targeted corrective actions and improve OEE performance.

Fault Tree Analysis

The next step involves using standard logic symbols to create a fault tree diagram that illustrates the root causes of the defect issues. The figure below presents the fault tree analysis of breakdown losses on the SMBS packaging machine:

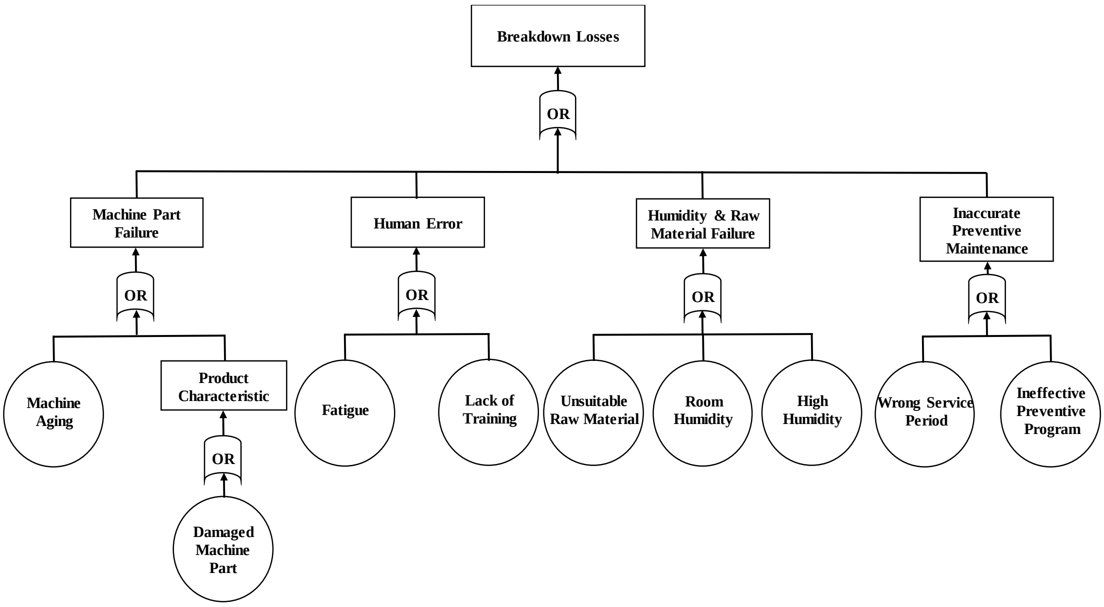


Figure 4 Fault Tree Analysis Of Breakdown Losses

The fault tree logic for breakdown losses identifies four main contributing factors. Machine part failure, human error, humidity and raw material failure, and inaccurate preventive maintenance. Machine part failure is usually caused by component aging or product-related defects, while human error results from fatigue or insufficient operator training. Humidity and raw material issues come from unsuitable materials or excessive room humidity, and inaccurate maintenance results from improper service intervals or ineffective preventive programs. These causes are connected through OR gates, indicating that any single factor can trigger breakdown losses.

The figure below presents the fault tree analysis of setup and adjustment on the SMBS packaging machine:

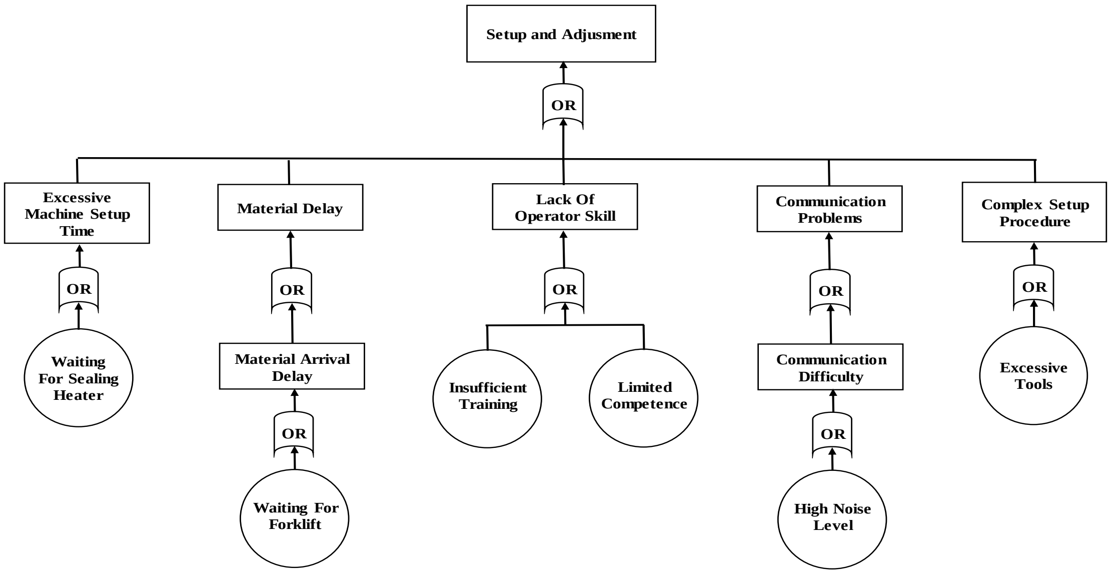


Figure 5 Fault Tree Analysis Of Setup and Adjustment

The fault tree logic for setup and adjustment losses identifies five main causes. Excessive machine setup time, material delays, lack of operator skill, communication issues, and complex setup procedures. Excessive setup time often happens because of waiting for sealing heaters, while material delays are caused by late material arrivals or forklift unavailability. Operator skill problems result from inadequate training or limited competence. Communication issues are usually due to coordination difficulties or high noise levels in the work area. Lastly, complex setup procedures are associated with using too many or unnecessary tools. These factors are connected through OR gates, meaning that the occurrence of any of them can lead to setup and adjustment losses.

Proposed Improvement

Considering that the current OEE performance remains below the internationally accepted benchmark of 85% and taking into account the Six Big Losses analysis, which highlights two dominant sources of loss, along with the results of the two FTA diagrams, several targeted improvement strategies can be proposed for PT. DKJ to address the identified root causes [36][23], [26], [37], [38]. To reduce breakdown losses, a structured preventive maintenance program is necessary, including regular inspections, timely replacement of worn machine parts, and managing environmental factors such as humidity that may affect raw material quality. Additionally, systematic operator training combined with the development of clear, standardized maintenance procedures is vital to decrease human error and ensure consistent preventive maintenance implementation. Simultaneously, to cut setup and adjustment losses, comprehensive operator training and standardized operating procedures should be developed to optimize complex setup activities. Addressing communication gaps can be achieved through standardized handover checklists or digital scheduling systems. Enhancing coordination between production planning and material supply is also essential to prevent material delivery delays and reduce excessive setup times. Implementing these focused measures is expected to improve OEE performance more effectively than broad, non-specific corrective actions [39], [40] [41], [42].

Industrial Implications

This study emphasizes the practical advantages of using OEE and FTA together as tools for continuous improvement in manufacturing. By applying the suggested strategies, PT. DKJ can improve machine reliability, reduce production losses, and increase equipment utilization. Additionally, the findings can serve as a reference for other industries looking to enhance operational efficiency through data-driven maintenance planning and systematic loss analysis.

Conclusion

Based on calculations for the period from December 2024 to May 2025, the average Overall Equipment Effectiveness (OEE) of the SMBS packaging machine was 63.262%, which falls below the international benchmark standard of 85%. The OEE components included 78.89% availability, 80.62% performance rate, and 99.977% quality rate, indicating that performance and availability were the main factors contributing to reduced effectiveness. The analysis of the six big losses identified breakdowns at 21.11% and setup and adjustment losses at 15.75% as the primary causes of OEE decline. The Fault Tree Analysis confirmed that these two loss categories were the most critical factors affecting machine performance. Improvements should involve implementing a comprehensive preventive maintenance program, standardizing maintenance procedures, providing systematic operator training, and maintaining effective environmental controls. Additionally, strengthening operator skills, enforcing clear standard operating procedures, and improving coordination between production planning and material supply are essential to reducing setup and adjustment losses. Future research should expand the analysis by incorporating data-driven predictive maintenance models and real-time condition monitoring systems, along with applying cost-benefit analysis and reliability-centered maintenance approaches to create a sustainable framework for ongoing equipment performance improvements.

Acknowledge

The author would first like to express deepest gratitude to the parents and family for their endless prayers, support, and motivation, which made it possible to complete this research successfully. Sincere thanks are also extended to PT. DKJ for the valuable information and support provided during the interview and observation activities, which greatly contributed to this research. Furthermore, the author conveys appreciation to the academic supervisors for their guidance, direction, and constructive feedback throughout the research process. The author also wishes to extend heartfelt gratitude to a beloved partner for the unwavering encouragement, patience, and understanding that have been a constant source of strength during this journey. In addition, the author would like to express sincere appreciation to all colleagues who have provided valuable support and assistance throughout the completion of this research. Furthermore, the author wishes to express personal gratitude for the perseverance, dedication, and commitment demonstrated throughout this process. Appreciation is also extended for the ongoing self-motivation, resilience in facing challenges, and consistency in maintaining integrity and effort to achieve the objectives of this study.

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