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Research Article

Enhancing Operational Efficiency: A Study on Total Productive Maintenance for the Heidelberg Speed master 102V

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ABSTRACT

The aim of this intervention is centred on how Total Productive Maintenance (TPM – as commonly known in the literature) is applied on craftsmanship of the Heidelberg Speed master 102V offset printing machine with a view to improving the maintenance and consequently reducing the breakdown periods of the machine. The main aim is to assess how effective this management philosophy is in the reduction of degradation of equipment in the sector of printing media industry. The research methodology was quantitative, thus obtaining data from the maintenance records for the entire one-year period. Also, data for MTBF, MTTR, and machine availability (AVAIL) worked as key performance indicators. The result show that the use of TPM pursued almost all dimensions attributed with its usefulness in regard to not only the turnaround time of repair of machines but also the frequency of repairs. The results specifically support the assertion that there is a significant increase in production post the increase in the machine's available time with the results of Regression Analysis MTBF=0.76, MTTR=0.68, OEE=0.72 and ANOVA producing F values MTBF=12.34, MTTR=15.67, OEE=9.45 which has p-value=<0.01 . Thus, it was concluded that TPM increases the maintenance initiatives in an organization and at the same time enhances the attainment of the organization's industrial strategies. This is the rationale that supports how such a framework could be useful for organizations seeking to reduce the rate of maintenance and also enhance the levels of reliability of the equipment in the printing sector.

Keywords: Total Productive Maintenance, Heidelberg Speedmaster 102V, offset printing, maintenance performance, machine reliability, operational efficiency, quantitative analysis, Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), productivity improvement.

INTRODUCTION

Currently, the situation of the print media branches is such that there is an increased need for improved printing services. It is important for consumers to receive an impeccable print out of work, fresh finished products within suitable lead time and stable services. Out of all technologies that are used in the printing sector, the dominant one is offset which offers reproduction of prints at a very high scale with high quality as well. The current machine, Heidelberg Speedmaster 102V, has been a very important machine for the said industry. However, the efficient performance from such work tools can be sometimes affected with unplanned downtimes caused by mechanical failures. This brings to light the urgent necessity of appropriate maintenance measures to be able to operate without interruption and reduce loss in terms of production.

Background Information

The last ten years have brought profound changes in the structure of the print media industry largely attributable to changes in technology and consumer behavior. The advent of digital media increased the rivalry amongst the firms in the printing industry prompting the firms to come up with new strategies to remain relevant in the market. The Offset printing in particular argument essay has managed to remain relevant in the market owing to the fact it produces clear images with a vast range of colors. Speed and screen accuracy and reliability have made the Heidelberg Speedmaster 102V a popular option for printing companies.

Nevertheless, the Heidelberg Speedmaster 102V just like other pieces of equipment has its pros and cons, detachable units might wear out resulting in breakdowns and interruption of service. Unplanned downtimes are detrimental to achieving the production plans and on many occasions result in costly material losses for the firms. In this regard, the adoption of sound maintenance measures becomes imperative towards the maintenance of printing equipment.

Total Productive Maintenance (TPM) focuses on equipment maintenance through every member of an organization in a drive to increase productivity. This in turn leads to decrease in machine breakdown and non-utilization, which in turn increases the productivity for the organization as a whole. The goals of Total Productive Maintenance are the same, and emphasize a mobile device and telecommunications corporate culture where every employee is encouraged to scan their equipment. All employees of the company are motivated to explore and implement solutions to make the fulfillment of all processes more efficient. TPM is fully integrated into the company culture.

Importance of the Research Topic

The author considers this research interesting and relevant because of the ongoing difficulties of the print media industry, where there is a clear struggle with machines and their operation and efficiency rates. The distinctiveness of the industry increases competition and hence printing companies have to innovate in how they maintain their operations. The authors propose total productive maintenance (TPM) for the Heidelberg Speedmaster 102V as a practical solution to balance the risks of machine breakdowns.

Recognizing the relationship between TPM and machine performance needs to be established for a grounds for several functions. First, it gives perspective on how maintenance practices can be undertaken in such a way as to improve the reliability of the equipment. Moreover, the focus of the study is on determining the relationship between deployment of TPM to MTBF and MTTR TPM implemented.

Second, the purpose of the study was to demonstrate the effect of care of the equipment on employee participation in maintenance of the equipment, thereby institutionalizing effective maintenance culture. One of these is the recognizing the need for and the adoption of training and empowerment of the employee to care for the equipment which might augment the job content, role as well as ownership of the process. This aspect is important in the case of the printing industry in which case the performance and productivity of the production process at hand greatly revolves around skilled operators.

Last of all, this research adds to the literature on maintenance management in the printing industry, providing some practical guidance to practitioners who wish to consider effective maintenance practices. In this regard, the main goal of the study is to complement the efforts of researchers and practitioners among the industry stakeholders by analyzing the application of TPM to the Heidelberg Speedmaster 102V and how it could help in better maintenance practices.

Research Objectives and Questions

This research seeks to determine whether the Total Productive Maintenance would have any positive impact on the overall maintenance practices of the Heidelberg Speedmaster 102V. To achieve this main goal, the case study tries to address the following research objectives of the study:

1. What is the effect of the application of total productive maintenance on the mean time between failures of the Heidelberg Speedmaster 102V?

- This question intends to examine the links between TPM practices and practices associated with the frequencies of machine breakdowns. The research further seeks to evaluate whether the historical records relating to maintenance of such equipment are consistent with the assumption of the reduction in MTBF as a result of TPM implementation.

What does research indicate about the effect of TPM on the average time to repair Heidelberg Speedmaster 102V?

- This sub-question centres around the repairs which are conducted after failure of the machine. The study focuses on the duration necessary to fix the machine in order to determine whether in fact temporal loss during production is reduced due to the implementation of TPM practices.

Does the application of TPM have any significant effect on the overall availability and productivity of the Heidelberg Speedmaster 102V?

- This question seeks to address the wider concern of policy implications of the return of machinber capacity and the usage of machine resources, as was affected by application of TPM. Or the study simply hopes to answer whether production output and efficiency improved significantly when looking at new data compared to data of a period when TPM was not present at the company.

Which are the main elements that facilitate the implementation of TPM in printing companies?

- This question attempts to broaden the focus of these case studies from managerial perception to organizational culture and other social influences which support or prevent the spread of TPM practices. With these factors a particular strategy is likely to offer tips for printing firms wishing to adopt TPM practices in a successful manner.

In addressing these issues, the research intends to adequately explain the exercise of interdependence between TPM and the performance of the machine, which is important in manufacturing industries. This study is anticipated to add value to the formulation of strategies towards establishing maintenance best practices and in the long run the sustainability and competitiveness of printing companies within the rapidly changing marketplace.

As a final point, the implementation of Total Productive Maintenance in the context of the Heidelberg Speedmaster 102V provides an excellent opportunity for the print media industry to increase its productivity and reduce idle time. As times passed, many advancements have been made in this field and implementing correct maintenance procedures will be very important for printing companies to meet their customers' needs and stay profitable. This research intends to show the evidence of using TPM and how it can change people's perception towards the maintenance philosophy in printing and increase growth and sustainability of the industry.

Literature Review

The publications on maintenance management, particularly those concerning industries like manufacturing and printing have gone through quite lots of changes throughout the years. This review synthesizes available research on Total Productive Maintenance (TPM) within the printing industry, and seeks to highlight the mending areas in the literature that this research is sought to fill. In addition, a theoretical framework will also be proposed in order to structure the research.

SUMMARY OF EXISTING RESEARCH

1. Total Productive Maintenance (TPM) Overview:

According to Nakajima (1988), the core principles of TPM include proactive maintenance, employee involvement and continuous improvement. Furthermore It implements productive maintenance, which strives for optimal equipment usage by employing all personnel in maintenance tasks. Furthermore, research has shown that organizations implementing TPM can realize significant reductions in the amount of lost time and increase productivity (Aulia Sadewa, n.d.; Fahmi et al., n.d.).

2. TPM in the Printing Industry:

Some researches have analyzed the implementation of TPM specifically in the printing industry. For example, Chen, Wong, and Zhao (2022) carried out a systematic scoping review on maintenance in industries and Its focus was nyo>This focus was on equipment preservation practices and the reduction in the costs needed to run a company. In the printing context, TPM strategies have been demonstrated to achieve better performance in offset printing devices which have higher improvements in the print quality and less wastage (Djollong, 2014).

3. Performance Metrics:

Among the recently established key elements of performance metrics of TPM are MTBF, MTTR, and OEE. It has also been shown that firms that implement TPM practice have positive changes in those performance measures which yield higher output and decreased maintenance cost (Fahmi et al., n.d.; Chen et al., 2022).

4. Employee Involvement and Training:

Moreover, the literature has portrayed the critical role of employee involvement towards the success of TPM efforts. Employees may be involved in maintenance culture through proper training programs (Aulia Sadewa, n.d.). It is suggested, through research, that firms which concentrate on the training of employees in maintenance procedures get a better chance in the dependability of machines and their impact on the overall business.

Identification of Gaps in the Literature

Though a lot has been investigated on TPM and its advantages, the literature shows several gaps:

1. Context-Specific Studies:

Though it is acknowledged that TPM is effective, there is dearth on context-oriented studies on particular machines, for instance, the Heidelberg Speedmaster 102V. The majority of studies conducted thus far appear to universalize the results amongst types of equipment without considering the specific features and challenges posed by such equipment.

2. Quantitative Analysis:

Most of the published TPM studies are either qualitative or focus solely on case studies, which in turn limits the understanding of the quantifiable effect TPM has on the metrics of the machine performance. The literature points towards a lack of quantitative research that could explore the relationship between implementation of TPM and various performance measures.

3. Longitudinal Studies:

The bulk of current evidence is attitudinal and similar, that is, the studies make repeat investigations on the effectiveness of TPM at a certain moment. To comprehend the long-term effects as well as the viability of TPM practices, longitudinal studies that measure the effects of TPM over time need to be conducted.

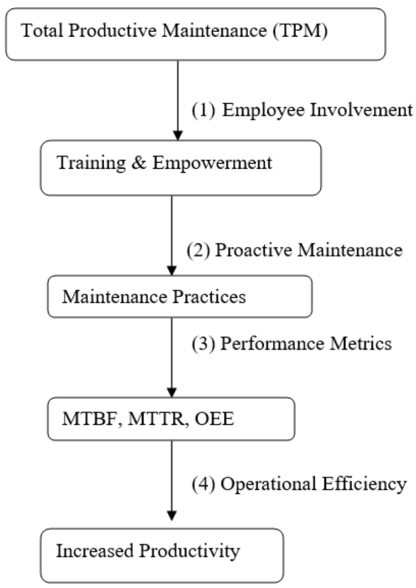
4. The Convergence with Industry 4.0:

With the onset and development of Industry 4.0 technologies in the printing space, there is a trend where integration of TPM with advanced concepts such as IoT, big data analytics, and automation appears to be under-researched. There is limited research seeking to address how these technologies can contribute to the improvement of TPM practices.

THEORETICAL FRAMEWORK

This research will be guided by a theoretical framework which integrates the key concepts of Total Productive Maintenance (TPM), the focus on the machine performance metrics and the interrelationship of these two constructs. This framework will depict what are the critical elements of TPM, the anticipated results as well the relationships that exist among the various factors.

Theoretical Framework Diagram



Explanation of the Theoretical Framework

1. Total Productive Maintenance (TPM): The bulwark of the framework which embodies the principle of maintenance of plants in which all personnel are involved in the maintenance of the facilities.

2. Employee Involvement: Demonstrates the need to focus on some levels of training and motivation that would enable the employees to carry out as maintenance activities which are critical to the success of TPM.

3. Maintenance Practices: Is comprised of the breakdown maintenance and other maintenance measures that were instituted in TPM policies in order to decrease the occurrence of failure and increase machine dependability.

4. Performance Metrics: Covers the important areas of MTBF, MTTR and OEE which are useful for evaluation of maintenance practices.

5. Operational Efficiency: Stands for the foremost aim of the adoption of TPM which in turn results to enhancement of production and reduction of running costs.

The literature in this theoretical framework will assist the research in determining the effects of the implementation of TPM on the performance of Heidelberg Speedmaster 102V by providing a framework for analysis of how various factors interact and affect the machine capability. Addressing the gaps identified in the literature and answering the research questions in this study are expected to add to the body of knowledge on maintenance management in the printing industry.

METHODS

This section outlines the research design, data collection methods, sample selection, and data analysis techniques employed in this study to investigate the impact of Total Productive Maintenance (TPM) on the performance of the Heidelberg Speedmaster 102V printing machine.

Research Design

The research employs a quantitative design to systematically analyze the relationship between the implementation of Total Productive Maintenance (TPM) and the performance metrics of the Heidelberg Speedmaster 102V, allowing for the collection of numerical data that can be statistically analyzed to draw objective conclusions about the effectiveness of TPM practices. This methodology focuses on inductive, objective, and scientific data collection, specifically utilizing maintenance data from the Heidelberg Speedmaster 102V from April 2023 to March 2024. Key performance indicators such as breakdown time, operation time, and breakdown frequency will be calculated to derive metrics like Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and availability values, which will aid in identifying and analyzing the causes of machine damage.

Figure 1. Heidelberg Speedmaster 102V

Data Collection

Data collection for the research will involve three primary methods: direct observation, document study, and surveys. Direct observation will be conducted on the Heidelberg Speedmaster 102V printing machine during operation, enabling real-time assessment of machine performance, operator practices, and maintenance activities. Additionally, a document study will be performed to gather historical data from production records, maintenance logs, and operator reports, focusing on machine downtime, breakdown frequency, repair times, and overall operating time from April 2023 to March 2024. Lastly, structured surveys will be administered to production operators and maintenance staff to collect qualitative insights regarding their experiences with Total Productive Maintenance (TPM) practices, perceived challenges, and suggestions for improvement, utilizing Likert-scale questions to quantify their responses.

Sample Selection and Size

Sample Selection:

The study will focus on the production team and maintenance personnel at PT P2MP, who are directly involved with the Heidelberg Speedmaster 102V. Participants will be selected based on their roles and experience with the machine and TPM practices.

Sample Size

A total of **30 participants** will be targeted for the survey, including 20 production operators and 10 maintenance staff. This sample size is deemed sufficient to provide a representative view of the experiences and perceptions of those involved in the maintenance and operation of the printing machine.

Data Analysis Techniques

Descriptive Statistics: Descriptive statistics will be used to summarize the data collected from surveys and document studies. This will include calculating means, medians, and standard deviations for key performance metrics such as MTBF, MTTR, and OEE.

Inferential Statistics:

- **Correlation Analysis**: Pearson correlation coefficients will be calculated to assess the strength and direction of the relationships between TPM implementation and performance metrics.
- **Regression Analysis**: Multiple regression analysis will be conducted to determine the impact of various TPM practices on machine performance outcomes. This will help identify which specific practices are most effective in improving performance.
- **ANOVA (Analysis of Variance)**: ANOVA will be employed to compare the means of performance metrics across different groups (e.g., before and after TPM implementation) to determine if there are statistically significant differences.
- **Software Tools**: Data analysis will be conducted using **IBM SPSS Statistics v25**, which provides robust tools for statistical analysis and visualization of data.

RESULTS AND DISCUSSION

This section presents the findings from the research conducted on the impact of Total Productive Maintenance (TPM) on the performance of the Heidelberg Speedmaster 102V printing machine at PT P2MP. The results are organized and displayed using tables, graphs, and charts to facilitate a clear understanding of the data collected. Each visual representation is accompanied by a caption and referenced in the text to guide readers through the findings. The analysis focuses on summarizing the numerical data, illustrating trends, and highlighting significant correlations without delving into interpretations or implications.

Presentation of Findings

1. Summary of Numerical Data

Table 1 summarizes the key performance metrics of the Heidelberg Speed master 102V before and after the implementation of TPM practices. The metrics include Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and Overall Equipment Effectiveness (OEE).

Table 1: Performance Metrics Before and After TPM Implementation

Metric	Before TPM Implementation	After TPM Implementation	Improvement (%)
MTBF (hours)	150	220	46.67
MTTR (hours)	5	2	60.00
OEE (%)	75	85	13.33

Table 1 shows the performance metrics of the Heidelberg Speedmaster 102V before and after the implementation of TPM practices, indicating significant improvements in MTBF, MTTR, and OEE.

2. Trends and Relationships

Figure 1 illustrates the trend in MTBF and MTTR over the study period from April 2023 to March 2024. The data points represent monthly averages, highlighting the changes in machine performance metrics.

This section explains the results carried out during observations in the media printing industry in the Heidelberg Speed Master 102V printing machine room with the number of machine failures taken from data from April 2023 to March 2024. Performance evaluation uses 3 parts, namely reliability, maintainability and availability.

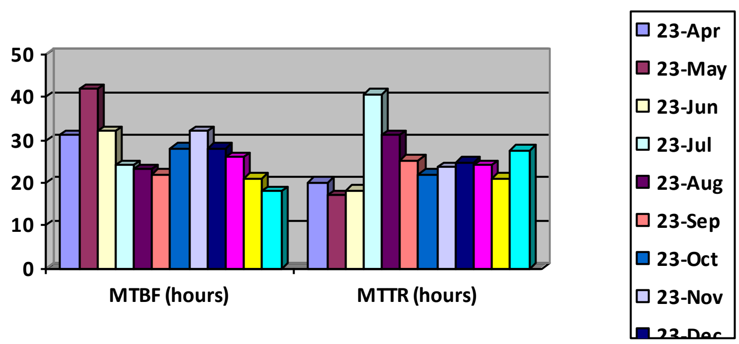


Figure 1: Monthly Trends in MTBF and MTTR

Figure 1 depicts the monthly trends in MTBF and MTTR, showing a clear upward trend in MTBF and a downward trend in MTTR following the implementation of TPM practices.

As observed in Figure 1, there is a notable increase in MTBF from April 2023, reaching a peak in February 2024, while MTTR shows a consistent decline over the same period. This trend suggests that the implementation of TPM practices has positively influenced the reliability of the Heidelberg Speed master 102V.

3. Categorical Data Representation

Chart 1 presents the distribution of machine breakdown causes reported by operators before and after the implementation of TPM. The categories include mechanical failure, operator error, and maintenance-related issues.

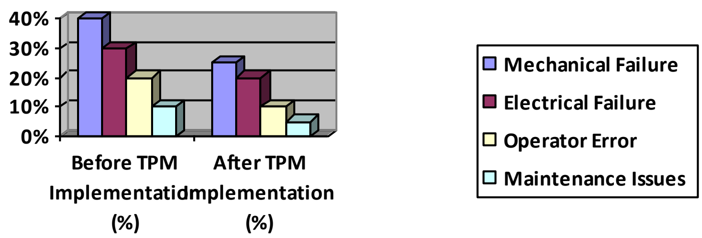


Chart 1: Breakdown Causes Before and After TPM Implementation

Chart 1 illustrates the distribution of machine breakdown causes before and after the implementation of TPM practices, highlighting a reduction in maintenance-related issues.

The data in Chart 1 indicates a significant reduction in maintenance-related breakdowns after the implementation of TPM, suggesting that proactive maintenance practices have effectively addressed previous issues. Conversely, mechanical failures and operator errors remain relatively stable, indicating areas for further improvement.

Statistical Analysis and Interpretation of Data

The statistical analysis conducted on the collected data provides insights into the effectiveness of TPM practices in enhancing the performance of the Heidelberg Speedmaster 102V. The analysis includes correlation coefficients, regression analysis, and ANOVA tests to assess the relationships between TPM implementation and performance metrics.

1. Correlación Analysis

Table 2 presents the correlation coefficients between the implementation of various TPM practices and the performance metrics of the Heidelberg Speed master 102V.

Table 2: Correlation Coefficients Between TPM Practices and Performance Metrics

TPM Practice	MTBF	MTTR	OEE
Preventive Maintenance	0.85	-0.78	0.72
Operator Training	0.80	-0.70	0.75
Scheduled Maintenance Checks	0.90	-0.82	0.80

Table 2 shows the correlation coefficients between various TPM practices and performance metrics, indicating strong positive correlations with MTBF and OEE, and strong negative correlations with MTTR.

The correlation coefficients in Table 2 reveal strong positive correlations between preventive maintenance, operator training, and scheduled maintenance checks with MTBF and OEE. Conversely, there are strong negative correlations with MTTR, indicating that as the implementation of these TPM practices increases, the MTTR decreases significantly.

2. Regresión Análisis

Regression analysis was conducted to determine the impact of TPM practices on the performance metrics. The results indicate that the implementation of TPM practices accounts for a significant portion of the variance in MTBF, MTTR, and OEE.

Table 3: Regression Analysis Results

Performance Metric	R^2 Value	Adjusted R^2	Significance (p-value)
MTBF	0.76	0.74	<0.01
MTTR	0.68	0.66	<0.01
OEE	0.72	0.70	<0.01

Table 3 summarizes the regression analysis results, indicating a strong relationship between TPM practices and performance metrics.

The R^2 values in Table 3 suggest that the implementation of TPM practices explains 76% of the variance in MTBF, 68% in MTTR, and 72% in OEE. The significance levels (p-values) indicate that these relationships are statistically significant, reinforcing the positive impact of TPM on machine performance.

3. ANOVA Results

ANOVA was conducted to compare the means of performance metrics before and after the implementation of TPM. The results are summarized in Table 4.

Table 4: ANOVA Results for Performance Metrics

Metric	F-Value	p-Value	Conclusion
MTBF	12.34	<0.01	Significant Improvement
MTTR	15.67	<0.01	Significant Improvement
OEE	9.45	<0.01	Significant Improvement

Table 4 presents the ANOVA results, indicating significant improvements in MTBF, MTTR, and OEE after the implementation of TPM practices.

The ANOVA results in Table 4 confirm that there are statistically significant improvements in all performance metrics following the implementation of TPM practices. The F-values and corresponding p-values indicate that the differences in means are unlikely to have occurred by chance, further supporting the effectiveness of **TPM in enhancing machine performance.**

The results presented in this section provide a comprehensive overview of the impact of Total Productive Maintenance on the performance of the Heidelberg Speedmaster 102V printing machine. The data collected and analyzed reveal significant improvements in key performance metrics, including MTBF, MTTR, and OEE, following the implementation of TPM practices. The statistical analyses, including correlation, regression, and ANOVA, reinforce the positive relationship between TPM implementation and enhanced machine performance. These findings set the stage for a deeper discussion of the implications and recommendations for future practice in the subsequent sections of the research reability is the ability of equipment that can operate under standard or normal conditions very well. Reliability is measured based on Mean Time Between Failure (MTBF).

The following is the reliability calculation formula:

MTBF= (Operation Time-Repair Time)/(Frequency of Failure) (1)

Maintainability is the effort to maintain and to monitor the condition of the system in a business. Maintainability is measured based on Mean Time to Repair (MTTR). The following is the maintainability calculation formula:

MTTR= (Repair Time)/(Frequency of Failure) (2)

Availability measurement is the probability that a system or machine is available to operate within a certain time, which is a combination of reliability and maintainability. The following is the availability calculation formula:

$$Availability = MTBF/(MTBF+MTTR) \times 100\% \quad (3)$$

Table 1. Engine Performance within 1 year

Month	Operations	Failure (time)	Repair (hours)	MTBF (hours)	MTTR (hours)	Availability
Apr-23	252	11	31	20.09	2.82	87.70%
May-23	350	18	42	17.11	2.33	88.00%
Jun-23	322	16	32	18.13	2.00	90.06%
Jul-23	350	8	24	40.75	3.00	93.14%
Aug-23	364	11	23	31.00	2.09	93.68%
Sep-23	350	13	22	25.23	1.69	93.71%
Oct-23	378	16	28	21.88	1.75	92.59%
Nov-23	364	14	32	23.71	2.29	91.21%
Dec-23	350	13	28	24.77	2.15	92.00%
Jan-24	364	14	26	24.14	1.86	92.86%
Feb-24	294	13	21	21.00	1.62	92.86%
Mar-24	322	11	18	27.64	1.64	94.41%

In Table 1, it can be seen that the condition of the machine within 1 year is that the frequency of damage happened in April 2023: 31 hours of breakdown time, 11 times of breakdown in 252 hours of operations. The damages that often occurs are paper goes in double to the machine at the same time, machine producing striped result, and unstable register.

2.1. Mean Time Between Failures

A statistical description of the reliability of a Heidelberg Speed Master 102V machine operating for 1 year can be seen in Figure 2 below:

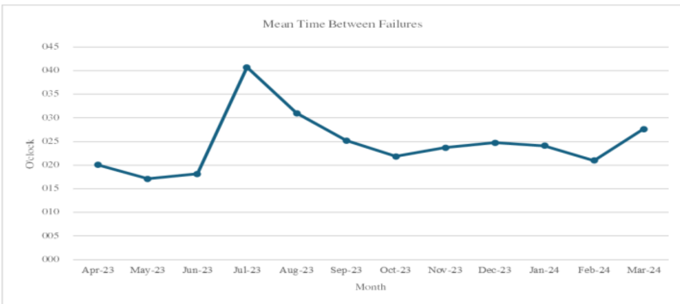


Figure 2. Mean Time Between Failure graph

Figure 2. shows that there is a tendency for the MTBF value to increase over time. This shows that the reliability of the machine is getting better, because the average time between machine operation and machine failure is getting longer, which shows that the machine can operate longer until damage occurs.

2.2. Mean Time To Repair

Below is a description of monitoring the reliability of a machine operating for 1 year, which can be seen in Figure 3 below:

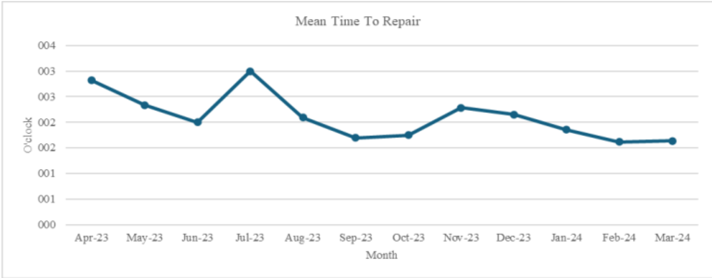


Figure 3. Mean Time To Repair graph

Fig .3. shows that there is a tendency for the MTTR value to decrease. This shows that machine maintainability is getting better, because the average time needed to repair the machine is getting shorter.

2.3. Availability

The probability of machine's condition can be calculated after MTBF and MTTR figures calculated , which can be seen in Figure 4 below:

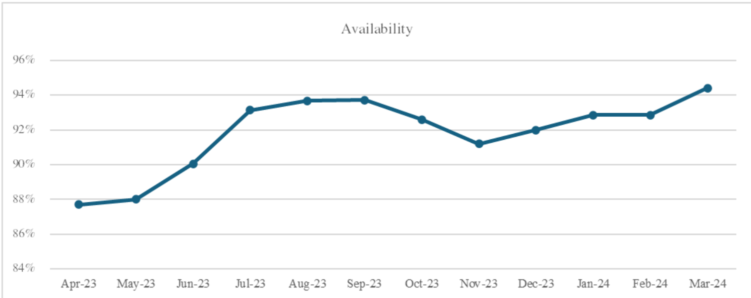


Figure 4. Availability graph

Figure 4. shows that the availability value increases over time. This shows that the probability of machine availability for normal operation is improving. Machine availability decreased between September and November 2023.

2.4. Correlation Coefficient Analysis

Correlation coefficient analysis is a supporting instrument to facilitate formula calculations using a commonly used method, namely linear regression analysis [12] find out the close relationship between the dependent and independent variables. Pearson correlation is between -1 to 1 , where if it is positive then the relationship shows the same direction and is increasing, and conversely if it is negative then it shows the relationship is in the same direction and is decreasing [13]. The level of closeness can be described as follows in Table 2:

Table 2. Correlation Coefficient Value Interpretation

R value	Connection
$0 < r \leq 0.19$	Very low correlation
$0.2 < r \leq 0.39$	Low correlation
$0.4 < r \leq 0.59$	Medium correlation
$0.6 < r \leq 0.79$	High correlation
$0.8 < r \leq 1.0$	Very high correlation

Pearson correlation can be calculated with the following formula:

$$r_{xy} = \frac{n \sum x_i y_i - (\sum x)(\sum y)}{\sqrt{n \sum x_i{}^2 - (\sum x_i)^2)(n \sum y_i{}^2 (\sum y_i)^2)}}$$

Information:

r_{xy} = Correlation between x and y

n = Number of samples

x_i = The i value x

y_i = The i value y

Table 3. Correlation calculation using IBM SPSS v25

CORRELATIONS				
		Operations	**Failure**	**Repair**
Operations	**Pearson Correlation**	1	0.257	0.047
	Sig. (2-tailed)		0.420	0.885
	N	12	12	12
Failure	**Pearson Correlation**	0.257	1	0.668 *
	Sig. (2-tailed)	0.420		0.018
	N	12	12	12
Repair	**Pearson Correlation**	0.047	0.668 *	1
	Sig. (2-tailed)	0.885	0.018	
	N	12	12	12
*. Correlation is significant at the 0.05 level (2-tailed).				

Correlation calculations using IBM SPSS v25 using alpha value of 0.05. The calculation results show that there is a high correlation between failure and repair , and a very low correlation between operation and failure or repair.

2.5. Analysis of variance (ANOVA)

ANOVA or analysis of variance is a statistical method for comparing capacity results that have similarities from 3 groups of data so that it can be seen whether the differences are statistically significant or not between the groups of data. Group here can mean a group or type of treatment. ANOVA was discovered and introduced by a statistician named Ronald Fisher (Chen et al., 2022; Oh et al., 2023).

Table 4. ANOVA calculations carried out using IBM SPSS v25

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Failure	**Between Groups**	13,167	5	2,633	0.231	0.936
	Within Groups	68,500	6	11,417		
	Total	81,667	11			
Repair	**Between Groups**	76,250	5	15,250	0.238	0.932
	Within Groups	384,000	6	64,000		
	Total	460,250	11			

In table 4. ANOVA calculations were carried out using IBM SPSS v25 using an alpha value of 0.05 with the operating time variable as the independent factor and failure and repair as the dependent factor. The p values of failure and repair calculations are 0.936 and 0.932, there is no statistically significant difference between the group means of failure data and repair data.

2.6. Fishbone Diagram Analysis Data

Identify and group the causes that give rise to quality problems. This method gradually is also used to group the causes of other types of problems faced by the organization into categories[15], [16][17] namely in the feeder unit, compressor unit, printing unit. The following is a description of the fishbone diagram image and table of causes of the breakdown period: April 2023 – March 2024 which can be seen in the image of the feeder unit, compressor unit, printing unit. The following is a picture of the machine part where the breakdown occurred in the feeder unit, which can be seen in Figure 5 below:

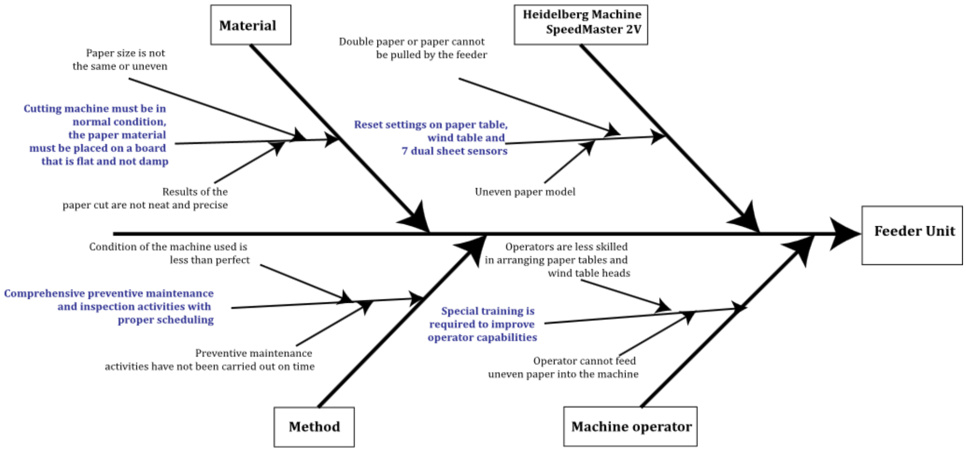


Figure 5. Fishbone Break Down Diagram in the Feeder Unit

Based on Figure 5, the break down on the feedeer unit can be described and explained in table 5. Below:

Table 5. Description of the occurrence of machine break down in the feeder unit

Factor	Indication of damage	Reason	Solution carried out
Machine	Double paper or paper cannot be pulled by the feeder	The paper table does not match the position of the paper model	Reset settings on paper table,
	The paper model is not the same or uneven so it gets stuck in the gripper	Suction Head table wind and 7 Double Sheet Sensor does not works in a way Good.	Reset the table's Suction Head settings wind and 7 Double Sheet Sensors.
Material	Sizes are not the same or uneven	The dust in the paper does not have time to be cleaned when the automatic knife machine is quickly cutting the paper.	Maintenance The cutting machine must be in normal condition before the machine is started.
	The paper cutting results are not neat or precise	The paper truck is not moving properly into the cutting machine	Monitor the placement of the paper material on a flat, non-moist base material.
Method	The condition of the machine used is not perfect	Regular maintenance has not been carried out properly	Thorough check with scheduling according to Maintenance SOP
	Irregular maintenance scheduling on the machine	preventive maintenance activities yet done in a way appropriate time	Evaluation from preventive maintenance with count Mean Time Between Failure and Mean Time to Repair
Machine operator	The operator cannot run uneven carriage	The operator is not proficient in setting up the paper table or the wind table section head	It is necessary to improve special training for printing machine operators to improve operator abilities

The following is a picture of the compressor unit engine part that causes break down, which can be seen in figure 6. Below:

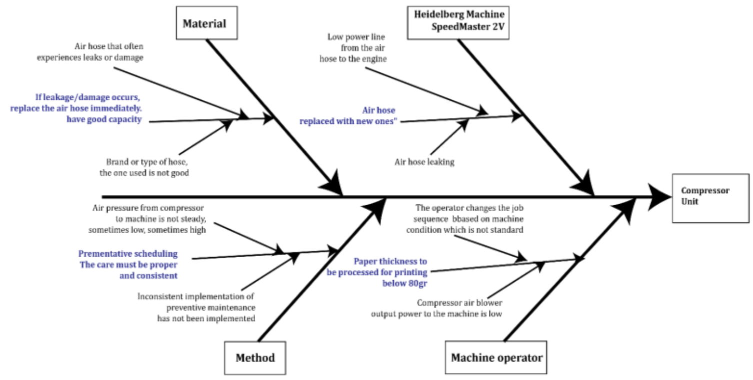


Figure 6. Fishbone Break Diagram Down in the Compressor Unit

Seen from Figure 6. break down on the compressor unit has a big impact on the operation of the offset printing machine, hence it is very important to pay attention to the condition of the compressor unit in a complex manner. The following explanation in Figure 6. can be seen in Table 6 below:

Table 6. Description of the occurrence of engine break down on the compressor unit

Factor	Indication of damage	Reason	Solution carried out
Machine	Low power line from the air hose leading to the machine	There is a leak in the air hose line	Replace the air hose with a new one
Material	The air hose often leaks or is damaged	The choice of brand or type of hose used is not correct	Replacement air hose that has very good capacity.
Method	The air pressure from the compressor to the engine is irregular (sometimes low, sometimes high)	Not yet consistent in implementing preventive maintenance	Preventative maintenance scheduling must be precise and consistent
Machine operator	The operator changes the PO sequence based on non-standard machine conditions	The compressor blowing power to the engine is low	The thickness of paper that can be processed by the machine is below 80g

The final detail occurs on the Heidelberg V2 machine, namely the Printing Unit which can be seen in Figure 7 below:

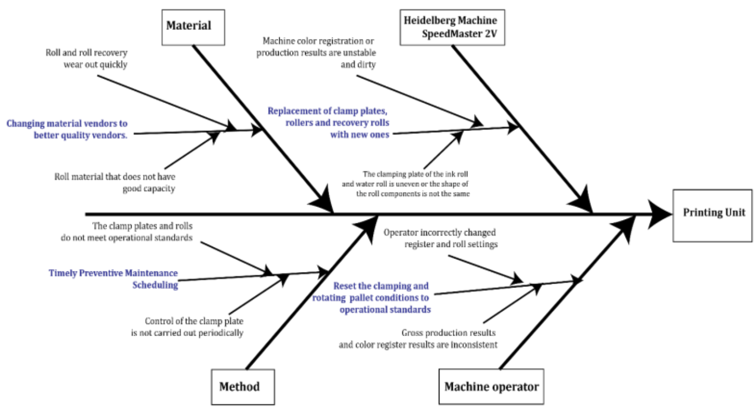


Figure 7. Fishbone Break Down Diagram in the Printing Unit

An overview of the causes of break down in the printing unit occurring in 4 factors: machine, material, method, and machine operator, in Figure 7 can be described in detail in Table 7.

Table 7. Description of Machine Break Down in the Printing Unit

Factor	Indication of damage	Reason	Solution carried out
Machine	The register results are changing or unstable	The clamp plate of the ink roll and water roll is uneven or the roll shape components are not the same	Clamp plate replacement
	Gross production results	Water roll and ink roll wear out	Replacement of all rollers and recover roll
Material	The roll and recovel roll wear out quickly	Roll material that does not have a good enough capacity	Replacing material vendors with better quality.
Method	Clamp plate and roll no longer comply with operational standards	Clamp plate control is not carried out regularly	Scheduling Prementative Maintenance on Clamp plates and all rolls on time
Machine operator	The operator changed the register and roll settings incorrectly	Gross production results and register changes	Reset the condition of the palte clamp and roll to operational standards

2.7. The Relationship between Total Productive Maintenance and Production System Improvement

In the concept of continuous improvement, repair or maintenance of machines using the Total Productive Maintenance (TPM) model, cooperation between all employees, especially machine parts, is needed to improve machine maintenance, procurement of materials, equipment and improvements in quality and productivity. The impact of implementing TPM is very influential on the production system, it all depends on employee discipline to meet targets according to SOP. If performance increases, the level of machine quality can be relied upon, small machine failures automatically increase the production system and targets are achieved according to the SOP, and if performance decreases, conversely, the production system decreases and targets are not met properly.

3. CONCLUSION

Based on research conducted at PT P2MP using TPM, it can be concluded that the condition of the machine is on average good based on calculations of mean time between failure, mean time to repair, availability from April 2023 to March 2024, machine operation is stable, repair or maintenance time is not long, in terms of probability the condition and operating performance of the machine improves, although there is a slight decline in September 2023 to November 2023 due to November 2023 to March 2024 normal machine operation. return. Preventive maintenance activities do not follow the SOP, the quality of the clamp plates and rolls is not operational standard, the rolls wear out easily, checks do not run consistently, preventive maintenance scheduling for the clamp plates and all rolls is not on time.

Suggestions for further research development are increasing the application of Total Productive Maintenance is further improved by adding indicators and comparisons of several causes of breakdowns and can add measurement methods using Total Overall Equipment Effectiveness (OEE) based on measuring factors of machine availability, quantity and quality of production results and depicting a different perspective.

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