



Analysis of Machine Performance Using the Overall Equipment Effectiveness and Six Big Losses on Double Saw Machines

Muhammad Naufal Nazhif¹, Joumil Aidil Saifuddin¹

¹Universitas Pembangunan Nasional Veteran, Jawa Timur, Indonesia

*Corresponding Author: Muhammad Naufal Nazhif

Email: nofalnofal1878@gmail.com



Article Info

Article history:

Received 2 February 2025

Received in revised form 4

March 2025

Accepted 10 July 2025

Keywords:

Performance Effectiveness

Machine Breakdown

Overall Equipment

Abstract

PT Sumber Mas Indah Plywood is a manufacturing company engaged in the furniture sector with product specialization in plywood manufacturing furniture and plywood furniture. The research was conducted in January-December 2023 using the Overall Equipment Effectiveness (OEE) method to determine the effectiveness value of the machine. The objective of this study is to improve the performance of the double saw machine and propose improvements at PT Sumber Mas Indah Plywood to improve production quality. This study was conducted to measure the effectiveness of the double saw machine to determine its effectiveness value. The Overall Equipment Effectiveness (OEE) method is used here to measure it. The OEE value is affected by three factors, which are the availability, performance, and quality. The results obtained are that the effectiveness of the machine is still quite high, with an OEE value of 83.54% and still below the OEE standard value of 85%. To improve OEE, additional steps could include the identification of emerging problem. This allows improvement efforts to be directed towards addressing major challenges. The recommendation for the proposed repair of the double saw machine owned by PT Sumber Mas Indah Plywood should be used as a preventive maintenance strategy where the strategy can be carried out to monitor the machine so that it is in prime condition and ready to use and preventive steps can be taken before a problem occurs on the double saw machine.

Introduction

The development of the manufacturing industry is increasing from year to year, this of course makes competition in the manufacturing industry even faster. The company needs to make efforts to improve in terms of equipment by increasing the effectiveness of existing machinery or equipment as optimally as possible. The machinery or equipment used must be in good condition so that it can work optimally (Zhou et al., 2022; Li et al., 2022). To maintain the condition of the machine so that there is no damage or interference that causes the production process to stop, good maintenance is needed so that the results can increase the effectiveness of the machine or equipment and damage to the machine or equipment can be avoided.

As the production processed runs at PT Sumber Mas Indah Plywood, the condition of the machine will tend to experience a decrease in the ability to do its job. In addition to age problems as an internal factor, there are several external factors that affect machine performance, namely errors in the operation of errors in the operation of the machine, improper input of raw materials and incorrect installation of supporting equipment or other causes that result in the machine not being able to work. Other causes that result in the machine not being able to work as usual, can be imagined when production is taking place in

a state of increased demand. when production is taking place in a state of increased demand for a product, but the machine is damaged or less ready to use, it will affect the profit from production will decrease and increase the cost of repairing damaged machines.

Production System

A production system is an activity or a process that converts inputs into outputs. In a global interpretation, a production system is considered as an activity that produces goods or services (Eswaran & Bahubalendruni, 2022; Oluyisola et al., 2022; de Assis Dornelles et al., 2022). In a small interpretation of the production system, every running system requires data input. In an information system, data consists of basic facts that are the main material of the system. which are the main ingredients of the system. The structural components or elements that make up the production system consist of materials, machinery and equipment, labour, capital, energy, information, land, and others (Melnyk et al., 2022; Zhang et al., 2022; Agote-Garrido et al., 2023; Li & Zhou, 2022). While the functional components or elements consist of supervision, planning, control, coordination, and leadership, all of which are related to management and organisation. A process in a production system can be defined as the sequential integration of labour, materials, information, work methods, and machinery or equipment in an environment to produce added value for products, in order to be sold at competitive prices in the market. The process converts measurable inputs into measurable outputs through a number of organised sequential steps (Andayati, 2019; Guo et al., 2024; Jedermann & Lang, 2022).

Maintenance

Maintenance is a concept of activity needed to maintain the quality of the machine so that it can function properly as its normal condition. Maintenance is a form of activity carried out to restore or maintain the condition of the machine so that it can always function. Maintenance is also a supporting activity that ensures the continuity of machinery and equipment so that when needed it can be used as expected (Zhao et al., 2022; Rojek et al., 2023; Hamasha et al., 2023). So that maintenance activities are a whole series of activities carried out to maintain machinery and equipment in operational and safe conditions, and in the event of damage can be controlled. The production process requires maintenance activities which include cleaning, inspection, adding lubricant and procurement of spare parts for its sustainability (Pranowo, 2019; Lanzilotti et al., 2022; Ramiya & Suresh, 2021). The other function of maintenance is to extend the economic life of existing production machinery or equipment and strive to keep the production machinery or equipment always in an optimal condition and ready to use state for production process activities (Nursanti et al., 2019; Mobley, 2002; Nakagawa, 2005; Oluyisola et al., 2022; Pimenov et al., 2022).

Total Productive Maintenance

Total Productive Maintenance is an innovative approach to maintenance that aims to optimise equipment effectiveness, eliminate breakdowns, and promote autonomous maintenance by operators through daily activities that involve the entire workforce. To fulfil these objectives, preventive and predictive maintenance is required (Simanjuntak, 2020; Achouch et al., 2022; Moya, 2004). Total productive maintenance (TPM) as an innovative approach in maintenance by optimising the effectiveness of equipment and reducing / eliminating sudden damage (breakdown) by identifying it first. In other words, total productive maintenance is often defined as productive maintenance carried out by all employees, based on the principle that improving equipment capabilities must involve everyone in the organisation, from the lower layers to top management (Agustiady & Cudney, 2023; Mendes et al., 2023; Setyawan et al., 2021).

Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a method of measuring the company's overall effectiveness to evaluate how well equipment performs or functions. In addition, Overall Equipment Effectiveness (OEE) is used as an opportunity to increase productivity in the company, which is ultimately used as a step in making decisions (Muhajir, 2023; Al Hazza et al., 2021; Doyer & Bean, 2023; Sobirov, 2025). Overall Equipment Effectiveness (OEE) is also a matrix that focuses on how effectively a production operation is run. Overall Equipment Effectiveness (OEE) is also called the overall level of facility effectiveness obtained by analysing three ratios, namely availability, performance rate and quality rate (Wahid, 2020; Garza-Reyes, 2015; Ghafoorpoor Yazdi et al., 2018).

The purpose of Overall Equipment Effectiveness is to measure the performance of a maintenance system. By using this method, the availability of machinery or equipment (availability), production efficiency (performance) and the quality of the output of machinery or equipment (quality) can be known. according to the world class standard set by the Japan institute of plant maintenance or can be called JIPM is 85%, with each factor namely availability (A) of 90%, performance rate (PR) of 95% and quality ratio (QR) of 99%. (Sultan, 2021). For this reason, the correlation between the three elements of productivity can be seen in the formula below:

$$OEE = \text{Availability} \times \text{Performance Efficiency} \times \text{Rate of Quality Product} \quad (1)$$

Availability (A) is a measures how efficiently time is utilised for machine or equipment operation. This parameter reflects how ready and available the equipment or machinery is for use. A low availability ratio indicates that the equipment maintenance is not effective. To calculate the Availability value, the required data is about operation time, loading time and downtime (Rafi et al., 2022).

$$\text{Availability} = \frac{\text{Loading Time} - (\text{Breakdown} + \text{Setup})}{\text{Loading Time}} \times 100\% \quad (2)$$

Performance Rate (PR) is a calculation based on the number of products produced, multiplied by the ideal cycle time, compared to the total time available for the production process (operation time). available for the production process (operation time). Ideal cycle time refers to the duration of the process that can be achieved by the machine under optimal conditions, without any interruptions (Singh, 2020).

$$\text{Performance} = \frac{\text{Processed Amount} \times \text{Ideal Cycle Time}}{\text{Operation Time}} \times 100\% \quad (3)$$

Quality ratio (QR) is a measure that shows how well the equipment can produce products that meet the set quality standards. The way it is calculated is by subtracting the number of defective products from the total production, then dividing the result by the total production amount. It shows the proportion of produced by the equipment (Gian, 2023).

$$\text{Quality} = \frac{\text{Processed Amount} - \text{Defect Product}}{\text{Processed Amount}} \times 100\% \quad (4)$$

After analysing OEE, it will be known whether the calculation of the average OEE value has met the standards set by the world or not. If the average OEE value does not meet the standard, it is necessary to analyse the six big losses to find out in more detail the cause of the OEE value being below the standard. Six Big Losses are common factors that most often cause machinery or production equipment to work inefficiently during the production process. There are six equipment losses that cause low levels of equipment effectiveness, including

equipment failure losses (EF), setup and adjustment losses (SL), idle and minor stoppage losses (IL), reduce speed losses (RSL), defect losses (PD) and Yield losses (YL).

Referring to the research conducted, there have previously been studies using similar topics and methods. However, there are differences in the object, time and location carried out in this study, namely research on double saw machines located at PT Sumber Mas Indah Plywood which is engaged in the plywood industry located in Gresik district, East Java for the period 2023. Information and data were obtained by directly interviewing the head of the mechanical department, the machining department and taking secondary data. Secondary data was obtained for the period January to December 2023.

Methods

Field research in this study was undertaken in a manufacturing business PT Sumber Mas Indah Plywood that have specifications to make furniture plywood at Jl. Kapten Darmo Sugondo No. 99, Sidorukun, Gresik Regret, East Java, Indonesia. The production facility will be the core area of this research and specifically, the unit that will interest it is the so-called double saw machine; an equipment that is essential in the cut and shape department of the firm. The choice of this setting is based on the fact that the machine is always used daily in the day- to day production in combination with strategic significance towards ensuring that quality and volume of the output is maintained. The research was conducted in the mechanical department and the production floor where working conditions actually existed in which the double saw machine was manufactured, followed and kept in order. The study time frame was January to December 2023 hence giving a comprehensive picture of the behaviour of the machine working under the various loading and operating conditions.

The population included every single equipment and the operational conditions of the double saw machine during the mentioned period as well as the technical personnel directly engaged in the direct operation and maintenance of the machine. Information taken into consideration involved run times, idling, downtimes, failure, production levels and quality of products. To use in the research, the sample was purposefully selected to be able to represent the monthly operating performance of machines volume in the 12 months period of time. The months retained an individual observational entity, which allowed them to perform time-based studies across patterns, anomalies, and trends in machines effectiveness. Due to the nature of the object of study (the unique machine) total sampling was made on all the available time-series data over the given time-span. No probabilistic sampling was used since there was no purpose of generalisation of the case unit but rather an overall and detailed checking of performance of the working condition of the machine.

Primary and secondary methods were used in collection of data. Principal information was achieved through first-hand observation in the field and semi-structured interviewing with the key staff, such as the Head of the Mechanical Department as well as the machine operators. Observational data was used to give information on daily operating practice, maintenance procedures and counter action to the failures of machineries. The interviews generated qualitative data raring around operator customs and maintenance schedules as well as compliance to standard operating procedures (SOPs). The qualitative study was instrumental in uncovering technical deviations as well as outlining the human or procedural factors to operational inefficiency. In the quantitative analysis, secondary data was relied on. The data were systematically obtained as the production and maintaining charts of the firm were duly recorded on a monthly basis. They included the number of hours machines worked, planned maintenance time and downtimes, unplanned breakdown time, setup time and adjustment time, the total plywood sheets processed, and the amount of defective products made. Data validity was achieved through triangulation, where operational logs, maintenance forms along

with verbal account of technical team were used as a form of cross-referencing. The data also fit the format of numerical computation and follow-up performance measurement to this day.

Regarding the analytical framework, the work has integrated diversity of technical measuring framework and analysis tools. The main analysis tool was the Overall Equipment Effectiveness (OEE) model that is a universally accepted measure within the realms of manufacturing performance evaluation. OEE is broken down into three fundamental measures namely availability, which is a reflection of the ratio of scheduled time versus the time in which the machine is ready to work; performance efficiency which measures the actual speed of production against the theoretically conceived cycle time; and quality rate which determines the ratio of the proportion of outputs that are not defective. They calculated all the dimensions monthly and together amalgamated into one OEE percent to measure the effectiveness of machines.

In addition to the calculations of the OEE the researcher also used the Six Big Losses model, which helped to further diagnose individual inefficiency contributors when the value of the OEE pointed that the figure was not optimal. This model made it possible to quantify a number of losses associated with equipment failure, set-up and adjustment, idle time, and minor shutdowns, slack speed, defects in processes, and yield losses. Loss calculations were supported by data processing tools such as Microsoft Excel for tabulating monthly metrics, performing arithmetic operations, and visualizing data trends. The study also utilized cause-and-effect diagrams (fishbone diagrams) to illustrate root causes associated with the most significant loss categories, integrating qualitative insights with quantitative loss data.

Results and Discussion

Data on the quantity of overall machine working time in production, and data on the amount of production and product defects refer to internal data obtained from the company regarding the production of Plywood using a double saw machine, Table 1 presents data on the quantity of machine working time for Plywood production from January 2023 to December 2023.

Table 1. Overall Machine Working Time Data and production quantity data and product defects at PT Sumber Mas Indah Plywood

Month	Working Time	Planned Downtime	Breakdown Time	Setup Time	Processed Amount	Defect Amount	Total Product
January	9800	208	158	188	382	24	406
Februari	9956	170	323	225	386	21	407
March	9600	226	218	178	394	12	406
April	9600	134	140	224	402	19	421
May	10020	230	210	212	412	14	426
June	9600	170	412	248	416	23	439
July	9906	122	240	232	436	19	455
August	9600	180	176	226	386	13	399
September	10050	172	270	196	398	21	419
October	9600	108	212	223	381	8	389
November	9600	186	182	210	372	6	378
December	9986	108	98	213	402	3	405
Total	9776,5	167,83	219,92	214,58	397,25	15,25	412,5

Source: PT Sumber Mas Indah Plywood

Utilizing the information provided, processing spanned over the course of 12 months, from January to December, with an aim to evaluate the monthly efficacy of machine operations. This analysis identifies the total defects, total repairs, and various other metrics that can later

serve for improvement initiatives within the company. According to the data, the total working time is 9776.5; planned downtime is 167.83; breakdown time amounts to 219.92; setup time comes to 214.58; the processed quantity equals 397.25; defect quantity totals 15.25, and the total products amount to 412.5. Despite these insights, there are still significant defects each month, contributing to a substantial final total.

Availability (A) is the use of time available for machine or equipment operation. The data used in measuring the Availability ratio include loading time data, operating time and downtime (breakdown + Setup and Adjustment). The availability ratio value of the double saw machine represented in January can be calculated using the following formula:

$$\text{Availability} = \frac{\text{Loading Time} - (\text{Breakdown} + \text{Setup})}{\text{Loading Time}} \times 100\%$$

$$= \frac{(9800 - 208) - (158 + 188)}{9800 - 208} \times 100\% = 96.39\%$$

Table 2. Double saw machine availability calculations

Month	Loading Time	Operating Time	Downtime	Availability Ratio
January	9592	9246	346	96.39%
Februari	9786	9238	548	94.40%
March	9374	8978	396	95.78%
April	9466	9102	364	96.15%
May	9790	9368	422	95.69%
June	9430	8770	660	93.00%
July	9784	9312	472	95.18%
August	9420	9018	402	95.73%
September	9878	9412	466	95.28%
October	9492	9057	435	95.42%
November	9414	9022	392	95.84%
December	9878	9567	311	96.85%
Average				95.48%

Source: Personal Analysed Data

From the information in Table 2, one can observe a percentage comparison between the availability percentage of PT Sumber Mas Indah Plywood's double saw machine and the benchmark set by JIPM. The double saw machine at PT Sumber Mas Indah Plywood exhibits impressive availability, maintaining a value exceeding 90% consistently throughout 2023, spanning from January to December. The minimum availability figure was recorded in June at 93%, while the maximum was noted in December at 96.85%. These availability figures indicate that the machine's readiness and uptime at PT Sumber Mas Indah Plywood are in excellent condition, surpassing the JIPM standard.

Performance Efficiency (PE) assesses the quantity of products generated, which is then multiplied by the ideal cycle time relative to the available production process time. The ideal cycle time is defined during the production process. At PT Sumber Mas Indah Plywood, with an average net working time of 8,400 minutes producing approximately 420 sheets of plywood, the ideal cycle time for the double saw machine is determined by dividing the average net working time by the average product output, yielding $8400/420 = 21$ minutes. To measure performance efficiency, data regarding product output and operating time is employed. The performance efficiency for the double saw machine in January can be evaluated using the subsequent formula:

$$\text{Performance} = \frac{\text{Processed Amount} \times \text{Ideal Cycle Time}}{\text{Operating Time}} \times 100\%$$

$$= \frac{382 \times 21}{9246} \times 100\% = 86.76\%$$

Table 3. Double saw machine performance calculations

Month	Processed Amount	Operating Time	Ideal Cycle Time	Performance Ratio
January	382	9246	21	86.76%
Februari	386	9238	21	87.75%
March	394	8978	21	92.16%
April	402	9102	21	92.75%
May	412	9368	21	92.36%
June	416	8770	21	99.61%
July	436	9312	21	98.32%
August	386	9018	21	89.89%
September	398	9412	21	88.80%
October	381	9057	21	88.34%
November	372	9022	21	86.59%
December	402	9567	21	88.24%
Average				90.96%

Source: Personal Analysed Data

According to Table 3, a comparison is drawn between the percentage of performance efficiency of the double saw machine at PT Sumber Mas Indah Plywood and the JIPM standard. The double saw machine shows poor performance efficiency, except in June and July, where efficiency exceeds 95%. However, from January to May and August to December, efficiency percentages range from 85% to 88%. These calculations suggest that the performance efficiency at PT Sumber Mas Indah Plywood is inadequate, as it falls below the JIPM standard. Consequently, it is essential for the company to make improvements to enhance machine effectiveness and optimize ongoing production.

Quality Ratio (QR) of product is the value of good products that are in accordance with predetermined product quality specifications against the number of products processed so that it requires product defect data. The data used in measuring the rate of quality product is processed amount data and defect amount data. The Rate of Quality Product value of the double saw machine represented in January can be calculated using the following formula:

$$\text{Quality Ratio} = \frac{\text{Processed Amount} - \text{Defect Product}}{\text{Processed Amount}} \times 100\%$$

$$= \frac{382 - 24}{382} \times 100\% = 93.72\%$$

Table 4. Double saw machine quality calculations

Month	Processed Amount	Defect Amount	Quality Ratio
January	382	24	93.72%
Februari	386	21	94.56%
March	394	12	96.95%
April	402	19	95.27%
May	412	14	96.60%
June	416	23	94.47%
July	436	19	95.64%
August	386	13	96.63%
September	398	21	94.72%
October	381	8	97.90%

November	372	6	98.39%
December	402	3	99.25%
Average			96.19%

Source: Personal Analysed Data

Based on Table 4, a comparison is presented of the percentage between the product quality ratio value of PT. Sumber Mas Indah Plywood's double saw machine and the standard value set by JIPM. Except for December, where the quality ratio exceeded 99%, the machine consistently shows a poor product quality ratio. The calculations demonstrate that PT. Sumber Mas Indah Plywood's product quality ratio falls short of the JIPM standard of 99%, indicating its poor condition. Consequently, it is essential for the company to implement improvements to ensure that the quality ratio meets the 99% target consistently each month.

Calculation of Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a method of measuring the effectiveness of companies globally to evaluate how well equipment performs or functions. Processing machine effectiveness data using the overall equipment effectiveness (OEE) method can be done after the availability value (table 2), performance efficiency (table 3) and rate of quality product (table 4) on the double saw machine are known. Then proceed with the calculation of the OEE value based on the multiplication of the 3 important factor values in the effectiveness of the machine above using the following formula:

$$\begin{aligned} \text{OEE} &= \text{Availability} \times \text{Performance Ratio} \times \text{Rate of Quality} \\ &= 95.48\% \times 90.96\% \times 96.19\% \\ &= 83.54\% \end{aligned}$$

Based on the results of the above calculations, it can be seen that the percentage of Overall Equipment Effectiveness of the double saw machine used at PT Sumber Mas Indah Plywood is 83.54% with details of availability of 95.48%, performance efficiency of 90.96% and rate of quality product of 96.19%. Of the three factors that affect the value of Overall Equipment Effectiveness, it can be seen that the double saw machine has the lowest factor value among the other two factors, namely the value of the performance efficiency factor.

Six Big Losses

The Six Big Losses can be considered as common factors that cause ineffectiveness in machines. The six factors are equipment failure (EF), tuning and adjustment losses (SL), idle losses and minor stoppages (IL), reduced speed losses (RSL), process defect losses (PD) and yield loss (YL). Based on the OEE value, it is necessary to evaluate the factors that cause the low OEE value, especially on performance and quality levels. Therefore, an analysis of the Six Big Losses is carried out, so that it will be known what factors affect the low OEE value. The six methods of six big losses of the double saw machine represented in January 2023 can be calculated using the following formula:

$$\begin{aligned} \text{EF} &= \frac{\text{Breakdown Time}}{\text{Operating Time}} \times 100\% \\ &= \frac{158}{9246} \times 100\% = 1.71\% \\ \text{SL} &= \frac{\text{Total Setup}}{\text{Loading Time}} \times 100\% \\ &= \frac{188}{9592} \times 100\% = 1.96\% \\ \text{IL} &= \frac{(\text{Breakdown Time} + \text{Setup Time} + \text{Planned Downtime})}{\text{Loading Time}} \times 100\% \end{aligned}$$

$$= \frac{(158+188+208)}{9592} \times 100\% = 5.78\%$$

$$\text{RSL} = \frac{\text{Operating Time} - (\text{ICT} \times \text{Processed Amount})}{\text{Loading Time}} \times 100\%$$

$$= \frac{9246 - (21 \times 382)}{9592} \times 100\% = 12.76\%$$

$$\text{PD} = \frac{\text{ICT} \times \text{Defect Amount}}{\text{Loading Time}} \times 100\%$$

$$= \frac{21 \times 24}{9592} \times 100\% = 5.25\%$$

$$\text{YL} = \frac{\text{ICT} \times \text{Reject}}{\text{Loading Time}} \times 100\%$$

$$= \frac{21 \times 0}{9592} \times 100\% = 0\%$$

Table 5. Average Value of Six Big Losses Component

Month	Equipment Failure	Setup Losses	Idling Losses	Reduced Speed Losses	Process Defect	Yield Losses
January	1.71%	1.96%	5.78%	12.76%	5.25%	0%
Februari	3.50%	2.30%	7.34%	11.57%	4.51%	0%
March	2.43%	1.90%	6.64%	7.51%	2.69%	0%
April	1.54%	2.37%	5.26%	6.97%	4.22%	0%
May	2.24%	2.17%	6.66%	7.31%	3.00%	0%
June	4.70%	2.63%	8.80%	0.36%	5.12%	0%
July	2.58%	2.37%	6.07%	1.59%	4.08%	0%
August	1.95%	2.40%	6.18%	9.68%	2.90%	0%
September	2.87%	1.98%	6.46%	10.67%	4.46%	0%
October	2.34%	2.35%	5.72%	11.13%	1.77%	0%
November	2.02%	2.23%	6.14%	12.85%	1.34%	0%
December	1.02%	2.16%	4.24%	11.39%	0.64%	0%
Average	2.41%	2.23%	6.27%	8.65%	3.33%	0%

Source: Personal Analysed Data

According to the calculations of the Six Big Losses, the most significant loss is attributed to reduced speed loss, which involves a decrease in engine speed, accounting for 8.65%. Following this is idle and minor stoppage, resulting from frequent engine stops, at 6.27%. Third in line is defect loss, coming in at 3.33%. Breakdown loss ranks fourth at 2.36%, followed by setup loss at 2.23%, and lastly, yield loss is at 0%. It's evident that the most impactful losses are reduced speed loss and idle and minor stoppage, with several factors contributing to their substantial impact. Causes for reduced speed loss might include tool wear, insufficient maintenance, raw material variations, or subpar machine settings. This leads to decreased production output and reduced work efficiency. For idle and minor stoppage, the causes could be issues like material congestion, faulty sensors, minor machine adjustments, or operator interventions. Although this downtime might seem minor, its repetition can significantly diminish production efficiency.

Analysis of Cause and Effect Diagram

The following is a causal analysis diagram obtained based on the results of the calculation of the six big losses. It can be seen that the factors causing the decline in OEE value on the heading machine are idle and minor stoppage values and reduced speed losses with the highest loss value among others caused by several factors, namely humans, machines, and the

environment, machines, and the environment. The factors that cause a decrease in OEE value can be seen in Figure 1 below.

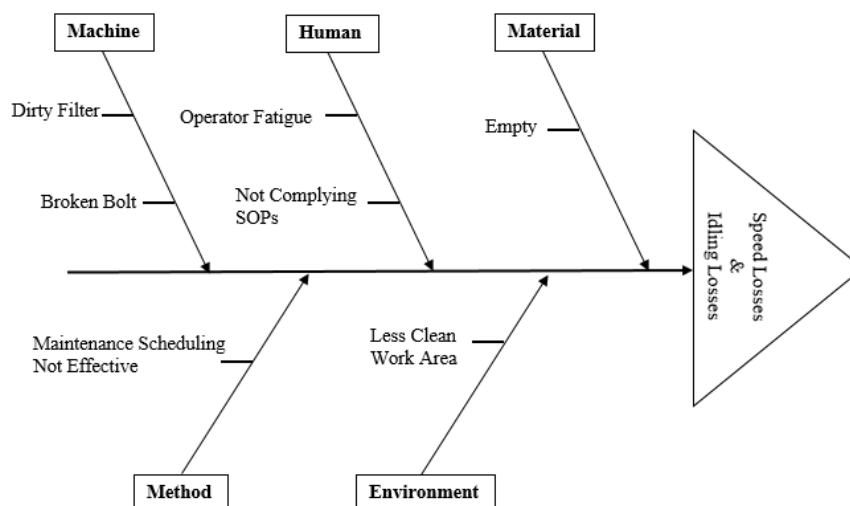


Figure 1. Fishbone Diagram

Based on the fishbone diagram above, the causes of damage and maintenance proposals for double saw machines can be analysed in the table below:

Table 6. Fishbone Diagram Analysis

Consequences	Causal Factors	Root Causes	Suggested Improvement
Reduce Speed Losses & Idling Losses	Human	Operator Fatigue	Rest periods for operators and work shift changes at certain times.
		Not Complying SOPs	Conduct training and socialisation of applicable SOPs to operators
	Machine	Dirty Filter	Periodically direct cleaning of area filters
		Broken Bolt	Schedule component replacement and check component condition regularly
	Environment	Less Clean Work Area	Always keep the surrounding environment clean before and after work
	Method	Maintenance Scheduling not Effective	Make a maintenance schedule for components and production machines on periodically

Based on the results of the analysis in the table above, there are 4 factors that affect the decrease in OEE value including, factors caused by humans, namely operator fatigue due to repetitive activities pursuing production targets so that their work performance decreases and operator performance is still less effective in monitoring and checking each machine component before production activities. Factors caused by the machine are the many damages that hinder the production rate such as bolts that are often broken, and oil filters that are often jammed due to dirt that is carried in during the production process. While factors caused by the environment include the workspace or production area that is still less clean, causing dirt or dust to be easily absorbed and carried into the oil filter which can hinder and slow down engine performance. The last factor that affects the decrease in OEE value is the method factor, including the absence of regular maintenance scheduling of production machines so that machine repairs are carried out when damage occurs. The four factors above need to be considered specifically so that improvements can be made to the maintenance system which will increase the OEE value. After the analysis is carried out, it can be seen what factors most affect the low OEE value and from these factors further treatment will be carried out in order to increase OEE and minimise existing losses.

Enhancing Machine Effectiveness through Loss Reduction and Maintenance Strategy

The OEE analysis and the Six Big Losses model results support fairly healthy performance of the double saw machine at PT Sumber Mas Indah Plywood as a whole. The relatively small differences with the benchmarks however indicate that there are still some possibilities of increased optimization. Intermittent or long-run inefficient production should be seen as a chance and not as the given floor. Additional instances of such occurrences typically witnessed in wood-related manufacturing systems whereby mechanical tools are exposed to high loads, or the consistency of the process is made to depend on the material properties and environmental factors furnish a barrier to improved productivity, material usage rates, and equipment life. Garza-Reyes (2015) points out that even a highly dependable equipment will fall victim to micro-losses that can gradually wear off the overall production. So, the careful mapping of these small but persistent losses is an important requirement to all manufacturing companies which are aiming at gaining a competitive edge.

Out of the losses analyzed, Reduced Speed Losses was seen as the most effective one with over 90 % of the recorded performance gap. The extent of this issue lies in the fact that volume production is not the only aspect of the problem as the sequencing of downstream operations is also affected. Any deviation in machine speed outside the desired cycle time translates to ripple effect going through the entire production schedule of the plant in producing backlog, increasing exhaustion of those who operate the machine and even resulting to weaker quality of products. According to the empirical studies of Singh & Gurtu (2022), this phenomenon can be caused by the wear of tools that have accumulated over time or by the inefficiencies in alignment during the work, of which Rojek et al. (2023), support the findings and state that the delay in the change of dulled or misaligned parts leads to a decrease in performance even when the machine itself is not at fault. On-going operation at sub optimum speeds has a predisposition of covering the underlying mechanical degradation thus promoting the instability exhibited in the performance.

Idling and minor stoppage losses are the issues that will be addressed in the present discussion and which can normally appear in the manufacturing setting where the cultures requires the occurrence of numerous, but short-time interruptions. Such jams as seen in sensor failure, jammed materials, or in latent in human response in production anomaly are made to seem inconsequential in their individual occurrence, but when added together they can prove very significant. Evidence based research- studies by Agustady & Cudney (2023) and by Ghafoorpoor Yazdi et al. (2018) confirm the contention that treating such stoppages as normal in the day to day functioning of the work does impose a systematic loss on the workflow. Without compensation, these losses are entrenched into normal production processes, which limit their long run performance. Fortunately, most of the idling and small stoppage losses can be easily corrected, such as, by training to allow faster response times, by relocating workstations to allow for enhanced material flow, or by a minimal design adjustment to ensure that the design is less susceptible to mechanical manipulation.

A major variable during the analysis is the defect rate. In spite of the fact that the ratio of the quality level is always above 96 %, the fact that defects do appear each month shows that there is still a lack in overall control over uniformity in products. This outcome leads to the suspects of other factors like a lack of consistent input materials, vibration of the machine or ineffective inspection procedures. Achouch et al. (2022), as an example, report that preventive maintenance models do not work as expected when there is a deviation in the density of raw materials or the direction of fibers beyond specified specifications, a fact also confirmed by Zhao et al. (2022), who confirm that an increase in cutting precision errors because of poor machine cleanliness or nonalignment of blades further contributes to the problem. To resolve these problems, it requires the investment in quality monitoring devices, in-line defect

checking tools and computerized inspection applications, which enable immediate action and maintain the process cycles without stopping.

The other notable fact is the disaggregation of equipment failure and setup losses. This disaggregation implies that most process downtimes are due to equipment failures, as opposed to set up times, a trend not consistent with preconceived notions of the major cause of downtimes. Further studies will be needed to clarify why such a gap occurs, especially in regard of equipment design, maintenance of operations, configuration of workflow. The tendencies to get speed and idling losses were the main factors that contributed to overall inefficiency, yet the discussed ancillary concepts whether the setup time, the quality loss, or the human factors were also presented through the existence of strain on the cumulative capacity. With the high levels of batch modifications and component reconfigurations, the delay due to setup was particularly harmful to the production pace and in many cases revealed weaknesses in the work preparation process and cooperation of people involved in production and maintenance. Garza-Reyes (2015) and Simanjuntak (2020) highlight the idea that non-value-adding time can be significantly reduced with the help of well-structured setup procedures, standardization of components, and clearly defined practices. The predictive maintenance that Hamasha et al. (2023) promote through time-series information and machine-learning models also allows predicting crashes and planning intersections without sudden breakdowns.

The observation that there is no apparent loss of yield comes as good news but should not temper with complacency. The badly undocumented waste and rework of products often finds itself lurking behind total defect rates. According to Ramiya & Suresh, (2021), it is important to decouple yield and process defects, especially in high-volume productions, where the smallest waste can become high relatively quickly. As a result, keeping track of the rework rate, reprocessing time, and volumes of waste materials gives a more comprehensive overview of these idle productivity costs.

Another inference of the study relates to the human aspects and behaviour of the operators. Some of the inefficiencies were categorized as root causes related to operator fatigue and deficiency in the standard operating procedures, which is congruent with the results by Achouch et al. (2022) and Agustiady & Cudney (2023). A feeling of fatigue lessens the ability to respond and increases the percentage of error that occurs in both normal maintenance and the normal operations. Human-related solutions and approaches such as the management of the work and its following the procedures should, therefore, become the key to preserving the high level of machine functioning. This paper explores how simple interventions such as rotating shifts, improved ergonomics and operator-based training programs influenced production stability. These results validate that these measures can significantly increase stability of processes. In addition, Zhou et al. (2022) highlight the benefits of real-time human to machine feed back systems whereby operators spontaneously get time sensitive alerts or performance nudges regarding the current operational status of the machine in use.

The other sharp identification of environmental condition as a predictor; especially in machine filter quality and efficiency of the blade. In spite of the fact that the importance of environmental cleanliness in the context of manufacturing environments is often underestimated, the studies by Lanzilotti et al. (2022) and Ghafoorpoor Yazdi et al. (2018) prove its direct implication on the effectiveness of airflow, the quality of lubrication, and the presence of dust. Airborne particles can trigger jamming, overheating and an increase in dragging of the blade and hence this reduces performance in the case of saw machines. Constant cleaning programs, combined with the monitoring of the filter performance, increase the life of the components and relieve unnecessary breakdowns.

The findings of the research emphasize the significances of the digitally combined maintenance and operational tracking. The established procedures involve manual data input and recollection of the operator, leaving room to errors, delays, and negligence. Oluyisola et al. (2022) are convinced that such a shift to digital production dashboards and automated alerts enhances cross-functional visibility, speed to identify the root causes, and the culture of continuous improvement. Additionally, the evidence-based maintenance and spare-parts management (scheduling) can be achieved by integrating predictive analytics, as explained by Hamasha et al. (2023) and Eswaran & Bahubalendruni (2022).

Conclusion

The research conducted at PT Sumber Mas Indah Plywood revealed that the analysis of Total Productive Maintenance (TPM), focusing on the effectiveness of the double saw machine's performance through the Overall Equipment Effectiveness (OEE) method for the period from January to December 2023, showed an average value of 83.54%. This figure falls short of the ideal OEE benchmark of 85%, which aligns with the world-class standard set by the Japan Institute of Plant Maintenance. As such, there is a necessity for improvements to elevate the OEE value to meet the 85% target. The lowest contributing factor to OEE was found to be the Performance Efficiency, at 90.96%. Updating the maintenance schedule for the machines is critical to enhancing the performance efficiency of the double saw machine, thereby boosting the company's production speed. The next value is the Availability Ratio standing at 95.48%, followed by the Rate of Quality at 96.19%.

Improvement recommendations target machines that offer the most substantial potential to increase OEE values, with particular focus on the double saw machine in this study. PT Sumber Mas Indah Plywood's approach to repairing the double saw machine should pivot towards a preventive maintenance strategy. This involves monitoring the machine to ensure it remains in optimal working condition, implementing preventive measures before issues arise, and scheduling the replacement of spare parts and components based on the most frequently occurring wear, rather than waiting for a breakdown. Additionally, regularly cleaning the machine and inspecting its components is crucial. To optimize the machine, recommendations include adjusting cutting speeds, enhancing the quality of the machine blade, and ensuring accurate calibration. To reduce downtime, suggestions include regular operator training, implementing a sensor system to assess machine wear, and maintaining an efficient inventory of spare parts.

References

- Achouch, M., Dimitrova, M., Ziane, K., Sattarpanah Karganroudi, S., Dhoub, R., Ibrahim, H., & Adda, M. (2022). On predictive maintenance in industry 4.0: Overview, models, and challenges. *Applied Sciences*, 12(16), 8081. <https://doi.org/10.3390/app12168081>
- Agote-Garrido, A., Martín-Gómez, A. M., & Lama-Ruiz, J. R. (2023). Manufacturing system design in industry 5.0: incorporating sociotechnical systems and social metabolism for human-centered, sustainable, and resilient production. *Systems*, 11(11), 537. <http://dx.doi.org/10.3390/systems11110537>
- Agustiady, T., & Cudney, E. A. (2023). *Total productive maintenance: strategies and implementation guide*. CRC press.
- Al Hazza, M. H. F., Ali, M. Y., & Razif, N. F. B. M. (2021). Performance improvement using analytical hierarchy process and Overall Equipment Effectiveness (OEE): Case study. *Journal of Engineering Science and Technology*, 16(3), 2227-2244. <http://dx.doi.org/10.36842/jomase.v67i3.351>

- Andayati, D. (2019). Sistem Informasi Produksi Untuk Meningkatkan Kualitas Sistem Manufaktur Dan Jasa Dina. *Jurnal Teknologi Dan Manajemen*, 12(1), 87–92. <https://doi.org/10.30872/jinv.v20i2.1793>
- de Assis Dornelles, J., Ayala, N. F., & Frank, A. G. (2022). Smart Working in Industry 4.0: How digital technologies enhance manufacturing workers' activities. *Computers & Industrial Engineering*, 163, 107804. <http://dx.doi.org/10.1016/j.cie.2021.107804>
- Doyer, I., & Bean, W. L. (2023). As easy as OEE: enabling productivity improvement in schools by using overall equipment effectiveness as framework for classroom data analysis. *International Journal of Lean Six Sigma*, 14(5), 1055-1074. <https://doi.org/10.1108/IJLSS-03-2022-0057>
- Eswaran, M., & Bahubalendruni, M. R. (2022). Challenges and opportunities on AR/VR technologies for manufacturing systems in the context of industry 4.0: A state of the art review. *Journal of Manufacturing Systems*, 65, 260-278. <http://dx.doi.org/10.1016/j.jmsy.2022.09.016>
- Garza-Reyes, J. A. (2015). From measuring overall equipment effectiveness (OEE) to overall resource effectiveness (ORE). *Journal of Quality in Maintenance Engineering*, 21(4), 506-527. <http://dx.doi.org/10.1108/JQME-03-2014-0014>
- Ghafoorpoor Yazdi, P., Azizi, A., & Hashemipour, M. (2018). An empirical investigation of the relationship between overall equipment efficiency (OEE) and manufacturing sustainability in industry 4.0 with time study approach. *Sustainability*, 10(9), 3031. <https://doi.org/10.3390/su10093031>
- Guo, J., Hao, Z., Wang, C., Tang, Y., Wu, H., Hu, H., ... & Xu, C. (2024). Data-efficient large vision models through sequential autoregression. *arXiv preprint arXiv:2402.04841*. <https://doi.org/10.48550/arXiv.2402.04841>
- Hamasha, M. M., Bani-Irshid, A. H., Al Mashaqbeh, S., Shwaheen, G., Al Qadri, L., Shbool, M., ... & Al-Bashir, A. (2023). Strategical selection of maintenance type under different conditions. *Scientific Reports*, 13(1), 15560. <http://dx.doi.org/10.1038/s41598-023-42751-5>
- Jedermann, R., & Lang, W. (2022). Wrapper functions for integrating mathematical models into digital twin event processing. *Sensors*, 22(20), 7964. <https://doi.org/10.3390/s22207964>
- Lanzilotti, C. O., Pinto, L. F. R., Facchini, F., & Digiesi, S. (2022). Embedding product-service system of cutting tools into the machining process: an eco-efficiency approach toward sustainable development. *Sustainability*, 14(3), 1100. <https://doi.org/10.3390/su14031100>
- Li, L., & Zhou, M. (2022). *Sustainable Manufacturing Systems: An Energy Perspective*. John Wiley & Sons.
- Li, Z., Sun, Y., Yang, L., Zhao, Z., & Chen, X. (2022). Unsupervised machine anomaly detection using autoencoder and temporal convolutional network. *IEEE Transactions on Instrumentation and Measurement*, 71, 1-13. <http://dx.doi.org/10.1109/TIM.2022.3212547>
- Melnyk, L. H., Kovalov, B. L., Mykhailov, S. O., Mykhailov, O. O., & Starodub, I. A. (2022). Dynamics of reproduction of economic systems in the transition to digital economy—in the light of synergetic theory of development. Mechanism of an Economic Regulation, (3-4(97-98), 7-14. <https://doi.org/10.32782/mer.2022.97-98.01>

- Mendes, D., Gaspar, P. D., Charrua-Santos, F., & Navas, H. (2023). Integrating TPM and Industry 4.0 to increase the availability of industrial assets: A case study on a conveyor belt. *Processes*, 11(7), 1956. <https://doi.org/10.3390/pr11071956>
- Mobley, R. K. (2002). *An introduction to predictive maintenance*. Elsevier.
- Moya, M. C. C. (2004). The control of the setting up of a predictive maintenance programme using a system of indicators. *Omega*, 32(1), 57-75. <http://dx.doi.org/10.1016/j.omega.2003.09.009>
- Muhajir, S. M., & Yuamita, F. (2023). Analisis Total Productive Maintenance Dengan Menggunakan Metode Overall Equipment Effectiveness Pada Mesin Mixing Batching Di PT. Wijaya Karya Beton Tbk Boyolali. *Jurnal Inovasi Dan Kreativitas*, 3(1), 9. <https://dx.doi.org/10.22441/ijiem.v5i2.23832>
- Nakagawa, T. (2005). *Maintenance theory of reliability*. Springer Science & Business Media.
- Nursanti, E., Avief, R. M. S., Sibut, & Kertaningtyas, M. (2019). *Maintenance Capacity Planning*. Dream Litera Buana.
- Oluoyisola, O. E., Bhalla, S., Sgarbossa, F., & Strandhagen, J. O. (2022). Designing and developing smart production planning and control systems in the industry 4.0 era: a methodology and case study. *Journal of Intelligent Manufacturing*, 33(1), 311-332. <https://link.springer.com/article/10.1007/s10845-021-01808-w>
- Oluoyisola, O. E., Bhalla, S., Sgarbossa, F., & Strandhagen, J. O. (2022). Designing and developing smart production planning and control systems in the industry 4.0 era: a methodology and case study. *Journal of Intelligent Manufacturing*, 33(1), 311-332. <https://link.springer.com/article/10.1007/s10845-021-01808-w>
- Pimenov, D. Y., Mia, M., Gupta, M. K., Machado, Á. R., Pintaude, G., Unune, D. R., ... & Kuntoğlu, M. (2022). Resource saving by optimization and machining environments for sustainable manufacturing: A review and future prospects. *Renewable and Sustainable Energy Reviews*, 166, 112660. <https://doi.org/10.1016/j.rser.2022.112660>
- Pramula, G., & Hamdy, M. I. (2023). Evaluasi Efektivitas Mesin Ripple Mill Melalui Pendekatan Overall Equipment Effectiveness (OEE). *Jurnal Teknologi dan Manajemen Industri Terapan*, 2(4), 301-309. <https://doi.org/10.55826/tmit.v2i4.281>
- Pranowo, I. D. (2019). Sistem dan manajemen pemeliharaan. *Sleman: Deepublish*.
- Rafi, F. A., Wahyudin, W., & Nugraha, B. (2023). Analisis Overall Equipment Effectiveness untuk Meningkatkan Efektivitas Mesin Filling Multiline pada PT-XYZ. *UNISTEK*, 10(2), 126-133. <https://doi.org/10.33592/unistek.v10i2.3890>
- Ramiya, S., & Suresh, M. (2021). Factors influencing lean-sustainable maintenance using TISM approach. *International Journal of System Assurance Engineering and Management*, 12, 1117-1131. <http://dx.doi.org/10.1007/s13198-021-01304-7>
- Rojek, I., Jasiulewicz-Kaczmarek, M., Piechowski, M., & Mikołajewski, D. (2023). An artificial intelligence approach for improving maintenance to supervise machine failures and support their repair. *Applied Sciences*, 13(8), 4971. <https://doi.org/10.3390/app13084971>
- Setyawan, W., Sutoni, A., & Munandar, T. (2021, February). Calculation and Analysis of Overall Equipment Effectiveness (OEE) Method and Six Big Losses toward the Production of Corter Machines in Oni Jaya Motor. In *Journal of Physics: Conference Series* (Vol. 1764, No. 1, p. 012162). IOP Publishing. <http://dx.doi.org/10.1088/1742-6596/1764/1/012162>

- Simanjuntak, A. W. P. (2020). Studi Penerapan Total Productive Maintenance (TPM) Untuk Peningkatan Efisiensi Pada Pabrik Pupuk Organik PT. AGRO ENERGI INDONESIA.
- Singh, R. K., & Gurtu, A. (2022). Prioritizing success factors for implementing total productive maintenance (TPM). *Journal of Quality in Maintenance Engineering*, 28(4), 810-830. <https://doi.org/10.1108/JQME-09-2020-0098>
- Sobirov, K. (2025). *Overall equipment effectiveness (OEE) analysis in Solar Panel Manufacturing* (Doctoral dissertation, Politecnico di Torino).
- Sultan, K. S., & Moshref, M. E. (2021). Stochastic analysis of a priority standby system under preventive maintenance. *Applied Sciences*, 11(9), 3861. <https://doi.org/10.3390/app11093861>
- Wahid, A. (2020). Penerapan Total Productive Maintenance (TPM) Produksi Dengan Metode Overall Equipment Effectiveness (OEE) Pada Proses Produksi Botol (PT. XY Pandaan – Pasuruan). *Jurnal Teknologi Dan Manajemen Industri*, 6(1), 12–16 <https://doi.org/10.36040/jtmi.v6i1.2624>
- Zhang, X., Jie, X., Ning, S., Wang, K., & Li, X. (2022). Coupling and coordinated development of urban land use economic efficiency and green manufacturing systems in the Chengdu-Chongqing Economic Circle. *Sustainable Cities and Society*, 85, 104012. <https://doi.org/10.1016/j.scs.2022.104012>
- Zhao, J., Gao, C., & Tang, T. (2022). A review of sustainable maintenance strategies for single component and multicomponent equipment. *Sustainability*, 14(5), 2992. <https://doi.org/10.3390/su14052992>
- Zhou, H., Huang, X., Wen, G., Lei, Z., Dong, S., Zhang, P., & Chen, X. (2022). Construction of health indicators for condition monitoring of rotating machinery: A review of the research. *Expert Systems with Applications*, 203, 117297. <https://doi.org/10.1016/j.eswa.2022.117297>