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Analysis of Overall Equipment Effectiveness and Six Big Losses for Performance Improvement

Case Study of the Versant 3100i Printing Machine at CV XYZ

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Abstract. This study examines machine performance inefficiencies in a digital printing production system by applying the Overall Equipment Effectiveness (OEE) method to the Versant 3100i digital printing machine at CV XYZ. The objective of this research is to evaluate machine effectiveness, identify dominant sources of production losses, and analyze their root causes to support operational performance improvement. An integrated analytical approach is employed by combining OEE measurement, Six Big Losses analysis, and Fishbone Diagram techniques to systematically diagnose machine performance issues. The results show that the average OEE value of the Versant 3100i machine is 82.92%, which remains below the international benchmark of 85%, indicating that machine performance has not yet reached an optimal level. Analysis of the Six Big Losses reveals that Reduced Speed is the most significant contributor to performance loss, accounting for 36.24% of total losses. Further analysis using a Fishbone Diagram indicates that Reduced Speed is mainly caused by human-related factors and the absence of standardized Standard Operating Procedures (SOPs). Based on these findings, targeted improvement strategies are proposed, including structured operator training, the implementation of standardized operating procedures, and the strengthening of quality control mechanisms. This study demonstrates that the integrated use of OEE, Six Big Losses, and Fishbone Diagram analysis is effective in identifying priority improvement areas and formulating practical improvement strategies. The proposed approach can be applied by manufacturing companies to enhance machine effectiveness and operational efficiency, particularly in digital printing production environments.

Keywords: fishbone diagram; overall equipment effectiveness; six big losses; total productive maintenance; machine performance

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1. Introduction

The production process in the manufacturing industry often faces challenges in maintaining machine efficiency, quality, and availability in a consistent manner. Inefficient machine utilization can lead to increased production downtime, reduced operating speed, and a higher rate of defective products. In line with this condition, Ramadhani et al. (2022) stated that product success is influenced by the interaction between human resources, raw materials, and machine performance. Therefore, a measurable and systematic machine performance evaluation framework is required to identify potential losses and formulate effective improvement strategies.

One widely adopted approach to maintaining equipment reliability and preventing breakdowns and production delays is Total Productive Maintenance (TPM) (Mahardika & Noubnome, 2024). The effectiveness of TPM implementation is commonly measured using Overall Equipment Effectiveness (OEE), which evaluates machine performance based on three key indicators: availability, performance, and quality (Mario et al., 2024). In practice, OEE is often combined with Six Big Losses analysis to classify six major sources of inefficiency in production systems, including downtime losses, speed losses, and quality defects (Indriawanti & Bernik, 2020). Identifying dominant losses enables organizations to develop more focused and data-driven improvement initiatives. Furthermore, root cause analysis of critical losses can be systematically conducted using a Fishbone Diagram, which categorizes causal factors into human, machine, method, material, and environmental aspects (Budianto, 2021).

CV XYZ operates in the digital printing industry and produces A3+ printed products through three main stages: prepress, press, and finishing. Among these stages, the press process represents the most critical operation, as it directly determines production output and quality. The primary machine used in this stage is the Versant 3100i digital printing machine, which operates at high intensity on a daily basis. Preliminary problem identification was carried out through direct field observations and structured discussions with the production team. Feedback from senior operators consistently indicated recurring issues related to reduced operating speed and extended setup times, particularly during short-run production orders. Although these observations were qualitative in nature, their consistency necessitated a comprehensive quantitative analysis to determine their impact on overall productivity.

Operational data collected from January to March 2025 revealed a concerning decline in the productivity of the Versant 3100i machine. Capacity utilization decreased from 13.11% in January to 9.37% in March. Further analysis indicated that this decline was not primarily caused by major machine breakdowns. The Availability Rate remained relatively stable at 96.19%; however, the overall OEE value declined significantly from 89.85% to 77.23%, largely due to a substantial decrease in the Performance Rate. This decline was accompanied by high levels of waste, averaging approximately 2,200 units per month. Such conditions illustrate a critical challenge in modern manufacturing systems, where high machine availability does not necessarily correspond to optimal production speed or efficiency.

Several previous studies have highlighted the significance of speed-related losses in manufacturing performance. Amelia et al. (2024), in a study of the packaging industry, found that Reduced Speed Losses were the dominant contributor to efficiency loss, accounting for 49.1% and surpassing losses caused by physical machine breakdowns. Similar findings were reported by Wardani et al. (2021), who identified Reduced Speed as contributing 51.92% of total effectiveness losses, underscoring that operational speed stability is often more critical than machine uptime alone. In addition, Pratitis & Maryanty (2024) demonstrated that the gradual implementation of TPM, particularly through the Autonomous Maintenance pillar, can enhance machine reliability by up to 98%. While Indriawanti & Bernik (2020) successfully applied the OEE framework to evaluate the performance of an SM 102 offset printing machine, research focusing on the effectiveness of digital printing equipment remains limited.

The novelty of this study lies in the application of the OEE framework and Six Big Losses analysis specifically to the Versant 3100i digital printing machine. Unlike offset printing machines, which are predominantly constrained by mechanical factors and setup activities such as plate installation, digital printing machines operate under different performance dynamics influenced by electronic systems, automatic color calibration, and data processing mechanisms such as ripping. Existing studies have not sufficiently addressed losses unique to digital printing environments, including micro-stoppages caused by automated sensors and inefficiencies in handling short-run production orders. Consequently, this research seeks to bridge this gap by empirically examining how conventional efficiency measurement tools must be adapted to identify bottlenecks within contemporary digital printing technologies.

Accordingly, this study aims to evaluate the effectiveness of the Versant 3100i digital printing machine at CV XYZ using the Overall Equipment Effectiveness (OEE) framework, identify the most significant production losses based on the Six Big Losses method, and systematically analyze the root causes of these losses using a Fishbone Diagram in order to formulate practical and actionable improvement strategies.

2. Methods

2.1 Place, Time, and Scope of Research

This study was conducted at CV XYZ, a digital printing company located in Jakarta, Indonesia. The study specifically focuses on evaluating the operational performance of the Versant 3100i digital printing machine during its primary operational shift. The observation and data collection period spanned from January 1, 2025, to March 31, 2025, covering three full production months to account for potential monthly variations in order volume and machine utilization. This multi-month approach aligns with best practices in manufacturing performance analysis to ensure the robustness of the findings (Dwijayanto & Irjayanti, 2026).

2.2 Data Collection Techniques

Data for this study were collected using a triangulation approach involving three primary methods to ensure data comprehensiveness and validity, as commonly adopted in operational and industrial engineering studies. The primary quantitative data used for Overall Equipment Effectiveness (OEE) and Six Big Losses calculations were obtained from the company's official monthly production reports for the Versant 3100i printing machine covering January, February, and March 2025. These reports provided the core variables required for the calculations, including loading time, operating time, total output, and defect counts (Farquhar et al., 2020).

a) Direct Observation

Non-participant observations were conducted over 15 working days, evenly distributed across the three-month period (five days per month). Observations focused on the press stage and involved recording machine operating time, setup and changeover activities, minor stoppages, speed fluctuations, and occurrences of defective output. This observational method enabled real-time identification of operational inefficiencies that are often not fully documented in formal production reports.

b) Structured Interviews

Semi-structured interviews were conducted with five key informants: two printing machine operators, one maintenance technician, the production supervisor, and the quality control head. Each interview lasted approximately 45–60 minutes and followed a predefined interview protocol designed to gather insights into operational challenges, maintenance practices, perceived causes of downtime and speed reductions, and quality control procedures. Interview data were recorded and transcribed to support qualitative analysis.

c) Document Analysis

Historical quantitative data were extracted from the company's monthly production reports for January, February, and March 2025. These reports provided structured data on loading time, operating time, total processed output, defective product quantities (waste), and planned downtime. The use of archival production data ensured objectivity and facilitated longitudinal analysis (Wiyatno et al., 2024).

d) Data Validation

To ensure data reliability, information obtained from interviews and observations was cross-verified against the logged data in the production reports. Any significant discrepancies were clarified through discussions with the production supervisor and machine operators until a consensus was reached. This iterative validation process enhanced the credibility of the data used for subsequent quantitative analysis.

e) Research Variables

Based on the research framework and data collected, the variables in this study are defined as follows:

Dependent Variables:

Dependent variables are variables whose values are influenced by other variables (Harahap et al., 2021). In this study, these include the Overall Equipment Effectiveness (OEE) value, Availability Rate, Performance Rate, Quality Rate, and the magnitude of losses categorized under the Six Big Losses framework.

Independent Variables:

Independent variables are variables that influence dependent variables (Harahap et al., 2021). In this study, these consist of operational parameters that directly affect machine effectiveness, namely breakdown time, setup and adjustment time, actual production speed, ideal cycle time, number of defective products, and total production output. These parameters are used to identify the sources of inefficiencies that impact machine performance. The overall research flow is illustrated in Figure 1.

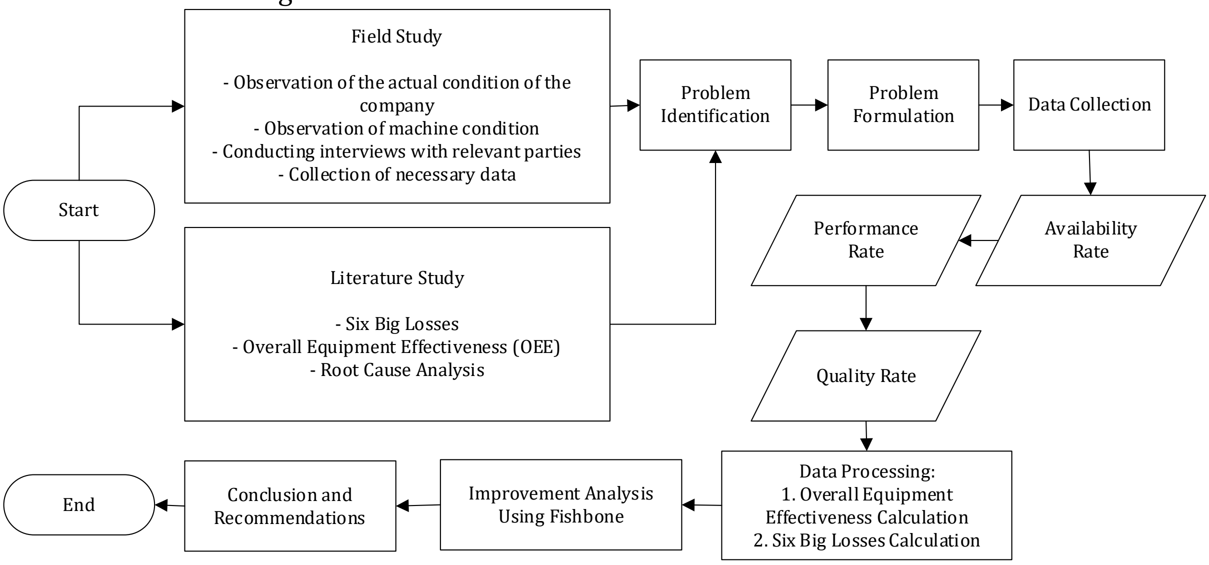

Figure 1. Research Flow Diagram

Data collection in this study was carried out using three methods: direct observation, interviews, and literature studies. Direct observation involved monitoring the production process and working conditions in the operational area. In-depth interviews were conducted with relevant stakeholders, including production, maintenance, quality control, and Total Productive Maintenance (TPM) personnel, to obtain technical and operational insights. In addition, a literature study was conducted to review internal company documents and external references related to production processes and TPM implementation.

2.3 Calculation of Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a metric used in the implementation of Total Productive Maintenance (TPM) to maintain equipment in optimal condition (Ramadhani et al., 2022). The OEE value is used to measure how effectively a machine performs (Dewanti & Putra, 2019). The calculation of OEE requires determining three components: Availability Rate, Performance Rate, and Quality Rate.

2.3.1 Availability Rate

Availability Rate represents the proportion of available time used for machine operation. Availability is influenced by equipment failure and setup and adjustment losses. The Availability Rate is calculated using the following formula:

$$\text{Availability Ratio} = \frac{Operation\ Time}{Loading\ Time} \times 100\% \quad (1)$$

2.3.2 Performance Rate

Performance Rate reflects the ability of equipment to operate at its designed production speed. This metric requires data on operating time, ideal cycle time, and processed output. The Performance Rate is calculated as follows:

$$\text{Performance Ratio} = \frac{processed\ amount \times ideal\ cycle\ time}{operation\ time} \times 100\% \quad (2)$$

2.3.3 Quality Rate

Quality Rate represents the ability of equipment to produce products that meet quality standards. The Quality Rate is calculated using the following formula:

$$\text{Quality Ratio} = \frac{processed\ amount - defect\ amount}{processed\ amount} \times 100\% \quad (3)$$

After calculating the Availability Rate, Performance Rate, and Quality Rate, the Overall Equipment Effectiveness (OEE) value is determined using the following equation:

$$\text{OEE} = Availability\ x\ Performance\ x\ Quality \quad (4)$$

2.4 Calculation of Six Big Losses

The Six Big Losses calculation is used to identify the causes of OEE values that fall below standard targets. Six Big Losses represent six categories of losses that can reduce machine effectiveness and are grouped into three main types: downtime losses, speed losses, and defect losses (Dewanti & Putra, 2019). This calculation was conducted to identify the loss factors that most significantly reduced the productivity of the Versant 3100i printing machine.

The six categories of losses include failure losses, setup and adjustment losses, idle and minor stoppage losses, reduced speed losses, process defect losses, and yield losses. The formulas used to calculate each loss are as follows:

Failure Losses *(EF)* calculation formula:

$$\text{EF} = \frac{Breakdown\ Time}{Operating\ Time}\ x\ 100\% \quad (5)$$

Setup and Adjustment Losses (SL) Calculation formula:

$$\text{SL} = \frac{Total\ Setup}{Loading\ Time}\ x\ 100\% \quad (6)$$

Idle and Minor Stoppage Losses (IL) Calculation formula:

$$\text{IL} = \frac{Breakdown\ Time + Setup + Planned\ Downtime)}{Loading\ Time}\ x\ 100\% \quad (7)$$

Reduce Speed (RSL) Calculation formula:

$$\text{RSL} = \frac{Operation\ Time - (ICTxProcessed\ Amount)}{Loading\ Time}\ x\ 100\% \quad (8)$$

$$\text{RSL} = 100\% - Performance\ Rate \quad (9)$$

Process Defect Losses (PD) Calculation formula:

$$\text{PD} = \frac{ICT\ x\ Rework}{Loading\ Time}\ x\ 100\% \quad (10)$$

Yield Losses (YL) Calculation formula:

$$\text{YL} = \frac{ICT\ x\ Reject}{Loading\ Time}\ x\ 100\% \quad (11)$$

2.5 Improvement Analysis Using Fishbone Diagram

The Fishbone Diagram is an effective visual tool for identifying and analyzing factors that influence quality characteristics in a work process (Adha et al., 2019). This cause-and-effect diagram is commonly referred to as the Fishbone or Ishikawa Diagram, as it was first introduced by Prof. Kaoru Ishikawa of the University of Tokyo in 1953 (Dewanti & Putra, 2019). The Fishbone Diagram facilitates comprehensive problem analysis by enabling stakeholders to contribute insights from multiple perspectives (Fajaranie & Khairi, 2022).

Improvement analysis in this study was conducted using the Fishbone Diagram to identify the root causes of the most significant losses affecting the OEE value. This method categorizes causal factors into major dimensions, including human factors, machines, methods, materials, and measurements. Through this systematic approach, dominant causes of inefficiencies were identified and analyzed. The results of the Fishbone Diagram analysis served as the basis for formulating targeted improvement strategies from operational, technical, and managerial perspectives.

3. Results and Discussion

This chapter presents the results of the analysis of the effectiveness of the Versant 3100i digital printing machine based on the Overall Equipment Effectiveness (OEE) approach. The analysis is carried out through three main components, namely *availability rate*, *performance rate*, and *quality rate*, each of which represents aspects of availability, speed, and quality in the production process. The results of this calculation are the basis for identifying dominant losses and formulating strategies to improve engine performance in a measurable manner.

3.1 Calculation of Availability Rate Value

The *Availability Rate* value reflects the proportion of time the machine operates effectively compared to the available uptime, and is an important indicator for evaluating the extent to which maintenance factors and technical faults affect the effectiveness of the machine. The data used includes scheduled working time, *breakdown* time, and actual running *time*. Table 1 shows the results of the Availability Rate calculation.

Table 1. *Availability Rate Calculation*

	LOADING TIME	OPERATION TIME	AVAILABILITY
JAN	283375,30	272575,30	96,19%
FEB	283389,80	272575,30	96,19%
MAR	283415,90	272575,30	96,19%

The Availability rate is determined by calculating the ratio of Operation Time to Loading Time, with both metrics measured in minutes. Loading Time refers to the total duration available for production. It is calculated by aggregating the actual working time, planned downtime, and breakdown durations over a one-month period. Conversely, Operation Time represents the productive period, derived by subtracting planned production stops and downtime losses from the Loading Time. The data used for these calculations were extracted from daily machine logs and maintenance records. For instance, in January, the recorded Loading Time was 283,375.30 minutes and the Operation Time was 272,575.30 minutes. Consequently, the Availability calculation yields a value of 96.19%, as shown below:

$$January = \frac{272575.30}{283375.30} x100\% \; = \; 96.19\%$$

3.2 Performance Rate Calculation

The Performance Rate reflects the machine's operating efficiency relative to its ideal capacity. This value is determined using three key variables: Process Amount, Operation Time, and Standard Speed. Process Amount represents the total output, calculated by aggregating the total quantity of good products and waste generated during the production run. Operation Time refers to the actual duration the machine was running, as recorded in the daily production logs. Regarding the Standard Speed, a value of 52 ppm (pages per minute) was used as the ideal cycle time for this calculation. Although the Versant 3100i is capable of higher speeds for plain paper, this specific rate was selected based on manufacturer specifications for the heavyweight media (e.g., Art Carton/Coated Paper) and high-resolution settings used in actual production. This adjustment ensures the performance metric accounts for the necessary speed reduction required to maintain print quality on thicker substrates. The following are the results of the performance rate calculation shown by Table 2.

Table 2. *Performance Rate Calculation*

	PROCESS AMOUNT	OPRATION TIME	STANDARD SPEED	PERFORMANCE RATE
JAN	134.982	272575,30	52	95,23%
FEB	122.964	272575,30	52	86,75%
MAR	115.929	272615,90	52	81,78%

*Process*es ammount is obtained by adding the total product and the total waste output, while the standard speed is the standard speed of the Versant 3100i machine according to manufacturer data. For example, the calculation for January is as follows:

$$January = \frac{134,982}{272575.30\ x\ 52} x100\% = 95.23\%$$

3.3 *Quality Rate Calculation*

The *Quality Rate value* reflects the proportion of outputs that meet quality standards compared to the total output produced. This indicator is important for evaluating the extent to which production defects or defective products affect the effectiveness of the production process. The data used includes the total output produced, the number of *defective products*, and the number of products that have passed quality inspection. The following are the results of the calculation of *the Quality Rate* value:

Table 3. *Quality Rate Calculation*

	PROCESS AMOUNT	WASTE	QULITY RATE
JAN	134982	2113	98,00%
FEB	122964	2592	97,00%
MAR	115929	2113	98,00%

As an example of the calculation using the January period, as follows:

$$Januari = \frac{134982 - 2113}{134982} x100\% = 98\%$$

3.4 Calculation of Overall Equipment Effectiveness (OEE)

After the *availability rate, performance rate, and quality rate* values are obtained, the next step is to calculate the OEE. OEE is a measure in TPM used to assess how effectively equipment operates. The following are the calculation results from the OEE shown by Table 4.

Table 4. OEE Measurement Values

	Availability	Performance	Quality	OEE
Jan	96,19%	95,23%	98,09%	89,85%
Feb	96,19%	86,75%	97,89%	81,69%
Mar	96,19%	81,78%	98,18%	77,23%
Mean	**96,19%**	**0,8792**	**0,9805**	**82,92%**

As an example of the calculation using the January period, as follows:

OEE = 0,9619 x 0,9523 x0,9809 $=$ 0,8985

OEE = 89,85%

The following are the results of the visualization of OEE CV data. XYZ for three months:

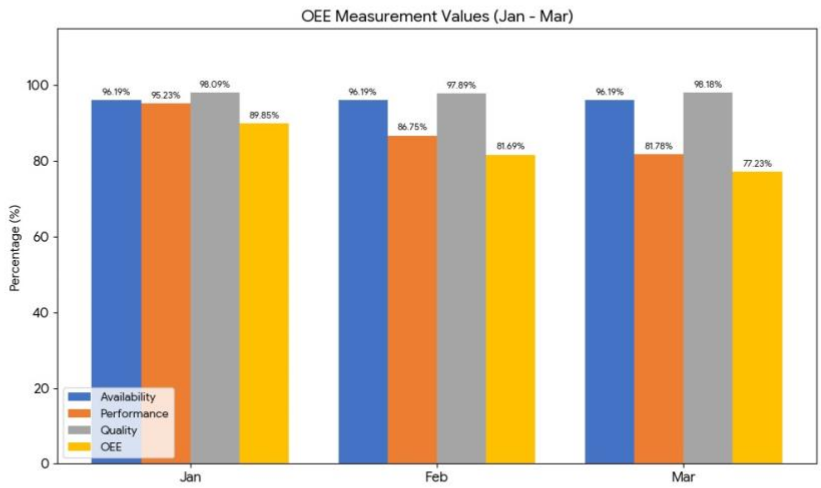

Figure 2. Bar chart of OEE calculation results

Based on Figure 2, the declining trend in OEE from January (89.85%) to March (77.23%) is predominantly driven by a deteriorating *Performance Rate*, while the *Availability Rate* remained stable and high. This indicates that the primary issue lies not in machine breakdowns, but in the machine's inability to reach its ideal production speed during operation. This finding aligns with the study by Anrinda et al., (2021) in the offset printing industry, which concluded that low OEE values are primarily caused by a low *Performance Rate* due to actual production numbers being significantly lower than the machine's standard output. In the context of this research, the gap between actual and standard output is caused by operational hurdles that slowed down the production cycle, thereby drastically reducing machine efficiency even though machine uptime remained high. To find out the factors of declining performance, *the Six Big Losses* were calculated.

3.5 Calculation of Six Big Losses

The Six Big Losses are the six main categories that cause the loss of effectiveness in the production process, which directly affects the OEE (*Overall Equipment Effectiveness*) value. By knowing the magnitude of each loss, companies can design more targeted repair strategies to improve overall production efficiency. Here's an example of the calculation of six big losses with an example for the January period:

Failure Losses (EF) *Calculation*:

$$\text{EF} = \frac{0}{24.300-125}\ x\ 100\% = 0{,}00\%$$

Setup and Adjustment Losses (SL) *Calculation*:

$$\text{SL} = \frac{125}{283.375{,}30}\ x\ 100\% = 4\%$$

Idle and Minor Stoppage Losses (IL) *Calculation*:

$$\text{IL} = \frac{0+125+8100}{284.375{,}30}\ \text{x}\ 100\% = 2{,}90\%$$

Reduce Speed (RSL) *Calculation*:

$$\text{RSL} = 100\% - 95{,}23\% = 4{,}77\%$$

Process Defect Losses (PD) *Calculation*:

$$\text{PD} = \frac{52\ x\ 0}{24300}\ x\ 100\% = 0{,}00\%$$

Yield Losses (YL) *Calculation*:

$$\text{YL} = \frac{0{,}018\ x\ 2583}{24300}\ x\ 100\% = 0{,}20\%$$

So the overall result of the calculation of six big losses is as follows:

Table 5. Results of Calculation of Six Big Losses

	EF	SL	IL	RSL	PD	YL
Jan	0,00%	4%	2,90%	4,77%	0,00%	0,20%
Feb	0,00%	4%	2,90%	13,25%	0,00%	0,16%
Mar	0,00%	3%	2,89%	18,22%	0,00%	0,20%
Total	**0,00%**	**11%**	**8,69%**	**36,24%**	**0,00%**	**0,57%**

The following are the results of the visualization of Six Big Losses data:

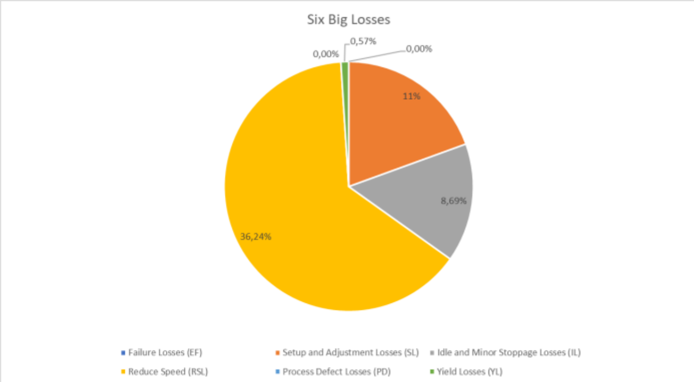

Figure 3. Pie chart of Six Big Losses calculation result

Based on the figure 3, Reduced Speed emerges as the most significant loss factor for the Versant 3100i machine at 36.34%. This high value is attributed to a shift in production toward fragmented, short-run jobs due to declining print volumes, where processing and calibration lags are often recorded as operation time. Additionally, the lack of Standard Operating Procedures (SOP) leads to inefficient queue management; the failure to batch similar jobs forces repeated machine adjustments, significantly dragging down the average production speed. The fishbone diagram method is used to find out the root cause of the problem of high reduced speed.

3.6 Analysis of Improvements Using Fishbone Diagrams

The causation diagram and causal analysis made based on the results of the calculation of the six major losses are shown below. The decrease in the OEE value in the Versant 3100i is indicated by the value of the speed drop with a high loss value, caused by various factors, including human, method, machine, measurement, and material. Figure 3 shows the components.

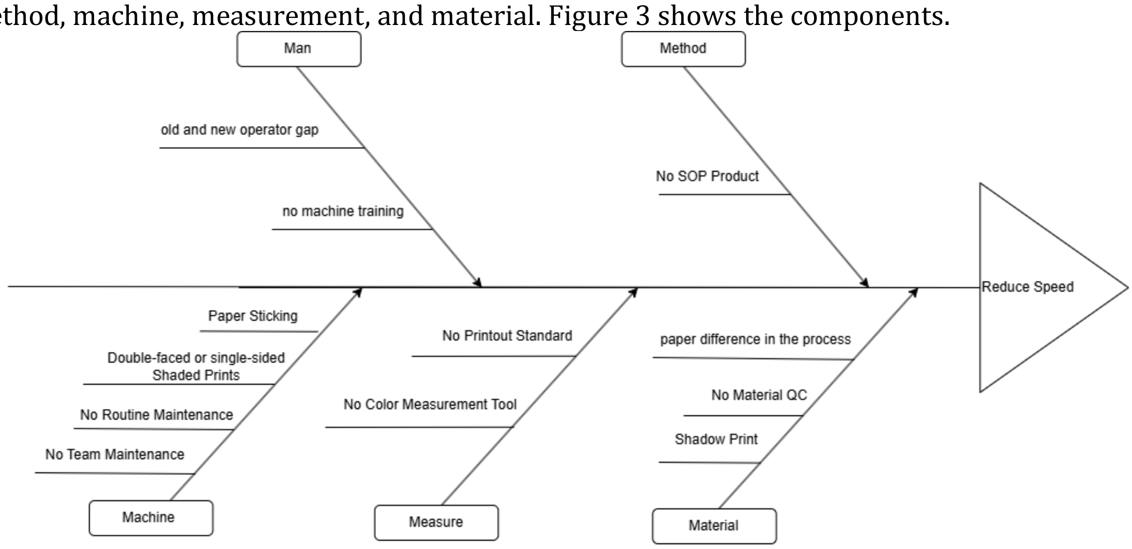

Figure 4. Fishbone Diagram

Based on the fishbone diagram above, the causes of the damage and the maintenance proposals of the Versan 3100i engine can be analyzed from table 6.

Table 6. *Fishbone* analysis diagram

Consequences	Causal Factors	Main Causes	In-Depth Causality Analysis & Performance Metrics	Suggestions for Improvement
Reducted Speed	Human	Differences in the skills of new and old operators No training to operate the machine	The wide skill gap leads to inconsistent output and variable *setup times*. Lack of formal training increases the probability of **human error**, contributing to high **MTTR** (Mean Time To Repair).	Conduct thorough training to equalize competencies by implementing mentorship programs such as old operators to new mentors Create a regular training schedule for all operators by including post-training evaluations to ensure understanding
	Method	No SOP	The absence of Standard Operating Procedures (SOPs) results in high process variation. This non-standardized operation hinders systematic root cause analysis and extends the time required to stabilize production runs.	Digital & Audited SOP Implementation: Develop clear, visual SOPs and socialize them across the team. Implement a mandatory Process Compliance Audit (PCA) schedule to monitor adherence.
	Machine	Stuck paper Double-sided or single-sided shaded prints No maintance team No routine maintance	Symptoms like Stuck Paper and Shaded Prints are direct indicators of degraded components (rollers, fuser unit) operating past their optimal wear curve. This deficiency drastically reduces machine Availability and increases the Breakdown Rate and MTTR (Mean Time To Repair).	Scheduled Preventive Maintenance (PM) System: Implement a PM schedule covering daily (operator check-in), weekly (technician), and monthly (in-depth technician) activities, including the replacement of critical components based on service life (lifetime) rather than failure (breakdown). Critical Spare Parts Logistics Provision: Identify and maintain minimum stock (buffer stock) for the most frequently replaced

				spare parts (e.g., feed rollers, cleaning blades). Operator's Role in Daily Maintenance (Total Productive Maintenance - TPM): Provide detailed visual inspection checklists to operators to conduct daily cleaning and inspection before the printing process begins.
	Measurement	Absence of print standards No color gauge	Quality assessment (color accuracy, density) is subjective without quantitative standards. This leads to inconsistent results and time-consuming, inefficient rework cycles.	Set a standard physical/digital example as a reference by conducting periodic audits to compare the results with the standard Buy a color analyzer such as a spectrometer with periodic calibration of the tool for accuracy
	Material	Paper differences in the process No Quality Control on the Material Shadowy prints	Variation in material properties (humidity, weight) influences machine performance, often acting as the primary trigger for Stuck Paper and Shading Uncontrolled material input undermines all standardization efforts.	Standardize materials with suppier by creating a list of approved materials for production Create a QC Team for pre-production material inspection by using the material quality inspection parameter checklist Check the print condition such as ink and material by doing test printing before mass production Specify and Monitor Critical Material Properties (e.g., Humidity and Grammage Tolerance): Mandate strict technical specifications from suppliers and perform internal checks upon delivery to ensure stability and compatibility with the Versan 3100i's operating environment.

The decrease in the Versan 3100i's production speed is a complex issue resulting from systemic failures across five causal categories. The most critical challenge lies in the Machine factor, where the absence of both routine maintenance and a specialist team has led to component degradation, severely compromising machine Availability. This is amplified by Human inconsistency stemming from inadequate training, Method variability due to missing SOPs, and Material instability due to the lack of Incoming Quality Control (IQC). To restore efficiency, a holistic strategy is mandatory: implementing Condition-Based Maintenance (CBM) and Total Productive Maintenance (TPM) to stabilize the machine, concurrently standardizing operator competency through certification, and establishing quantitative Measurement controls and robust material quality assurance. These measures are essential to shift the operation from a reactive, high-cost model to a stable, predictable, and highly efficient production system.

4. Conclusions

The measurement of the Versant 3100i digital printing machine over the period of January to March 2025 resulted in an average Overall Equipment Effectiveness (OEE) value of 82.92%, which remains below the World Class Standard of 85%. The analysis of OEE components reveals a significant disparity: while the Availability Rate (96.19%) and Quality Rate (98.05%) were satisfactory, the Performance Rate (87.92%) was the primary factor dragging down the overall effectiveness.

Further analysis using Six Big Losses identified Reduced Speed as the dominant loss factor, contributing 36.34% of total losses. The root cause analysis indicates that this speed reduction is not due to machine defects, but rather operational characteristics inherent to short-run digital printing, such as frequent job changeovers and calibration lags. This condition is exacerbated by the absence of Standard Operating Procedures (SOP) for job batching and material handling, forcing the machine to undergo repetitive setups that degrade average running speed. Therefore, improvement strategies must focus on developing strict SOPs for print queue management, standardizing material inputs, and enhancing operator competency in handling job transitions. For future research, it is recommended to implement these proposed SOPs and conduct a comparative study to validate the improvement in OEE values, or to explore the integration of real-time IoT monitoring to detect minor stoppages more accurately.

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