Performance Assessment Based on Reliability of Weaving M251 Machine Using Reliability, Availability & Maintainability (RAM) and Cost of Unreliability (COUR) Methods (Case Study at PT Buana Intan Gemilang)

Devi Julietta Nainggolan[1], Judi Alhilman[2], and Nurdinintya Athari Supratman[3]
[1,2,3]Department of Industrial Engineering, School of Industrial Engineering, Telkom University
[1]devijulietta@gmail.com, [2]alhilman@telkomuniversity.ac.id, [3]nurdinintya@telkomuniversity.ac.id

Corresponding author: devijulietta@gmail.com
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Abstract— The textile industry is one of industries that has an important role in the national economy. *PT Buana Intan Gemilang* (BIG) is one of textile industry in Indonesia which uses Weaving machine to produce *motif* and *sajadah* fabrics. The purpose of this research is to analyze the reliability of Weaving M251 machine that has the most damage in 2014. To avoid losses due to machine damage, the reliability, availability and maintainability of the machine need to be improved by using Reliability, Availability & Maintainability (RAM) Analysis method. In addition, the total cost caused by RAM problems can be calculated by using Cost of Unreliability (COUR) method. Based on the evaluation using Reliability Block Diagram (RBD) modeling, it is found that the critical subsystem reliability = 44.36% for 144 working hours and the total repair time that the critical subsystem needs to perform in acceptable operational condition , at least in 1 to 70 hours. There are two different forms of availability that have been calculated, therefore inherent availability = 95,546% which is used as leading indicator, and operational availability = 85,572% which used as lagging indicator. as it is compared, lagging indicator does not meet the performance of leading indicator. The total of unreliability cost when the machine is in active repair time = 39,580,689.02 IDR and within downtime = 135,588,452.13 IDR.

Keywords—Cost of Unreliability (COUR), Lagging Indicator, Leading Indicator, Reliability, Availability & Maintainability (RAM) Analysis.

I. INTRODUCTION

1.1. Research Background

Textile industry is one of the priority industries in Indonesia because it has an important role in the national economy. According to the Bureau of Public Affairs and The Ministry of Public Relations of Industry Jakarta, when the global economic crisis happened, the national *Indsutri Tekstil dan Produk Tekstil* (ITPT) can still earn not less than US $ 5 billion, 1.34 million labor absorption, up to 63% *Tingkat Komponen Dalam Negeri* (TKDN) and contribute to meet domestic needs for about 46%. However, this cannot be a warranty due to Indonesia's export-import performance that is still slow compared to other countries caused by several potential factors, such as internal factors; old machining technology conditions that need maintenance, etc.

PT *Buana Intan Gemilang* (BIG) is a textile industry that produce *motif* and *sajadah* fabrics as the main products. In the production process, PT BIG uses 281 similar Weaving machines in which the work processes are divided by the type of fabric produced. Weaving machine at PT BIG is distinguished by using serial number 001 (M001) up to 281 (M281), where Weaving machine M001-M141 produce *sajadah*, and M142-M281 produce *motif* fabric product. Fig. 1 presents the failure data of Weaving machine that produce *motif* fabrics in 2014.

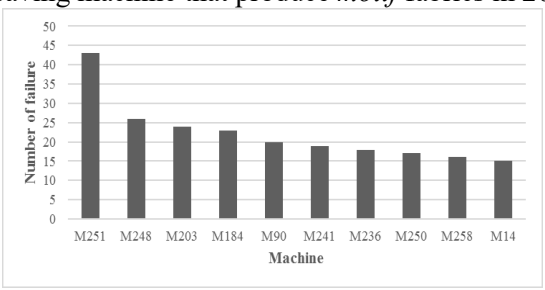

Fig. 1 Failures Data of Weaving Machine that Produce *Motif* Fabrics in 2014

Fig. 1 shows that the largest number of failure is from Weaving M251 machine. Fig. 2 pictures the availability of Weaving M251 machine in 2014.

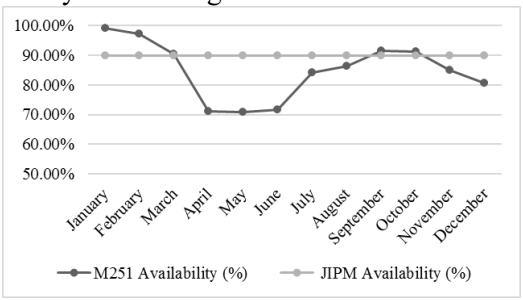

Fig. 2 Availability of Weaving M251 Machine

Fig. 2 displays that in certain month, the existing availability of Weaving M251 machine is still below the standard of availability of Japan Institute of Plant Maintenance (JIPM), which is 90% [1]. To avoid losses due to machine damage, the reliability,

availability and maintainability of the machine needs to be improved by using Reliability, Availability & Maintainability (RAM) Analysis method, using Reliability Block Diagram (RBD) modeling. The availability results that are obtained from RAM Analysis can be used as Maintenance Performance Indicator as leading and lagging indicator to know the work performance of machine in real operation condition. The total cost due to the unreliability of the machine can be calculated by using Cost of Unreliability (COUR) method.

1.2. Research Problem

Based on the company conditions in the research background, there are some research problems that have been concluded, they are:

1. How is the Reliability, Availability and Maintainability of Weaving M251 machine?
2. How is the Cost of Unreliability of Weaving M251 machine?
3. How is the Maintenance Performance Indicator of Weaving M251 machine?

1.3. Research Objective

Based on the research problems that have been mentioned, there are some objectives of this research, such as:

1. Knowing the Reliability, Availability and Maintainability of Weaving M251 machine.
2. Knowing the Cost of Unreliability of Weaving M251 machine.
3. Knowing the Maintenance Performance Indicator of Weaving M251 machine.

II. THEORETICAL BACKGROUND

2.1 System Breakdown Structure

System Breakdown Structure (SBS) is a tool that is used to divide the hierarchical structure of a machine into system level, subsystem and component in the work function of machine [2].

2.2 Risk Priority Number

Risk Priority Number (RPN) is used to determine the main risk of failure mode in a system by multiplying the value of severity (S), occurrence (O) and detection (D) factor of a system failure [3]. Severity means the frequency of effect (seriousness) of a failure. Occurrence means the frequency of failure and detection, it means the ability of the system to detect a failure before the failure appears [4].

2.3 Life Data Analysis

Life Data Analysis is used to predict the life of a machine by adjusting a statistical distribution of life data from the time samples during operation time of machine [5]. The statistical distribution is used to estimate the characteristics of a machine, such as: reliability, mean life and failure rate.

2.4 Reliability

Reliability is defined as the probability of a machine or system that will give a satisfactory ability to achieve a goal in a specified period of time under certain environmental conditions [6]. The reliability functions based on failure distribution are expressed as (1), (2) and (3) [2].

1. Exponential Distribution

$$R(t) = e^{-\lambda t} \tag{1}$$

where λ = failure rate
t = operation time

2. Weibull Distribution

$$R(t) = 1 - \Phi\left(\frac{t-\mu}{\sigma}\right) \tag{2}$$

where μ = mean time
σ = standard deviation

3. Normal Distribution

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \tag{3}$$

where β = *shape parameter*
η = *scale parameter*

2.5 Maintainability

Maintainability is related to the maintenance duration required for a damage machine to be restored into a good working condition within a predetermined period and with certain maintenance procedures, refer to (4). The following formulation illustrates the function for calculating maintainability value [7].

$$M(t) = 1 - \exp\left(\frac{-t}{MTTR}\right) \tag{4}$$

where MTTR = Mean Time to Repair

2.6 Availability

Availability is the probability that a system can ~~be~~ work as its function within a certain period of time in predefined operating conditions [2]. Equation (5) and (6) show the calculation of availability value [8].

1. Inherent Availability

$$Ai = \frac{MTTF}{MTTF + MTTR} \tag{5}$$

where MTTF = Mean Time to Failure

2. Operational Availability

$$Ao = \frac{Uptime}{TotalTime} = \frac{CH - MH}{CH} \quad (6)$$

where CH = Calendar Hours (Total Time)
MH = Maintenance Hours

2.7 Cost of Unreliability (COUR)

Cost of Unreliability (COUR) is an effort that can be used to evaluate and minimize the cost of a failure system. There are three main steps for calculating COUR. First, calculating the failure rate of machine based on failure data, calculating the time lost caused by the active repair and downtime of the machine and then calculating the money lost caused by the unreliability of the machine [9]. The equation to determine the money loss due to the unreliability of the machine can be defined as (7) [10].

$$COUR = Cost\ of\ component\ replacement + Cost\ of\ lost\ availability \quad (7)$$

2.8 Maintenance Performance Indicator

Maintenance Performance Indicator (MPI) is used to measure the effect of maintenance activities to the work performance of a system [11] [12]. In this research, performance indicators for maintenance activities are divided into two categories, they are leading indicator and lagging indicator. Leading indicator is a performance driver used to evaluate and maintain the work performance that has been planned on the target that has been set [13]. Lagging indicator is used to determine what needs to be improved in the future to improve the performance of the entire system [13].

III. The Comparison with Previous Studies

Table 1. illustrates differences between the current research and the previous research, although using the same several combinations of methods. In this study, the research focus on Weaving machine at PT BIG by using RAM Analysis and COUR methods, the purpose is to know the reliability, availability & maintainability and total cost due to unreliability of machine.

TABLE 1
THE COMPARISON WITH PREVIOUS STUDIES

Author	Rahmawati, D. N., Ya'umar & Hs. M. I.	Saputra, M. T. D., Alhilman, J., & Supratman, N. A.	Author
Research Title	The Evaluation of Reliability and Safety on The Controlling System of Level Syn Gas 2ND Interstage Seperator at PT Petrokimia Gresik	Maintenance Policy Suggestion on Printing Machine GOSS Universal Using Reliability Availability Maintainability (RAM) Analysis and Overall Equipment Effectiveness (OEE)	Performance Assessment based on Reliability of Weaving M251 Machine by Using Reliability Availability Maintainability Analysis (RAM) and Cost of Unreliability (COUR) Methods
Year of Research	2013	2016	2017
Focus of The Study	Level Syn Gas 2ND Interstage Seperator - PT Petrokimia, Gresik	Printing Machine GOSS - PT Pikiran Rakyat, Bandung	Weaving Machine – PT Buana Intan Gemilang
Research Method	RAM Analysis & Quantitative method of the human and cost risks.	RAM Analysis & Overall Equipment Effectiveness (OEE)	RAM Analysis & COUR
Research Objective	Evaluating the calculation of reliability and Safety Integrity Level (SIL) that used in Separator Level Controlling System.	Obtaining the availability rate, performance rate, quality rate and plant availability factor to determine the maintenance policies of machine.	Knowing the reliability, availability factor & maintainability and the total cost of unreliability problems of machine.

IV. Result and Discussion

There are some initial calculations for maintenance data of Weaving M251 machine in 2014. the data are as follows:

1. System Breakdown Structure
   Divide the hierarchical structure of the Weaving M251 machine into system level, subsystems and components. System breakdown is based on machine movement system.
2. Determining the Critical Subsystem
   In determining the critical subsystem, this research is using Risk Priority Number (RPN) tools based on severity, occurrence and detection criteria. As the result, Shedding Motion is chosen as the critical subsystem, with the priority components such as Card, Needle, Hook and Harness Rope.
3. RBD Modelling
   Then, the critical subsystem is defined by using RBD modeling. Fig. 3 is a RBD modelling that has been determined based on the priority components of the critical subsystem.

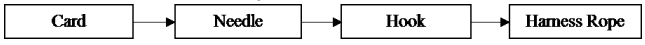

Fig. 3 Reliability Block Diagram of Weaving M251 Machine

4. Determining the Representative Distribution

In determining the representative distribution, this research is using Anderson-Darling test with Minitab software. The data that being tested are Time to Failure (TTF), Time to Repair (TTR) and Downtime (DT) data of critical components by using Exponential, Weibull and Normal distributions.

5. Distribution Plotting
   Distribution plotting for TTF, TTR and DT. The Parameter data is obtained based on representative distribution by using AvSim+ software.

3.1 Reliability

Reliability calculation of each component is done by using parameters of TTF data. The time given is about 8 to 144 hours (6 working days or 1 week), with time interval is 8 hours in accordance with the working time of the machine in one shift (company's policy). After calculating the reliability value of each component, then calculating the reliability of critical subsystem using analytical reliability formula based on RBD model that has been determined in Fig. 3, Table 2 shows the results of reliability calculation of critical subsystem.

TABLE 2
RELIABILITY RESULT

t (hours)	R Card	R Needle	R Hook	R Harness Rope	R Subsystem
8	92.40%	90.41%	99.99%	99.54%	83.15%
16	88.35%	90.17%	99.96%	99.00%	78.84%
24	85.13%	89.92%	99.92%	98.43%	75.29%
32	82.37%	89.67%	99.86%	97.83%	72.16%
40	79.93%	89.42%	99.79%	97.22%	69.33%
48	77.72%	89.16%	99.70%	96.59%	66.73%
56	75.69%	88.89%	99.60%	95.95%	64.30%
64	73.81%	88.62%	99.48%	95.31%	62.02%
72	72.06%	88.35%	99.35%	94.66%	59.87%
80	70.41%	88.07%	99.20%	94.01%	57.83%

TABLE 3
RELIABILITY RESULT (a)

t (hours)	R Card	R Needle	R Hook	R Harness Rope	R Subsystem
88	68.85%	87.79%	99.04%	93.35%	55.88%
96	67.38%	87.51%	98.86%	92.69%	54.03%
104	65.98%	87.21%	98.67%	92.02%	52.25%
112	64.65%	86.92%	98.47%	91.36%	50.55%
120	63.37%	86.62%	98.25%	90.69%	48.91%
128	62.15%	86.31%	98.02%	90.02%	47.34%
136	60.98%	86.00%	97.78%	89.35%	45.82%
144	59.86%	85.69%	97.52%	88.68%	44.36%

3.2 Maintainability

Maintainability calculation of each critical component is done by using repair time data (TTR) of the machine. The time interval is 2 hours with the time given is 2 to 70 hours until each component reaches the maximum maintainability value = 100%. Table 3 shows the maintainability of each critical component.

TABLE 4
MAINTAINABILITY RESULT

t (hours)	Card	Needle	Hook	Harness Rope
2	52%	15%	19%	14%
4	77%	29%	35%	27%
6	89%	40%	48%	37%
8	95%	49%	58%	46%
10	97%	57%	66%	54%
12	99%	64%	73%	61%
14	99%	69%	78%	66%
16	100%	74%	82%	71%
18	100%	78%	86%	75%
20	100%	81%	89%	79%
22	100%	84%	91%	82%
24	100%	87%	93%	84%
26	100%	89%	94%	87%
28	100%	90%	95%	89%
30	100%	92%	96%	90%
32	100%	93%	97%	92%
34	100%	94%	97%	93%
36	100%	95%	98%	94%
38	100%	96%	98%	95%
40	100%	97%	99%	96%
42	100%	97%	99%	96%
44	100%	98%	99%	97%
46	100%	98%	99%	97%
48	100%	98%	99%	98%
50	100%	99%	100%	98%
52	100%	99%	100%	98%
54	100%	99%	100%	98%
56	100%	99%	100%	99%
58	100%	99%	100%	99%
60	100%	99%	100%	99%
62	100%	99%	100%	99%
64	100%	100%	100%	99%
66	100%	100%	100%	99%
68	100%	100%	100%	99%
70	100%	100%	100%	100%

3.3 Availability

Availability calculation is done by using RBD model in Fig. 3. Referring to Table 4 and Table 5, there are two types of availability that have been obtained such as inherent availability and operational availability.

TABLE 4
INHERENT AVAILABILITY RESULT

t (hours)	A Card	A Needle	A Hook	A Harness Rope	A Sub-system
8760	99.51%	98.44%	98.94%	98.59%	95.55%

TABLE 5
OPERATIONAL AVAILABILITY RESULT

t (hours)	A Card	A Needle	A Hook	A Harness Rope	A Sub-system
8760	95.46%	95.80%	97.74%	95.74%	85.57%

3.4 Cost of Unreliability (COUR)

COUR calculation begins with failure rate calculation by using MTTF data that shows on Table 6.

TABLE 6
FAILURE RATE RESULT

	Card	Needle	Hook	Harness Rope
Study Interval (Hours)	8760	8760	8760	8760
Number of Failure(s)	16	10	9	8
MTTF	554.23	751.33	858.17	898.12
Failure Rate	0.00180	0.00133	0.00117	0.00111

Then, determining the time lost during corrective time and downtime as is calculated on Table 7 and Table 8.

TABLE 7
CORRECTIVE TIME LOST RESULT

	Card	Needle	Hook	Harness Rope
Failure Rate	0.18%	0.13%	0.12%	0.11%
Number of Failures	16	10	9	8
Corrective Time/Failure (MTTR)	2.73	11.90	9.22	12.88
Corrective Lost Time Hour/Year	43.74	119.00	83.00	103.00

TABLE 8
DOWNTIME LOST RESULT

	Card	Needle	Hook	Harness Rope
Failure Rate	0.18%	0.13%	0.12%	0.11%
Number of Failures	16	10	9	8
Downtime/Failure (MDT)	21.39	31.40	19.36	43.85
Downtime Lost Time Hour/Year	342.17	314.00	174.23	350.79

After determining the failure rate and time lost for the subsystem, then, calculating the money lost during corrective time and downtime by using lost production, equipment cost and labor maintenance data as is shown on Table 9 and Table 10.

TABLE 9
CORRECTIVE COUR RESULT

	Card	Needle	Hook	Harness Rope
Corrective Lost Time Hours/Year	43.740	119	83.002	103
Number of Failure	16	10	9	8
Loss Production Cost	Rp3,341,283.28	Rp9,090,277.78	Rp6,340,400.96	Rp7,868,055.56
Equipment/ Component Cost	Rp4,909,848.80	Rp968,655.50	Rp2,761,789.95	Rp974,924.40
Engineer Cost	Rp417,089.81	Rp1,134,732.35	Rp791,467.35	Rp982,163.29
Corrective COUR	Rp8,668,221.89	Rp11,193,665.62	Rp9,893,658.26	Rp9,825,143.25

TABLE 10
DOWNTIME COUR RESULT

	Card	Needle	Hook	Harness Rope
Downtime Lost Time Hours/Year	342.165	314	174.234	350.792
Number of Failure	16	10	9	8
Loss Production Cost	Rp26,137,616.60	Rp23,986,111.11	Rp13,309,575.13	Rp26,796,601.45
Equipment/ Component Cost	Rp11,029,848.80	Rp7,088,655.50	Rp8,881,789.95	Rp7,094,924.40
Engineer Cost	Rp3,262,738.47	Rp2,994,167.70	Rp1,661,423.97	Rp3,344,999.04
Downtime COUR	Rp40,430,203.87	Rp34,068,934.31	Rp23,852,789.05	Rp37,236,524.89

Referring to Table 9 and Table 10, the total cost during downtime machine is much greater than the corrective time machine. This is because the downtime lost is higher than the corrective time lost, it means that the machine cannot works effectively and the company needs to do more efficient maintenance policies.

V. CONCLUSION

Based on calculation using RAM Analysis with RBD modeling it is found that the critical subsystem reliability = 44.36% with operation time = 144 hours. Based on maintainability calculations, it is found that the total repair time that the critical subsystem needs to perform in acceptable operational condition is at least in 1 to 70 hours. For availability calculation, there are two different forms of availability that have been obtained, therefore inherent availability = 95.546% and operational availability = 85.572%. If it is compared to JIPM standards = 90%, the operational availability value does not meet the standard, so it is necessary to improve the operational condition of the company.

Based on the calculation using COUR method, the total cost due to the unreliability of machine within active repair = 39,580,689.02 IDR and within downtime = 135,588,452.13 IDR. Thus, the calculated loss is 96,007,763.10 IDR that must be paid by the company as a result of activities other than active repair (waste).

Based on the analysis using Maintenance Performance Index to the availability value, it is shown that the lagging indicator value (operational availability) = 85.572% it does not meet the target value of leading indicator (inherent availability) =

95.546%. This suggests that some maintenance policies are required to improve the efficiency of machine.

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