DETERMINING PREVENTIVE MAINTENANCE SCHEDULING OF TIRE BUILDING MACHINE IN PT. ABC

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THESIS ADVISOR
RECOMMENDATION LETTER

This thesis entitled "**Determining Preventive Maintenance Scheduling of Tire Building Machine in PT. ABC"** prepared and submitted by **Aldino Fajri** in partial fulfillment of the requirements for the degree of Bachelor Degree in the Faculty of Engineering has been reviewed and found to have satisfied the requirements for a thesis fit to be examined. I therefore recommend this thesis for Oral Defense.

Cikarang, Indonesia, January 25, 2017

Anastasia Lidya Maukar, ST.,M.Sc.,M.MT.

DECLARATION OF ORIGINALITY

I declare that this thesis, entitled "**Determining Preventive Maintenance Scheduling of Tire Building Machine in PT. ABC"** is, to the best of my knowledge and belief, an original piece of work that has not been submitted, either in whole or in part, to another university to obtain a degree.

Cikarang, Indonesia, January 25, 2017

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ABSTRACT

Maintenance activity is one of the most important and critical matter during production process in the company. PT. ABC as one of tire manufacturer currently deals with problem regarding to reliability in Tire Building Machine. Tire Building Machine (TBM) is required to be always in a good condition over the time since TBM is one of the critical machine in producing tire. Machine breakdown in TBM Samson 1 contributes to the stoppage of producing green tire. Therefore this condition will make the company gain more losses especially in cost due to the breakdown and green tire shortage. The stages of this researches begins by determining the critical machine and determining the most critical components using Pareto chart. After that probability densitiy function, cummulative density function, reliability function and failure distribution are needed in order to determine the maintenance interval time. This research will contribute to give suggestion and recommendation for the company due preventive maintenance schedule in order to increase the reliability in TBM and reduce maintenance cost. The company was given three scenario based on the desired realibility in TBM. PT. ABC has a full right to choose which scenario fits with the condition. By implementing the first scenario (65% of reliability), the reliability of TBM Samson 1 increases 22.34% and can reduces cost as much as 60.19% from the current cost. In the second scenario (75% of reliability), the reliability increases 32.34% and reduces cost 38.92% from current cost. The last scenario (85% of reliability), the reliability increases 42.34% and can reduces cost 16.65%.

Keywords: *Tire Building Machine, probability density function, cummulative density function, reliability, failure distribution, maintenance interval time*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TERMINOLOGIES

Tire building machine	: Machine used to assembly all of the compound in order to produce green tire
Green tire	: The result of assembling all of compound in tire building machine
Ply servicer	: Part of tire building machine that used to transfer ply from let off to the conveyor
Downtime	: A period of time when a system is unavailable or fails to perform its primary function
Mean time to repair	: Average time required to repair a failed component or machine
Mean time to failure	: Average time that an item will function before it fails, commonly used for non-repairable component
Mean time between failure	: Average time between failures for repairable system with a constant failure rate
Preventive maintenance	: A maintenance activity that performed periodically at a certain time to find out the conditions that can caused failure on the machine or components
Corrective maintenance	: A maintenance activity that is completed after the failure happends on the machine or equipment where it is not functioning properly
Waiting time	: A period of time that starts from the machine stops until the maintenance process starts
Parameter	: Indicator of the measurement results of a distribution

CHAPTER I

INTRODUCTION

1.1 Problem Background

PT. ABC well-known as tire manufacturer in Indonesia. The tires produced in PT. ABC consist of various types that differentiated in size, function, and materials. In general, PT. ABC produce 4 types of tires known as Passenger Car Radial (PCR), Truck Bus Radial (TBR), motorcycle tire, and solid tire. In line with the company's objective to be a leader and trend setter in the tire industry, PT. ABC has to produce high quality tire consistently over the time. The company has to ensure that all of the production processes already well-organized and the existing machine are in the good condition. In order to keep the existing machine perform in the good condition PT. ABC should have well-organized maintenance process.

Maintenance activity is organized to keep the machine or equipment always performing in the same condition to its initial condition. Breaks down machine that happend during production process can disrupt the production process to achieve the targets. By doing preventive maintenance the company can schedule regular maintenance for the machine and its components optimally. Preventive maintenance is an approach to enhance the reliability and quality of a system and its components. The implementation of preventive maintenance is to replace the need of corrective maintenance. Therefore, unncessary cost after the failure occurs can be reduced or avoided (Shah *et al.*, 2014).

The maintenance activities in PT. ABC has not managed well. The maintenance has not done regulary or periodically. It can be seen that there is no specific scheduling of machine maintenance that based on the reliability and failure rate of the machine. According to collected data from the company, during January 2016 until July 2016, machine downtime from PCR tire building machine (TBM) Samson 1 reached 171.48 hours or 6.38% from the total working hours (2,688 hours). TBM Samson 1 is a machine that used to assembly all material required in producing green tire before it transfers to the curing machine and become ready-made tire.

Cutter ply 1, sensor machine and cutter ply 3 are the part of the machine that contribute most towards downtime in TBM Samson 1. Even though during January until July 2016 the machine downtime is only 6.38% from total working hours, it causes loss of production and the company pay more costs that will reduce the profit. From 33.46 hours downtime that caused by cutter ply 1, sensor machine and cutter ply 3, the company can not produce 635 green tires. In the end, the company gain loss as much as IDR 635,000,000 during January 2016 until July 2016. Besides that from waiting time which start from machine stops until it starts the production process, those 3 components above contribute 19.68 hours or 58.8% from total downtime. Because of that the company can not produce 373 tires and gain loss as much as IDR 373,000,000.

In current condition, from 3 components of machine the average reliability of machine when performing maintenance is 41.71% which categorize as low performance. Reflecting the current condition in PT. ABC, the company desperately needs to have preventive maintenance and scheduled maintenance. This kind of activity can reduce the downtime and other losses that caused by breakdown machine.

1.2 Problem Statement

The problem background leads into research question below;

- What is the reliability of the Tire Building Machine (TBM) Samson 1?
- What is mean time to repair (MTTR), mean time between failures (MTBF) and mean time to failure (MTTF) of tire building machine Samson 1?
- What is the maintenance scheduling for tire building machine (TBM) Samson 1?

1.3 Research Objective

The objectives of this research are:

- To determine the reliability of tire building machine (TBM) Samson 1
- To determine mean time to repair (MTTR), mean time between failures (MTBF) and mean time to failure (MTTF) of tire building machine (TBM) Samson 1

- To determine the maintenance scheduling for tire building machine (TBM) Samson 1

1.4 Scope

Due to limited time and resources in doing this research, there will be some scopes in the observation:

- The observation was only done in tire building machine (TBM) Samson 1.
- The maintenance data were taken from January 2014 until July 2016.
- Downtime is considered only when the machine stops due to the failure.
- Storage cost and ordering cost for the component are not included in the cost calculation.
- The price is constant.

1.5 Assumption

These are the assumption to be made to run the analysis properly

- Tire building machines (TBM) Samson are identical.
- The skill of mechanic while doing maintenance process is same.
- Every component for replacement component is always available.

1.6 Research Outline

Chapter I **Introduction**

This chapter consists of problem background, problem statements as the things to be solved, objectives to be achieved in this research, scope as the limitation, assumption, and research outline of the study.

Chapter II **Literature Study**

This chapter provides the theory about the reliability, maintainability, failure rate, failures distribution such as Weibull distribution, Lognormal distribution, Exponential distribution, parameter distribution, and other related data from books, journal, and expertise works that can be used to solve the problem of this research.

Chapter III **Research Methodology**

This chapter describes the flow of this research and explanation of each step to conduct this research start from initial observation until analyze the collected data which come up with an improvement and recommendation.

Chapter IV **Data Analysis**

The data observation is processed and analyzed in this chapter. This result of data analysis is the improvement process on maintenance process which expected to determine the interval time for maintaining the machine's component and the cost savings of preventive maintenance.

Chapter V **Conclusion and Recommendation**

This chapter contains the result of the research to answer the problem statement and to obtain the objective of the research. The conclusion will consist of the main component that is causing the machine failure, the failure rate of the component, the interval time for the maintenance process and cost savings by implementing preventive maintenance based on the calculation that already done before. Furthermore, the improvement result and recommendation for the future research are also provided.

This chapter consists of problem background and problem statement that have been explained thoroughly. After the problem has been identified, research objectives, scopes and assumptions of this research also specifically stated in this chapter. The outline of this research that stated in the end of this chapter give the information about the flow of the research. Literature studies will be explained in the next chapter.

CHAPTER II

LITERATURE STUDY

2.1 Maintainability Concept

Maintenance process is an activity to maintain or keep the facility, machine or equipment, adjustments or replacements required to obtain a satisfactory operating conditions of production as planned before. With a good maintenance, all facilities and machines owned by the company can be operated in accordance with the predetermined schedule. Maintenance can be defined as the sequence of activities to return the component or machine to a state in which it can perform its assigned function (Shah *et al.*, 2014). Maintenance is used to repair broken components, maintain the initial condition of the machine or equipments and prevent the failure which obviously will reduce production losses and downtime (Nguyen, 2008).

The advantages of maintenance process (Sobral, 2016) are;

- Lower number of failures
- The production capacity will fulfilled the production demand.
- Keep the standard of the quality
- Higher useful life time
- Higher availability
- Higher safety (Regarding to a lower probability of occurence of a dangerous failure)
- Helps reduce consumption and deviations beyond the limit and will not disturbing the production process.
- Achieve maintenance cost as low as possible to carry out maintenance activities effectively and efficiently.

Maintenance process plays an important role in the production process that related on smoothness of the production, bottleneck, delays and production capacity. Maintenance activities will require good maintenance scheduling. With a good maintenance activities the probability of breakdown machine can be reduced to a minimum level and also can reduce the cost to maintain the machine. There are some of maintenance activity such as;

- **Component replacement,** is replacing or substituting the component in the machine or equipment that is not working anymore. The replacement activity can be done unexpectedly or with a planning that made by maintenance department.
- **Repair,** is return the degraded functions of tools or component through fixing the broken parts instead of replacing the parts, so that the component can operate again according to the functions and capabilities as state before it breaks.
- **Inspection,** is kind of periodical maintenance activity to prevent unexpected breakdown and to ensure that the machine is working properly based on its function.
- **Zero hours maintenance (Overhaul),** is the set of assignment which has goals to review the equipment or machine at scheduled intervals before performing any failure (Hunt *et al.*, 2010). This review is based on leaving the equipment to zero hours of operation when the equipments or machines were new. The review will repair or replace all items in order to ensure with the high probability , a good working time fixed in advance.

The type of maintenance process (Rusavel, 2015) are;

1. Planned Maintenance

   Planned maintenance is an organized action or activity that conducted based on the planning that was made before. This kind of maintenance activity is expected to change the maintenance system from reactive become proactive in order to optimize the function of the worker to maintain the machine still remains in the good condition. Planned maintenance are categorized into two categories which are as follows;

   a) Preventive Maintenance

      Preventive maintenance is a maintenance activity that performed periodically at a certain time to find out the conditions that can caused failure on the machine or components. The purpose of maintenance activity in general is to achieve a level of maintenance in all of the production machine or equipment in order to obtain an optimum quality of machine at a low cost (Dwi, 2013).

Preventive maintenance can reduce equipment or process failure where there will be an effective cost in maintaining the machine. The component and machine life cycle will also increase while the downtime will decrease. Preventive maintenance is estimated to save 12% to 18% cost over reactive maintenance program. In preventive maintenance, spare parts waste can occur due to spare parts replacement prior to breakdown

The example of preventive maintenance are scheduled maintenance and condition based maintenance (Rusavel, 2015).

- Scheduled maintenance
  Preventive maintenance commonly in the form of inspection towards any kind of componens in the machines periodically to determine whether the maintenance activity such as setting/adjustment, repairing or replacement are needed or not.
- Condition based maintenance
  Condition based maintenance is a maintenance activity that performed based on the actual condition where the time is not precisely known. The policy in line with that condition is predictive maintenance (Dwi, 2013). Predictive maintenance is maintenance activity which performed bby doing an inspection on the equipment, machine of facility assets to predict when the failure will occur. This maintenance needs several data such as performance data of machine, testing teechniques and also visual inspection of the machine (Adiprabowo, 2014).

b) Corrective Maintenance

Corrective maintenance is maintenance activity that is completed after the failure happends on the machine or equipment where it is not functioning properly (Dhillon, 2002). Corrective maintenance activity is done in order to returning the machine or system to a condition where the machine or system is able to operates normally again. Corrective maintenance activity are categorized into two kind of activities which are as follows (Dwi, 2013);

- **Minor repair,** is a sequence of maintenance activity where the mechanic repair the components in the machine which not found during the inspection.
- **Overhaul,** is maintenance activity either replacement of the components simultaneously and comprehensively.

Corrective maintenance only waiting until the machine or component breakdown. Therefore, only for the broken parts and components are going to be repaired. The disadvantages of doing corrective maintenance are increase the cost due to unplanned downtime of machine and equipment, increase labor cost especially if overtime is needed, and possible additional component or process damage from the failure.

2. Unplanned Maintenance

Unplanned maintenance is one of maintenance that is carried out without prior planning. The example of unplanned maintenance is breakdown maintenance. This type of maintenance occurs on the machine or equipments that were broken when the machine is used. Breakdown maintenance can affect the productivity and availability of the machine.

2.2 Reliability Concept

Reliability is the probability of a component or system will work in accordance with its function when operated during a certain time period. According to Jardine (2013), in the book with the title "Maintenance, Replacement and Reliability applications", reliability means the probability that a equipments or machine from a certain system will perform a specified function within a certain limits under given enviromental conditions for a specified time. The reliability of a component or tool as the probability that the component will function properly for at least up to a certain time period in a state of a particular experiment. Reliability can be defined as the probability of successful operation or performance of systems and their related equipment, with minimum risk of loss or system failure.

Reliability is defined as the probability that a device, machine or system will perform a specified function within given limits, under given environmental conditions, for a specified time (Stapelberg, 2009). Reliability is one of the characteristic that determines the quality. Reliability is defined by the various definitions, but in general that reliability is the ability of a product apply in accordance with a specific function in the design environment or specific operating conditions. Reliability can be expressed in several ways such as failure rate, reliability function, and probability density function (Sodikin, 2010).

There are four element in the reliability concept which are:

- Probability

  Probability mean the reliability value exists between o and 1.
- Performance

  Reliability is a performance characteristic of the system where a reliable system must be able to demonstrate a satisfactory performance if operated. In this case the performance expected or desired goal should be described clearly and specifically. For each unit there is a standard to determine what is meant by the performance or the expected goals
- Time

  As an important parameter to assess the probability of the success of the systems. In here, the reliability concept is expressed in a time period.
- Condition

  Means that the treatment received by a system or machine has an effect to the level of the reliability.

The function of the machine is the main factor that determine the reliability of a machine. A machine can be said reliably if these machines can do the job according to the function of the machine itself. If the machine can't function properly, the machine could be said as unreliable. A certain condition called the limit of the machine is the condition when the machine can work optimal. The limit of the machine is stated in the specification of the machine. If the machine is forced to work beyond the limit, the machine will lead to breakdown and the reliability will reach its lowest point. The reliability of a machine will drop significantly when it used out of the limit of the machine.

The useful life of the machine is athe use of a machine can be optimally work. All of the machine have different level of boredom. Figure 2.1 below shows the reliability-time curve. A machine that has been used for a certain period of time will show decline in performance that will lead to the decreasing of the reliability.

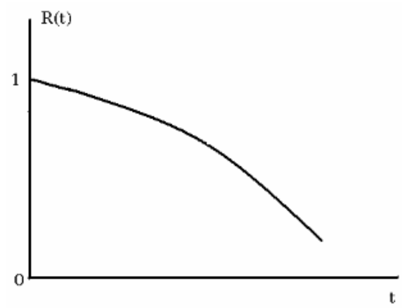


Figure 2.1 Reliability-Time Curve

2.3 Failure Rate

In correlation with the reliability of a system there are things that need to be considered, namely the failure of the machine. It means when the system can not work properly. The failure characteristic (product, machine or equipment) in relation with time period can be described as the graph berlow,

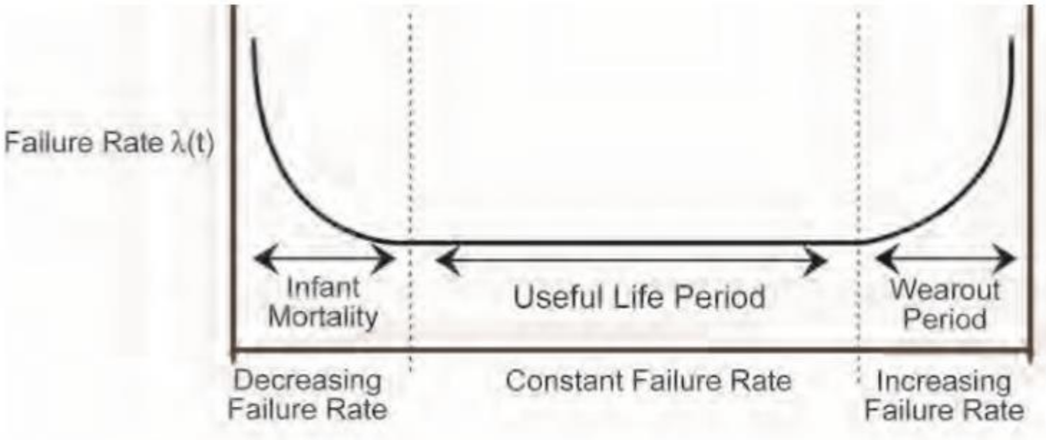


Figure 2.2 Typical Life-Cycle Curve

The Figure 2.2 above shows the variation of the failure rate as function of time. For the phase II, which represents the useful life of the product. There are three phase in the system, which are;

- Phase I, called as Burn-in Region, is the area when the new machine or equipment used. In this area there is a decreasing failure rate.
- Phase II, called chance-failure phase, is the useful life of the machine. In this area, the probability of failure can not be predicted.
- Phase III, called wear-out phase, is the area when the useful life of the machine have been exhausted or exceeded the allowed limit. In this area, preventive maintenance is required to reduce the failure rate of the machine.

There are four factors that related to the reliability which are (Jardine, 2013);

- Numerical value, is the probability of the product will has good function in a certain time period
- Intended function, means that the product was design to used properly and expected to run the function maximally.
- Life, means how long the product will expected to survive.
- Environmental conditions, is a product designed for use in the room or can be used outside.

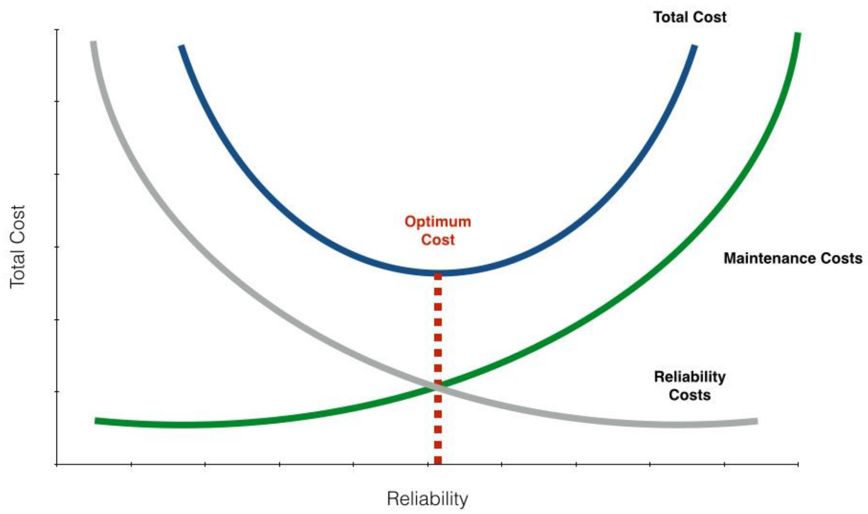


Figure 2.3 Relationship Between Reliability, Failure Rate and Maintenance Cost

Figure 2.3 above explains the relationship between maintennace cost with reliability and failure rate. Maintenance cost and reliability is in the opposite direction with reliability. When the reliability of the machine is decreasing then the maintenance cost will increasing.

2.4 Statistical Approach

Statistical approach is used to predict when will the machine breakdown. Machine and equipment used will not be known exactly when it will breakdown. The condition was just a probability.

2.4.1 Probability Density Function

Probability function is the form of relative frequency that describes in continious curve, $f(t)$. The probability of failure from a machine or components is determined by the probability density function (Rusavel, 2015). The example of probability density function curve can be seen in Figure 2.4

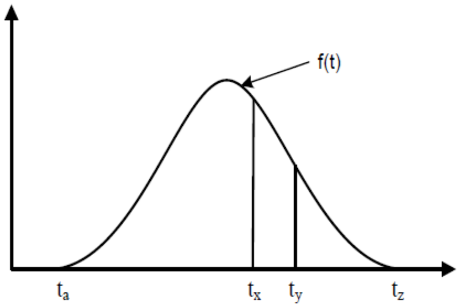


Figure 2.4 Probability Density Function

If x as continious random variable which mentioned as a failure time of a system or machine from total data of failure time and has distribution function fx at each point in the real axis then fx can be said as probability density function of variable x.

The area between tx and ty can be expressed as

$$\int_{tx}^{ty} f(t)dt \quad (2\text{-}1)$$

The probabiliy of failure ocuring between times tx and ty is then

$$\int_{tx}^{ty} f(t)dt = 1 \quad (2\text{-}2)$$

2.4.2 Cummulative Distribution Function

Cummulative distribution function is a function that decribes the probability or chance of failure in machine or components before time (t). Cummulative distribution function can be formulated in the form of ;

$$F(t) = P(x < t) \quad (2\text{-}3)$$

Or

$$F(t) = \int_{tx}^{ty} f(t)dt \text{ , which } t \geq 0 \quad (2\text{-}4)$$

The integral of $\int_{tx}^{ty} f(t)dt$ is denoted by F(t) and is termed the cummulative distribution function. The value of cummuative distribution function is between $0 \leq F(t) \leq 1$, and if there is value of t tends to infinity (∞) then F(t) is equal to 1.

2.4.3 Reliability Function

Reliability function is a probability function of a system or machine that will function until a certain time (t). Reliability function is the probability that a system or component will operate properly without experiencing any kind of failure over a period of time (t) in a predetermined operational function (Rusavel, 2015). Reliability function can be formulated in the form of;

$$R(t) = \int_{t}^{\infty} f(t)dt \qquad (2\text{-}5)$$

Then,

$$R(t) = 1 - F(t), \text{ for } t \geq 0 \qquad (2\text{-}6)$$

2.4.4 Failure Distribution

Continious random variables is used in order to determine the reliability of the system. The distribution that often used in determining the reliability of the system are normal distribution, weibull distribution, lognormal distribution and exponential distribution. Below is the description of each distribution.

- Normal distribution

The normal distribution is a distribution that has a shape like a bell curve with the two forming parameters which are mean (μ) and standard deviation (σ). Normal distribution often called as *Gaussian* distribution. The form of normal distribution curve is symmetrical towards the average mean value.

Functions that used in Normal distribution are;

i. Probability density function

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left[\frac{(t-\mu)^2}{2\sigma^2}\right]} \qquad (2\text{-}7)$$

For $-\infty \leq t \leq \infty$; $\sigma > 0$; $-\infty \leq \mu \leq \infty$

Where ;

μ : Mean of the data

σ : Standard deviation from distribution t : Time

e : Nature Logarithm (e = 2.71828)

ii. Cummulative distribution function

$$F(t) = \phi\left(\frac{t - \mu}{\sigma}\right) \quad (2\text{-}8)$$

iii. Realibility function

$$R(t) = 1 - F(t) \quad (2\text{-}9)$$

iv. Failure Rate Function

$$\lambda(t) = \frac{\Phi\left(\frac{t-\mu}{\sigma}\right)}{\sigma R(t)} \quad (2\text{-}10)$$

v. Mean Time to Failure in Normal Distribution

$$MTTF = \mu \quad (2\text{-}11)$$

- Exponential Distribution

Exponential distribution is used to describe the reliability from the time to failure of the machine or component if the failure rate is constant (Rusavel, 2015). This distribution has a constant failure rate over the time, in other words the chance or probability of failure is not depend on the useful life of the component or machine. The parameter that is used in exponential distribution is λ, which means the average arrival of failures that occured (Dwi, 2013)

Functions that used in Exponential distribution are;

i. Probability density function

$$f(t) = \lambda . e^{-\lambda t} \quad (2\text{-}12)$$

ii. Cummulative distribution function

$$F(t) = 1 - e^{(-\lambda . t)} \quad (2\text{-}13)$$

iii. Realibility function

$$R(t) = e^{-\lambda t} \quad (2\text{-}14)$$

iv. Failure Rate Function

$$\lambda(t) = \frac{f(t)}{R(t)} = \lambda \quad (2\text{-}15)$$

v. Mean Time to Failure in Normal Distribution

$$\text{MTTF} = \int_{t}^{\infty} tf(t)dt \quad (2\text{-}16)$$

$$\text{MTTF} = \frac{1}{\lambda}$$

- Weibull Distribution

Weibull distribution is a type of distribution that frequently used to model the strength of material and time of failure for machine and component. It can be used when the faiure rate is increasing or even when the failure rate is decreasing. In weibull distribution there are two parameter which are scale parameter and shape parameter. The shape parameter determines the failure of rate from the data. The value of shape parameter that shows the failure of rate can be seen in Table 2.1 below (Stapelberg, 2009).

Table 2.1 Shape Parameter Values of Weibull Distribution

Values	Failure rate
$0< \beta <1$	Decreasing Failure Rate (DFR)
$\beta =1$	Constant Failure Rate (CFR)
	Exponential Distribution
$1< \beta <2$	Increasing Failure Rate (IFR)
	Concave-shaped curve
$\beta =2$	Linier Failure Rate (LFR)
	Rayleigh Distribution
$\beta >2$	Increasing Failure Rate (IFR)
	Convex-shaped curve
$3\leq \beta \leq 4$	Increasing Failure Rate (IFR)
	Symmetric-shaped curve
	Normal Distribution

If the shape parameter influence the shape of the curve (Whether the failure of rate is increasing or decreasing), then the scale parameter will influence the mean of the data. The increasing of scale parameter causes the increasing of the reliability and failure rate.

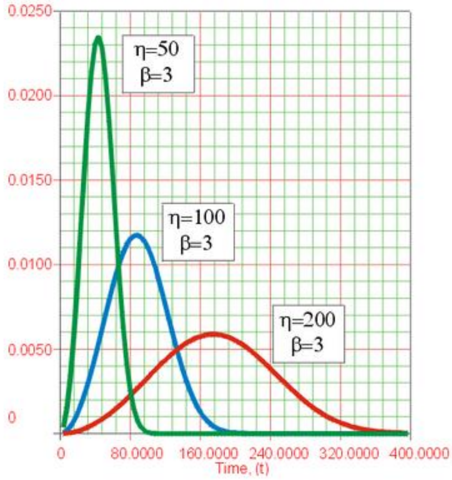


Figure 2.5 The Effect of Scale Parameter in Weibull Distribution

Figure 2.5 shows the effect of scale parameter in Weibull Distribution. If the scale parameter is increased while the shape parameter is kept the same, the distribution gets streched out to the right and its height decreases. If the scale parameter is decreased while shape parameter is kept the same, then the distribution gets pushed in towards the left and its height increases (Stapelberg, 2009).

Functions that used in Weibull distribution are shown in equation below ;

i. Probability density function

$$f(t) = \frac{\beta}{\theta}\left(\frac{t}{\theta}\right)^{\beta-1} e^{\left(\frac{t}{\theta}\right)^{\beta}} \quad (2\text{-}17)$$

Where ;

β : Shape parameter

θ : Scale parameter

t : Time

e : Nature Logarithm (e = 2.71828)

ii. Cummulative distribution function

$$F(t) = 1 - e^{-\left(\frac{t}{\theta}\right)^{\beta}} \qquad (2\text{-}18)$$

iii. Realibility function

$$R(t) = e^{-(\frac{t}{\theta})^{\beta}} \qquad (2\text{-}19)$$

iv. Failure Rate Function

$$\lambda(t) = \frac{\beta}{\theta}\left(\frac{t}{\theta}\right)^{\beta-1} \qquad (2\text{-}20)$$

v. Mean Time to Failure in Normal Distribution

$$\text{MTTF} = \theta)(\Gamma)\left(1 + \frac{1}{\beta}\right) \qquad (2\text{-}21)$$

Which Γ(x) = Gamma Function

- Lognormal Distribution

Lognormal distribution is using two parameters which are shape parameter and location parameter which is the median of failure distribution. This distribution is understandable only for positive t value and more appropriate than the normal distribution in the case of failure. As well as weibull distribution, lognormal distribution also has a variety of forms. Therefore, it is often found that data relevant to the distribution weibull also in accordance with the lognormal distribution (Dwi, 2013). Lognormal distibution is a distribution that describes the failure distribution for a diverse and varied situation.

i. Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}} e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]} \qquad (2\text{-}22)$$

Where ;

s : Scale parameter

μ : Mean of the data

t_{med} : Median of the data

t : Time

e : Nature Logarithm (e = 2.71828)

ii. Cummulative distribution function

$$F(t) = \Phi\left[\frac{1}{s}\ln\frac{t}{tmed}\right] \quad (2\text{-}23)$$

iii. Realibility function

$$R(t) = 1 - F(t) \quad (2\text{-}24)$$

iv. Failure Rate Function

$$\lambda(t) = \frac{\Phi\left(\frac{1}{s}ln\frac{t}{tmed}\right)}{stR(t)} \quad (2\text{-}25)$$

v. Mean Time to Failure in Normal Distribution

$$MTTF = tmed.e^{\left(\frac{s^2}{2}\right)} \quad (2\text{-}26)$$

2.5 Maintenance Interval Time

In determining maintenance interval time the following failure data must fit with certain distribution. Then, all of the function related with fitted distribution is used in order to determine the maintenance interval time. Probability density function, cummulative density function, reliability function and hazard or failure rate must be calculated. Cost per unit of time also should be calculated. The equation that is used in calculating the maintenance cost is stated as follows:

$$C(t) = \frac{total\ cost\ in\ interval\ [0,t]}{time\ of\ interval} \quad (2\text{-}27)$$

Then,

$$C(t) = \frac{Cp + Cf.\ H(t)}{t} \quad (2\text{-}28)$$

Where;

C(t)	: Cost per unit of time
Cp	: Cost of preventive maintenance
Cf	: Cost of corrective maintenance
H(t)	: Cumulative hazard function in the interval of t
Cp	: Component price + [maintenance time (hours) x salary of mechanic per hours] + loss of production
Cf	: Component price + [downtime (hours) x salary of mechanic per hours] + loss of production

Loss of production : Maintenance time (hours) x production capacity (product/ hour) x price of product

2.6 Pareto Chart

Pareto chart is a chart that is used to identify the characteristics or condition that need priority quality improvement and control that introduced by economic analysis from Italy named V.Pareto. Pareto chart aims to find or know the main priority of the problems that is happening right now. Pareto chart shows what is the first problem that we have to solve to eliminate failure and improve the operations. Defective items that appear mostly frequently addressed first and then follow by the second highest defective item and so on.

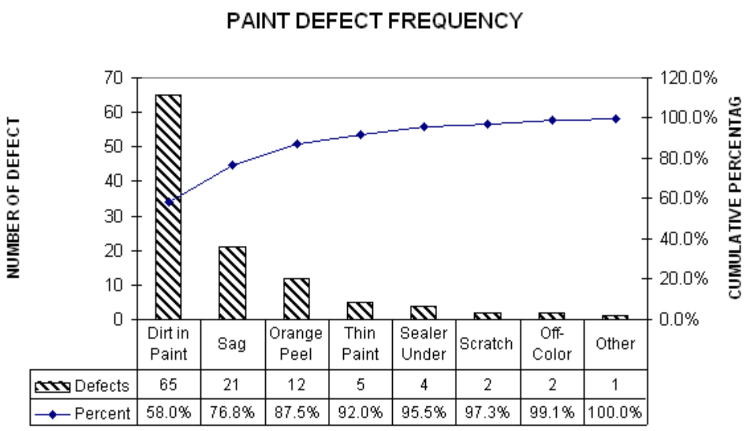
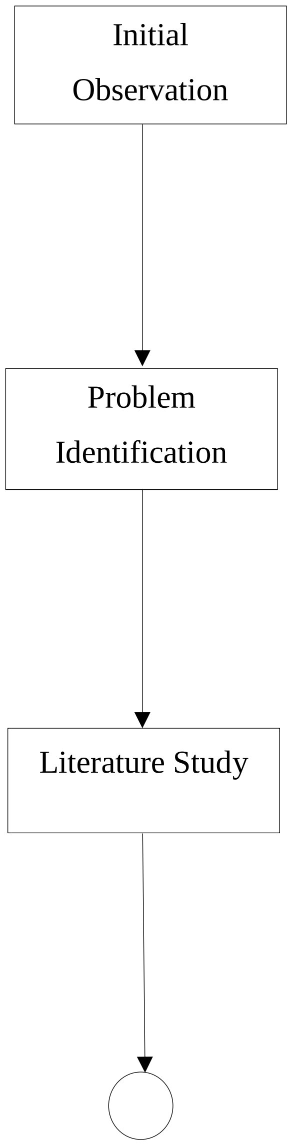


Figure 2.6 The Example of Pareto Chart

CHAPTER III

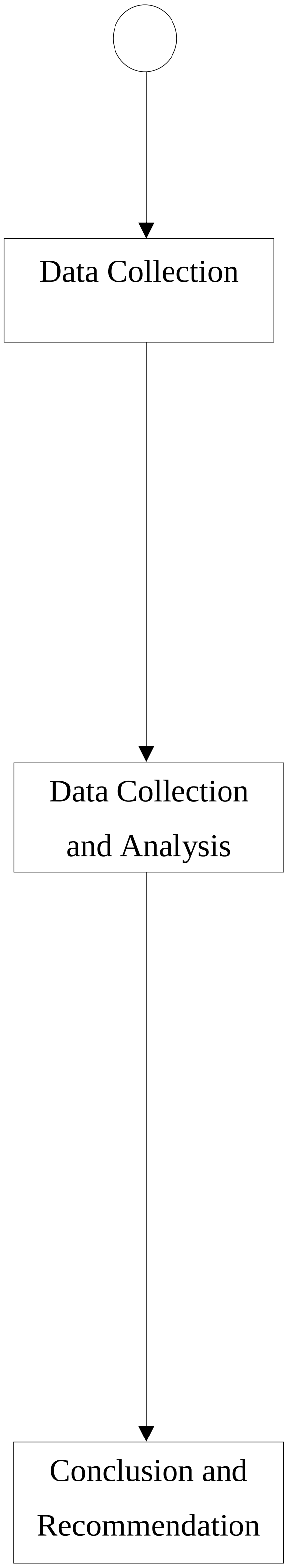
RESEARCH METHODOLOGY

In this part, the phase of the entire process in completing research is explained. The flow chart and the explanation of the research methodology also stated in this part. This steps can be a guidance for the researcher to start and do the research effectively until the goals of the research are accomplished. Hereby, the step performed to solve the existing problems in this research as follows:



1. Initial Observation
   - Going to Tire Building Machine (TBM) to observe the working process in the area and try to looking for any kind of problems that occur in the TBM area.
2. Problem Identification
   - Identify the background and problem mapping. The problem in TBM is related with maintenance activity in Tire Building Machine in PT.ABC.
   - Observe the current system and the effect of current system.
   - Determine the objectives of research, scope, limitations and assumptions.
3. Literature Study
   - Searching for literature refferences such as books, journals, and websites that related to reliability concept, failure rate and distribution, parameter distribution, maintenance interval time and schedulling of maintenance system.

Figure 3.1 Theoretical Framework of The Research



4. Data collection
   - Collect the required data from maintenance department. The collected data are the problem and the maintenance activityies for all machine in the production line start from January 2014 until July 2016.
   - Determine the selected machine
   - Perform knowledge sharing with person in charge in TBM area.
   - Perform observation and interview in maintenance department.
5. Data Analysis
   - Perform pareto analysis to know the critical components.
   - Perform Time to Repair (TTR) and Time Between Failure (TBF).
   - Perform Time to Failure distribution and Time Between Failure distribution.
   - Perform distribution parameter.
   - Perfom maintenance interval time for critical components.
   - Perform proposed preventive maintenance schedule.
   - Perform component realibility comparison.
   - Perform maintenance cost comparison.
6. Conclusion and Recommendation
   - Conclusion based on calculation and analysisfor the research.
   - Give recommendation for further research.

Figure 3.1 Theoretical Framework of The Research (Cont'd)

3.1 Initial Observation

The observation is conducted in PT.ABC that responsible for producing high-quality of tire in many kind of type and size. There are 25000 of products that produced in production floor every day. High production capacity and the amount of products that have to fulfilled every day requires every machine in production line have good performances. In order to maintain the performance of the machine, the company have to make the scheduling for maintenance. Unfortunately in PT.ABC the maintenance activities has not managed well. It can be seen from there is no schedulling of machine maintenance that based on the reliability and failure rate of the machine.

3.2 Problem Identification

The observation in production floor leads to find the cause of the problem. In doing this research, the objectives and scope has to be defined. The objetives are mentioned in the chapter I. Observation and interview will be done in maintenance department in order to collect the require data and information. The maintenance activities has not managed well. If the production process stops then it would cost a significant loss in the company. The company will lose a lot of income and a lot of money to fix the breakdown machine. So , to prevent it the company has to determine the good maintenance scheduling. The limitation of this research are also stated. The observation was only done in Tire Building Machine, maintenance data were taken from January 2014 until July 2016.

3.3 Study Literature

The importance of this step is to collect appropiate theoretical sources from books, journal, etc, that will support the analysis in chapter IV. The main useful literature studies for the analysis are reliability concept, time to repair and time to failure concept, failure distribution and its parameter, maintenance interval time, preventive maintenance etc.

3.4 Data Collection

The next phase to conduct the research is data collection phase. The data that will be used is maintenance data from tire building machine start from January 2014 untill July 2016.

3.5 Data Calculation

After collecting all the data that needed to analyze the research, the next phase is to calculate, process and analyze the result of the data as the output of this research. The step to calculate the data are;

- Perform pareto analysis to know the critical components
- Perform Time to Repair (TTR) and Time Between Failure (TBF)
- Perform Time Between Failure distribution and Time to Repair distribution
- Perform distribution parameter
- Peform reliability function
- Perform maintenance interval time for critical components
- Perfom proposed preventive maintenance schedule
- Perform component reliability and maintenance cost comparison

3.6 Data Analysis

After data collection and processing, there will be an analysis of the results of the data processing. The analysis that will be done are analysis of pareto chart for critical components, time to repair and time between failure distribution, distribution parameter analysis, realibility comparison, maintenance interval time for critical components, proposed maintenance schedule, and maintenance cost comparison.

3.7 Conclusion and Sugestion

The final phase of conducting this research is explaining and identifying the conclusion from the data calculation and data analysis in order to fulfilled the research objective and answers the problem statements. This conclusion is made based on the analysis in the chapter IV. The recommendation contains several suggestions made in order to improve the current maintenance schedulling system.

3.8 Detailed Research Framework

Figure 3.2 below shows the detailed research framework for this research. In the figure below, the breakdowns of every step in completing the research were explained. The step that conducted in data calculation and analysis are also mentioned. Machine failure data in PT. ABC is used to know which machine are critical and need to be investigated further. The machine with the most frequently failure indicates that the machine has low reliability. Therefore, the research will focus on the selected machine.

Pareto chart is used to identify the most critical breakdowns that exists based on the data collection. From pareto chart there are three components that contributes from the total failure in the selected machine. Besides that, machine downtime is used as the complementary data to see the effect from the machine failure that caused by those components. Machine downtime will affect the production output in the selected machine.

The failure data that used in the research are taken from January 2014 until July 2016. After gain all of required data, the next step are determining the time to failure (TTF) and time to repair (TTR). Then, the distribution that fits with the collected data must be determined. After know the fitted distribution, then parameter of distribution is needed in order to calculate MTBF, MTTF and MTTR.

Maintenance interval is used to setting the preventive maintenance intervals based on the interval of failure. The type of distribution must be known before determining the maintenance interval time. The proposed maintenance schedule is based on the target of realibility for the machine that set by the company. There are 3 scenarios were proposed as the new maintenance system. The interval time for every scenario is calculated from maintenance interval time. In the end of this research, there will be a comparison related to realibility and cost in order to know the impact of the improvement. Therefore, there will be preventive maintenance schedule from June 2016 untill June 2017 when the proposed system proved has a possitive impact on the company.

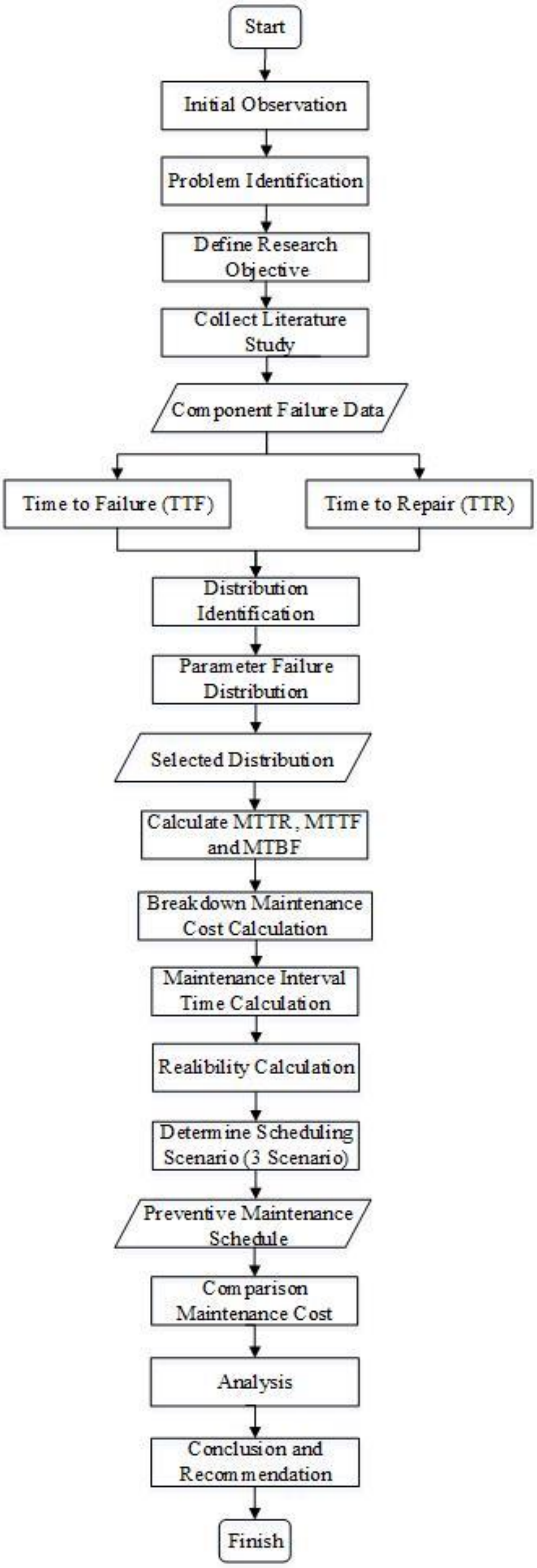


Figure 3.2 Detail Framework of The Research

CHAPTER IV
DATA COLLECTION AND ANALYSIS

4.1 Data Collection

Data collection is based on the certain data and information gathered from the observation. The data required to perform data calculation of this research will be explained in this part. This data are needed in the beginning of the research to identify the problem and to find the solution of the problem.

4.1.1 Overview Production Process in PT. ABC

Figure 4.1 below shows the production process of PT.ABC where the Passenger Car Radial (PCR), Truck-Bus Radial (TBR), Motorcycle tire as the main products. This figure also has a part given by red line. The red line means the working area where occur problems and need to do an improvement in there.

All of detailed information about the process can be described as the major points below.

- Raw material : The function is used to place the material temporary from the truck container before those materials move to the specific machine or area. The raw material are wire fabric, nylon fabric, rubber, carbon black, oil and other chemical ingredients.
- Banbury : All of the ingredients such as rubber, oil, carbon and chemical ingredients are mixed together. The result of this process is called as compound.
- Calender : Process where the material such as polyster, nylon and some certain compound will be coated. The material will be processed become ply, steel belt, JLB and cap ply.
- Extruder : Assembly process from several compound. The result of this process are treadband and sidewall.
- Cushion : The assembling process for all of the compound. The result of this process is inner liner (Substitue part of inner tube).

- Bead Building : Rubberising process of wire and coated with compound . The result of this process is bead.
- Bead Apexing : Making process for apex and then will be assembly with bead and apex. The result is bead apexing.
- Bias Cutter : The process to cutting nylon. The result is ply.
- Tire Building : Assembling process from all of the previous component. The first stage is assembling ply, inner liner and under liner. The next process is assembling ply 1, ply 2, bead apexing and treadband. The result of this process is Green Tire.
- Curing : Tire maturation process of green tire and tire pattern formation. Smearing tire-lubricant liquid on the inside of the green tire is intended to prevent the green tire does not attached in the *bladder* during during curing process. Curing process requires high temperature and pressure. Green tire will melt into the mold and forming tread and side wall.
- Inspection : Tire inspection process after curing machine. The tires will visually examined whether there are a defect or not. During the inspection the operator will trim rubber scraps from curing process.
- Balance : Process of checking the lightes and heaviest point in the tire.
- Uniformity : Checking process for tire force in all part of tire.

4.1.2 Overview Working Process in PCR Tire Building Machine

Tire building machine is an assembly process from all the required components in the tire. The next process after tire building is curing process. All the required compoents are come from semi manufacturing process. There are two stage in tire building machine. The first stage is assembling ply, inner liner and under liner. The result of first stage in tire building machine is known as carcass. The second stage is assembling steel belt, cap ply, bead apexing, carcass and treadband. The result of second stage is green tire. The detailed information about tire manufacturing process and also the used machine is already explained before. Figure 4.2 shows the operation process chart of PCR tire building machine.

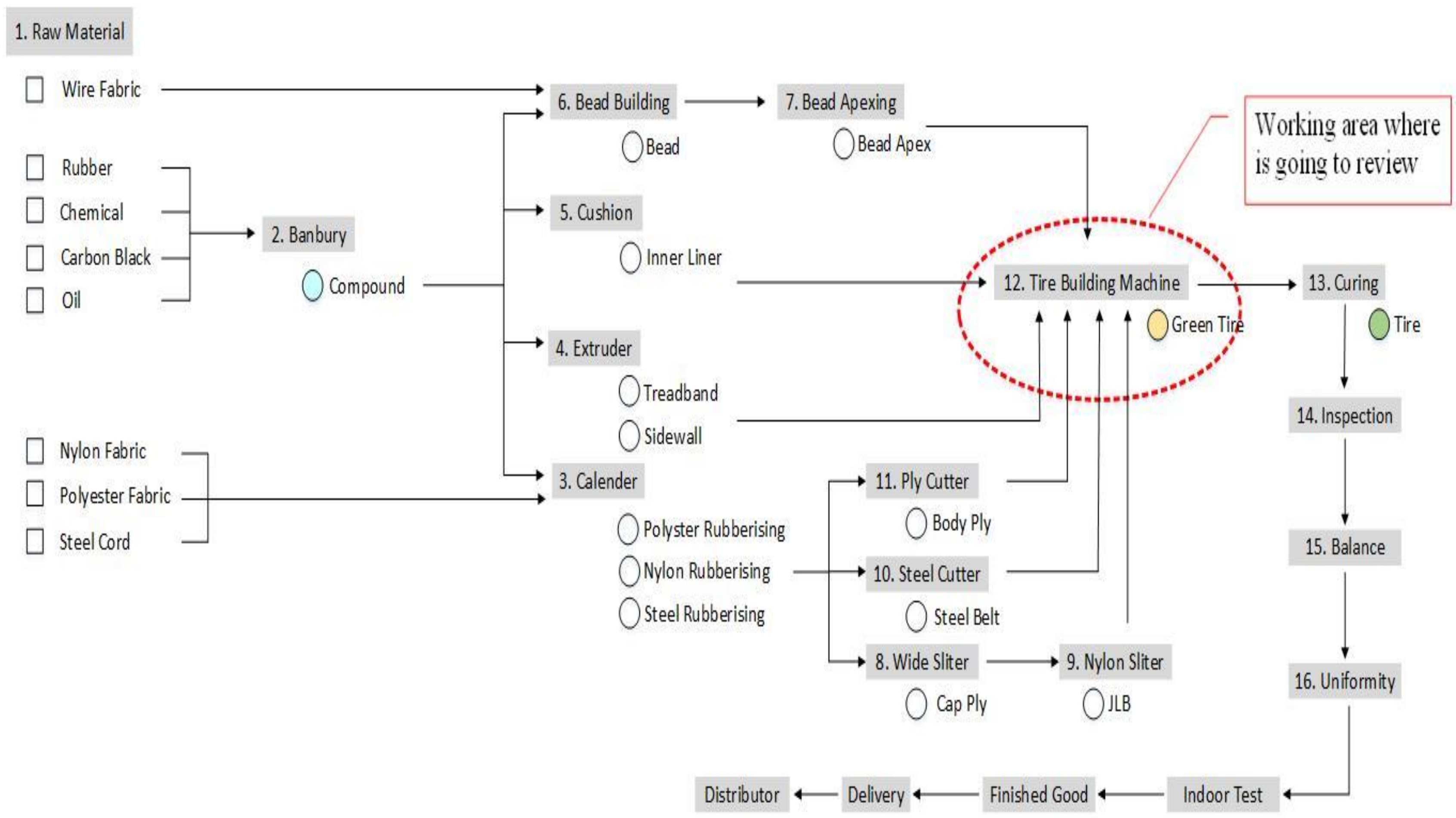


Figure 4.1 Flow of Production Process in PT. ABC

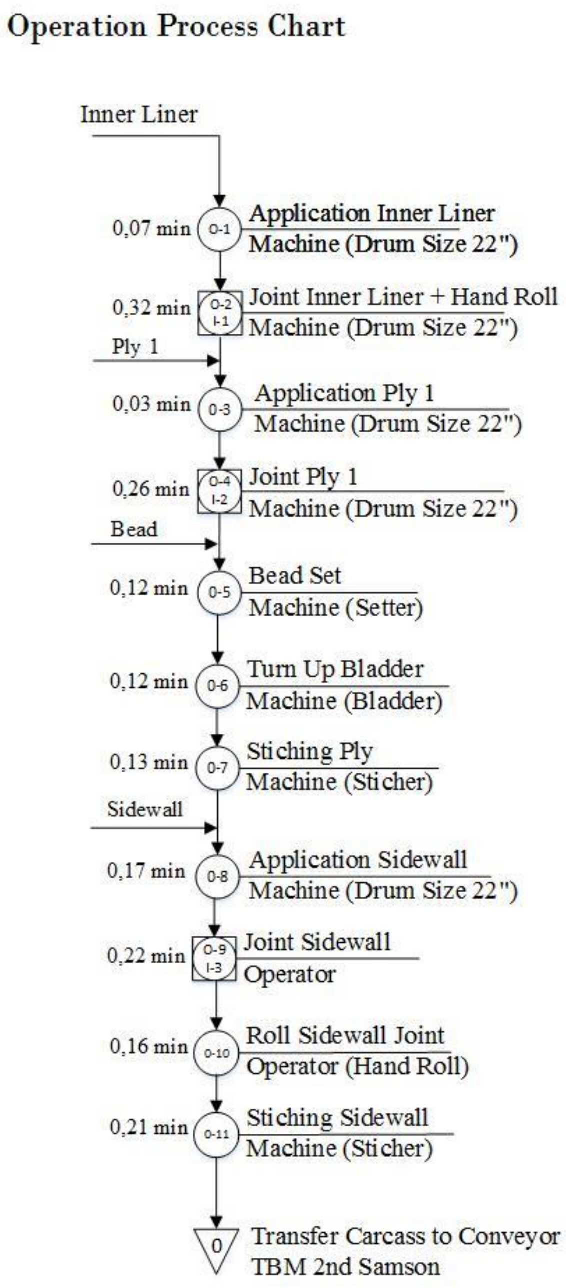


Figure 4.2 Operation Process Chart Tire Building Machine Samson 1

Figure 4.2 above shows the operation process chart in Tire Building Machine Samson 1. In TBM Samson 1 all of required material will assembled. Inner liner, ply 1, bead and side wall will assembled become carcass. Then, carcass will transfer to the second phase of tire building in TBM Samson 1.

4.1.3 Identification of Machine Failures

Figure 4.3 below shows the frequency of failure for every machine in PT. ABC which start from January 2014 untill July 2016. The information in the figure become a basic information to determine which machine is critical and need to be investigated further. The data in Figure 4.3 are presented in appendix 1.

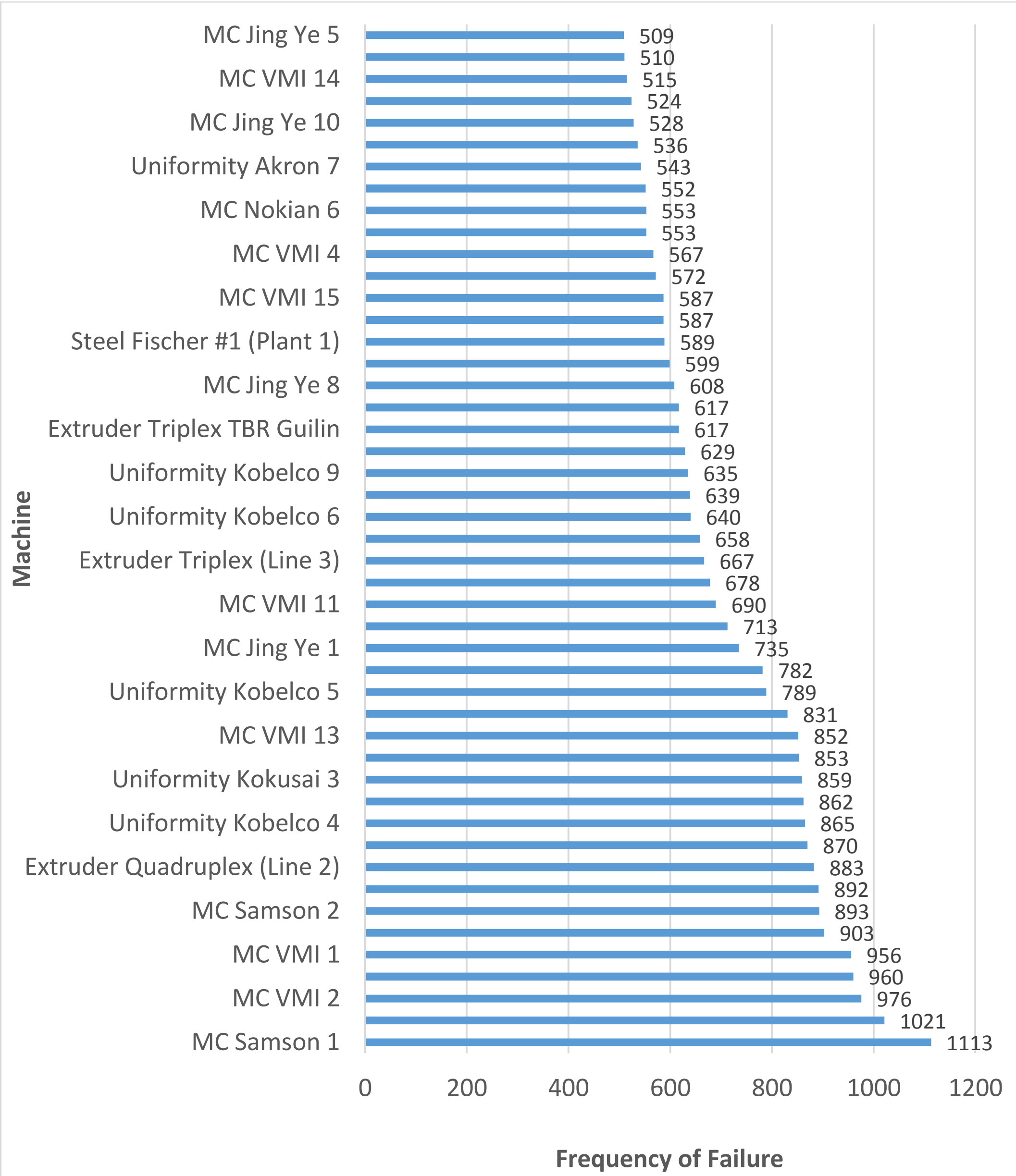


Figure 4.3 Frequency of Failure Machine (January 2014 – July 2016)

Based on the graph in Figure 4.3, Tire Building Machine (TBM) Samson 1 is the most critical machine in the production line of PT. ABC. During period January

2014 untill July 2016, Samson 1 had broken down 1,113 times. This condition means that the machine has low reliability since every month the machine breaks down 37 times. Furthermore, the calculation and analysis will focus in TBM Samson 1.

4.1.4 Identification of Component Machines Failure

After knowing the critical machine in the production process, the next steps in this research is to determine which components machine that breaks down most frequently and contributes to the stoppage of the production process. According to that, below is graph that inform the component machine breakdown data started from January 2014 until July 2016.

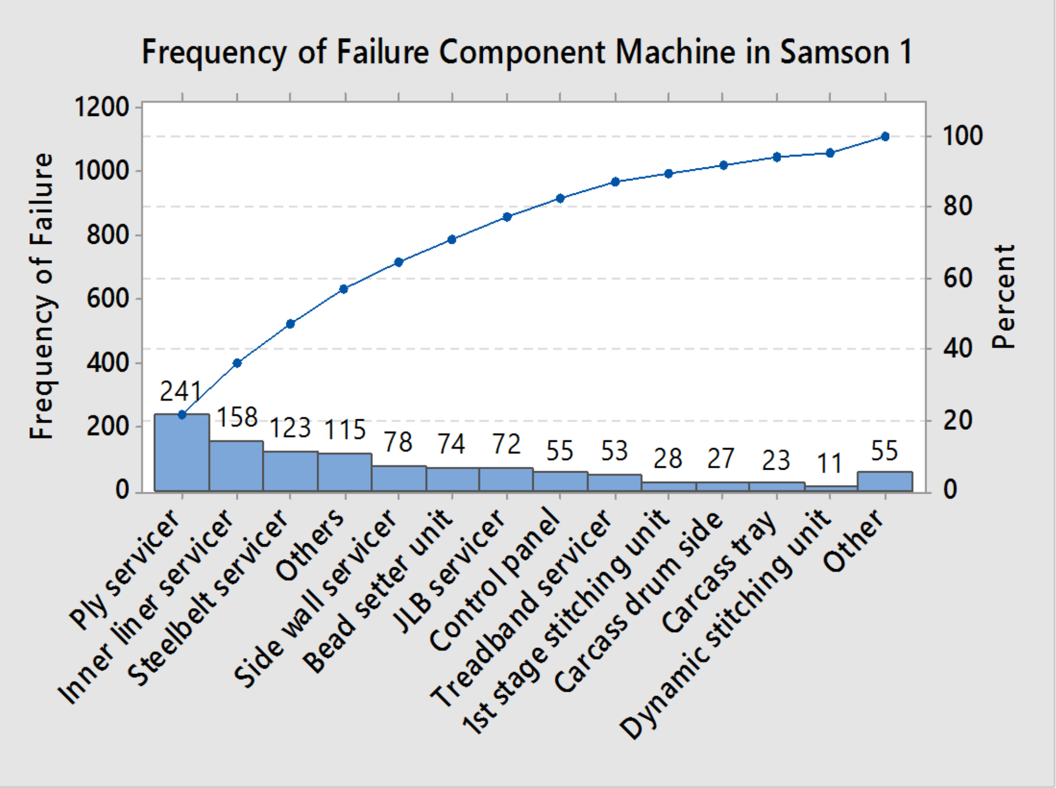


Figure 4.4 Frequency of Failure Component Machine in Samson 1 (From January 2014 – July 2016)

From the Figure 4.4, ply servicer is the most critical component machine in TBM Samson 1. From total 1,113 times failure in TBM Samson 1, 241 times or 22% from the failure caused by ply servicer. Inner liner servicer breaks down 158 times or 14% from the total failure in Samson 1 while 123 failures or 11% from total failure caused by steel belt servicer. Based on the graph in Figure 4.4, there are 3 critical component in TBM Samson 1 which are ply servicer, inner liner servicer, and steel belt servicer. 47% from the failure in Samson 1 that contributes to the stoppage of production process is caused by those three components.

4.1.5 Function of Component Machines

TBM Samson 1 is an important machine in the production line which has function to assembly all the required components such as ply, inner liner, side wall and others. This machine has 20 components. Below is the function of every components in TBM Samson 1;

Table 4.1 Function of Component Machine in TBM Samson 1

Sub Machine	Function
1st Stiching Unit	To flatten the side wall
2nd Stiching Unit	To flatten the side wall and wing tread
Bead Setter	To put on the bead
Bladder Setter	To fold the ply and bead
Carcass Drum	To put on the carcass
Carcass Tray	To apply ply and inner liner
Dynamic Stiching	To flatten the bead, ply and side wall
Control Panel	As a parameter and operator instructions
IL Servicer	To transfer inner liner from let off to the conveyor
Ply Servicer	To transfer ply from let off to the conveyor
JLB Servicer	To transfer JLB from let off to the conveyor
Tread Servicer	To transfer tread from let off to the conveyor
Let Off	To store ply, inner liner and tread
Pneumatic Panel	To control all parts in the machine
Tail Stock	For the base and the pedestal drum
Centering Lamp	To reposition tread material, steel belt and ply
B&T Drum Side	The applicator for tread and steel belt
Shapping Drum	Charging wind carcass before apply to steel belt and tread
Transfering Unit	Transfer assembly steel belt dan tread dari B&T drum side ke shapping drum
Van Belt	Connecting motor rotation to conveyor

4.1.6 Identification of Sub Component Machines Failure

According to Figure 4.4, ply servicer is the most critical component machine in TBM Samson 1. Ply servicer is consists of 22 sub components. Those sub components hand-in-hand to support the main function of ply servicer. In order to accomplish the objective of the research, the freqency of failures for all sub components are definitely needed. According to that, below is the sub component failure that contributes to the stoppage of the machine. The frequency of failure sub components breakdown can be seen in Table 4.2.

Table 4.2 The Frequency of Failure in Sub Component Ply Servicer

Part of Machine	Frequency of Failure
Alarm aplikasi	5
Conveyor ply 1	13
Conveyor ply 2	7
Conveyor ply 3	5
Main conveyor	10
Conveyor inner liner	3
Cutter ply 1	71
cutter ply 2	13
cutter ply 3	16
Cutter bar inner liner	3
Cutter steel belt	3
Finger cutter ply	6
Let off	10
Wind hose	6
Sensor machine	25
Van belt conveyor	9
Cutter ply 2 chain	5
Motor ply	3
Reflektor	2
MC 1st stage	4
Baut cutter	4
Others	18
Total	241

Pareto chart is a common method to be used in the research to identify the most critical breakdowns that exists based on the data collection. Below is the pareto chart from frequency of failure in sub component ply servicer.

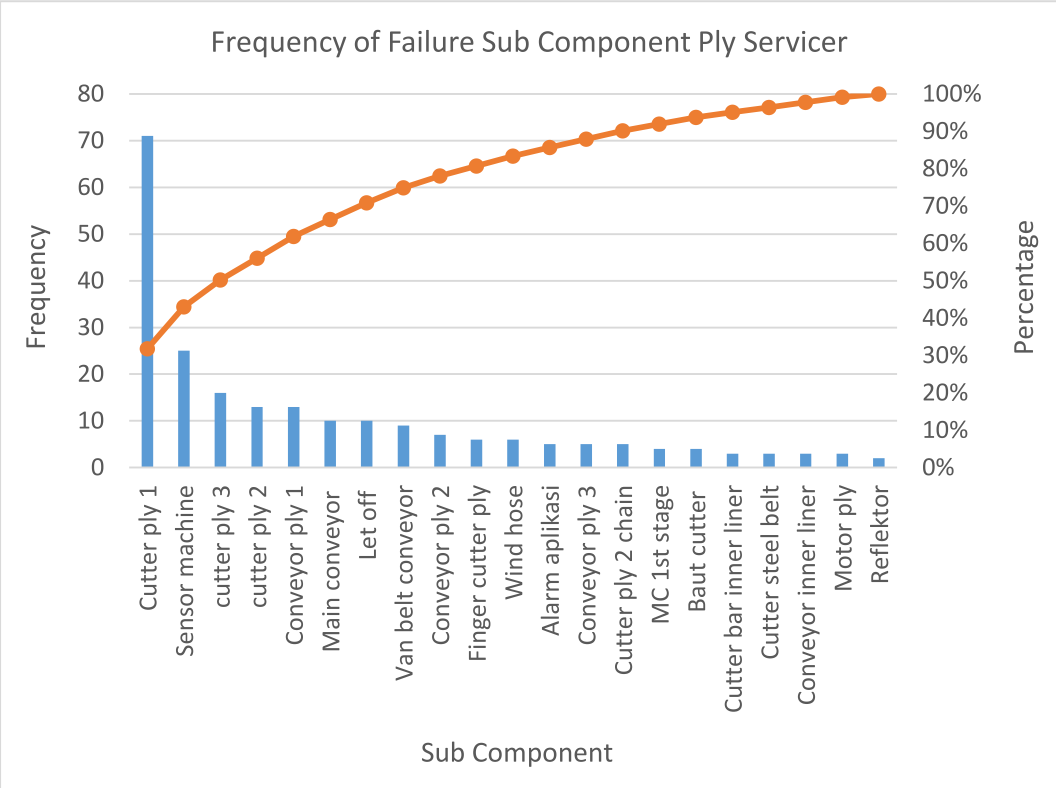


Figure 4.5 Pareto Chart of Sub Component Ply Servicer

In Figure 4.5 above, there are three components that become the main cause of the machine breakdowns which are cutter ply 1, sensor machine and cutter ply 2. During January 2014 until July 2016, cutter ply 1 breaks down 71 times. This means that 31.28% of the failure is caused by cutter ply 1. Sensor machine breaks down 25 times while cutter ply 3 breaks down 16 times. Those components contribute to the machine failure up to 50%. Based on that data, the critical components that will be researched and calculated further are focused on cutter ply 1, sensor machine and cutter ply 3.

Machine downtime is used as the complementary data to see the effect from the machine failure that caused by those components. Machine downtime will affect the production output in tire building machine. If the downtime is longer than before, it will cause the losses that obtained by the company become more greater. Preventive maintenance activity is expected to reduce the downtime that occurs when the breakdown machine happend.

Table 4.3 Comparison Between Downtime and Operating Time in TBM Samson 1

Period	Year	Downtime (min/year)	Operating Time (min/year)	% Downtime
Jan-Dec	2014	15,057	293,760	5.13%
Jan-Dec	2015	21,788	293,760	7.42%
Jan-July	2016	10,289	161,280	6.38%

Table 4.3 explains about the comparison between the total downtime in TBM Samson 1 from 2014 until 2016 and the operating time in the same period. In 2014 the downtime is 15,057 minutes/year while the operating time is 293,760 minutes/year. The percentage of failure in TBM Samson 1 is 5.13%. This condition is increasing 2.29% in 2015 become 7.42%. In the first semester in 2016, the downtime machine is 10,289 min/year. Then, the percentage of failure in January-July 2016 is 6.38%. The detail data are presented in appendix 2.

Table 4.4 Comparison Between Sub Component Ply Servicer Downtime and Total Downtime in 2014

Sub Machine	Period	Year	Time (min/year)	
Cutter Ply 1	Jan-Dec	2014	1,410	
Sensor Machine			657	
Cutter Ply 3			498	
Total			2,565	17.04%

Table 4.4 explains about the comparison between sub component downtime in ply servicer and total downtime started in January until December 2014. The total downtime for 3 sub components in 2014 are 2,565 minutes/year while the total downtime in the machine that already mentioned in Table 4.3 is 15,057 minutes/year. The detail downtime that caused by each sub component can be seen in the table above. The failure in 3 sub components are 17,04% towards the total downtime in 2014. The detail data are presented in appendix 2.

Table 4.5 Comparison Between Sub Component Ply Servicer Downtime and Total Downtime in 2015

Sub Machine	Period	Year	Time (min/year)	
Cutter Ply 1	Jan-Dec	2015	1,565	
Sensor Machine			1,018	
Cutter Ply 3			840	
Total			3,423	15.71%

Table 4.5 explains about the comparison between sub component downtime in ply servicer and total downtime in January until December 2015. The total downtime for 3 sub components are increasing 858 minutes become 3,423 min/year while the total downtime for the machine in 2015 as mentioned in Table 4.3 is 21,788 minutes/year. The detail information about downtime in each sub component is mentioned in the Table 4.5. The failure in 3 sub machine above is 15.71% towards the total downtime in 2015. The detail data are presented in appendix 2.

Table 4.6 Comparison Between Sub Component Ply Servicer Downtime and Total Downtime in 2016

Sub Machine	Period	Year	Time (min/year)	
Cutter Ply 1	Jan-July	2016	1,453	
Sensor Machine			330	
Cutter Ply 3			225	
Total			2,008	19,52%

In Table 4.6 the period for downtime information is different with the previous table. The collected data is started from January 2016 until July 2016. The total downtime for 3 sub components are 2,008 min/year while the total downtime for the machine in the same period as mentioned in Table 4.3 is 10,289 minutes/year. The failure in 3 sub machine that already mentioned above is 19,52% towards the total downtime in the same period. The detail data are presented in appendix 2.

4.1.7 Failure Data of Sub Components

The failure data are taken from January 2014 until July 2016. Among all of the components as mentioned in the previous part, it can conclude that ply servicer is the most often breaks down component in Tire Building Machine (TBM) Samson 1. Based on failure data in ply servicer, the research are focussed on the three sub component in ply servicer which are cutter ply 1, sensor machine and cutter ply 3 as the critical components that contribute to failure machine.

The failure data for those sub components are differentiated based on the type of the maintenance process. In PT. ABC, there are 3 types of maintenance process which are setting/adjustment, repairing and spare part replacement. Furthermore, the calculation and analysis for this research are based on the type of maintenance for each sub components.

In general, setting/adjustment activity is a process to fix the error or problem by setting the component into the proper standard that related to speed, position, or tighten the parts. Repairing is kind of maintenance activity when the mechanic fix the failure by repairing the component without changing or replace the component into the new one. Replacement is the further activity compare with repairing. In replacement activity, the mechanic will fix the failure by replacing or changing the component into the new one. After repairing process the component that already repaired still can be used while in replacement process the component can no longer be used.

The example of setting/adjestment activity is when the position of cutter bar ply is slopping then the mechanic will setting the position of cutter bar ply again. The other example is when the result of cutting ply does not cut well and not fit the standard then the mechanic setting the position of the plat support. The example of repairing is when the bolt sliding cutter is detached then the mechanic will take the material from the parts and then reassemble the bolt sliding cutter into the proper position. The example of replacement is when the cutter ply S/R can not reach the standard temperature that caused by malfunction of heater cutter then the mechanic will replace the heater cutter into the new one.

Table 4.7, Table 4.8, Table 4.9 below are the brief examples of failure data for sub components which differentiated based on the maintenance activities. The complete failure data are presented in appendix 2.

Table 4.7 Failure Data of Cutter Ply 3 (Setting/Adjustment)

Stop Machine		TTR Start		TTR Finish		
Day	Time	Day	Time	Day	Time	TBF (hours)
14/02/2014	23:23:00	14/02/2014	23:40:00	14/02/2014	0:02:00	0
25/05/2014	21:00:00	25/05/2014	21:20:00	25/05/2014	21:49:00	2,396.967
28/08/2014	2:52:00	28/08/2014	3:15:00	28/08/2014	3:41:00	2,261.050
31/01/2015	17:16:00	31/01/2015	17:40:00	31/01/2015	18:13:00	3,757.583
08/06/2015	0:51:00	08/06/2015	1:17:00	08/06/2015	2:00:00	3,054.633
12/12/2015	20:00:00	12/12/2015	20:23:00	12/12/2015	21:20:00	4,506

Table 4.8 Failure Data of Cutter Ply 1 (Repairing)

Stop Machine		TTR Start		TTR Finish		
Day	Time	Day	Time	Day	Time	TBF (hours)
03/01/2014	10:27:00	03/01/2014	10:42:00	03/01/2014	11:05:00	0
09/01/2014	19:41:00	09/01/2014	19:55:00	09/01/2014	20:17:00	152.600
20/01/2014	6:00:00	20/01/2014	6:20:00	20/01/2014	6:40:00	249.717
13/02/2014	19:18:00	13/02/2014	19:35:00	13/02/2014	20:15:00	588.633
01/03/2014	6:00:00	01/03/2014	6:17:00	01/03/2014	6:40:00	369.750
01/04/2014	14:21:00	01/04/2014	14:31:00	01/04/2014	14:55:00	751.683

Table 4.9 Failure Data of Cutter Ply 1 (Replacement)

Stop Machine		TTR Start		TTR Finish		
Day	Time	Day	Time	Day	Time	TBF (hours)
22/02/2014	13:00:00	22/02/2014	13:40:00	22/02/2014	14:25:00	0
11/04/2014	19:42:00	11/04/2014	20:20:00	11/04/2014	21:00:00	1,157.283
21/07/2014	6:40:00	21/07/2014	7:15:00	21/07/2014	8:10:00	2,409.667
20/10/2014	13:39:00	20/10/2014	14:20:00	20/10/2014	15:10:00	2,189.483
21/11/2014	0:40:00	21/11/2014	1:17:00	21/11/2014	1:50:00	753.500
22/01/2015	19:30:00	22/01/2015	20:01:00	22/01/2015	20:35:00	1,505.667

4.2 Data Calculation

After gathering the data needed in solving the problems, then the data will processed to determine the scheduling maintenance on the components in TBM Samson 1. Scheduling maintenance is performed for sub components in ply servicer needed in the tire building process.

4.2.1 Time to Repair and Time to Failure of Sub Components in Ply Servicer

The data of critical sub components in ply servicer as the component in TBM Samson 1 are taken from January 2014 until July 2016. The machine has 5 working day in a week. 4 days in a week the machine operates 24 hours and 1 days operates 16 hours a day. The interval time to repair is calculated from the mechanic starts to repair until the mechanic finish to repair the machine. The time to failure is calculated from the machine start the production process after maintenance activity until the machine breaks down again in the same sub component. Below are the failure data of the sub components followed by time to failure and time to repair of the sub components.

4.2.1.1 Calculation of Time to Failure and Time to Repair for Cutter Ply 1

Table 4.10, Table 4.12 and Table 4.14 below shows time between failure, time to failure and time to repair for cutter ply 1 based on maintenance activities from January 2014 until July 2016. Table 4.10 shows the details for setting/adjustment activity. Table 4.12 and Table 4.14 shows the details for repairing and replacement respectively.

Table 4.10 TTR and TBF Cutter Ply 1 (Setting/adjustment)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	Repair Time (hours)
03/01/2014	0:34:00	03/01/2014	0:46:00	03/01/2014	1:05:00	0	0.317
12/01/2014	16:00:00	12/01/2014	16:05:00	12/01/2014	16:21:00	230.917	0.267
16/01/2014	2:28:00	16/01/2014	2:40:00	16/01/2014	2:56:00	82.117	0.267
08/02/2014	2:25:00	08/02/2014	2:43:00	08/02/2014	3:07:00	551.683	0.400
14/05/2014	19:41:00	14/05/2014	19:52:00	14/05/2014	20:21:00	2,296.817	0.483
18/05/2014	9:21:00	18/05/2014	9:30:00	18/05/2014	9:45:00	85	0.250
27/10/2014	19:17:00	27/10/2014	19:23:00	27/10/2014	19:35:00	3,897.533	0.200
02/11/2014	10:33:00	02/11/2014	10:40:00	02/11/2014	10:56:00	134.967	0.267
03/11/2014	19:43:00	03/11/2014	19:56:00	03/11/2014	20:15:00	32.783	0.317
05/11/2014	11:35:00	05/11/2014	11:40:00	05/11/2014	11:50:00	39.333	0.167
10/11/2014	2:45:00	10/11/2014	2:55:00	10/11/2014	3:23:00	110.917	0.467
12/03/2015	1:05:00	12/03/2015	1:12:00	12/03/2015	1:30:00	2,925.700	0.300
31/03/2015	14:07:00	31/03/2015	14:18:00	31/03/2015	14:38:00	468.617	0.333
09/04/2015	13:54:00	09/04/2015	14:00:00	09/04/2015	14:10:00	215.267	0.167
05/06/2015	1:55:00	05/06/2015	2:30:00	05/06/2015	3:00:00	1,355.750	0.500
09/06/2015	10:48:00	09/06/2015	11:00:00	09/06/2014	11:22:00	103.800	0.367
21/06/2015	20:42:00	21/06/2015	20:55:00	21/06/2015	21:20:00	297.333	0.417
10/09/2015	23:58:00	11/09/2015	0:12:00	11/09/2015	0:55:00	1,946.633	0.717
14/10/2015	19:32:00	14/10/2015	19:44:00	14/10/2015	20:00:00	810.617	0.267
21/10/2015	3:41:00	21/10/2015	5:00:00	21/10/2015	5:25:00	151.683	0.417
21/10/2015	13:49:00	21/10/2015	13:59:00	21/10/2015	14:15:00	8.4	0.267
05/12/2015	2:26:00	05/12/2015	2:40:00	05/12/2015	3:00:00	1,068.183	0.333
12/12/2015	23:38:00	12/12/2015	23:45:00	12/12/2015	23:58:00	188.633	0.217
05/01/2016	9:10:00	05/01/2016	9:20:00	05/01/2016	9:35:00	561.200	0.250
06/01/2016	0:16:00	06/01/2016	0:28:00	06/01/2016	0:45:00	14.683	0.283
03/05/2016	19:53:00	03/05/2016	20:05:00	03/05/2016	20:25:00	2,851.133	0.333
30/05/2016	22:09:00	28/05/2016	22:20:00	28/05/2016	22:38:00	649.733	0.300
08/06/2016	12:26:00	08/06/2016	12:41:00	08/06/2016	12:54:00	253.800	0.217
12/06/2016	14:17:00	12/06/2016	14:31:00	12/06/2016	14:48:00	97.383	0.283

Below is the example of detail calculation in cutter ply 1 for setting/adjustment activity in February, 8th 2014;

- Time to repair is obtained from time to repair (TTR) finish minus time to repair (TTR) start. In table above, the machine started to repair at 2.43 a.m and finished at 3.07 a.m. From the data, the duration of repairing the failure is 24 minutes (3:07:00 – 2:43:00 = 24 minutes).
- Time between failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after setting/adjustment activity in February, 8th 2014 at 3.07 a.m, then the machine stopped again in May, 14th 2014 at 19.41 p.m. The time between failure of the sub component cutter ply 1 for setting/adjustment activity is 2296.817 hours.

Table 4.11 Waiting Time for Cutter Ply 1 (Setting/adjustment)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
03/01/2014	0:34:00	03/01/2014	0:46:00	0.20
12/01/2014	16:00:00	12/01/2014	16:05:00	0.08
16/01/2014	2:28:00	16/01/2014	2:40:00	0.20
08/02/2014	2:25:00	08/02/2014	2:43:00	0.30
14/05/2014	19:41:00	14/05/2014	19:52:00	0.18
18/05/2014	9:21:00	18/05/2014	9:30:00	0.15
27/10/2014	19:17:00	27/10/2014	19:23:00	0.10
02/11/2014	10:33:00	02/11/2014	10:40:00	0.12
03/11/2014	19:43:00	03/11/2014	19:56:00	0.22
05/11/2014	11:35:00	05/11/2014	11:40:00	0.08
10/11/2014	2:45:00	10/11/2014	2:55:00	0.17
12/03/2015	1:05:00	12/03/2015	1:12:00	0.12
31/03/2015	14:07:00	31/03/2015	14:18:00	0.18
09/04/2015	13:54:00	09/04/2015	14:00:00	0.10
05/06/2015	1:55:00	05/06/2015	2:30:00	0.58
09/06/2015	10:48:00	09/06/2015	11:00:00	0.20
21/06/2015	20:42:00	21/06/2015	20:55:00	0.22
10/09/2015	23:58:00	11/09/2015	0:12:00	0.23
14/10/2015	19:32:00	14/10/2015	19:44:00	0.20
21/10/2015	3:41:00	21/10/2015	5:00:00	1.32
21/10/2015	13:49:00	21/10/2015	13:59:00	0.17
05/12/2015	2:26:00	05/12/2015	2:40:00	0.23

Table 4.11 Waiting Time for Cutter Ply 1 (Setting/adjustment) Cont'd

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
12/12/2015	23:38:00	12/12/2015	23:45:00	0.12
05/01/2016	9:10:00	05/01/2016	9:20:00	0.17
06/01/2016	0:16:00	06/01/2016	0:28:00	0.20
03/05/2016	19:53:00	03/05/2016	20:05:00	0.20
30/05/2016	22:09:00	28/05/2016	22:20:00	0.18
08/06/2016	12:26:00	08/06/2016	12:41:00	0.25
12/06/2016	14:17:00	12/06/2016	14:31:00	0.23

Table 4.11 above shows the waiting time for setting/adjustment in cutter ply 1 during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in January, 3rd 2014. In table above, the machine stopped at 0.34 a.m in January, 3rd 2014. The time to repair started at 0.46 a.m. The waiting time for the breakdown machine is 12 minutes or 0.20 hours (00:34:00 – 00:46:00 = 12 minutes).

Table 4.12 TTR and TBF Cutter Ply 1 (Repairing)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	Repair Time (hours)
03/01/2014	10:27:00	03/01/2014	10:42:00	03/01/2014	11:05:00	0	0.383
09/01/2014	19:41:00	09/01/2014	19:55:00	09/01/2014	20:17:00	152.60	0.367
20/01/2014	6:00:00	20/01/2014	6:20:00	20/01/2014	6:40:00	249.72	0.333
13/02/2014	19:18:00	13/02/2014	19:35:00	13/02/2014	20:15:00	588.63	0.667
01/03/2014	6:00:00	01/03/2014	6:17:00	01/03/2014	6:40:00	369.75	0.383
01/04/2014	14:21:00	01/04/2014	14:31:00	01/04/2014	14:55:00	751.68	0.400
07/06/2014	9:14:00	07/06/2014	9:35:00	07/06/2014	9:55:00	1,602.32	0.333
10/07/2014	20:46:00	10/07/2014	20:58:00	10/07//2014	21:30:00	802.85	0.533
12/08/2014	14:34:00	12/08/2014	14:45:00	12/08/2014	15:03:00	785.07	0.300
23/08/2014	17:20:00	23/08/2014	17:35:00	23/08/2014	18:00:00	266.28	0.417
07/09/2014	1:12:00	07/09/2014	1:27:00	07/09/2014	1:50:00	343.20	0.383
18/10/2014	5:58:00	18/10/2014	6:15:00	18/10/2014	6:38:00	988.13	0.383
30/10/2014	23:29:00	30/10/2014	23:41:00	31/10/2014	0:43:00	304.85	1.033
17/11/2014	9:14:00	17/11/2014	9:30:00	17/11/2014	10:00:00	416.75	0.500
01/12/2014	14:05:00	01/12/2014	14:25:00	01/12/2014	14:50:00	340.08	0.417
25/12/2014	9:24:00	25/12/2014	9:39:00	25/12/2014	10:06:00	570.57	0.450
11/01/2015	20:55:00	11//01/2015	21:09:00	11/01/2015	21:30:00	418.82	0.350
09/02/2015	11:01:00	09/02/2015	11:20:00	09/02/2015	11:45:00	685.52	0.417

Table 4.12 TTR and TBF Cutter Ply 1 (Repairing) Cont'd

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	Repair Time (hours)
14/03/2015	1:00:00	14/03/2015	1:17:00	14/03/2015	1:40:00	781.25	0.383
21/06/2015	6:00:00	21/06/2015	7:30:00	21/06/2015	8:20:00	2,380.33	0.833
19/08/2015	2:40:00	19/08/2015	2:55:00	19/08/2015	3:26:00	1,410.33	0.517
04/09/2015	21:45:00	04/09/2015	22:00:00	04/09/2015	22:30:00	402.32	0.500
25/10/2015	12:45:00	25/10/2015	13:00:00	25/10/2015	13:35:00	1,214.25	0.583
10/11/2015	15:35:00	10/11/2015	15:50:00	10/11/2015	16:15:00	386	0.417
18/11/2015	3:28:00	18/11/2015	5:00:00	18/11/2015	6:00:00	179.22	1
30/11/2015	11:02:00	30/11/2015	11:15:00	30/11/2015	13:20:00	293,03	2.083
28/12/2015	13:20:00	28/12/2015	13:37:00	28/12/2015	14:00:00	672	0.383
18/03/2016	10:45:00	18/03/2016	11:00:00	18/03/2016	11:35:00	1,940.75	0.583
07/05/2016	16:29:00	07/05/2016	16:45:00	07/05/2016	17:40:00	1,204.90	0.917
20/05/2016	3:16:00	20/05/2016	3:40:00	20/05/2016	4:05:00	297.60	0.417
18/06/2016	8:46:00	18/06/2016	15:50:00	18/06/2016	16:30:00	700.68	0.667

Below is the example of detail calculation in cutter ply 1 for repairing activity in January, 9th 2014;

- Time to repair is obtained from time to repair (TTR) finish minus time to repair (TTR) start. In table above, the machine started to repair at 7.55 p.m and finished at 8.17 p.m. From the data, the duration of repairing the failure is 22 minutes (20:17:00 – 19:55:00 = 22 minutes).
- Time between failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after repairing activity in January, 9th 2014 at 8.17 p.m, then the machine stopped again in January, 20th 2014 at 6.00 a.m. The time between failure of the sub component cutter ply 1 for repairing activity is 249.72 hours.

Table 4.13 Waiting Time for Cutter Ply 1 (Repairing)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
03/01/2014	10:27:00	03/01/2014	10:42:00	0,25
09/01/2014	19:41:00	09/01/2014	19:55:00	0,23

Table 4.13 Waiting Time for Cutter Ply 1 (Repairing) Cont'd

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
20/01/2014	6:00:00	20/01/2014	6:20:00	0.33
13/02/2014	19:18:00	13/02/2014	19:35:00	0.28
01/03/2014	6:00:00	01/03/2014	6:17:00	0.28
01/04/2014	14:21:00	01/04/2014	14:31:00	0.17
07/06/2014	9:14:00	07/06/2014	9:35:00	0.35
10/07/2014	20:46:00	10/07/2014	20:58:00	0.20
12/08/2014	14:34:00	12/08/2014	14:45:00	0.18
23/08/2014	17:20:00	23/08/2014	17:35:00	0.25
07/09/2014	1:12:00	07/09/2014	1:27:00	0.25
18/10/2014	5:58:00	18/10/2014	6:15:00	0.28
30/10/2014	23:29:00	30/10/2014	23:41:00	0.20
17/11/2014	9:14:00	17/11/2014	9:30:00	0.27
01/12/2014	14:05:00	01/12/2014	14:25:00	0.33
25/12/2014	9:24:00	25/12/2014	9:39:00	0.25
11/01/2015	20:55:00	11//01/2015	21:09:00	0.23
09/02/2015	11:01:00	09/02/2015	11:20:00	0.32
14/03/2015	1:00:00	14/03/2015	1:17:00	0.28
21/06/2015	6:00:00	21/06/2015	7:30:00	1.50
19/08/2015	2:40:00	19/08/2015	2:55:00	0.25
04/09/2015	21:45:00	04/09/2015	22:00:00	0.25
25/10/2015	12:45:00	25/10/2015	13:00:00	0.25
10/11/2015	15:35:00	10/11/2015	15:50:00	0.25
18/11/2015	3:28:00	18/11/2015	5:00:00	1.53
30/11/2015	11:02:00	30/11/2015	11:15:00	0.22
28/12/2015	13:20:00	28/12/2015	13:37:00	0.28
18/03/2016	10:45:00	18/03/2016	11:00:00	0.25
07/05/2016	16:29:00	07/05/2016	16:45:00	0.27
20/05/2016	3:16:00	20/05/2016	3:40:00	0.40
18/06/2016	8:46:00	18/06/2016	15:50:00	7.07

Table 4.13 above shows the waiting time for repairing in cutter ply 1 during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in January, 20th 2014. In table above, the machine stopped at 6.00 a.m in January, 20th 2014. The time to repair started at 6.20 a.m. The waiting time for the breakdown machine is 20 minutes or 0.33 hours (06:20:00 – 06:00:00 = 20 minutes).

Table 4.14 Time to Repair and Time to Failure Cutter Ply 1 (Replacement)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TTF (hours)	Repair Time (hours)
22/02/2014	13:00:00	22/02/2014	13:40:00	22/02/2014	14:25:00	0	0.750
11/04/2014	19:42:00	11/04/2014	20:20:00	11/04/2014	21:00:00	1,157.283	0.667
21/07/2014	6:40:00	21/07/2014	7:15:00	21/07/2014	8:10:00	2,409.667	0.917
20/10/2014	13:39:00	20/10/2014	14:20:00	20/10/2014	15:10:00	2,189.483	0.833
21/11/2014	0:40:00	21/11/2014	1:17:00	21/11/2014	1:50:00	753.500	0.550
22/01/2015	19:30:00	22/01/2015	20:01:00	22/01/2015	20:35:00	1,505.667	0.567
20/06/2015	6:00:00	20/06/2015	6:55:00	20/06/2015	7:45:00	3,561.417	0.833
15/09/2015	5:46:00	15/09/2015	6:07:00	15/09/2015	6:56:00	2,086.183	0.817
28/11/2015	21:58:00	28/11/2015	22:37:00	28/11/2015	23:15:00	1,791.033	0.633
07/03/2016	0:38:00	07/03/2016	7:40:00	07/03/2016	8:10:00	2,377.383	0.500
28/06/2016	7:22:00	28/06/2016	8:06:00	28/06/2016	10:35:00	2,711.200	2.483

Below is the example of detail calculation in cutter ply 1 for replacement activity in April, 11st 2014;

- Time to repair is obtained from time to repair (TTR) finish minus time to repair (TTR) start. In table above, the machine started to repair at 8.20 p.m and finished at 9.00 p.m. From the data, the duration of repairing the failure is 40 minutes (20:20:00 – 21:00:00 = 40 minutes).
- Time to failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after repairing activity in April, 11st 2014 at 9.00 p.m, then the machine stopped again in July, 21st 2014 at 6.40 a.m. The time to failure of the sub component cutter ply 1 for replacement activity is 2,406.667 hours.

Table 4.15 Waiting Time for Cutter Ply 1 (Replacement)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
22/02/2014	13:00:00	22/02/2014	13:40:00	0.67
11/04/2014	19:42:00	11/04/2014	20:20:00	0.63
21/07/2014	6:40:00	21/07/2014	7:15:00	0.58

Table 4.15 Waiting Time for Cutter Ply 1 (Replacement) Cont'd

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
20/10/2014	13:39:00	20/10/2014	14:20:00	0.68
21/11/2014	0:40:00	21/11/2014	1:17:00	0.62
22/01/2015	19:30:00	22/01/2015	20:01:00	0.52
20/06/2015	6:00:00	20/06/2015	6:55:00	0.92
15/09/2015	5:46:00	15/09/2015	6:07:00	0.35
28/11/2015	21:58:00	28/11/2015	22:37:00	0.65
07/03/2016	0:38:00	07/03/2016	7:40:00	7.03
28/06/2016	7:22:00	28/06/2016	8:06:00	0.73

Table 4.15 above shows the waiting time for replacement in cutter ply 1 during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in April, 11st 2014. In table above, the machine stopped at 7.42 p.m in April, 11st 2014. The time to repair started at 8.20 p.m. The waiting time for the breakdown machine is 38 minutes or 0.67 hours (19:42:00 – 20:20:00 = 38 minutes).

4.2.1.2 Calculation of Time to Failure and Time to Repair for Sensor Machine

Table 4.16 and Table 4.18 below shows time between failure, time to failure and time to repair for sensor machine based on maintenance activities during January 2014 until July 2016. Table 4.16 shows the details for setting/adjustment activity. Table 4.18 shows the details for repairing respectively.

Table 4.16 Time to Repair and Time Between Failure Sensor Machine (Setting/adjustment)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	TTR (hours)
12/01/2014	15:06:00	12/01/2014	15:25:00	12/01/2014	16:10:00	0	0.750
19/07/2014	20:36:00	19/07/2014	20:54:00	19/07/2014	21:25:00	4,516.433	0.517
21/08/2014	0:45:00	21/08/2014	1:05:00	21/08/2014	1:35:00	771.333	0.500
18/09/2014	19:14:00	18/09/2014	19:40:00	18/09/2014	20:35:00	689.650	0.917
08/11/2014	1:52:00	08/11/2014	2:10:00	08/11/2014	2:30:00	1,205.283	0.333
19/01/2015	3:44:00	19/01/2015	4:00:00	19/01/2015	4:37:00	1,729.233	0.617
01/04/2015	0:53:00	01/04/2015	1:15:00	01/04/2015	1:47:00	1,723.267	0.533
25/07/2015	1:27:00	25/07/2015	1:40:00	25/07/2015	2:00:00	2,759.667	0.333

Table 4.16 Time to Repair and Time Between Failure Sensor Machine (Setting/adjustment) Cont'd

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	TTR (hours)
12/01/2014	15:06:00	12/01/2014	15:25:00	12/01/2014	16:10:00	0	0.750
19/07/2014	20:36:00	19/07/2014	20:54:00	19/07/2014	21:25:00	4,516.433	0.517
21/08/2014	0:45:00	21/08/2014	1:05:00	21/08/2014	1:35:00	771.333	0.500
18/09/2014	19:14:00	18/09/2014	19:40:00	18/09/2014	20:35:00	689.650	0.917
08/11/2014	1:52:00	08/11/2014	2:10:00	08/11/2014	2:30:00	1,205.283	0.333
19/01/2015	3:44:00	19/01/2015	4:00:00	19/01/2015	4:37:00	1,729.233	0.617
01/04/2015	0:53:00	01/04/2015	1:15:00	01/04/2015	1:47:00	1,723.267	0.533
25/07/2015	1:27:00	25/07/2015	1:40:00	25/07/2015	2:00:00	2,759.667	0.333
28/09/2015	1:10:00	28/09/2015	1:30:00	28/09/2015	2:06:00	1,559.167	0.600
04/11/2015	13:17:00	04/11/2015	13:55:00	04/11/2015	15:18:00	899.183	1.383
13/01/2016	15:17:00	13/01/2016	15:36:00	13/01/2016	16:00:00	1,679.983	0.400
12/05/2016	18:50:00	12/05/2016	19:05:00	12/05/2016	19:30:00	2,882.833	0.417

Below is the example of detail calculation in sensor machine for setting/adjustment activity in July, 19th 2014;

- In table above, the machine started to repair at 8.54 p.m and finished at 9.25 p.m. From the data, the duration of setting/adjustment the failure is 40 minutes (21:25:00 – 20:54:00 = 31 minutes).
- Time between failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after setting/adjustment activity in July, 19th 2014 at 9.25 p.m, then the machine stopped again in August, 21st 2014 at 0.45 a.m. The time between failure of the sub component sensor machine for setting/adjustment activity is 771.333 hours.

Table 4.17 Waiting Time for Sensor Machine (Setting/adjustment)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
12/01/2014	15:06:00	12/01/2014	15:25:00	0.32
19/07/2014	20:36:00	19/07/2014	20:54:00	0.30
21/08/2014	0:45:00	21/08/2014	1:05:00	0.33
18/09/2014	19:14:00	18/09/2014	19:40:00	0.43

Table 4.17 Waiting Time for Sensor Machine (Setting/adjustment) Cont'd

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
08/11/2014	1:52:00	08/11/2014	2:10:00	0.30
19/01/2015	3:44:00	19/01/2015	4:00:00	0.27
01/04/2015	0:53:00	01/04/2015	1:15:00	0.37
25/07/2015	1:27:00	25/07/2015	1:40:00	0.22
28/09/2015	1:10:00	28/09/2015	1:30:00	0.33
04/11/2015	13:17:00	04/11/2015	13:55:00	0.63
13/01/2016	15:17:00	13/01/2016	15:36:00	0.32
12/05/2016	18:50:00	12/05/2016	19:05:00	0.25

Table 4.17 above shows the waiting time for setting/adjustment in sensor machine during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in January, 12nd 2014. In table above, the machine stopped at 3.06 p.m in January, 12nd 2014. The time to repair started at 3,25 p.m. The waiting time for the breakdown machine is 19 minutes or 0.32 hours (15:06:00 – 15:25:00 = 19 minutes).

Table 4.18 Time to Repair and Time Between Failure Sensor Machine (Repairing)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TTF (hours)	Repair Time (hours)
16/03/2014	17:50:00	16/03/2014	18:40:00	16/03/2014	20:41:00	0	2.017
18/05/2014	1:30:00	18/05/2014	2:30:00	18/05/2014	3:33:00	1,492.817	1.050
20/07/2014	14:28:00	20/07/2014	14:55:00	20/07/2014	15:49:00	1,522.917	0.900
23/10/2014	19:35:00	23/10/2014	20:05:00	23/10/2014	21:00:00	2,283.767	0.917
11/01/2015	14:54:00	11/01/2015	15:20:00	11/01/2015	16:20:00	1,913.900	1
22/04/2015	0:14:00	22/04/2015	1:05:00	22/04/2015	2:46:00	2,407.900	1.683
28/06/2015	10:05:00	28/06/2015	10:42:00	28/06/2015	11:34:00	1,615.317	0.867
01/09/2015	6:09:00	01/09/2015	6:35:00	01/09/2015	7:31:00	1,554.583	0.933
05/11/2015	8:36:00	05/11/2015	9:12:00	05/11/2015	11:23:00	1,561.083	2.183
17/12/2015	9:22:00	17/12/2015	10:00:00	17/12/2015	11:27:00	1,005.983	1.450
10/03/2016	9:44:00	10/03/2016	10:08:00	10/03/2016	11:44:00	2,014.283	1.600
15/06/2016	11:35:00	15/06/2016	12:15:00	15/06/2016	13:42:00	2,327.850	1.450

Below is the example of detail calculation in sensor machine for repairing/replacement activity in May, 18th 2014;

- In table above, the machine started to repair at 2.30 a.m and finished at 3.33 a.m. From the data, the duration of repairing/replacement the failure is 63 minutes (03:33:00 – 02:30:00 = 63 minutes).
- Time to failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after repairing/replacement activity in May, 18th 2014 at 3.33 a.m, then the machine stopped again in July, 20th 2014 at 2.28 p.m. The time to failure of the sub component sensor machine for repairing activity is 1,522.917 hours.

Table 4.19 Waiting Time for Sensor Machine (Repairing)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
16/03/2014	17:50:00	16/03/2014	18:40:00	0.83
18/05/2014	1:30:00	18/05/2014	2:30:00	1.00
20/07/2014	14:28:00	20/07/2014	14:55:00	0.45
23/10/2014	19:35:00	23/10/2014	20:05:00	0.50
11/01/2015	14:54:00	11/01/2015	15:20:00	0.43
22/04/2015	0:14:00	22/04/2015	1:05:00	0.85
28/06/2015	10:05:00	28/06/2015	10:42:00	0.62
01/09/2015	6:09:00	01/09/2015	6:35:00	0.43
05/11/2015	8:36:00	05/11/2015	9:12:00	0.60
17/12/2015	9:22:00	17/12/2015	10:00:00	0.63
10/03/2016	9:44:00	10/03/2016	10:08:00	0.40
15/06/2016	11:35:00	15/06/2016	12:15:00	0.67

Table 4.19 above shows the waiting time for repairing in sensor machine during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in May, 18th 2014. In table above, the machine stopped at 1.30 a.m in May, 18th 2014. The time to repair started at 2.30 a.m. The waiting time for the breakdown machine is 60 minutes (2:30:00 – 1:30:00 = 60 minutes).

4.2.1.3 Calculation of Time to Failure and Time to Repair for Cutter Ply 3

Table 4.20 and Table 4.22 below shows time between failure, time to failure and time to repair for cutter ply 3 based on maintenance activities during January 2014 until July 2016. Table 4.20 shows the details for setting/adjustment activity. Table 4.22 shows the details for repairing/replacement.

Table 4.20 Time to Repair and Time Between Failure Cutter Ply 3 (Setting/adjustment)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TBF (hours)	Repair Time (hours)
14/02/2014	23:23:00	14/02/2014	23:40:00	14/02/2014	0:02:00	0	0.367
25/05/2014	21:00:00	25/05/2014	21:20:00	25/05/2014	21:49:00	2.396.967	0.483
28/08/2014	2:52:00	28/08/2014	3:15:00	28/08/2014	3:41:00	2.261.050	0.433
31/01/2015	17:16:00	31/01/2015	17:40:00	31/01/2015	18:13:00	3.757.583	0.550
08/06/2015	0:51:00	08/06/2015	1:17:00	08/06/2015	2:00:00	3.054.633	0.717
12/12/2015	20:00:00	12/12/2015	20:23:00	12/12/2015	21:20:00	4,506	0.950

Below is the example of detail calculation in sensor machine for setting/adjustment activity in May, 25th 2014;

- In table above, the machine started to repair at 9.20 p.m and finished at 9.49 p.m. From the data, the duration of setting/adjustment the failure is 29 minutes (21:49:00 – 21:20:00 = 29 minutes).
- Time to failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after repairing activity in May, 25th 2014 at 9.49 p.m, then the machine stopped again in August, 28th 2014 at 2.52 a.m. The time to failure of the sub component cutter ply 3 for seting/adjustment activity is 2,261.050 hours.

Table 4.21 Waiting Time for Cutter Ply 3 (Setting/adjustment)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
14/02/2014	23:23:00	14/02/2014	23:40:00	0.28
25/05/2014	21:00:00	25/05/2014	21:20:00	0.33
28/08/2014	2:52:00	28/08/2014	3:15:00	0.38
31/01/2015	17:16:00	31/01/2015	17:40:00	0.40
08/06/2015	0:51:00	08/06/2015	1:17:00	0.43
12/12/2015	20:00:00	12/12/2015	20:23:00	0.38

Table 4.21 above shows the waiting time for setting/adjustment cutter ply 3 during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in May, 25th 2014. In table above, the machine stopped at 9.00 p.m in May, 25th 2014. The time to repair started at 9.20 p.m. The waiting time for the breakdown machine is 20 minutes or 0.33 hours (21:20:00 – 21:00:00 = 20 minutes).

Table 4.22 Time to Repair and Time to Failure Cutter Ply 3 (Repairing)

Stop Machine		TTR Start		TTR Finish			
Day	Time	Day	Time	Day	Time	TTF (hours)	Repair Time (hours)
23/01/2014	22:45:00	23/01/2014	23:15:00	23/01/2014	0:05:00	0	0.833
28/03/2014	15:13:00	28/03/2014	15:44:00	28/03/2014	16:37:00	1,527.133	0.883
29/06/2014	1:08:00	29/06/2014	1:32:00	29/06/2014	2:31:00	2,216.517	0.983
08/10/2014	15:14:00	08/10/2014	16:00:00	08/10/2014	17:08:00	2,436.717	1.133
19/01/2015	2:00:00	19/01/2015	2:37:00	19/01/2015	3:51:00	2,456.867	1.233
29/04/2015	6:13:00	29/04/2015	7:00:00	29/04/2015	8:22:00	2,402.367	1.367
13/09/2015	11:04:00	13/09/2015	12:13:00	13/09/2015	13:30:00	3,290.7	1.283
12/12/2015	7:35:00	12/12/2015	10:01:00	12/12/2015	11:43:00	2,154.083	1.700
04/02/2016	17:30:00	04/02/2016	18:15:00	04/02/2016	19:20:00	1,301.783	1.083
05/05/2016	1:56:00	05/05/2016	2:45:00	05/05/2016	3:51:00	2,166.6	1.100

Below is the example of detail calculation in sensor machine for repairing/replacement activity in March, 28th 2014;

- In table above, the machine started to repair at 3.44 p.m and finished at 4.37 p.m. From the data, the duration of repairing/replacement the failure is 53 minutes (16:37:00 – 15:44:00 = 53 minutes).
- Time to failure is acquired from the duration from the production proces starts after maintenance until the machine breaks down again. The machine started operate after repairing/replacement activity in March, 28th 2014 at 4.37 p.m, then the machine stopped again in June, 29th 2014 at 1.08 a.m. The time to failure of the sub component cutter ply 3 for repairing/replacement activity is 2,216.517 hours.

Table 4.23 Waiting Time for Cutter Ply 3 (Setting/adjustment)

Stop Machine		TTR Start		
Day	Time	Day	Time	Waiting Time (hours)
23/01/2014	22:45:00	23/01/2014	23:15:00	0.50
28/03/2014	15:13:00	28/03/2014	15:44:00	0.52
29/06/2014	1:08:00	29/06/2014	1:32:00	0.40
08/10/2014	15:14:00	08/10/2014	16:00:00	0.77
19/01/2015	2:00:00	19/01/2015	2:37:00	0.62
29/04/2015	6:13:00	29/04/2015	7:00:00	0.78
13/09/2015	11:04:00	13/09/2015	12:13:00	1.15
12/12/2015	7:35:00	12/12/2015	10:01:00	2.43
04/02/2016	17:30:00	04/02/2016	18:15:00	0.75
05/05/2016	1:56:00	05/05/2016	2:45:00	0.82

Table 4.23 above shows the waiting time for repairing cutter ply 3 during January 2014 until July 2016. Waiting time is obtained from time to repair (TTR) start minus stop machine time. The example is in May, 28th 2014. In table above, the machine stopped at 3.15 p.m in March, 28th 2014. The time to repair started at 3.44 p.m. The waiting time for the breakdown machine is 31 minutes or 0.52 hours (15:44:00 – 15:15:00 = 31 minutes).

4.2.2 Distribution Identification

The further steps in completing this research after calculating TTR and TBF is choosing the proper distribution that will used in the research. Statistical software is used to choose the proper distribution for every sub component and also used to show all of parameters that are used for each distribution. Below are the result of the fit of distribution for time between failure (TBF) and time to repair (TTR). The detailed result can be seen in Table 4.24 and Table 4.25 respectively. The detail information are presented in appendix 3.

Table 4.24 TTF and TBF Distribution in Each Sub Component

No	Component	Type of Maintenance	Distribution	AD Value	P value	Result
1	Cutter Ply 1	Setting/Adjustment	Normal	3.163	<0.005	DO NOT FIT
			Lognormal	0.197	0.877	FIT
			Exponential	2.836	<0.003	DO NOT FIT
			Weibull	0.399	>0.250	FIT

Table 4.24 TTF and TBF Distribution in Each Sub Component (Cont'd)

No	Component	Type of Maintenance	Distribution	AD Value	P value	Result
2	Cutter Ply 1	Repairing	Normal	1.661	<0.005	DO NOT FIT
			Lognormal	0.282	0.615	FIT
			Exponential	1.728	0.016	DO NOT FIT
			Weibull	0.654	0.083	FIT
3	Cutter Ply 1	Spare part replacement	Normal	1.883	<0.005	DO NOT FIT
			Lognormal	0.889	0.015	FIT
			Exponential	2.266	0.004	DO NOT FIT
			Weibull	1.472	<0.010	DO NOT FIT
4	Sensor Machine	Setting/Adjustment	Normal	0.594	0.092	FIT
			Lognormal	0.245	0.689	FIT
			Exponential	1.178	0.062	FIT
			Weibull	0.370	>0.250	FIT
5	Sensor Machine	Repairing	Normal	0.419	0.268	FIT
			Lognormal	0.432	0.247	FIT
			Exponential	3.050	<0.003	DO NOT FIT
			Weibull	0.473	0.225	FIT
6	Cutter Ply 3	Setting/Adjustment	Normal	0.240	0.590	FIT
			Lognormal	0.225	0.648	FIT
			Exponential	1.292	0.037	DO NOT FIT
			Weibull	0.278	>0.250	FIT
7	Cutter Ply 3	Repairing	Normal	0.455	0.202	FIT
			Lognormal	0.541	0.119	FIT
			Exponential	2.499	<0.003	DO NOT FIT
			Weibull	0.476	0.219	FIT

Every sub component in ply servicer tend to follow particular distribution. Goodness of fit is used to determine whether the set of frequency or data fit with the frequency or data from certain distribution. Table 4.24 explains about time to failure distribution for every sub machine and followed by type of maintenance in TBM Samson 1. Besides that the information consit of lure distribution, *Anderson-Darling* value, P-value , correlation coefficient (r-value) and the result of the test whether the result is fit with the distribution or not.

Based on several journals that related to preventive maintenance schedulling, determining the distribution of Time to Repair, Time to Failure and Time Between Failure are done by comparing the P-value with significant level (α). If the P value is less than or equal the significant level (α) then the null hypothesis (Ho) is rejected. If the P value is greater than significant level (α) then the null hypothesis is accepted. In this research, the significant level (α) is 0.05. The null hypothesis (Ho) is the data fit to the following distribution, while the alternative hypothesis (H1) is the data do not fit to the following calculation. For example, in setting/adjustment cutter ply 1, the P value of Lognormal distribution is 0.877. Then, the null hypothesis is accepted because the P value is greater than the significant level (α).

Meanwhile, calculating index of fit (r) or coefficicient correlation also can be peformed. If the value of coefficient correlation is close to 1 then it can be said the relationship between parameters that create the distribution function is highly strong. Besides that goodness of fit test is needed to calculate in order to support the selection process and strengthen the result of index of fit (r). Based on the result of goodness of fit then it will be selected the distribution that has smallest Anderson-Darling (AD) value (Praharsi *et al*, 2015). Anderson-Darling (AD) statistic determines how well the data follow a particular distribution and whether a sample of data comes from a population with a specified distribution.

For example is in sub machine cutter ply 1, the type of maintenance that will use is setting/adjustment. The fitted distribution data is Lognormal distribution. Moreover, in some groups of data also can fits with two distributions. The distribution will be chosen due to the easiness in doing the calculation and the most frequently used in statistic or choose one of the distribution based on practical knowledge. For example, repairing activity in sub machine cutter ply 3 fits with normal distribution and weibull distribution. Therefore, normal distribution is chosen since the distribution is commonly used in statistic and easier to do the calculation.

All type of maintenance activities for sub component cutter ply 1 are fit with lognormal distribution. In sensor machine, for setting/adjustment activity fits with lognormal distribution while for repairing/replacement fits with normal distribution. In sub component cuter ply 3, for setting/adjustment activity fits with lognormal distribution while for repairing/replacement activity fits with normal distribution.

Table 4.25 Time to Repair Distribution in Each Sub Machine

No	Component	Type of Maintenance	Distribution	AD Value	P value	Result
1	Cutter Ply 1	Setting/Adjustment	Normal	0.951	0.014	DO NOT FIT
			Lognormal	0.324	0.509	FIT
			Exponential	6.425	<0.003	DO NOT FIT
			Weibull	0.965	0.014	DO NOT FIT
2	Cutter Ply 1	Repairing	Normal	3.555	<0.005	DO NOT FIT
			Lognormal	1.678	<0.005	FIT
			Exponential	5.672	<0.003	DO NOT FIT
			Weibull	2.847	<0.010	DO NOT FIT
3	Cutter Ply 1	Spare part replacement	Normal	0.162	0.920	FIT
			Lognormal	0.323	0.461	FIT
			Exponential	1.820	0.011	DO NOT FIT
			Weibull	0.174	>0.250	FIT
4	Sensor Machine	Setting/Adjustment	Normal	0.790	0.029	DO NOT FIT
			Lognormal	0.281	0.573	FIT
			Exponential	2.127	0.005	DO NOT FIT
			Weibull	0.613	0.095	FIT
5	Sensor Machine	Repairing	Normal	0.605	0.089	FIT
			Lognormal	0.565	0.113	FIT
			Exponential	2.651	<0.003	DO NOT FIT
			Weibull	0.595	0.107	FIT
6	Cutter Ply 3	Setting/Adjustment	Normal	0.316	0.413	FIT
			Lognormal	0.191	0.818	FIT
			Exponential	1.329	0.035	DO NOT FIT
			Weibull	0.316	>0.250	FIT
7	Cutter Ply 3	Repairing	Normal	0.247	0.672	FIT
			Lognormal	0.153	0.936	FIT
			Exponential	2.988	<0.003	DO NOT FIT
			Weibull	0.339	>0.250	FIT

Table 4.25 explains about time to repair distribution for every sub machine and followed by type of maintenance in TBM Samson 1. The information in the table above consist of type of maintenance for every sub machine, the repair distribution, *Anderson-Darling* value, P-value and the result of the test whether the result is fit with the distribution or not.

Based on several journals that related to preventive maintenance schedulling, determining the distribution of Time to Repair, Time to Failure and Time Between Failure are done by comparing the P-value with significant level (α). If the P value is less than or equal the significant level (α) then the null hypothesis (Ho) is rejected. If the P value is greater than significant level (α) then the null hypothesis is accepted. In this research, the significant level (α) is 0.05. The null hypothesis (Ho) is the data fit to the following distribution, while the alternative hypothesis (H1) is the data do not fit to the following calculation. For example, in setting/adjustment cutter ply 1, the P value of Normal distribution is 0.014. Then, the null hypothesis is rejected because the P value is less than the significant level (α).

Meanwhile, calculating index of fit (r) or coefficicient correlation also can be peformed. If the value of coefficient correlation is close to 1 then it can be said the relationship between parameters that create the distribution function is highly strong. Goodness of fit test is also needed to calculate in order to support the selection process and strengthen the result of index of fit (r). Based on the result of goodness of fit then it will be selected the distribution that has smallest Anderson-Darling (AD) value (Praharsi *et al,* 2015). Anderson-Darling (AD) statistic determines how well the data follow a particular distribution and whether a sample of data comes from a population with a specified distribution.

For example, in sub machine cutter ply 1, the type of maintenance that will use is setting/adjustment. distribution. The fitted distribution is Lognormal distribution. Moreover, in some groups of data also can fits with two distributions. The distribution will be chosen due to the easiness in doing the calculation and the most frequently used in statistic. For example, replacement activity in sub machine cutter ply 1 is fits with normal distribution and lognormal distribution. Therefore, normal distribution is chosen since the distribution is commonly used in statistic and easier to do the calculation.

In cutter ply 1, for repairing activity fits with lognormal distribution while for replacement activity fits with normal distribution. In sensor machine, setting/adjustment activity and repairing activity fit with lognormal distribution. Meanwhile, in cutter ply 3 for all type of maintenance are fit with lognormal distribution.

Table 4.26 Summary of Time to Failure Parameter for Each Sub Machine

No	Component	Type of Maintenance	Distribution	Parameter			
				Scale	Tmed	Shape	Std.Deviasi
1	Cutter Ply 1	Setting/Adjustment	Lognormal	1.57943	278.668	-	-
		Repairing	Lognormal	0.686423	563.838	-	-
		Spare part replacement	Lognormal	0.426079	1,894.04	-	-
2	Sensor Machine	Setting/Adjustment	Lognormal	0.554941	1,587.78	-	-
		Repairing/replacement	Normal	-	1,790.95	-	414.861
3	Cutter Ply 3	Setting/Adjustment	Lognormal	0.261822	3,086.93	-	-
		Repairing/replacement	Normal	-	2,216.97	-	538.830

Table 4.26 shows the summary of time to failure parameters for each sub component. The table contain several information such as type of maintenance, the fitted distribution and its parameter. In sub component cutter ply 1 setting/adjustment activity fits with lognormal distribution. Therefore, the parameters for lognormal distribution are scale parameter and Tmed parameter. The value of scale parameter in lognormal distribution for setting/adjustment in cutter ply 1 is 1.57943. Meanwhile the value of Tmed parameter is 278.668.

Setting/adjustment in sensor machine, repairing and replacement in cutter ply 1 are fit with lognormal distribution. In Sensor machine for repairing/replacement activity fits with normal distribution which consists of two parameters. The parameters are Tmed parameter and standard deviation parameter. The value of scale parameter is 1,790.95 while the shape parameter is 414.861. In cutter ply 3, setting/adjustment activity fits with lognormal distribution while for repairing/replacement activity fits with normal distribution.

Table 4.27 Summary of Mean Time to Failure Distribution for Each Sub Machine

No	Component	Type of Maintenance	Distribution	Mean (hours)	MTTF (hours)
1	Cutter Ply 1	Setting/Adjustment	Lognormal	970.031	970.031
		Repairing	Lognormal	713.624	713.624
		Spare part replacement	Lognormal	2,074.01	2,074.01

Table 4.27 Summary of Mean Time to Failure Distribution for Each Sub Machine (Cont'd)

No	Component	Type of Maintenance	Distribution	Mean (hours)	MTTF (hours)
2	Sensor Machine	Setting/Adjustment	Lognormal	1,852.09	1,852.09
		Repairing/replacement	Normal	1,790.95	1,790.95
3	Cutter Ply 3	Setting/Adjustment	Lognormal	3,194.57	3,194.57
		Repairing/replacement	Normal	2,216.97	2,216.97

Table 4.27 shows the summary of mean time to failure for every sub component and its maintenance activity. Based on the calculation, mean time between failure for cutter ply 1 for setting/adjustment activity that fits with lognormal distribution is 970.031 hours. Repairing and replacement activity for cutter ply 1 also fit with lognormal distribution. The mean time to failure are 713.624 and 2,074.01 respectively. In sensor machine, setting/adjustment activity fits with lognormal distribution. The mean time to failure is 1,852.09. Repairing/replacement for sensor machine fit with normal distribution. Meanwhile, the mean time to failure is 1,790.95. Mean time to failure for setting/adjustment the sub component in cutter ply 3 that fits with lognormal distribution is 3,194.57 hours. In cutter ply 3 for repairing/replacement activity fits with normal distribution and the mean time to failure is 2,216.97 hours.

Below are the example of detail calculation to determine the mean time to failure :

- Cutter ply 1 (setting/adjustment) : Lognormal distribution

  $MTTF = tmed.e^{\left(\frac{s^2}{2}\right)}$

  $MTTF = 278.668\ x\ e^{\left(\frac{1.57943^2}{2}\right)}$

  $MTTF = 970.031$

- Sensor machine (setting/adjustment) : Lognormal distribution

  $MTTF = tmed.e^{\left(\frac{s^2}{2}\right)}$

  $MTTF = 1{,}587.78\ x\ e^{\left(\frac{0.554941^2}{2}\right)}$

  $MTTF = 1{,}852.09$

- Cutter ply 3 (repairing/replacement) : Normal distribution

$$MTTF = \mu$$
$$MTTF = 2{,}216.97$$

Table 4.28 Summary of Time to Repair Parameter for Each Sub Machine

No	Component	Type of Maintenance	Distribution	Parameter			
				Scale	Tmed	Shape	Std.Deviasi
1	Cutter Ply 1	Setting/Adjustment	Lognormal	0.322614	0.305957	-	-
		Repairing	Lognormal	0.425018	0.500274	-	-
		Spare part replacement	Normal	-	0.868182	-	0.526876
2	Sensor Machine	Setting/Adjustment	Lognormal	0.40004	0.557313	-	-
		Repairing/replacement	Lognormal	0.320727	1.26919	-	-
3	Cutter Ply 3	Setting/Adjustment	Lognormal	0.317927	0.553508	-	-
		Repairing/replacement	Lognormal	0.200427	1.13650	-	-

Table 4.28 shows the summary of time to repair parameters for each sub component. The table contain several information such as type of maintenance, the fitted distribution and its parameter. In sub component cutter ply 1 setting/adjustment activity fits with lognormal distribution. The parameters for lognormal distribution are scale parameter and Tmed parameter. The value of scale parameter in lognormal distribution for setting/adjustment in cutter ply 1 is 0.322614. Meanwhile the value of Tmed parameter is 0.305957. Repairing sub component cutter ply 1 fits with lognormal distribution. The scale and Tmed parameter are 0.425018 and 0.305957 respectively.

In cutter ply 1 for replacement activity, the fitted distribution is normal distribution which has 2 parameters. The parameters of normal distribution are Tmed and standard deviation. The value of Tmed parameter is 0.868182 while the standard deviation parameter is 0.526876. In Sensor machine for setting/adjustment and repairing activity fit with lognormal distribution. The scale parameter for setting/adjustment and repairing activity in sensor machine are 0.40004 and 0.320727 respectively. While the Tmed parameter are 0.557313 and 1.26919 respectively. In cutter ply 3, setting/adjustment and repairing/replacement activity are fit with lognormal distribution.

Table 4.29 Summary of Mean Time to Repair Distribution for Each Sub Machine

No	Component	Type of Maintenance	Distribution	Mean (hours)	MTTR (hours)
1	Cutter Ply 1	Setting/Adjustment	Lognormal	0.322301	0.322301
		Repairing	Lognormal	0.547562	0.547562
		Spare part replacement	Normal	0.868182	0.868182
2	Sensor Machine	Setting/Adjustment	Lognormal	0.603739	0.603739
		Repairing/replacement	Lognormal	1.33617	1.33617
3	Cutter Ply 3	Setting/Adjustment	Lognormal	0.582201	0.582201
		Repairing/replacement	Lognormal	1.15956	1.15956

Table 4.29 shows the summary of mean time to repair for every sub component and its maintenance activity. Based on the calculation, mean time to repair for cutter ply 1 for setting/adjustment activity that fits with lognormal distribution is 0.322301 hours. Repairing activity for cutter ply 1 also fits with lognormal distribution. The mean time to failure is 0.547562. Replacement activity for cutter ply 1 fits with normal distribution which has mean time to repair is 0.868182. In sensor machine, setting/adjustment activity and repairing acitivity fit with logormal distribution. The mean time to failure are 0.610829 and 1.33617 respectively. Mean time to failure for setting/adjustment the sub component in cutter ply 3 that fits with lognormal distribution is 0.582201 hours. In cutter ply 3 for repairing/replacement activity fits with lognormal distribution and the mean time to failure is 1.15956 hours.

Below are the example of detail calculation to determine the mean time to failure :

- Cutter ply 1 (setting/adjustment) : Lognormal distribution

$$MTTF = tmed.e^{\left(\frac{s^2}{2}\right)}$$

$$MTTF = 0.305957\ x\ e^{\left(\frac{0.322614^2}{2}\right)}$$

$$MTTF = 0.322301$$

- Cutter ply 1 (replacement) : Normal distribution

$$MTTF = \mu$$

$$MTTF = 0.868182$$

4.2.3 Calculation of Production Output

The calculation of prodution output in Tire Building Machine (TBM) Samson 1 needs to be calculated in order to know the actual number of production that company can achieves for one production hour. Furthermore, this production output is an important variable in calculating the corrective maintenance cost and preventive maintenance cost. Below is the table that shows the production output in TBM Samson 1.

Table 4.30 Production Output in TBM Samson 1

Cycle time (min/tire)	3.15
Capacity (tire/day)	456
Capacity (tire/shift)	152
Production output (tire/hour)	21
Actual production output (tire/hours)	19

Table 4.30 shows the production output in TBM Samson 1. The information in the table above based on the data from PT. ABC. The operator in TBM Samson 1 can complete the task which is assembly all materials into green tire for 3.15 minutes. Based on cycle time in TBM Samson 1, the company can determine the capacity of the machine and the production output for one production hour. TBM Samson 1 can produce 456 green tires for 24 hours production (3 shift). Meanwhile, for 1 production hours, by using TBM Samson 1 the operator can assembly and produce 21 green tires. This number also becomes the production target for PT. ABC. According to the information that obtained from the company, the actual production in TBM Samson 1 is only 19 green tires. This number will be used to calculate the maintenance cost.

4.2.4 Calculation of Maintenance Cost

There are some data required to be known before calculating the maintenance cost. The required data are as follows;

- Actual production output in TBM Samson 1 is 19 green tire/hour.
- Component price in repairing cutter ply 1 is IDR 500,000
- Component price in replacing cutter ply 1 is IDR 1,200,000
- Component price in repairing sensor machine is IDR 1,800,000

- Component price in repairing cutter ply 3 is IDR 800,000
- The salary for mechanic is IDR 4,000,000 per month. It is assumed that the mechanic is working 8 hours per day. Therefore, the mechanic will work 40 hours in a week or 160 hours per month. So, the mechanic salary per hour becomes IDR 25,000.

4.2.4.1 Calculation of Corrective Maintenance Cost

The further step after knowing the actual production output and the price of components is calculating corrective maintenance cost. The cost is calculated based on **Equation 2-27** which already mentioned in Chapter II. The required formula is as follows;

Cf = component price + [downtime (hours) x salary of mechanic per hours] + loss of production

Loss of production = downtime (hours) x production capacity (tire/hour) x Price of product

Table 4.31 Total Downtime for Each Sub Component

Component	Type of maintenance	Waiting time (hours)	TTR (hours)	Downtime (hours)
Cutter Ply 1	Setting/adjustment	0.483	0.322	0.806
	Repairing	0.567	0.547	1.114
	Replacement	1.217	0.868	2.085
Sensor Machine	Setting/adjustment	0.333	0.603	0.936
	Repairing	0.617	1.336	1.953
Cutter Ply 3	Setting/adjustment	0.367	0.582	0.949
	Repairing	0.867	1.160	2.026

Table 4.31 above shows the total downtime for every sub component and its maintenance activity. The downtime data is needed in calculating the corrective maintenance cost. Downtime is obtained from the sum of waiting time (hours) and time to repair (hours). Downtime for setting/adjustment in cutter ply 1 is 0.806 hours which obtained from the sum of 0.483 hours and 0.322 hours. Waiting time is obtained from the average of whole waiting time during the period. For example is for setting/adjustment in cutter ply 1, the waiting time is obtained from the average of waiting time in cutter ply 1 from the machine stops untill repairing time

begins. Time to repair is already explained in the previous part. The detail waiting time and time to repair for every sub components are presented in appendix 2.

Table 4.32 Calculation of Corrective Maintenance Cost

Component	Type of maintenance	Component Price (IDR)	Downtime (hours)	Salary Mechanic (IDR)	Loss of Prod. per hours (IDR)	CM Cost (IDR)
Cutter Ply 1	Setting/adjustment	0	0.806	20,150	15,314,000	15,334,150
	Repairing	500,000	1.114	27,850	21,166,000	21,693,850
	Replacement	1,200,000	2.085	52,125	39,615,000	40,867,125
Sensor Machine	Setting/adjustment	0	0.936	23,400	17,784,000	17,807,400
	Repairing	1,800,000	1.953	48,825	37,107,000	38,955,825
Cutter Ply 3	Setting/adjustment	0	0.949	23,725	18,031,000	18,054,725
	Repairing	800,000	2.026	50,650	38,494,000	39,344,650

Table 4.32 shows the calculation of corrective maintenance cost. The cost is obtained from the formula that already mentioned above. Downtime is obtained from the sum of time to repair and waiting time for every type of maintenance in each sub component. The downtime is already explained in Table 4.31. The component price is based on the information from the company. The loss of production per hours and corrective maintenance cost are obtained from **Equation 2-27**. Below is the example of detailed calculation in calculated corrective maintenance cost ;

- Cutter ply 1 (setting/adjustment)
  - Downtime = Waiting time + time to repair
    = 0.483 + 0.322
    = 0.806
  - Loss of production = downtime (hours) x production capacity (tire/hour) x Price of product
    = 0.806 x 19 x IDR 1,000,000
    = IDR 15,314,000
  - Salary mechanic = downtime (hours) x salary mechanic per hours
    = 0.806 x IDR 25,000
    = IDR 20,150

- Cf = component price + salary mechanic + loss of production
  = IDR 0 + IDR 20,150 + IDR 15,314,000
  = IDR 15,334,150

- Cutter ply 3 (repairing)
  - Downtime = Waiting time + time to repair
    = 0.867 + 1.160
    = 2.026
  - Loss of production = downtime (hours) x production capacity (tire/hour) x Price of product
    = 2.026 x 19 x IDR 1,000,000
    = IDR 38,494,000
  - Salary mechanic = downtime (hours) x salary mechanic/hours
    = 2.026 x IDR 25,000
    = IDR 50,650
  - Cf = component price + salary mechanic + loss of production
    = IDR 800,000 + IDR 50,650 + IDR 38,494,000
    = IDR 39,344,650

4.2.4.2 Calculation of Preventive Maintenance Cost

The further step after knowing the actual production output and the price of components is calculating corrective maintenance cost. The cost is calculated based on **Equation 2-27** which already mentioned in Chapter II. The required formula is as follows;

Cp = component price + [replacement time (hours) x salary of mechanic per hours] + loss of production

Loss of production = replacement time (hours) x production capacity (tire/hour) x Price of product

Table 4.33 Total Maintenance Time for Each Sub Component

Component	Type of maintenance	Maintenance Time (hours)
Cutter Ply 1	Setting/adjustment	0.2
	Repairing	0.25
	Replacement	0.42
Sensor Machine	Setting/adjustment	0.2
	Repairing	0.42
Cutter Ply 3	Setting/adjustment	0.2
	Repairing	0.33

Table 4.33 above shows the total maintenance time for every sub component and its maintenance activity. The maintenance time data is needed in calculating the preventive maintenance cost. Replacement time data is based on the company's maintenance time standard. In preventive maintenance activity, there is no waiting time of mechanic to come since it is already scheduled and the component will be maintain in the exact time that is already scheduled. The standard time for setting/adjustment cutter ply 1 is 0.2 hours. In repairing component in cutter ply 1 the standard time is 0.25 hours. The detailed maitenance time for every sub components and its maintenance activity can be seen in Table 4.33.

Table 4.34 Calculation of Preventive Maintenance Cost

Component	Type of maintenance	Component Price (IDR)	Maintenance Time (hours)	Salary mechanic (IDR)	Loss of prod. per hours (IDR)	PM Cost (IDR)
Cutter Ply 1	Setting/adjustment	0	0.2	5,000	3,800,000	3,805,000
	Repairing	500,000	0.25	6,250	4,750,000	5,256,250
	Replacement	1,200,000	0.42	10,500	7,980,000	9,190,500
Sensor Machine	Setting/adjustment	0	0.2	5,000	3,800,000	3,805,000
	Repairing	1,800,000	0.42	10,500	7,980,000	9,790,500
Cutter Ply 3	Setting/adjustment	0	0.2	5,000	3,800,000	3,805,000
	Repairing	800,000	0.33	8,250	6,270,000	7,078,250

Table 4.34 shows the calculation of preventive maintenance cost. The cost is obtained from the formula that already mentioned above. Replacement time is based on the standard time for every maintenance activity in PT. ABC. The detailed maintenance time can be seen in Table 4.33. The component price is based on the information from the company. Below is the example of detailed calculation in calculated preventive maintenance cost ;

- Sensor machine (setting/adjustment)
    - Replacement time = Waiting time + time to repair
      = 0 + 0.2
      = 0.2
    - Loss of production = replacement time (hours) x production capacity (tire/hour) x Price of product
      = 0.2 x 19 x IDR 1,000,000
      = IDR 3,800,000
    - Salary mechanic = replacement time (hours) x salary mechanic per hours
      = 0.2 x IDR 25,000
      = IDR 5,000
    - Cp = component price + salary mechanic + loss of production
      = IDR 0 + IDR 5,000 + IDR 3,800,000
      = IDR 3,805,000
- Sensor machine (repairing)
    - Downtime = Waiting time + time to repair
      = 0 + 0.42
      = 0.42
    - Loss of production = replacement time (hours) x production capacity (tire/hour) x Price of product
      = 0.42 x 19 x IDR 1,000,000
      = IDR 7,980,000
    - Salary mechanic = replacement time (hours) x salary mechanic
      = 0.42 x IDR 25,000
      = IDR 10,500
    - Cp = component price + salary mechanic + loss of production
      = IDR 1,800,000 + IDR 10,500 + IDR 7,980,000
      = IDR 9,790,500

4.2.5 Calculation of Sub Component Maintenance Interval

Maintenance interval is used to setting the preventive maintenance intervals based on the failure that needs maintenance activity. The maintenance activity will be done when the sub component in machine has reached the useful life of the sub components.

4.2.5.1 Calculation of Maintenance Interval for Cutter Ply 1

The first thing that needs to do before determining the maintenance interval time for cutter ply 1 is to know what kind of distribution is used. All type of maintenance activity in cutter ply 1 are fit with lognormal distribution. Therefore, all of the calculation is based on formulas in lognormal distribution. Table 4.35 will explain about replacement interval time for sub component cutter ply 1 by doing setting/adjustment activity. Meanwhile, Table 4.36 and Table 4.37 below will explains about replacement interval time for repairing and replacement activity in cutter ply 1 respectively.

Table 4.35 Setting/adjustment Interval Time of Cutter Ply 1

t (Hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
960	0.0003576	0.78322706	0.216773	0.00238293	3,341
920	0.0003655	0.775232999	0.224767001	0.00237362	3,486
880	0.0003742	0.766707888	0.233292112	0.00236454	3,644
840	0.0003839	0.757597194	0.242402806	0.00235571	3,818
800	0.0003947	0.747838498	0.252161502	0.00234714	4,009
760	0.0004068	0.737359965	0.262640035	0.00233886	4,219
720	0.0004204	0.726078462	0.273921538	0.00233090	4,454
680	0.0004358	0.713897169	0.286102831	0.00232329	4,715
640	0.0004534	0.700702564	0.299297436	0.00231606	5,010
600	0.0004738	0.686360534	0.313639466	0.00230924	5,344
560	0.0004974	0.670711324	0.329288676	0.00230288	5,725
520	0.0005253	0.653562868	0.346437132	0.00229699	6,165
480	0.0005585	0.634681861	0.365318139	0.00229162	6,679
440	0.0005987	0.613781586	0.386218414	0.00228680	7,286
400	0.0006484	0.590505005	0.409494995	0.00228252	8,015
360	0.0007111	0.564400736	0.435599264	0.00227875	8,905
320	0.0007926	0.534888059	0.465111941	0.00227539	10,018
280	0.0009023	0.501204454	0.498795546	0.00227213	11,449
240	0.001057	0.462324295	0.537675705	0.00226837	13,357

Table 4.35 Setting/adjustment Interval Time of Cutter Ply 1 (Cont'd)

t (Hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
200	0.001291	0.416828044	0.583171956	0.00226272	16,028
160	0.001680	0.362683183	0.637316817	0.00225191	20,034
120	0.002427	0.296864906	0.703135094	0.00222761	26,708
80	0.004315	0.214718633	0.785281367	0.00216398	40,050
60	0.0067554	0.16545117	0.83454883	0.00209202	53,382
40	0.013442	0.10953327	0.89046673	0.001947009	80,017
20	0.050763	0.047670459	0.952329541	0.001584644	15,9757

The table above shows the setting/adjustment interval for cutter ply 1 component. The time to failure of cutter ply 1 (setting/adjustment) accept the logormal distribution. The result that written in the table above is obtained by using the formula for lognormal distribution. Below is the detail calculation for setting/adjustment cutter ply 1 that fits with lognormal distribution.

- Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}} e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]}$$

$$f(t) = \frac{1}{(1.57943)(960)\sqrt{6.28}} e^{\left[\frac{1}{2(1.57943)^2}\left(ln\frac{960}{278.668}\right)^2\right]}$$

$$f(t) = 0.0003576$$

- Cumulative distribution function

$$\mathrm{F}(t) = \phi\left[\frac{1}{S} \ \ln\frac{t}{tmed}\right]$$

$$\mathrm{F}(t) = \phi\left[\frac{1}{1.57943} \ \ln\frac{960}{278.668}\right]$$

$$F(t) = 0.78322706$$

- Reliability function

$$\mathrm{R}(t) = 1 - F(t)$$

$$\mathrm{R}(t) = 1 - 0.78322706$$

$$\mathrm{R}(t) = 0.216773$$

- Cumulative hazard function

$$H(t) = \frac{F(t)}{st \times R(t)}$$

$$H(t) = \frac{0.78322706}{1.57943 \times 960 \times 0.216773}$$

$$H(t) = 0.00238293$$

- Cost per unit of time

$$C(t) = \frac{Cp + [Cf \; x \; H(t)]}{t}$$

$$C(t) = \frac{\text{IDR } 3{,}170{,}833 + [\text{ IDR } 15{,}334{,}150 \; x \; 0.00238293 \;)]}{960}$$

$$C(t) = \text{IDR } 3{,}341$$

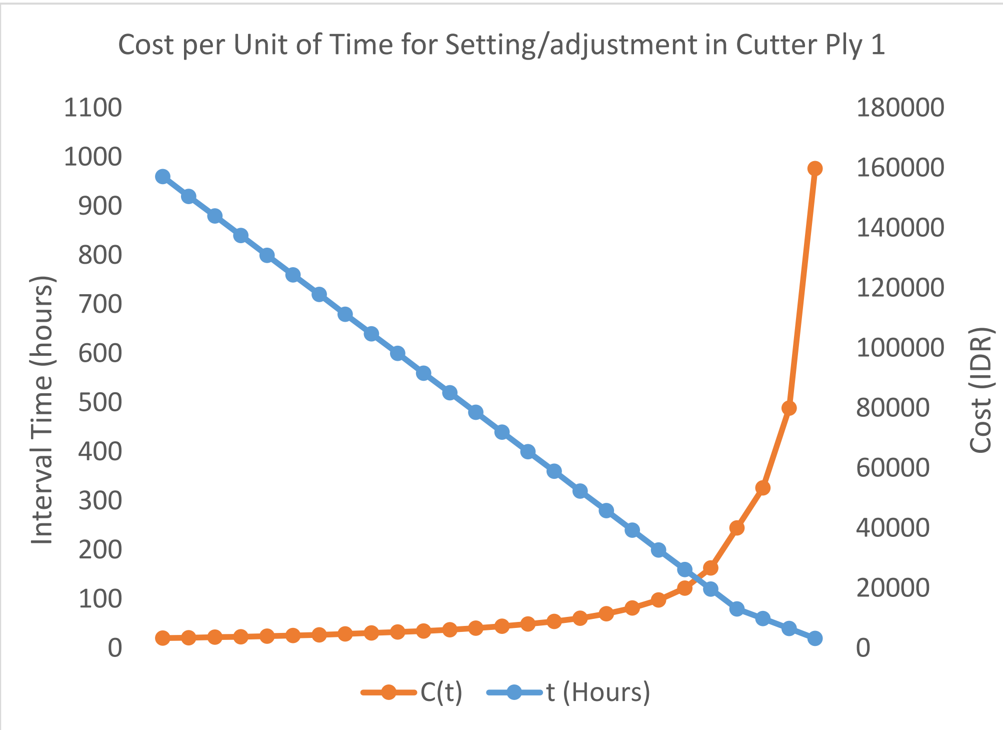


Figure 4.6 Cost per Unit of Time for Setting/adjustment Cutter Ply 1

Based on the cost calculation above, it can be seen that maintenance interval time has relationship with the cost. When the maintenance interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.6. The example is for the interval time is 120 hours the machine has 70% of reliability and the cost is IDR 26,708. If the interval time is getting shorter become 80 hours, then the cost and reliability of the machine will increase. The reliability of machine become 78% while the cost is IDR 40,050. The detailed information can be seen in Table 4.35.

Table 4.36 Repairing Interval Time of Cutter Ply 1

t (Hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
700	0.0008728	0.623669010	0.376330990	0.00344901	7,616
680	0.00088873	0.607535508	0.392464492	0.00331643	7,836
660	0.0008831	0.590725184	0.409274816	0.00318592	8,069
640	0.0009239	0.573221473	0.426778527	0.00305737	8,317
620	0.0009467	0.555009966	0.444990034	0.00293067	8,580
600	0.0009729	0.536079014	0.463920986	0.00280570	8,862
580	0.0010032	0.516420449	0.483579551	0.00268235	9,163
560	0.0010382	0.496030425	0.503969575	0.00256050	9,485
540	0.0010787	0.474910405	0.525089595	0.00244002	9,832
520	0.0011258	0.453068314	0.546931686	0.00232079	10,205
500	0.0011806	0.430519869	0.569480131	0.00220269	10,608
480	0.0012449	0.407290117	0.592709883	0.00208559	11,045
460	0.0012693	0.383415197	0.616584803	0.00196937	11,520
440	0.0014103	0.358944338	0.641055662	0.00185390	12,037
420	0.0015176	0.333942106	0.666057894	0.00173907	12,605
400	0.001647	0.308490903	0.691509097	0.00162477	13,229
380	0.0018047	0.282693683	0.717306317	0.00151090	13,918
360	0.0019994	0.256676852	0.743323148	0.00139738	14,685
340	0.0022432	0.230593243	0.769406757	0.00128416	15,541
320	0.0025536	0.065530842	0.934469158	0.00031926	16,447
300	0.0029566	0.178986161	0.821013839	0.00105866	17,597
280	0.003492	0.153924378	0.846075622	0.00094656	18,846
260	0.0042229	0.129721433	0.870278567	0.00083520	20,286
240	0.0052533	0.106691393	0.893308607	0.00072498	21,967
220	0.0067641	0.085175331	0.914824669	0.00061654	23,953
200	0.009088	0.065530842	0.934469158	0.00051081	26,337

The table above shows the repairing interval for cutter ply 1 component. The time to failure of cutter ply 1 (repairing) accept the logormal distribution. The result that written in the table above is obtained by using the formula for lognormal distribution. Below is the detail calculation for repairing cutter ply 1 that fits with lognormal distribution.

- Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}} e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]}$$

$$f(t) = \frac{1}{(0.686423)(700)\sqrt{6.28}} e^{\left[\frac{1}{2(0.686423)^2}\left(ln\frac{700}{563.838}\right)^2\right]}$$

$$f(t) = 0.0008728$$

- Cumulative distribution function

$$\mathrm{F}(t) = \phi\left[\frac{1}{S} \ \ln\frac{t}{tmed}\right]$$

$$\mathrm{F}(t) = \phi\left[\frac{1}{0.686423} \ \ln\frac{700}{563.838}\right]$$

$$F(t) = 0.62366901$$

- Reliability function

$$\mathrm{R}(t) = 1 - F(t)$$

$$\mathrm{R}(t) = 1 - 0.62366901$$

$$\mathrm{R}(t) = 0.37633099$$

- Cumulative hazard function

$$\mathrm{H}(t) = \frac{\mathrm{F(t)}}{\mathrm{st\ x\ R(t)}}$$

$$\mathrm{H}(t) = \frac{0.62366901}{0.686423 \text{ x } 700 \text{ x } 0.37633099}$$

$$\mathrm{H}(t) = 0.00344901$$

- Cost per unit of time

$$\mathrm{C(t)} = \frac{Cp + [Cf\ x\ H(t)]}{t}$$

$$\mathrm{C(t)} = \frac{\text{IDR } 5{,}256{,}250 + [\text{ IDR } 32{,}693{,}850\ x\ 0.00344901\ )]}{700}$$

C(t) = IDR 7,616

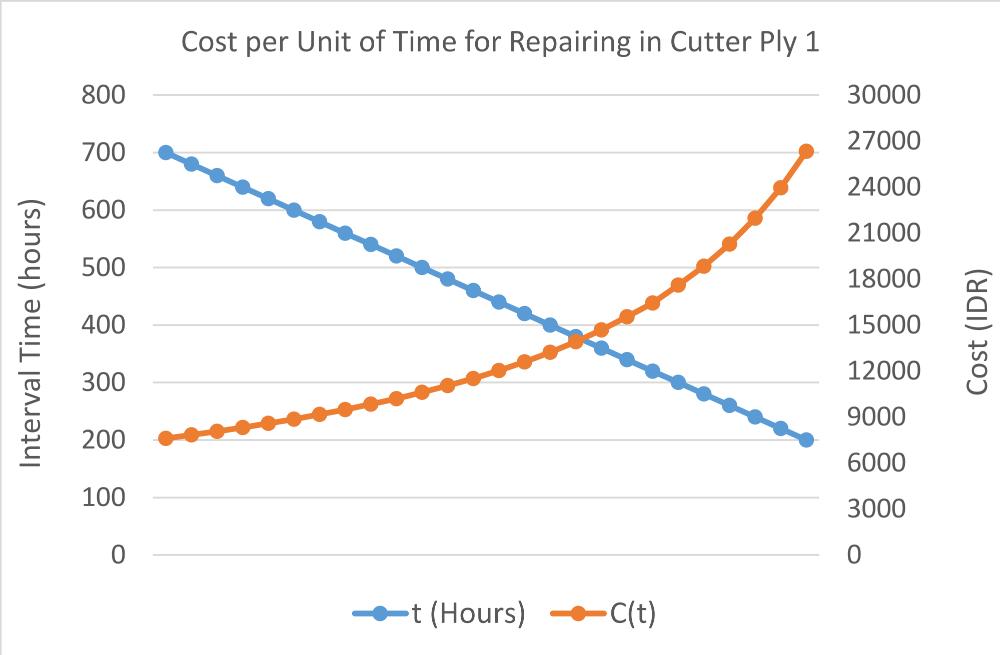


Figure 4.7 Cost per Unit of Time for Repairing Cutter Ply 1

Based on the cost calculation above, it can be seen that maintenance interval time has relationship with the cost. When the repairing interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.7. The example is for the interval time of 400 hours the machine has 69% of reliability and the cost is IDR 13,229. If the repairing interval time is getting shorter become 300 hours, then the cost and reliability of the machine will increase. The reliability of machine become 82% while the cost is IDR 17,597. The detailed information can be seen in Table 4.36.

Table 4.37 Replacement Interval Time of Cutter Ply 1

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
2,100	0.0004593	0.595713677	0.404286323	0.001646751	4,378
2,050	0.0004648	0.573664412	0.426335588	0.001540462	4,483
2,000	0.0004721	0.550829817	0.449170183	0.001439048	4,593
1,950	0.0004814	0.527241593	0.472758407	0.001342253	4,709
1,900	0.0004929	0.502941648	0.497058352	0.001249842	4,831
1,850	0.0005070	0.477983101	0.522016899	0.001161595	4,959
1,800	0.0005240	0.452431245	0.547568755	0.001077308	5,095
1,750	0.0005445	0.426364443	0.573635557	0.000996794	5,239
1,700	0.0005689	0.399874891	0.600125109	0.000919882	5,391

Table 4.37 Replacement Interval Time of Cutter Ply 1

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
1,650	0.0005981	0.37306921	0.62693079	0.000846417	5,553
1,600	0.0006331	0.346068789	0.653931211	0.000776263	5,724
1,550	0.0006749	0.319009803	0.680990197	0.000709300	5,907
1,500	0.0007253	0.29204282	0.70795718	0.000645427	6,102
1,450	0.0007862	0.265331906	0.734668094	0.000584560	6,311
1,400	0.0008603	0.239053116	0.760946884	0.000526636	6,535
1,350	0.0009513	0.213392282	0.786607718	0.000471613	6,775
1,300	0.0010641	0.188542003	0.811457997	0.000419467	7,034
1,250	0.0012056	0.164697755	0.835302245	0.000370197	7,314
1,200	0.0013851	0.142053086	0.857946914	0.000323823	7,617
1,150	0.0016166	0.120793888	0.879206112	0.000280385	7,947
1,100	0.0019201	0.10109183	0.89890817	0.000239942	8,306
1,050	0.0023259	0.083097112	0.916902888	0.000202569	8,700
1,000	0.0028806	0.066930821	0.933069179	0.000168349	9,134
950	0.0036584	0.052677314	0.947322686	0.000137373	9,613
900	0.0047809	0.040377202	0.959622798	0.000109722	10,146
850	0.0064563	0.030021664	0.969978336	0.000085458	10,742

The table above shows the replacement interval for cutter ply 1 component. The time to failure of cutter ply 1 for replacement activity accept the lognormal distribution. The result that written in the table above is obtained by using the formula for lognormal distribution.

Below is the detail calculation for replacement activity in cutter ply 1 that fits with lognormal distribution.

- Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}} e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]}$$

$$f(t) = \frac{1}{(0.426079)(2,100)\sqrt{6.28}} e^{\left[\frac{1}{2(0.426079)^2}\left(ln\frac{2100}{1894.04}\right)^2\right]}$$

$$f(t) = 0.0004593$$

- Cumulative distribution function

$$F(t) = \phi\left[\frac{1}{S}\ \ln\frac{t}{tmed}\right]$$

$$F(t) = \phi\left[\frac{1}{0.426079}\ \ln\frac{2,100}{1894.04}\right]$$

$$F(t) = 0.595713677$$

- Reliability function

$$R(t) = 1 - F(t)$$

$$R(t) = 1 - 0.595713677$$

$$R(t) = 0.404286323$$

- Cumulative hazard function

$$H(t) = \frac{F(t)}{st \times R(t)}$$

$$H(t) = \frac{0.595713677}{0.426079 \times 2,100 \times 0.404286323}$$

$$H(t) = 0.001646751$$

- Cost per unit of time

$$C(t) = \frac{Cp + [Cf\ x\ H(t)]}{t}$$

$$C(t) = \frac{\text{IDR } 9,127,083 + [\text{ IDR } 40,867,125\ x\ 0.000846417)]}{2100}$$

$$C(t) = \text{IDR } 4,378$$

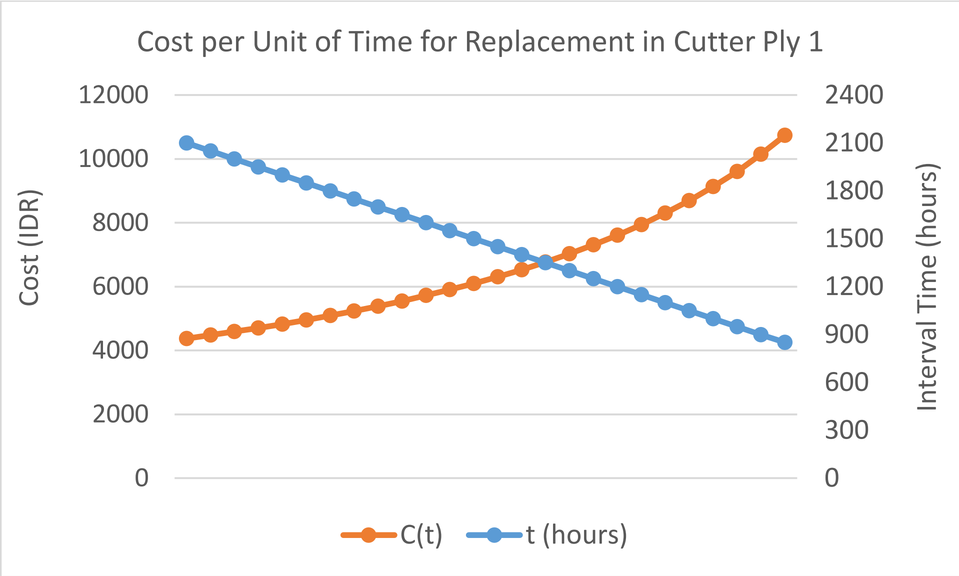


Figure 4.8 Cost per Unit of Time for Replacement Cutter Ply 1

Based on the cost calculation above, when the interval time is 2,100 hours, then the machine will has 40% of reliability and the cost is IDR 4,378. If the replacement interval time is getting shorter become 1,000 hours, then the cost and reliability of the machine will increase. The reliability of machine become 93% while the cost is IDR 9,134. The detailed information can be seen in Table 4.37. Hence it can be seen that maintenance interval time has relationship with the cost. When the replacement interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.8.

4.2.5.2 Calculation of Maintenance Interval for Sensor Machine

The first thing that needs to do before determining the maintenance interval time for sensor machine is to know what kind of distribution is used. Setting/adjustment activity fits with lognormal distribution while for repairing/replacement fits with weibull distribution. Therefore, all of the calculation for setting/adjustment and repairing/replacement are based on formulas in lognormal and weibull distribution repectively. Table 4.38 will explain about replacement interval time for sub component sensor machine by doing setting/adjustment activity. Table 4.39 will explain about repairing component in sub machine.

Table 4.38 Setting/adjustment Interval Time of Sensor Machine

t (hours)	f(t)	F(t)	R(t)	H(t)	C (t) IDR
1800	0.0004098	0.589422544	0.410577456	0.001437	286
1750	0.0004173	0.569576498	0.430423502	0.001363	316
1700	0.0004262	0.548970491	0.451029509	0.001290	350
1650	0.0004368	0.527611006	0.472388994	0.001220	387
1600	0.0004495	0.505511432	0.494488568	0.001151	429
1550	0.0004644	0.482693175	0.517306825	0.001085	477
1500	0.0004819	0.459186876	0.540813124	0.001020	530
1450	0.0005026	0.435033726	0.564966274	0.000957	590
1400	0.0005270	0.410286858	0.589713142	0.000896	659
1350	0.0005559	0.385012809	0.614987191	0.000836	736
1300	0.0005902	0.359293002	0.640706998	0.000777	824
1250	0.0006313	0.333225215	0.666774785	0.000720	926
1200	0.0006806	0.306924950	0.693075050	0.000665	1,042
1150	0.0007404	0.280526627	0.719473373	0.000611	1,178
1100	0.0008135	0.254184465	0.745815535	0.000558	1,336
1050	0.0009040	0.228072897	0.771927103	0.000507	1,522
1000	0.0010174	0.202386308	0.797613692	0.000457	1,744
950	0.0011616	0.177337852	0.822662148	0.000409	2,012
900	0.0013483	0.153157038	0.846842962	0.000362	2,339
850	0.0015946	0.130085743	0.869914257	0.000317	2,744
800	0.0019275	0.108372259	0.891627741	0.000274	3,257
750	0.0023898	0.088263009	0.911736991	0.000233	3,920
700	0.0030525	0.069991578	0.930008422	0.000194	4,800
650	0.0040393	0.053764908	0.946235092	0.000158	6,007
600	0.0055770	0.039746770	0.960253230	0.000124	7,724

The table above shows the setting/adjustment interval time for sensor machine component. The time to failure of sensor machine for setting/adjustment activity accept the lognormal distribution. The result that written in the table above is obtained by using the formula for lognormal distribution. Below is the detail calculation for setting/adjustment activity sensor machine that fits with lognormal distribution.

- Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}}\, e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]}$$

$$f(t) = \frac{1}{(0.554941)(1{,}800)\sqrt{6.28}}\, e^{\left[\frac{1}{2(0.554941)^2}\left(ln\frac{1{,}800}{1{,}587.78}\right)^2\right]}$$

$$f(t) = 0.0004098$$

- Cumulative distribution function

$$F(t) = \phi\left[\frac{1}{S}\ \ln\frac{t}{tmed}\right]$$

$$F(t) = \phi\left[\frac{1}{0.554941}\ \ln\frac{1800}{1587.78}\right]$$

$$F(t) = 0.589422544$$

- Reliability function

$$R(t) = 1 - F(t)$$

$$R(t) = 1 - 0.589422544$$

$$R(t) = 0.41057$$

- Cumulative hazard function

$$H(t) = \frac{F(t)}{st \text{ x } R(t)}$$

$$H(t) = \frac{0.589422544}{0.554941 \text{ x } 1800 \text{ x } 0.41057}$$

$$H(t) = 0.001437$$

- Cost per unit of time

$$C(t) = \frac{Cp + [Cf\ x\ H(t)]}{t}$$

$$C(t) = \frac{\text{IDR } 3{,}170{,}833 + [\text{ IDR } 17{,}807{,}400\ x\ 0.001437)]}{1800}$$

$$C(t) = \text{IDR } 286$$

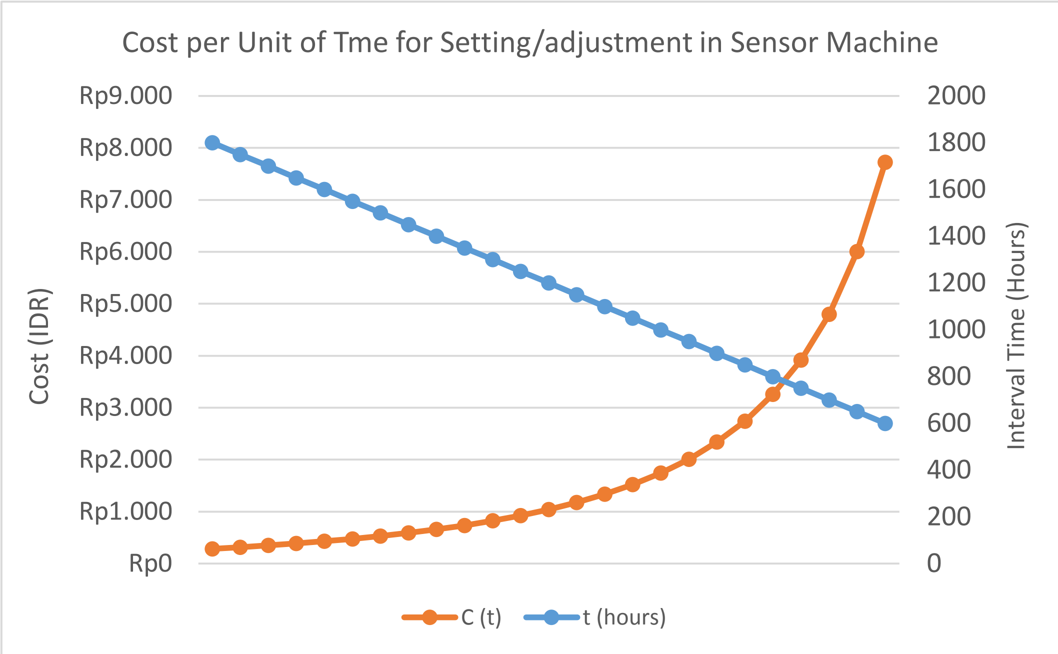


Figure 4.9 Cost per Unit of Time for Setting/adjustment Sensor Machine

Based on the cost calculation above, when the setting/adjustment interval time in sensor machine is 1600 hours, then the machine will has 49% of reliability and the cost is IDR 429. If the replacement interval time is getting shorter become 900 hours, then the cost and reliability of the machine will increase. The reliability of machine become 84% while the cost is IDR 2,339. The detailed information can be seen in Table 4.38. Hence it can be seen that maintenance interval time has relationship with the cost. When the setting/adjustment interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.9.

Table 4.39 Repairing Interval Time of Sensor Machine

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
1,800	0.000961400	0.508702050	0.491297950	0.00249583	5,458
1,750	0.000956955	0.460685154	0.539314846	0.00205901	5,604
1,700	0.000938795	0.413235422	0.586764578	0.00169758	5,761
1,675	0.000924794	0.389933944	0.610066056	0.00154067	5,843
1,650	0.000907699	0.367021517	0.632978483	0.00139765	5,928
1,625	0.000887690	0.344573287	0.655426713	0.00126722	6,016
1,600	0.000864976	0.322659549	0.677340451	0.00114824	6,107
1,575	0.000839788	0.301345093	0.698654907	0.00103967	6,202
1,550	0.000812378	0.280688658	0.719311342	0.00094060	6,299

Table 4.39 Repairing Interval Time of Sensor Machine (Cont'd)

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
1,800	0.000961400	0.508702050	0.491297950	0.00249583	5,458
1,750	0.000956955	0.460685154	0.539314846	0.00205901	5,604
1,700	0.000938795	0.413235422	0.586764578	0.00169758	5,761
1,675	0.000924794	0.389933944	0.610066056	0.00154067	5,843
1,650	0.000907699	0.367021517	0.632978483	0.00139765	5,928
1,625	0.000887690	0.344573287	0.655426713	0.00126722	6,016
1,600	0.000864976	0.322659549	0.677340451	0.00114824	6,107
1,575	0.000839788	0.301345093	0.698654907	0.00103967	6,202
1,550	0.000812378	0.280688658	0.719311342	0.00094060	6,299
1,525	0.000783014	0.260742471	0.739257529	0.00085018	6,400
1,500	0.000751976	0.241551906	0.758448094	0.00076768	6,505
1,475	0.000719550	0.223155243	0.776844757	0.00069242	6,613
1,450	0.000686027	0.205583546	0.794416454	0.00062378	6,725
1,425	0.000651695	0.188860641	0.811139359	0.00056123	6,841
1,400	0.000616836	0.173003200	0.826996800	0.00050425	6,962
1,375	0.000581726	0.158020920	0.841979080	0.00045238	7,087
1,350	0.000546626	0.143916798	0.856083202	0.00040522	7,217
1,325	0.000511782	0.130687476	0.869312524	0.00036237	7,352
1,300	0.000477422	0.118323661	0.881676339	0.00032349	7,492
1,275	0.000443755	0.106810601	0.893189399	0.00028825	7,638
1,250	0.000410966	0.096128603	0.903871397	0.00025636	7,790
1,225	0.000379221	0.086253594	0.913746406	0.00022754	7,948
1,200	0.000348659	0.077157689	0.922842311	0.00020153	8,112
1,175	0.000319399	0.068809780	0.931190220	0.00017812	8,284
1,150	0.000291533	0.061176118	0.938823882	0.00015707	8,464
1,125	0.000265134	0.054220889	0.945779111	0.00013819	8,651
1,100	0.000240252	0.047906761	0.952093239	0.00012128	8,847

The table above shows the repairing interval time for sensor machine component. The time to failure of sensor machine for repairing/replacement activity accept the normal distribution. The result that written in the table above is obtained by using the formula for normal distribution. Below is the detail calculation for repairing/replacement activity sensor machine that fits with normal distribution.

- Probability density function

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp[-\frac{(t-\mu)^2}{2}]$$

$$f(t) = \frac{1}{414.861\sqrt{6.28}} \exp[-\frac{(1800-1790.95)^2}{2}]$$

$$f(t) = 0.000961400$$

- Cumulative distribution function

$$F(t) = \phi\left(\frac{t-\mu}{\sigma}\right)$$

$$F(t) = \phi\left(\frac{1800-1790.95}{414.861}\right)$$

$$F(t) = 0.508702050$$

- Reliability function

$$\mathrm{R}(t) = 1 - \mathrm{F(t)}$$

$$\mathrm{R}(t) = 1 - 0.508702050$$

$$\mathrm{R}(t) = 0.491297950$$

- Cumulative hazard function

$$H(t) = \left(\frac{\mathrm{F(t)}}{\sigma R(t)}\right)$$

$$H(t) = \left(\frac{0.508702050}{414.861\ x\ 0.491297950}\right)$$

$$H(t) = 0.00249583$$

- Cost per unit of time

$$\mathrm{C(t)} = \frac{Cp + [Cf\ x\ H(t)]}{t}$$

$$\mathrm{C(t)} = \frac{\text{IDR } 9{,}727{,}083 + [\text{ IDR } 38{,}955{,}825\ x\ 0.00249583)]}{1800}$$

$$\mathrm{C(t)} = \text{IDR } 5{,}458$$

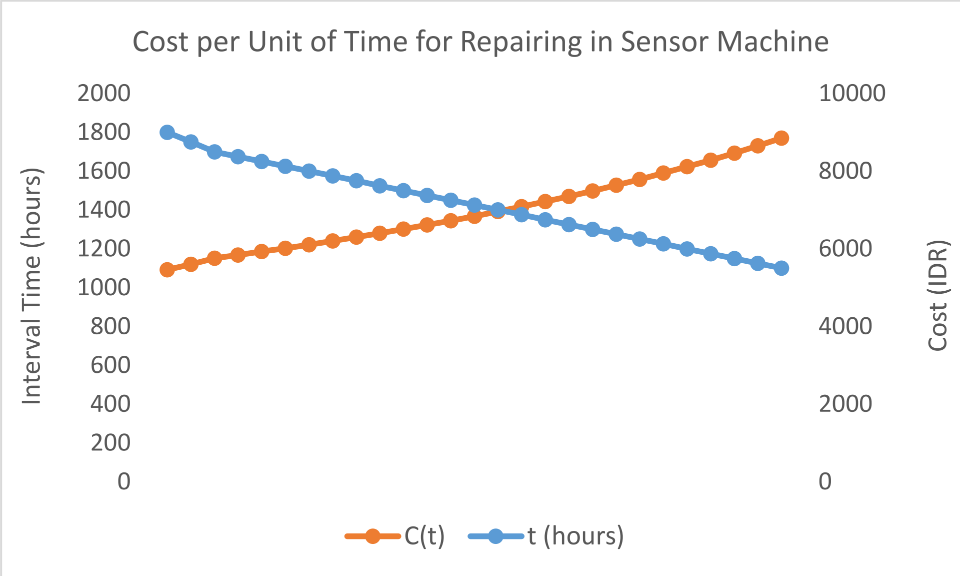


Figure 4.10 Cost per Unit of Time Repairing in Sensor Machine

Based on the cost calculation above, when the repairing interval time in sensor machine is 1,800 hours, then the machine will has 49% of reliability and the cost is IDR 5,458. If the repairing interval time is getting shorter become 1,200 hours, then the cost and reliability of the machine will increase. The reliability of machine become 92% while the cost is IDR 8,112. The detailed information can be seen in Table 4.39. Hence it can be seen that maintenance interval time has relationship with the cost. When the repairing interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.10.

4.2.5.3 Calculation of Maintenance Interval for Cutter Ply 3

The first thing that needs to do before determining the maintenance interval time for cutter ply 3 is to know what kind of distribution is used. Setting/adjustment activity fits with lognormal distribution while for repairing/replacement fits with normal distribution. Therefore, all of the calculation for setting/adjustment and repairing/replacement are based on formulas in lognormal and normal distribution repectively. Table 4.40 will explain about replacement interval time for sub component sensor machine by doing setting/adjustment activity. Table 4.41 will explain about repairing component in sub machine.

Table 4.40 Setting/adjustment Interval Time of Cutter ply 3

t (Hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
3,150	0.0004853	0.53078711	0.469213	0.00137162	1,014
3,110	0.0004903	0.511343535	0.488656465	0.00128512	1,027
3,070	0.0004966	0.49162093	0.50837907	0.00120309	1,040
3,030	0.0005043	0.471660747	0.528339253	0.00112530	1,053
2,990	0.0005135	0.451507892	0.548492108	0.00105152	1,067
2,950	0.0005245	0.431210594	0.568789406	0.00098154	1,081
2,910	0.0005372	0.410820227	0.589179773	0.00091518	1,095
2,870	0.0005520	0.390391072	0.609608928	0.00085224	1,110
2,830	0.0005690	0.369980026	0.630019974	0.00079256	1,125
2,790	0.0005886	0.349646251	0.650353749	0.00073598	1,141
2,750	0.0006109	0.329450764	0.670549236	0.00068237	1,158
2,710	0.0006365	0.309455964	0.690544036	0.00063159	1,174
2,670	0.0006656	0.289725113	0.710274887	0.00058350	1,192
2,630	0.0006988	0.270321747	0.729678253	0.00053801	1,209
2,590	0.0007367	0.251309054	0.748690946	0.00049499	1,228
2,550	00007801	0.2327492	0.7672508	0.00045436	1,247
2,510	0.0008297	0.21470262	0.78529738	0.00041603	1,266
2,470	0.0008867	0.197227291	0.802772709	0.00037990	1,287
2,430	0.0009523	0.180377987	0.819622013	0.00034591	1,307
2,390	0.0010281	0.164205541	0.835794459	0.00031397	1,329
2,350	0.0011159	0.14875612	0.85124388	0.00028402	1,351
2,310	0.0012181	0.13407053	0.86592947	0.00025600	1,375
2,290	0.0012754	0.127025302	0.872974698	0.00024269	1,387
2,250	0.0014049	0.11354870	0.88645130	0.00021744	1,411
2,210	0.0015573	0.100910483	0.899089517	0.00019397	1,436
2,190	0.0016438	0.094911538	0.905088462	0.00018288	1,449
2,150	0.0018408	0,083561387	0,916438613	0,00016198	1476
2,110	0.0020765	0,073079138	0,926920862	0,00014271	1504
1,970	0.0033695	0,043131036	0,956868964	0,00008739	1610
1,930	0.0039462	0,036422316	0,963577684	0,00007480	1644

The table above shows the setting/adjustment interval for cutter ply 3 component. The time to failure of cutter ply 3 for setting/adjustment activity accept the lognormal distribution. The result that written in the table above is obtained by using the formula for lognormal distribution.

Below is the detail calculation for setting/adjustment activity in cutter ply 3 that fits with lognormal distribution.

- Probability density function

$$f(t) = \frac{1}{st\sqrt{2\pi}} e^{\left[\frac{1}{2s^2}\left(ln\frac{t}{tmed}\right)^2\right]}$$

$$f(t) = \frac{1}{(0.261822)(3,150)\sqrt{6.28}} e^{\left[\frac{1}{2(0.261822)^2}\left(ln\frac{3,150}{3086.93}\right)^2\right]}$$

$$f(t) = 0.0004853$$

- Cumulative distribution function

$$\mathrm{F}(t) = \phi\left[\frac{1}{S}\ \ln\frac{t}{tmed}\right]$$

$$\mathrm{F}(t) = \phi\left[\frac{1}{0.261822}\ \ln\frac{3,150}{3086.93}\right]$$

$$F(t) = 0.53078711$$

- Reliability function

$$\mathrm{R}(t) = 1 - F(t)$$

$$\mathrm{R}(t) = 1 - 0.53078711$$

$$\mathrm{R}(t) = 0.469213$$

- Cumulative hazard function

$$\mathrm{H}(t) = \frac{\mathrm{F(t)}}{\mathrm{st\ x\ R(t)}}$$

$$\mathrm{H}(t) = \frac{0.53078711}{0.261822 \text{ x } 3150 \text{ x } 0.469213}$$

$$\mathrm{H}(t) = 0.00137162$$

- Cost per unit of time

$$\mathrm{C(t)} = \frac{Cp + [Cf\ x\ H(t)]}{t}$$

$$\mathrm{C(t)} = \frac{\text{IDR } 3,170,833 + [\text{ IDR } 18,054,725\ x\ 0.00137162)]}{3150}$$

$$\mathrm{C(t)} = \text{IDR } 1,014$$

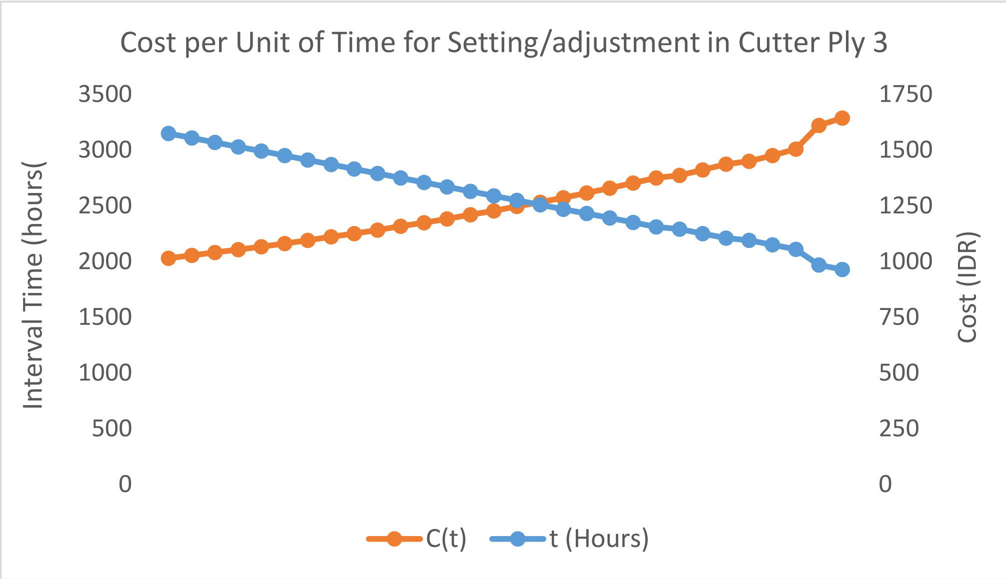


Figure 4.11 Cost per Unit of Time Setting/adjustment in Cutter Ply 3

Based on the cost calculation above, it can be seen that maintenance interval time has relationship with the cost. When the setting/adjustment interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.11. The example is for the interval time of 3,150 hours the machine has 46% of reliability and the cost is IDR 1,014. If the repairing interval time is getting shorter become 2,110 hours, then the cost and reliability of the machine will increase. The reliability of machine become 92% while the cost is IDR 1,504. The detailed information can be seen in Table 4.40.

Table 4.41 Repairing Interval Time of Cutter ply 3

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
2,300	0.000731648	0.561231847	0.438768153	0.002373862	3,146
2,250	0.000738996	0.524439648	0.475560352	0.002046624	3,210
2,200	0.000740019	0.487437723	0.512562277	0.001764903	3,278
2,150	0.000661235	0.806609728	0.193390272	0.007740643	3,463
2,100	0.000728622	0.771848515	0.228151485	0.006278516	3,518
2,050	0.000791298	0.733826077	0.266173923	0.005116534	3,582
2,000	0.000846973	0.692835481	0.307164519	0.004186078	3,653
1,950	0.000893492	0.649281512	0.350718488	0.003435758	3,732
1,900	0.000928974	0.603670419	0.396329581	0.002826778	3,817
1,850	0.000951937	0.556593022	0.443406978	0.002329611	3,910
1,800	0.000961400	0.508702050	0.491297950	0.001921617	4,010
1,750	0.000956955	0.460685154	0.539314846	0.001585295	4,117

Table 4.41 Repairing Interval Time of Cutter ply 3 (Cont'd)

t (hours)	f(t)	F(t)	R(t)	H(t)	C(t) IDR
1,700	0.000938795	0.413235422	0.586764578	0.001307019	4,231
1,650	0.000907699	0.367021517	0.632978483	0.001076095	4,354
1,600	0.000864976	0.322659549	0.677340451	0.000884068	4,485
1,550	0.000812378	0.280688658	0.719311342	0.000724196	4,626
1,450	0.000686027	0.205583546	0.794416454	0.000480273	4,938
1,400	0.000616836	0.173003200	0.826996800	0.00038824	5,112
1,350	0.000546626	0.143916798	0.856083202	0.00031199	5,299
1,300	0.000477422	0.118323661	0.881676339	0.00024906	5,501
1,300	0.000477422	0.118323661	0.881676339	0.00024906	5,501
1,250	0.000410966	0.096128603	0.903871397	0.00019738	5,720
1,200	0.000348659	0.077157689	0.922842311	0.00015517	5,956
1,150	0.000291533	0.061176118	0.938823882	0.00012093	6,214
1,100	0.000240252	0.047906761	0.952093239	0.00009338	6,496
1,050	0.000195136	0.037048018	0.962951982	0.00007140	6,804
1,000	0.000156206	0.028289949	0.971710051	0.000054031	7,144

The table above shows the repairing interval time for cutter ply 3 component. The time to failure of cutter ply 3 for repairing activity accept the normal distribution. The result that written in the table above is obtained by using the formula for normal distribution.

Below is the detail calculation for repairing activity cutter ply 3 that fits with normal distribution.

- Probability density function

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}}\exp[-\frac{(t-\mu)^2}{2}]$$

$$f(t) = \frac{1}{538.830\sqrt{6.28}}\exp[-\frac{(2300 - 2216.97)^2}{2}]$$

$$f(t) = 0.000731648$$

- Cumulative distribution function

$$F(t) = \phi\left(\frac{t-\mu}{\sigma}\right)$$

$$F(t) = \phi\left(\frac{2300 - 2216.97}{538.830}\right)$$

$$F(t) = 0.561231847$$

- Reliability function

$$R(t) = 1 - F(t)$$
$$R(t) = 1 - 0.561231847$$
$$R(t) = 0.438768153$$

- Cumulative hazard function

$$H(t) = \left(\frac{F(t)}{\sigma R(t)}\right)$$
$$H(t) = \left(\frac{0.561231847}{538.830\ x\ 0.438768153}\right)$$
$$H(t) = 0.002373862$$

- Cost per unit of time

$$C(t) = \frac{Cp + [Cf\ x\ H(t)]}{t}$$
$$C(t) = \frac{\text{IDR } 7{,}141{,}667\ [\text{ IDR } 39{,}344{,}650 \text{ x } 0.438768153]}{2300}$$
$$C(t) = \text{IDR } 3{,}146$$

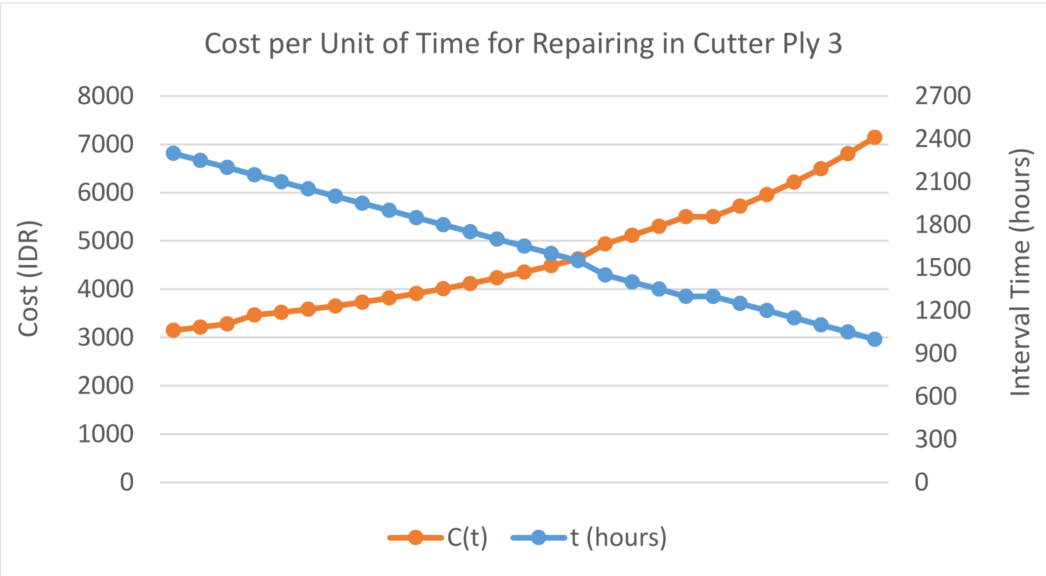


Figure 4.12 Cost per Unit of Time Repairing in Cutter Ply 3

Based on the cost calculation above, when the repairing interval time in cutter ply 3 is 2,300 hours, then the machine will has 43% of reliability and the cost is IDR 3,146. If the repairing interval time is getting shorter become 1,200 hours, then the cost and reliability of the machine will increase. The reliability of machine become 92% while the cost is IDR 5,956. The detailed information can be seen in Table 4.41. Hence it can be seen that maintenance interval time has relationship with the cost. When the repairing interval time is getting shorter then the cost is getting bigger. This condition can be seen in Figure 4.12.

4.3 Data Analysis and Improvement

The further step after calculating all required data is data analysis which will discuss in this part. The result of data analysis is the improvement process on maintenance process which expected to determine the proper interval time for maintaining the machine's component and the cost savings of the preventive maintenance

4.3.1 Current Reliability of Sub Components in TBM Samson 1

The current reliability of the machine must be calculated before determining the interval time for maintenance activity in sub components TBM Samson 1. Table 4.42 below shows the current reliabity of the machine before performing new proposed scheduling maintenance system.

Table 4.42 Current Reliability of Sub Components in TBM Samson 1

Component	Type of maintenance	Distribution	MTTF (hours)	Reliability
Cutter Ply 1	Setting/adjustment	lognormal	970.031	21.48%
	Repairing	lognormal	713.624	36.57%
	Replacement	lognormal	2,074.01	41.56%
Sensor Machine	Setting/adjustment	Lognormal	1,852.09	39.07%
	Repairing	normal	1,790.95	50%
Cutter Ply 3	Setting/adjustment	lognormal	3,194.57	44.79%
	Repairing	normal	2,216.97	50%

Table 4.42 shows the current reliability of sub component in TBM Samson 1 based on the maintenance activity. The detail calculation of mean time to failure for each components and its maintenance activity are already explained in the previous part. In the current condition based on the collected data, cutter ply 1 has 21.48% of reliability. 970.031 hours as mean time to failure means that cutter ply 1 will be set/adjust after it is used for 970.031 hours for operation. Cutter ply 1 will be

repaired after it is used for 713.624 hours and the machine has 36.57% of reliability. The detail reliability of the sub component can be seen in Table 4.42.

Calculation of current reliability fits with a certain distribution. The result that written in the table above is obtained by using the formula for the selected distribution. The value of variable time (t) in the formula is based on the value of MTTF for each component. Below are the detail calculation for calculating the current reliability of each component.;

- Cutter ply 1 (setting/adjustment) : Lognormal distribution

$$R(t) = 1 - \phi[\frac{\frac{\ln(t)}{tmed}}{s}]$$

$$R(t) = 1 - \phi[\frac{\frac{\ln(970.031)}{278.668}}{1,57943}]$$

$$R(t) = 0,2148$$

- Cutter ply 1 (repairing) : Lognormal distribution

$$R(t) = 1 - \phi[\frac{\frac{\ln(t)}{tmed}}{s}]$$

$$R(t) = 1 - \phi[\frac{\frac{\ln(713.624)}{563.638}}{0.686423}]$$

$$R(t) = 0,3657$$

- Cutter ply 1 (replacement) : Lognormal distribution

$$R(t) = 1 - \phi[\frac{\frac{\ln(t)}{tmed}}{s}]$$

$$R(t) = 1 - \phi[\frac{\frac{\ln(2074.01)}{1894.04}}{0.426079}]$$

$$R(t) = 0,2148$$

- Sensor machine (setting/adjustment) : Lognormal distribution

$$R(t) = 1 - \phi[\frac{\ln(\frac{t}{tmed})}{s}]$$

$$R(t) = 1 - \phi[\frac{\ln\left(\frac{1,852.09}{1,587.78}\right)}{0.554941}]$$

$$R(t) = 0.3907$$

- Sensor machine (repairing) : Normal distribution

$$\mathrm{R}(t) = 1 - F(t)$$

$$\mathrm{R}(t) = 1 - 0.50$$

$$\mathrm{R}(t) = 0.50$$

- Cutter ply 3 (setting/adjustment) : Lognormal distribution

$$R(t) = 1 - \phi[\frac{\ln(\frac{t}{tmed})}{s}]$$

$$R(t) = 1 - \phi[\frac{\ln\left(\frac{3194.57}{3086.93}\right)}{0.261822}]$$

$$R(t) = 0.4479$$

- Cutter ply 3 (repairing) : Normal distribution

$$\mathrm{R}(t) = 1 - F(t)$$

$$\mathrm{R}(t) = 1 - 0.50$$

$$\mathrm{R}(t) = 0.50$$

4.3.2 Interval Time of Maintenance Sub Component Analysis

Maintenance activity of the component is required to prevent a failure which will affected the production process. Based on collected data, the maintenance activity are categorized into 3 main activity which are setting/adjustment, repairing and replacement the component. The difference between each maintenance activity already explained in the previous part. Interval time of the maintenance activity will shows the proper time to reduce all the risk and loss that can caused by the breakdown machine.

The maintenance schedule proposed in three scenarios. Those scenarios are determined by the expected reliability that machine can obtained exactly before performing the maintenance activity. The first proposed schedule for maintenance activity in TBM Samson 1 is based on 65% of reliability in TBM Samson 1. The second scenario is based on 75% of reliability. Then the third scenario is based on 85%. In Table 4.43 below shows the interval time for sub components and its reliability in the proposed maintenance system.

Table 4.43 Maintenance Interval Time for Each Sub Component

		Interval Time (hours)		
Component	Type of maintenance	#1 (R=65%)	#2 (R=75%)	#3 (R=85%)
Cutter Ply 1	Setting/adjustment	150	95	52
	Repairing	430	350	270
	Replacement	1,600	1,410	1,200
Sensor Machine	Setting/adjustment	1,300	1,100	900
	Repairing	1,625	1,500	1,350
Cutter Ply 3	Setting/adjustment	2,790	2,570	2,350
	Repairing	1,620	1,500	1,350

In Table 4.43 can be seen the interval time for each sub components and its maintenance activity. If the company want to has 75% of reliability in TBM Samson 1 then the company has to follow the interval time that already stated in the table above. The example is in order to reaches realibility of TBM Samson 1 from this current condition become 75%, then the company has to perform preventive maintenance activity as mentioned in Table 4.42. Cutter ply 1 will be set/adjust, repair, and replacement after it is used for 95 hours, 350 hours and 1,410 hours respectively. After operating for 1,100 hours then sub component sensor machine will be set/adjust while it will be repaired after operating for 1,500 hours. Setting/adjustment activity will be held in cutter ply 3 after the sub component operates for 2,570 hours while repairing activity will be held after 1,500 hours.

4.3.3 Proposed Preventive Maintenance Schedule

As it is explained in the previous part that interval time of sub components maintenance activity will be a fundamental thing in developing a schedule of preventive maintenance. Each sub component has a different interval time based on its maintenance actiyity. The detailed interval time to do a certain maintenance activity in each sub component based on the reliability of the machine can be seen in Table 4.43.

4.3.3.1 until 4.3.3.3 below are the preventive maintenance schedule for each sub component based on the expected reliability of machine as mentioned in the scenarios above. This proposed maintenance schedule will start from June 2016 until June 2017.

4.3.3.1 Scenario 1 (65% of Reliability)

In order to reach 65% of reliability the preventive maintenance should be done based on the maintenance interval time as it is stated in Table 4.43 which shows the sub component in cutter ply 1 should be repair after 430 hours usage and should be replaced after 1,600 hours usage. The proposed preventive maintenance schedule is performed start from June 2016 until June 2017. The detail preventive maintenance schedule (scenario 1) can be seen in Appendix 3.

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Figure 4.13 Preventive Maintenance Scheduling in TBM Samson 1 From June 2016 Until July 2016 (Scenario 1)

Figure 4.13 shows the example of proposed schedule in TBM Samson 1. Maintenance activity interval as mentioned in Table 4.43 is used as the main indicator to determine the proposed schedule. The maintenance activity is made based on the last failure occurence in the collected data. When the interval time between maintenance activities are close to each other or exactly same, then the maintenance schedule can be merged to reduce time lost due to maintenance activity.

In 15th June 2016 there will be a repairing activity in sub component sensor machine. The replacement activity in cutter ply 1 will be done in 28th June 2016. During June 2016, cutter ply 1 will be set/adjust for 2 times which are in 18th and 24th June. Based on maintenance interval time in Table 4.43, the interval time in setting/adjustment activity in cutter ply 1 is close to repairing activity in cutter ply 3, then both of the maintenance activity can be merged. These activity will be held on 12nd July 2016. All of maintenance activity will be held during the break time that starts from 12 a.m until 1 p.m, so that the production process can not be disturbed by the activity.

In order to complete the schedule the mechanic can bring the preventive maintenance checksheet. This checksheet can be stored as the database. Below is the brief example preventive maintenance checksheet that created based on the proposed preventive maintenance schedule.

Table 4.44 Preventive Maintenance Checksheet TBM Samson 1 (June – July 2016) Scenario 1

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Repair setting machine	15 June 2016				
2	Setting/adjustment cutter ply 1	18 June 2016				
3	Setting/adjustment cutter ply 1	24 June 2016				
4	Replace cutter ply 1	28 June 2016				
5	Repair cutter ply 1	5 July 2016				
6	Setting/adjustment sensor machine					
7	Setting/adjustment cutter ply 1	12 July 2016				
8	Repair cutter ply 3					
9	Setting/adjustment cutter ply 1	18 July 2016				
10	Repair cutter ply 1	22 July 2016				
11	Setting/adjustment cutter ply 1	24 July 2016				
12	Setting/adjustment cutter ply 1	30 July 2016				
13	Setting/adjustment cutter ply 3					

Table 4.44 above shows the brief example of the preventive maintenance checksheet from June 2016 until July 2016. The operator must fill and complete all items in the checksheet such as time when the preventive maintenance started and

finished. If the operator is already finished doing preventive maintenance, then the operator has to put 'check' sign in the coloumn. If there is an additional information regarding to the machine or preventive maintenance then the operator can write it in the coloumn 'note'. The complete checksheet for the preventive maintenance schedule can be seen in Appendix 4.

4.3.3.2 Scenario 2 (75% of Reliability)

In order to reach 75% of reliability the preventive maintenance should be done based on the maintenance interval time as it is stated in Table 4.43 which shows the sub component in cutter ply 1 should be repair after 350 hours usage and should be replaced after 1,410 hours usage. The proposed preventive maintenance schedule is performed start from June 2016 until January 2017. The detail preventive maintenance schedule (scenario 2) can be seen in Appendix 3.

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Figure 4.14 Preventive Maintenance Scheduling in TBM Samson 1 From June 2016 Until July 2016 (Scenario 2)

Figure 4.14 shows the example of proposed schedule in TBM Samson 1. Maintenance activity interval as mentioned in Table 4.43 is used as the main indicator to determine the proposed schedule. The maintenance activity is made based on the last failure occurence in the collected data. When the interval time between maintenance activities are close to each other or exactly same, then the maintenance schedule can be merged to reduce time lost due to maintenance activity.

Setting/adjustment activity will be held on 12^{nd} June, 15^{th} June, 21^{st} June, 24^{th} June and 30^{th} June respectively. In 18^{th} June 2016 sub component cutter ply 1 will be repair. The interval time in setting/adjustment activity in cutter ply 1 is close to setting/adjustment activity sensor machine, then both of the maintenance activity can be merged. These activity will be held on 27th June 2016. All of maintenance activity will be held during the break time that starts from 12 a.m until 1 p.m, so that the production process can not disturbed by the activity.

In order to complete the schedule the mechanic can bring the preventive maintenance checksheet. This checksheet can be stored as the database. Below is the brief example preventive maintenance checksheet that created based on the proposed preventive maintenance schedule.

Table 4.45 Preventive Maintenance Checksheet TBM Samson 1 (June – July 2016) Scenario 2

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Setting/adjustment cutter ply 1	12 June 2016				
2	Setting/adjustment cutter ply 1	15 June 2016				
3	Repair cutter ply 1	18 June 2016				
4	Setting/adjustment cutter ply 1	21 June 2016				
5	Setting/adjustment cutter ply 1	24 June 2016				
6	Setting/adjustment cutter ply 1	27 June 2016				
7	Setting/adjustment sensor machine					
8	Setting/adjustment cutter ply 1	30 June 2016				
9	Repair cutter ply 1	3 July 2016				
10	Setting/adjustment cutter ply 1	6 July 2016				
11	Repair cutter ply 3	9 July 2016				
12	Setting/adjustment cutter ply 1	12 July 2016				
13	Setting/adjustment cutter ply 3					
14	Repair cutter ply 1	15 July 2016				
15	Setting/adjustment cutter ply 1	21 July 2016				
16	Setting/adjustment cutter ply 1	24 July 2016				
17	Setting/adjustment cutter ply 1	27 July 2016				
18	Repair cutter ply 1	30 July 2016				

Table 4.45 above shows the brief example of the preventive maintenance checksheet in June 2016. The operator must fill and complete all items in the checksheet such as time when the preventive maintenance started and finished. If the operator is already finished doing preventive maintenance, then the operator has

to put 'check' sign in the coloumn. If there is an additional information regarding to the machine or preventive maintenance then the operator can write it in the coloumn 'note'. The complete checksheet for the preventive maintenance schedule can be seen in Appendix 4.

4.3.3.3 Scenario 3 (85% of Reliability)

In order to reach 85% of reliability the preventive maintenance should be done based on the maintenance interval time as it is stated in Table 4.43 which shows the sub component in cutter ply 1 should be repair after 270 hours usage and should be replaced after 1,200 hours usage. The proposed preventive maintenance schedule is performed start from June 2016 until June 2017. The detail preventive maintenance schedule (scenario 3) can be seen in Appendix 3.

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Figure 4.15 Preventive Maintenance Scheduling in TBM Samson 1 From June 2016 Until July 2016 (Scenario 3)

Figure 4.15 shows the example of proposed schedule in TBM Samson 1. Maintenance activity interval as mentioned in Table 4.43 is used as the main indicator to determine the proposed schedule. The maintenance activity is made based on the last failure occurence in the collected data. When the interval time between maintenance activities are close to each other or exactly same, then the maintenance schedule can be merged to reduce time lost due to maintenance activity.

Setting/adjustment activity will be held on 14^{nd} June, 16^{th} June, 20^{st} June, 24^{th} June, 26^{th} June and 26^{th} June respectively. The interval time in setting/adjustment activity in sensor machine is close to repair activity cutter ply 1, then both of the maintenance activity can be merged. These activity will be held on 18^{th} June 2016. Setting/adjustment acitivity in cutter ply 1 and cutter ply 3 will be done in 22^{nd} June

2016 while repairing those components will be done in 30th June 2016. All of maintenance activity will be held during the break time that starts from 12 a.m until 1 p.m, so that the production process can not disturbed by the activity.

In order to complete the schedule the mechanic can bring the preventive maintenance checksheet. This checksheet can be stored as the database. Below is the brief example preventive maintenance checksheet that created based on the proposed preventive maintenance schedule.

Table 4.46 Preventive Maintenance Checksheet TBM Samson 1 (June 2016) Secenario 3

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Setting/adjustment cutter ply 1	14 June 2016				
2	Setting/adjustment cutter ply 1	16 June 2016				
3	Repair cutter ply 1	18 June 2016				
4	Setting/adjustment sensor machine					
5	Setting/adjustment cutter ply 1	22 June 2016				
6	Setting/adjustment cutter ply 3					
7	Setting/adjustment cutter ply 1	24 June 2016				
8	Setting/adjustment cutter ply 1	26 June 2016				
9	Setting/adjustment cutter ply 1	28 June 2016				
10	Repair cutter ply 1	30 June 2016				
11	Repair cutter ply 3					

Table 4.46 above shows the brief example of the preventive maintenance checksheet in June 2016. The operator must fill and complete all items in the checksheet such as time when the preventive maintenance started and finished. If the operator is already finished doing preventive maintenance, then the operator has to put 'check' sign in the coloumn. If there is an additional information regarding to the machine or preventive maintenance then the operator can write it in the coloumn 'note'. The complete checksheet for the preventive maintenance schedule can be seen in Appendix 4.

4.3.4 Component Reliability Comparison After Improvement

The comparison of reliability level for each sub component in TBM Samson 1 is needed to know whether the proposed maintenance system has significant impact to the production process or not. In the proposed preventive maintenance system, the expected reliability of the machine is based on the given scenarios which already explained before. The company can choose the proper scenario that fits with the actual condition in the production line. Table 4.47, Table 4.48, and Table 4.49 are explain about the comparison between initial maintenance system and the proposed system based on the scenario.

4.3.4.1 Scenario 1 Component Reliability Comparison After Improvement

Table 4.47 shows the reliability comparison between initial maintenance system and proposed preventive maintenance system (scenario 1). In scenario 1, the company sets 65% reliability in TBM Samson 1 which means that all the sub components will have 65% of reliability. The interval times to reach 65% of reliability for each component and its maintenance activity can be seen in Table 4.43.

Table 4.47 Reliability Comparison Between Initial Maintenance System and Proposed Preventive Maintenance System (Scenario 1)

		Current Maintenance System		Proposed Preventive Maintenance System	
Component	Type of maintenance	MTTF (hours)	Reliability	MTTF (hours)	Reliability
Cutter Ply 1	Setting/adjustment	970.031	21.48%	150	65%
	Repairing	713.624	36.57%	430	65%
	Replacement	2,074.01	41.56%	1,600	65%
Sensor Machine	Setting/adjustment	1,869.56	39.07%	1,300	65%
	Repairing	1,790.95	50%	1,625	65%
Cutter Ply 3	Setting/adjustment	3,194.57	44.79%	2,790	65%
	Repairing	2,216.97	50%	1,620	65%

In The current maintenance system, cutter ply was set after it is used for 970 hours. Due to that situation, the average reliability of cutter ply 1 is 33.2%. In the proposed maintenance system, sub component cutter ply 1 will be set after it is used for 150 hours and the reliability become 65%. After cutter ply 1 is used for 713.624 hours, the sub component will be repaired and the reliability is 36.57%. In the proposed maintenance system cutter ply 1 will be repaired after 430 hours usage. Therefore, the reliability become 65%. The detailed comparison can be seen in Table 4.47.

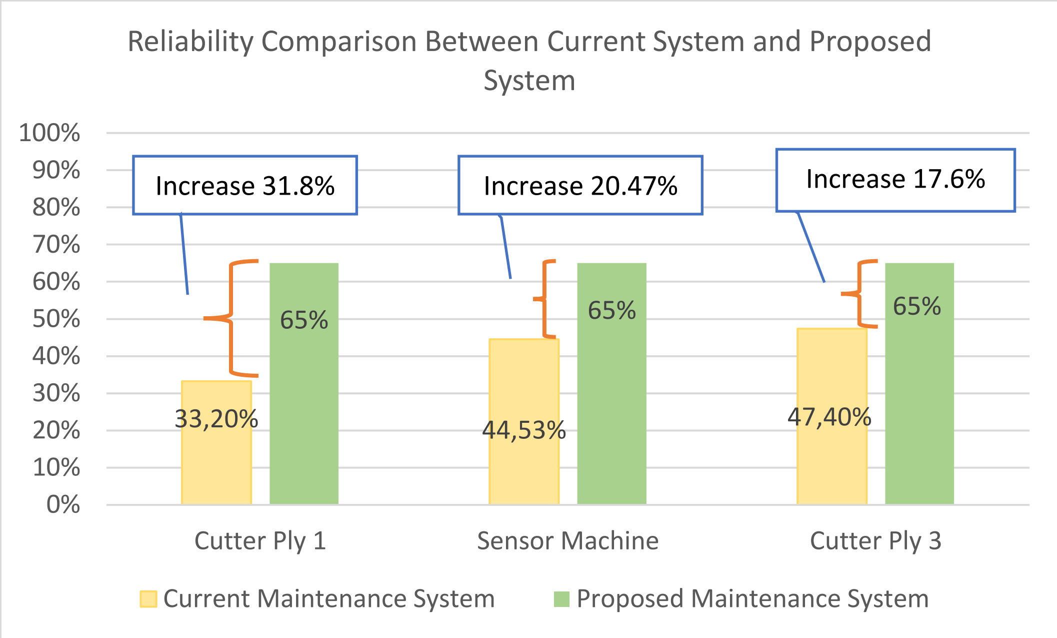


Figure 4.16 Reliability Comparison Between Current System and Proposed System (Scenario 1)

Figure 4.16 shows the reliability comparison between current system and proposed system. Based on scenario 1, the company wants to obtain 65% of reliability. Theerefore, the reliability of sub components in TBM Samson 1 have to reach 65% of reliability. By implementing the proposed system, in cutter ply 1 it expected to increase the reliability as much as 31.80% from 33.20% of reliability in current system into 65% of reliability in proposed system. The reliability of sensor machine and cutter ply 3 also increase as much as 20.47% and 17.60% respectively.

4.3.4.2 Scenario 2 Component Reliability Comparison After Improvement

Table 4.48 shows the reliability comparison between initial maintenance system and proposed preventive maintenance system (scenario 2). In scenario 2, the company sets 75% reliability in TBM Samson 1 which means that all the sub components will have 75% of reliability. The interval times to reach 75% of reliability for each component and its maintenance activity can be seen in Table 4.43.

Table 4.48 Reliability Comparison Between Initial Maintenance System and Proposed Preventive Maintenance System (Scenario 2)

		Current Maintenance System		Proposed Preventive Maintenance System	
Component	Type of maintenance	MTTF (hours)	Reliability	MTTF (hours)	Reliability
Cutter Ply 1	Setting/adjustment	970.031	21.48%	95	75%
	Repairing	713.624	36.57%	350	75%
	Replacement	2,074.01	41.56%	1,410	75%
Sensor Machine	Setting/adjustment	1,869.56	39.07%	1,100	75%
	Repairing	1,790.95	50%	1,500	75%
Cutter Ply 3	Setting/adjustment	3,194.57	44.79%	2,570	75%
	Repairing	2,216.97	50%	1,500	75%

In the proposed maintenance system, sub component cutter ply 1 will be set after it is used for 95 hours and the reliability become 75%. After cutter ply 1 is used for 713.624 hours, the sub component will be repaired and the reliability is 36.57%. In the proposed maintenance system cutter ply 1 will be repaired after 350 hours usage. Therefore, the reliability become 75%. The detailed comparison can be seen in Table 4.48.

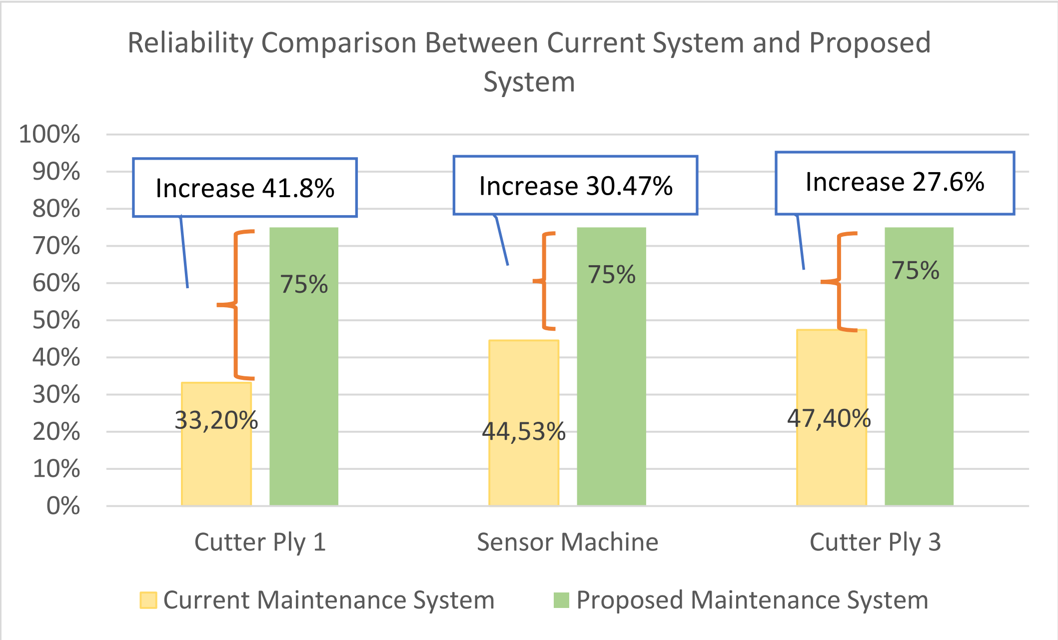


Figure 4.17 Reliability Comparison Between Current System and Proposed System (Scenario 2)

Figure 4.17 shows the reliability comparison between current system and proposed system. Based on scenario 2, the company wants to obtain 75% of reliability.

Theerefore, the reliability of sub components in TBM Samson 1 have to reach 75% of reliability. By implementing the proposed system, in cutter ply 1 it expected to increase the reliability as much as 41.80% from 33.20% of reliability in current system into 75% of reliability in proposed system. The reliability of sensor machine and cutter ply 3 also increase as much as 30.47% and 27.60% respectively.

4.3.4.3 Scenario 3 Component Reliability Comparison After Improvement

Table 4.49 shows the reliability comparison between initial maintenance system and proposed preventive maintenance system (scenario 3). In scenario 3, the company sets 85% reliability in TBM Samson 1 which means that all the sub components will have 85% of reliability. The interval times to reach 85% of reliability for each component and its maintenance activity can be seen in Table 4.43.

Table 4.49 Reliability Comparison Between Initial Maintenance System and Proposed Preventive Maintenance System (Scenario 3)

		Current Maintenance System		Proposed Preventive Maintenance System	
Component	Type of maintenance	MTTF (hours)	Reliability	MTTF (hours)	Reliability
Cutter Ply 1	Setting/adjustment	970.031	21.48%	52	85%
	Repairing	713.624	36.57%	270	85%
	Replacement	2,074.01	41.56%	1,200	85%
Sensor Machine	Setting/adjustment	1,869.56	39.07%	900	85%
	Repairing	1,790.95	50%	1,350	85%
Cutter Ply 3	Setting/adjustment	3,194.57	44.79%	2,350	85%
	Repairing	2,216.97	50%	1,350	85%

In the proposed maintenance system, sub component cutter ply 1 will be set after it is used for 52 hours and the reliability become 85%. In the proposed maintenance system cutter ply 1 will be repaired after 270 hours usage. Therefore, the reliability become 85%. In current maintenance system, sub component cutter ply 1 replaced after 1,869.56 hours usage and has 41.56% of reliability. In the proposed system, sub component cutter ply 1 will be replaced after it is used for 1,200 hours. The detailed comparison can be seen in Table 4.49.

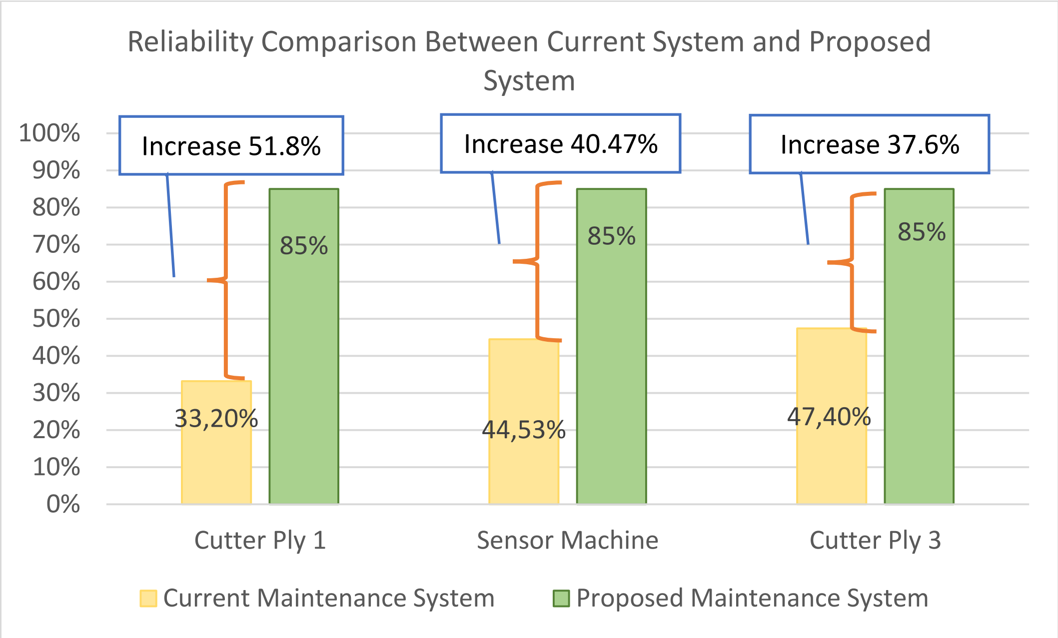


Figure 4.18 Reliability Comparison Between Current System and Proposed System (Scenario 3)

Figure 4.18 shows the reliability comparison between current system and proposed system. Based on scenario 3, the company wants to obtain 85% of reliability. Theerefore, the reliability of sub components in TBM Samson 1 have to reach 85% of reliability. By implementing the proposed system, in cutter ply 1 it expected to increase the reliability as much as 51.80% from 33.20% of reliability in current system into 85% of reliability in proposed system. The reliability of sensor machine and cutter ply 3 also increase as much as 40.47% and 37.60% respectively.

4.3.5 Maintenance Cost Comparison Between Current Maintenance System and Proposed Maintenance System

Cost calculation is needed in order to ensure that the proposed maintenance system has a positive impact towards production process. In general, all scenarios that already explained in the previous part has positive impact to the production process. In the proposed maintenance system, maintenance activity such as setting/adjustment repairing or replacement will occur more frequently rather than the current maintenance system, but the downtime when the machine breaks down will be reduced and fewer than before. When the preventive maintenance system is applied then there will be no time wasted for waiting the mechanic or finding the substitute component. Below is the cost comparison for each component between current maintenance system and proposed maintenance system.

4.3.5.1 Current Maintenance Cost

Table 4.50 below shows the total frequency of maintenance in PT. ABC from January 2016 until July 2016. The data above is counted from the maintenance report in PT. ABC in the same period. Total downtime is calculated from sum of waiting time and maintenance time. The detailed data about waiting time and repairing time for each components from January 2016 until July 2016 can be seen in appendix 2.

Table 4.50 Total Frequency of Maintenance and Downtime in The Current Maintenance System From January 2016 Until July 2016

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Cutter Ply 1	Setting/adjustment	6	0.522
	Repairing	4	2.547
	Replacement	2	4.751
Sensor Machine	Setting/adjustment	2	1.177
	Repairing	2	1.869
Cutter Ply 3	Setting/adjustment	0	0.582
	Repairing	2	1.942

During the first semester in 2016 cutter ply 1 has been set about 6 times where the average downtime for every failure is about 0.522 hours. Sensor machine has been repaired about 2 times during January until July 2016. Therefore the downtime for repaired the cub component in sensor machine is 1.869. During that period from all critical sub components and its maintenance activity, the downtime for repairing cutter ply 3 is the most wasted time rather than the others. The average downtime for repairing cutter ply 3 during the periods is 1.942 hours

Table 4.51 below shows the total maintenance cost by using current maintenance system from Janury until July 2016. The component price for each sub components is assumed constant. The production loss is obtained from the multiplication between current downtime, production capacity and price of the products. The price of the product and the production capacity are still remains the same. The price of product is IDR 1,000,000 while the production capacity is still 19 tires/hour.

Table 4.51 Total Maintenance Cost in The Current Maintenance System From January 2016 Until July 2016

Component	Type of maintenance	Component Price (IDR)	Production Loss (IDR)	Salary Mechanic (IDR)	Total cost (IDR)
Cutter Ply 1	Setting/adjustment	0	59,508,000	78,300	59,586,300
	Repairing	2,000,000	193,572,000	254,700	195,826,700
	Replacement	2,400,000	180,550,667	237,567	183,188,233
Sensor Machine	Setting/adjustment	0	44,713,333	58,833	44,772,167
	Repairing	3,600,000	71,034,667	93,467	74,728,133
Cutter Ply 3	Setting/adjustment	0	0	0	0
	Repairing	1,600,000	1,830,042,000	2,407,950	75,505,783
					633,607,317

In the current maintenance cost, the total cost spent to set/adjust cutter ply about 6 times during January until July 2016 is IDR 59,586,300. The total cost spent to repairing the sub component in cutter ply 1 is IDR 195,826,700. The total cost for every maintenance activity in sub components TBM Samson 1 from January 2016 until July 2016 can be seen in Table 4.51. Below is the example of detailed calculation about the total maintenance cost in the current system from January until July 2016;

- Total cost in setting/adjustment cutter ply 1
    - Total Component Price = Frequency of maintenance x component price
      = 6 x IDR 0
      = IDR 0

There is no cost incurred when the component was set because the mechanic only reset or readjustment the sub component without repair or replace the component.

- Total production loss = (Downtime x price of product x production capacity) x frequency of maintenance
  = (0.522 x IDR 1,000,000 x 19) x 6
  = IDR 59,508,000

- Total salary mechanic = (downtime x salary mechanic per hour) x frequency of maintenance
  = (0.522 x IDR 25,000) x 6
  = IDR 78,300
- Total cost = Total component price + total production loss + total salary mechanic
  = IDR 0 + IDR 59,508,000 + IDR 78,300
  = IDR 59,586,300

- Total cost in replacement cutter ply 1
  - Total Component Price = Frequency of maintenance x component price
    = 2 x IDR 1,200,000
    = IDR 2,400,000
  - Total production loss = (Downtime x price of product x production capacity) x frequency of maintenance
    = (4.751 x IDR 1,000,000 x 19) x 2
    = IDR 180,550,667
  - Total salary mechanic = (downtime x salary mechanic per hour) x frequency of maintenance
    = (4.751 x IDR 25,000) x 2
    = IDR 237,567
  - Total cost = Total component price + total production loss + total salary mechanic
    = IDR 2,400,000 + IDR 180,550,667 + IDR 237,567
    = IDR 183,188,233

4.3.5.2 Proposed Maintenance System Cost

There are some advantages that the company can gets when implementing the proposed maintenanace system. Besides reducing the downtime due to a long waiting time that makes the production time become more effecient, increasing the reliability of machine, the company also can reduce the production loss that caused when the machine has maintained. Furthermore, in the end of the process the company can reduce the total maintenance cost.

The proposed maintenance interval time is implemented in the same period with current maintenance system in order to know the differences about both systems. The period is started from January 2016 and ended in July 2016. Table 4.52, Table 4.54 and Table 4.56 show the frequency of maintenance during January 2016 until July 2016 if the company use the proposed maintenance system. Table 4.53, Table 4.55, and Table 4.57 show the detail maintenance cost that spent by the company when implement the proposed maintenance system.

4.3.5.2.1 Scenario 1 Maintenance System Cost Comparison

Table 4.52 below shows the total frequency maintenance and downtime when the company used the proposed maintenance system. In the preventive maintenance there will be no waiting time. The maintenance interval time is based on the certain scenario that the company want to implement. In this case the company implement the first scenario. The detail interval time for every maintenance activity in each sub component can be seen in Table 4.43. By implementing the first scenario, during January 2016 until July 2016 cutter ply 1 has been set/adjust about 35 times. Cutter ply 1 has been repaired about 12 times during that period and replaced about 3 times. Sensor machine has been set/adjust about 3 times and repaired about 3 times during January 2016 until July 2016. The detail frequency of maintenance from January until July 2016 can be seen in Table 4.52.

Table 4.52 Total Frequency Maintenance and Downtime in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 1)

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Cutter Ply 1	Setting/adjustment	35	0.17
	Repairing	12	0.25
	Replacement	3	0.42
Sensor Machine	Setting/adjustment	3	0.17
	Repairing	3	0.42
Cutter Ply 3	Setting/adjustment	1	0.17
	Repairing	3	0.33

Table 4.53 below shows the total maintenance cost from January until July 2016 when the company implemented the first scenario. The total cost that the company spent for all maintenance activity in each sub components from January until July 2016 is IDR 266,525,000. The total maintenance cost in scenario 1 is less than the total maintenance cost in the current condition because in the current condition the total maintenance cost is IDR 633,607,317. The detailed comparison can be seen in Figure 4.20.

Table 4.53 Total Maintenance Cost in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 1)

Component	Type of maintenance	Component Price (IDR)	Production Loss (IDR)	Salary Mechanic (IDR)	Total cost (IDR)
Cutter Ply 1	Setting/adjustment	0	110,833,333	145,833	110,979,167
	Repairing	6,000,000	57,000,000	75,000	63,075,000
	Replacement	3,600,000	23,750,000	31,250	27,381,250
Sensor Machine	Setting/adjustment	0	9,500,000	12,500	9,512,500
	Repairing	5,400,000	23,750,000	31,250	29,181,250
Cutter Ply 3	Setting/adjustment	0	3,166,667	4,167	3,170,833
	Repairing	4,200,000	19,000,000	25,000	23,225,000
					266,525,000

Figure 4.19 shows the frequency maintenance comparison between the current maintenance system and proposed maintenance system. In the proposed system scenario 1, the reliability of TBM Samson 1 is 65%. The maintenance interval time is performed to get 65% of reliability. The detail interval time in scenario 1 can be seen in Table 4.43. The frequency of maintenance will increase when the company use the propsed system. In the current system, cutter ply 1 has been set about 6

times while in the proposed system cutter ply 1 will be set 35 times. In the current system, during January 2016 until July 2016 cutter ply 1 has been repaired about 4 times. This maintenance activity will increase become 12 times in the same period when using the proposed system (scenario 1). The detail comparison can be seen in Figure 4.19.

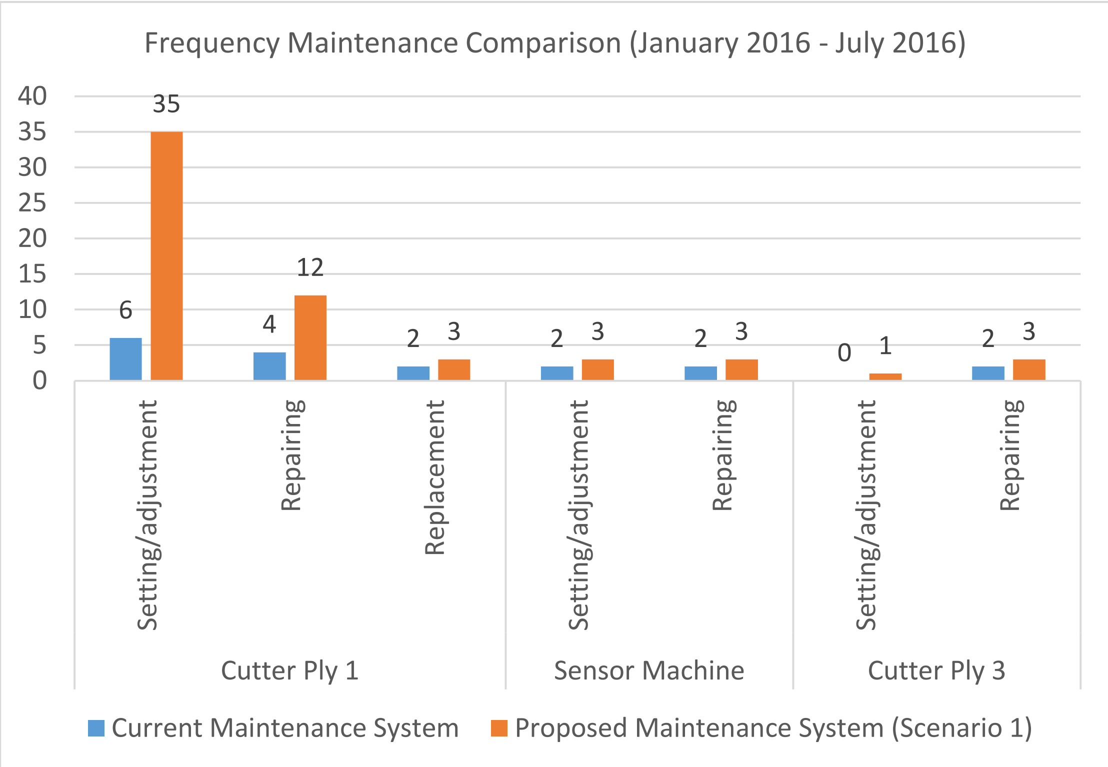


Figure 4.19 Frequency Maintenance Comparison Between Current System and Proposed System (Scenario 1) From January 2016 until July 2016

Figure 4.20 below shows the maintenance cost between current system and proposed system. In the current maintenance system, the cost spent by the company during January until July 2016 is IDR 633,607,317. In the proposed system, the maintenance cost is only IDR 266,525,000. By using proposed maintenance system (scenario 1), the company can save 57.93% compared the current maintenance cost or save IDR 367,082,317.

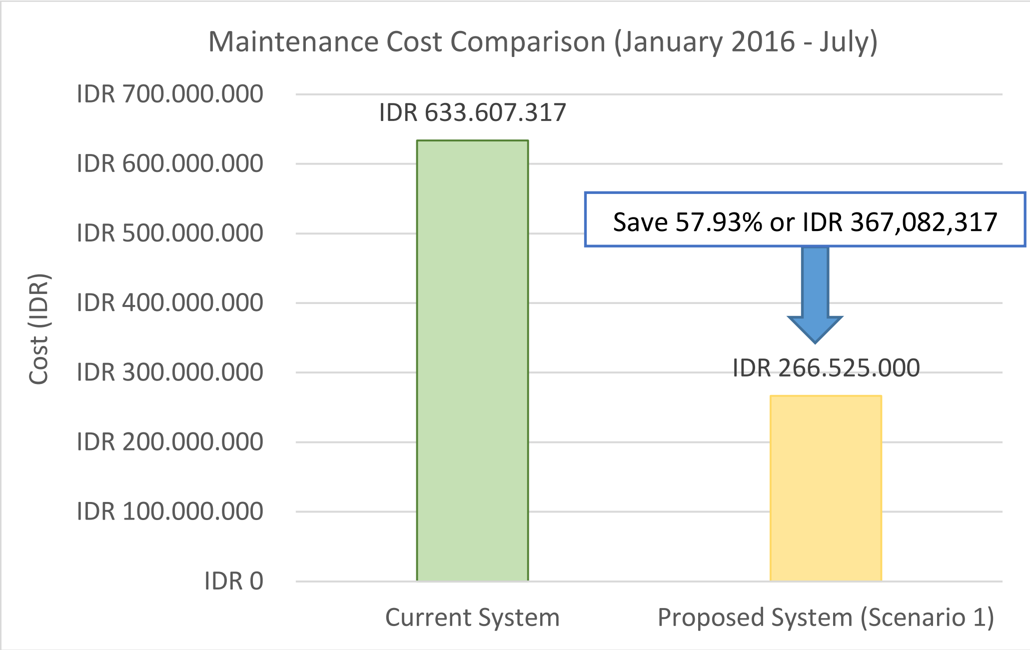


Figure 4.20 Maintenance Cost Comparison Between Current System and Proposed System (Scenario 1) From January 2016 until July 2016

4.3.5.2.2 Scenario 2 Maintenance System Cost Comparison

Table 4.54 shows the total frequency maintenance and downtime when the company used the proposed maintenance system. In the preventive maintenance there will be no waiting time. The maintenance interval time is based on the certain scenario that the company want to implement. In this case the company implement the second scenario. The detail interval time for every maintenance activity in each sub component can be seen in Table 4.43. By implementing the second scenario, during January 2016 until July 2016 cutter ply 1 has been set/adjust about 71 times. Cutter ply 1 has been repaired about 15 times during that period and so on. The detail frequency of maintenance from January until July 2016 can be seen in Table 4.54.

Table 4.54 Total Frequency Maintenance and Downtime in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 2)

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Cutter Ply 1	Setting/adjustment	71	0.17
	Repairing	15	0.25
	Replacement	3	0.42

Table 4.54 Total Frequency Maintenance and Downtime in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 2) Cont'd

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Sensor Machine	Setting/adjustment	4	0.17
	Repairing	3	0.42
Cutter Ply 3	Setting/adjustment	2	0.17
	Repairing	3	0.33

Table 4.55 shows the total maintenance cost from January until July 2016 when the company implemented the second scenario. The total cost that the company spent for all maintenance activity in each sub components from January until July 2016 is IDR 386,985,417. The total maintenance cost in scenario 2 is less than the total maintenance cost in the current condition because in the current condition the total maintenance cost is IDR 633,607,317. The detailed comparison can be seen in Figure 4.22.

Table 4.55 Total Maintenance Cost in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 2)

Component	Type of maintenance	Component Price (IDR)	Production Loss (IDR)	Salary Mechanic (IDR)	Total cost (IDR)
Cutter Ply 1	Setting/adjustment	0	224,833,333	295,833	225,129,167
	Repairing	7,500,000	71,250,000	93,750	78,843,750
	Replacement	3,600,000	23,750,000	31,250	27,381,250
Sensor Machine	Setting/adjustment	0	12,666,667	16,667	12,683,333
	Repairing	5,400,000	23,750,000	31,250	29,181,250
Cutter Ply 3	Setting/adjustment	0	6,333,333	8,333	6,341,667
	Repairing	4,200,000	19,000,000	25,000	23,225,000
					402,785,417

Figure 4.21 shows the frequency maintenance comparison between the current maintenance system and proposed maintenance system. In the proposed system scenario 2, the reliability of TBM Samson 1 is 75%. The maintenance interval time is performed to get 75% of reliability. The detail interval time in scenario 2 can be seen in Table 4.43. The frequency of maintenance will increase when the company use the propsed system. In the current system, cutter ply 1 has been set about 6 times while in the proposed system cutter ply 1 will be set 71 times. In the current system, during January 2016 until July 2016 cutter ply 1 has been repaired about 4

times. This maintenance activity will increase become 15 times in the same period when using the proposed system (scenario 2). The detail comparison can be seen in Figure 4.21.

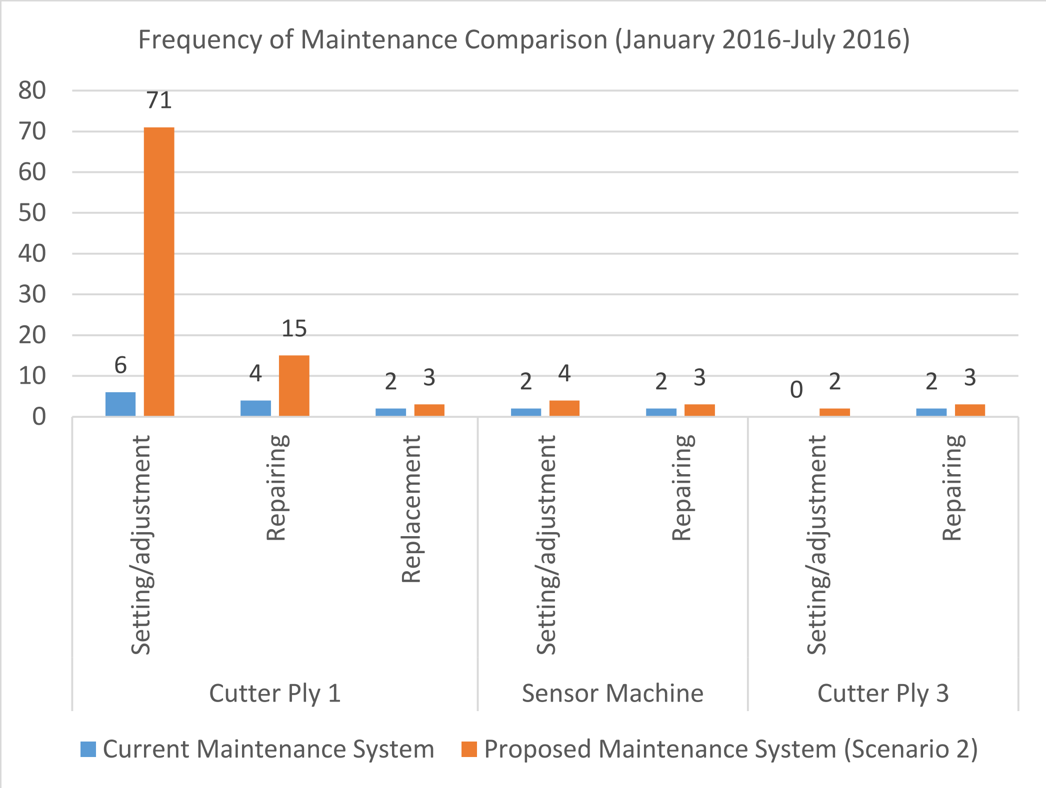


Figure 4.21 Frequency Maintenance Comparison Between Current System and Proposed System (Scenario 2) From January 2016 until July 2016

Figure 4.22 below shows the maintenance cost between current system and proposed system. In the current maintenance system, the cost spent by the company during January until July 2016 is IDR 633,607,317. In the proposed system, the maiantenance cost is IDR 402,785,417. By using proposed maintenance system (scenario 2), the company can save 36.42% compared the current maintenance cost or save IDR 230,821,900.

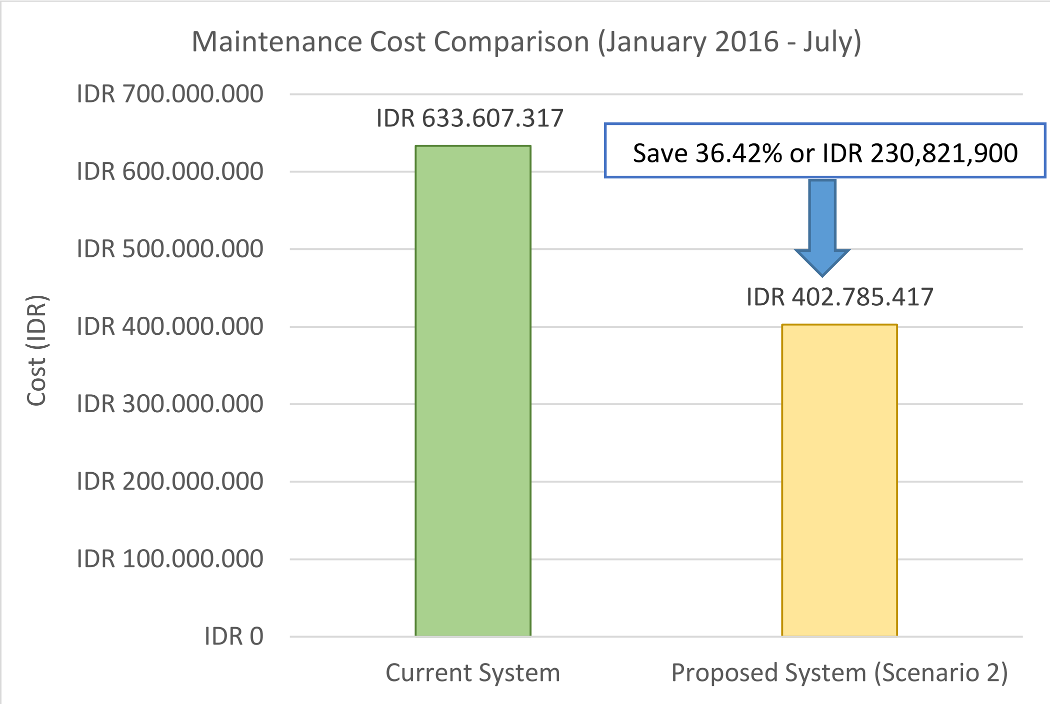


Figure 4.22 Maintenance Cost Comparison Between Current System and Proposed System (Scenario 2) From January 2016 until July 2016

4.3.5.2.3 Scenario 3 Maintenance System Cost Comparison

Table 4.56 shows the total frequency maintenance and downtime when the company used the proposed maintenance system. In this case the company implement the third scenario. The detail interval time for every maintenance activity in each sub component can be seen in Table 4.43. By implementing the third scenario, during January 2016 until July 2016 cutter ply 1 has been set/adjust about 106 times. Cutter ply 1 has been repaired about 19 times during that period. The detail frequency of maintenance from January until July 2016 can be seen in Table 4.56.

Table 4.56 Total Frequency Maintenance and Downtime in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 3)

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Cutter Ply 1	Setting/adjustment	106	0.17
	Repairing	19	0.25
	Replacement	4	0.42

Table 4.56 Total Frequency Maintenance and Downtime in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 3) Cont'd

Component	Type of maintenance	Freq. Maintenance	Downtime (hours)
Sensor Machine	Setting/adjustment	5	0.17
	Repairing	3	0.42
Cutter Ply 3	Setting/adjustment	2	0.17
	Repairing	3	0.33

Table 4.57 shows the total maintenance cost from January until July 2016 when the company implemented the third scenario. The total cost that the company spent for all maintenance activity in each sub components from January until July 2016 is IDR 547,087,500. The total maintenance cost in scenario 3 is less than the total maintenance cost in the current condition because in the current condition the total maintenance cost is IDR 633,607,317. The detail comparison can be seen in Figure 4.24.

Table 4.57 Total Maintenance Cost in The Proposed Maintenance System From January 2016 Until July 2016 (Scenario 3)

Component	Type of maintenance	Component Price (IDR)	Production Loss (IDR)	Salary Mechanic (IDR)	Total cost (IDR)
Cutter Ply 1	Setting/adjustment	0	335,666,667	441,667	336,108,333
	Repairing	9,500,000	90,250,000	118,750	99,868,750
	Replacement	4,800,000	31,666,667	41,667	36,508,333
Sensor Machine	Setting/adjustment	0	15,833,333	20,833	15,854,167
	Repairing	5,400,000	23,750,000	31,250	29,181,250
Cutter Ply 3	Setting/adjustment	0	6,333,333	8,333	6,341,667
	Repairing	4,200,000	19,000,000	25,000	23,225,000
					547,087,500

Figure 4.23 below shows the frequency maintenance comparison between the current maintenance system and proposed maintenance system. In the proposed system scenario 3, the reliability of TBM Samson 1 is 85%. The maintenance interval time is performed to get 85% of reliability. The detail interval time in scenario 3 can be seen in Table 4.43. The frequency of maintenance will increase when the company use the propsed system. In the proposed system cutter ply 1 will be set 71 times. In the current system, during January 2016 until July 2016 cutter ply 1 has been repaired about 4 times. This maintenance activity will increase

become 19 times in the same period when using the proposed system (scenario 3). The detail comparison can be seen in Figure 4.23.

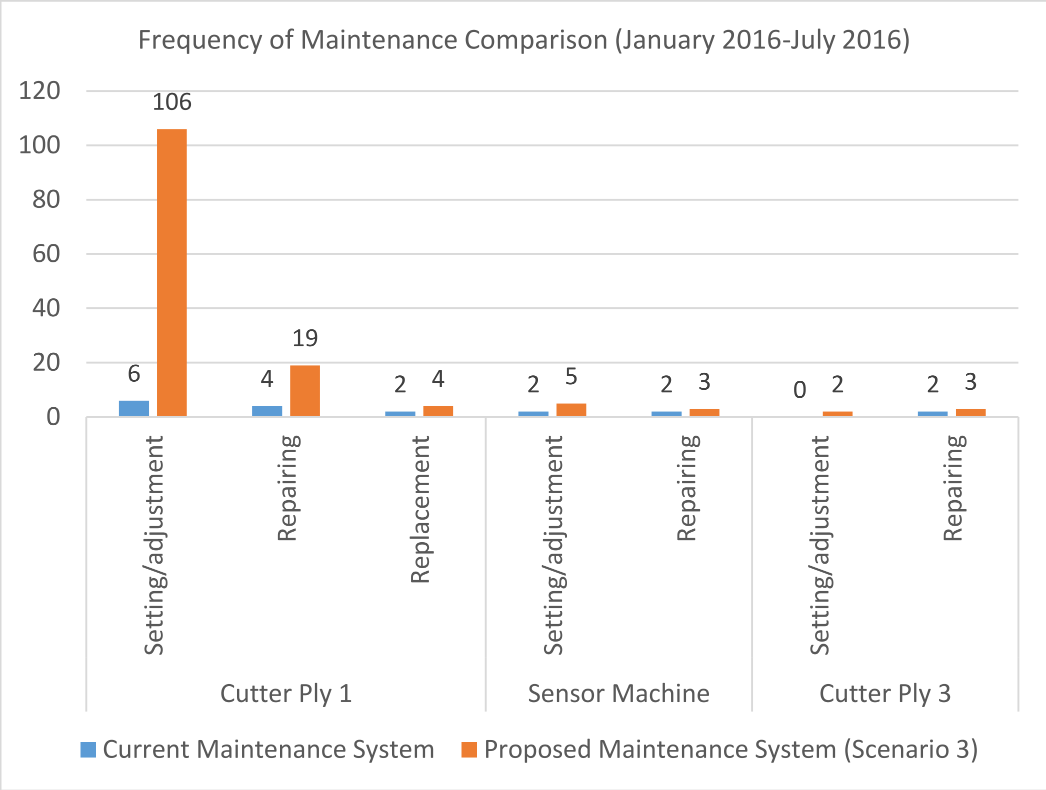


Figure 4.23 Frequency Maintenance Comparison Between Current System and Proposed System (Scenario 3) From January 2016 until July 2016

Figure 4.24 below shows the maintenance cost between current system and proposed system. In the current maintenance system, the cost spent by the company during January until July 2016 is IDR 633,607,317. In the proposed system, the maintenance cost is IDR 547,087,500. By using proposed maintenance system (scenario 3), the company can save 13.65% compared the current maintenance cost or save IDR 86,519,817.

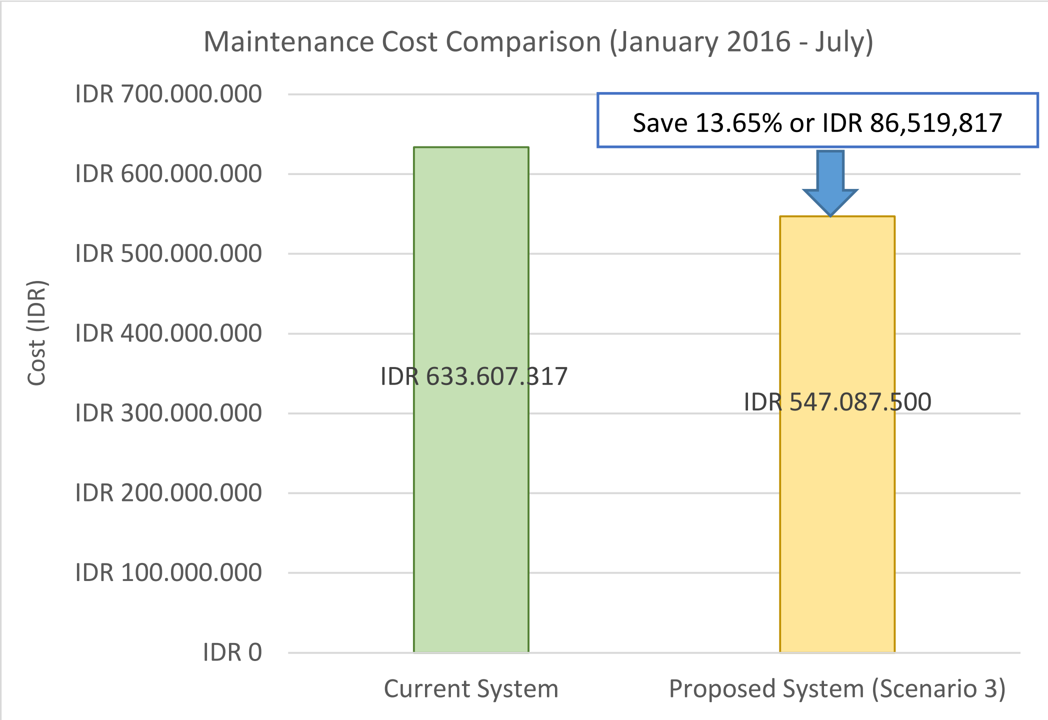


Figure 4.24 Maintenance Cost Comparison Between Current System and Proposed System (Scenario 3) From January 2016 until July 2016

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

After collecting and analyzing all required data, there are several conclusion that can be drawn to answer the objective of the research. The conclusion that can be obtained from the research are;

- The current reliability of sub component cutter ply 1, sensor machine and cutter ply 3 are 33.2%, 44.53% and 47.4% respectively. Therefore, the reliability of TBM Samson 1 is 41.71%.
- In current condition, mean time to repair for every sub components are differentiated based on the type of maintenance. In cutter ply for setting/adjustment, repairing and replacement, the mean time to repair are 0.322 hours, 0.547 hours and 0.868 hours respectively. The mean time to repair for setting/adjustment and repairing are 0.603 hours and 1.336 hours respectively. The mean time to repair for setting/adjustment and repairing cutter ply 3 are 0.582 hours and 1.159 hours respectively.
- In current condition, mean time between failure and mean time to failure are differentiated based on type of maintenance. Mean time between failure in setting/adjustment and repairing cutter ply 1 are 970.031 hours and 713.624 hours respectively. The mean time to failure for replacement sub component cutter ply 1 is 2,074.01 hours. Mean time between failure in setting/adjustment and repairing sensor machine are 1,869.56 hours and 1,790.95 hours respectively. Mean time between failure in setting/adjustment and repairing sub component cutter ply 3 are 3,194.57 hours and 2,216.97 hours respectively.
- The maintenance interval time to do maintenance activity whether setting/adjustment, repairing or replacement for each sub components are different. There are 3 scenario of maintenance interval times based on the expected reliability of machine. The first scenario is interval time to obtain 65% of reliability. The second scenario is interval time to obtain 75% of

reliability while the third scenario is to obtain 85% of reliability. By implementing first scenario, maintenance cost that will spent by the company is reduced significantly around 57.93% rather than initial maintenance system. Meanwhile, by implementing second and third scenario the maintenance cost that will spent by the company is reduced around 36.42% and 13.65% respectively.

5.2 Recommendation

The proposed system in this research is indeed still lacking in so many aspects. Hopefully there will be further research in the future to improve the maintenance system that is developed in this research. It is suggested for future research to develop a research related to spare parts and component inventory and policy about the resources that needed in maintaining Tire Building Machine (TBM) Samson 1. It is also suggested for the future researh to develop preventive maintenance schedule that integrated with the actual production schedule from the company.

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APPENDICES

Appendix 1 Frequency of Failure

Table 1 Frequency of Failure Machine (January 2014 – July 2016)

Machine	Frequency (times)

MC Samson 1	1,113
MC Jing Ye 3	1,021
MC VMI 2	976
MC VMI 3	960
MC VMI 1	956
Steel VMI	903
MC Samson 2	893
MC Jing Ye 2	892
Extruder Quadruplex (Line 2)	883
Cushion Troester #1	870
Uniformity Kobelco 4	865
Calender 1	862
Uniformity Kokusai 3	859
Calender 2	853
MC VMI 13	852
Extruder Quadruplex (Line 4)	831
Uniformity Kobelco 5	789
Steel TTM	782
MC Jing Ye 1	735
Cushion Comerio	713
MC VMI 11	690
MC VMI 16	678
Extruder Triplex (Line 3)	667
MC Nokian 1	658
Uniformity Kobelco 6	640
MC VMI 7	639
Uniformity Kobelco 9	635
MC Pirelli 5	629
Extruder Triplex TBR Guilin	617
MC Samson 3	617
MC Jing Ye 8	608
MC Pirelli 2	599
Steel Fischer #1 (Plant 1)	589

Table 1 Frequency of Failure Machine (January 2014 – July 2016)

Machine	Frequency (times)
MC VMI 12	587
MC VMI 15	587
MC VMI 10	572
MC VMI 4	567
MC Jing Ye 9	553
MC Nokian 6	553

MC Pirelli 1	552
Uniformity Akron 7	543
MC Nokian 3	536
MC Jing Ye 10	528
MC Jing Ye 4	524
MC VMI 14	515
MC Pirelli 4	510
MC Jing Ye 5	509

Appendix 2 Failure Data of Sub Components

Table 3 Failure Data of Cutter Ply 1 for Setting/adjsutment Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
03/01/2014	0:34:00	03/01/2014	0:46:00	03/01/2014	1:05:00	03/01/2014	1:05:00	0	0.200	0.317
12/01/2014	16:00:00	12/01/2014	16:05:00	12/01/2014	16:21:00	12/01/2014	16:21:00	230.92	0.083	0.267
16/01/2014	2:28:00	16/01/2014	2:40:00	16/01/2014	2:56:00	16/01/2014	2:44:00	82.12	0.200	0.267
08/02/2014	2:25:00	08/02/2014	2:43:00	08/02/2014	3:07:00	08/02/2014	2:52:00	551.68	0.300	0.400
14/05/2014	19:41:00	14/05/2014	19:52:00	14/05/2014	20:21:00	14/05/2014	20:21:00	2296.82	0.183	0.483
18/05/2014	9:21:00	18/05/2014	9:30:00	18/05/2014	9:45:00	18/05/2014	9:45:00	85.00	0.150	0.250
27/10/2014	19:17:00	27/10/2014	19:23:00	27/10/2014	19:35:00	27/10/2014	19:35:00	3897.53	0.100	0.200
02/11/2014	10:33:00	02/11/2014	10:40:00	02/11/2014	10:56:00	02/11/2014	10:56:00	134.97	0.117	0.267
03/11/2014	19:43:00	03/11/2014	19:56:00	03/11/2014	20:15:00	03/11/2014	20:15:00	32.78	0.217	0.317
05/11/2014	11:35:00	05/11/2014	11:40:00	05/11/2014	11:50:00	05/11/2014	11:50:00	39.33	0.083	0.167
10/11/2014	2:45:00	10/11/2014	2:55:00	10/11/2014	3:23:00	10/11/2014	3:23:00	110.92	0.167	0.467
12/03/2015	1:05:00	12/03/2015	1:12:00	12/03/2015	1:30:00	12/03/2015	1:30:00	2925.70	0.117	0.300
31/03/2015	14:07:00	31/03/2015	14:18:00	31/03/2015	14:38:00	31/03/2015	14:38:00	468.62	0.183	0.333
09/04/2015	13:54:00	09/04/2015	14:00:00	09/04/2015	14:10:00	09/04/2015	14:10:00	215.27	0.100	0.167
05/06/2015	1:55:00	05/06/2015	2:30:00	05/06/2015	3:00:00	05/06/2015	3:00:00	1355.75	0.583	0.500
09/06/2015	10:48:00	09/06/2015	11:00:00	09/06/2014	11:22:00	09/06/2015	11:22:00	103.80	0.200	0.367
21/06/2015	20:42:00	21/06/2015	20:55:00	21/06/2015	21:20:00	21/06/2015	21:20:00	297.33	0.217	0.417
10/09/2015	23:58:00	11/09/2015	0:12:00	11/09/2015	0:55:00	11/09/2015	0:55:00	1946.63	0.233	0.717
14/10/2015	19:32:00	14/10/2015	19:44:00	14/10/2015	20:00:00	14/10/2015	20:00:00	810.62	0.200	0.267

Table 3 Failure Data of Cutter Ply 1 for Setting/adjsutment Activity (Cont'd)

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Day	TBF (hours)	Waiting Time (hours)	TTR (hours)
05/01/2016	9:10:00	05/01/2016	9:20:00	05/01/2016	9:35:00	05/01/2016	05/01/2016	561.20	0.167	0.250
06/01/2016	0:16:00	06/01/2016	0:28:00	06/01/2016	0:45:00	06/01/2016	06/01/2016	14.68	0.200	0.283
03/05/2016	19:53:00	03/05/2016	20:05:00	03/05/2016	20:25:00	03/05/2016	03/05/2016	2851.13	0.200	0.333
30/05/2016	22:09:00	28/05/2016	22:20:00	28/05/2016	22:38:00	28/05/2016	30/05/2016	649.73	0.183	0.300
08/06/2016	12:26:00	08/06/2016	12:41:00	08/06/2016	12:54:00	08/06/2016	08/06/2016	253.80	0.250	0.217
12/06/2016	14:17:00	12/06/2016	14:31:00	12/06/2016	14:48:00	12/06/2016	12/06/2016	97.38	0.233	0.283

Table 4 Failure Data of Cutter Ply 1 for Repairing Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
03/01/2014	10:27:00	03/01/2014	10:42:00	03/01/2014	11:05:00	03/01/2014	11:05:00	0	0.250	0.383
09/01/2014	19:41:00	09/01/2014	19:55:00	09/01/2014	20:17:00	09/01/2014	20:17:00	152.600	0.233	0.367
20/01/2014	6:00:00	20/01/2014	6:20:00	20/01/2014	6:40:00	20/01/2014	6:40:00	249.717	0.333	0.333
13/02/2014	19:18:00	13/02/2014	19:35:00	13/02/2014	20:15:00	13/02/2014	20:15:00	588.633	0.283	0.667
01/03/2014	6:00:00	01/03/2014	6:17:00	01/03/2014	6:40:00	01/03/2014	6:40:00	369.750	0.283	0.383
01/04/2014	14:21:00	01/04/2014	14:31:00	01/04/2014	14:55:00	01/04/2014	14:55:00	751.683	0.167	0.400
07/06/2014	9:14:00	07/06/2014	9:35:00	07/06/2014	9:55:00	07/06/2014	9:55:00	1602.317	0.350	0.333
10/07/2014	20:46:00	10/07/2014	20:58:00	10/07//2014	21:30:00	10/07/2014	21:30:00	802.850	0.200	0.533
12/08/2014	14:34:00	12/08/2014	14:45:00	12/08/2014	15:03:00	12/08/2014	15:03:00	785.067	0.183	0.300
23/08/2014	17:20:00	23/08/2014	17:35:00	23/08/2014	18:00:00	23/08/2014	18:00:00	266.283	0.250	0.417

Table 4 Failure Data of Cutter Ply 1 for Repairing Activity (Cont'd)

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
07/09/2014	1:12:00	07/09/2014	1:27:00	07/09/2014	1:50:00	07/09/2014	1:50:00	343.200	0.250	0.383
18/10/2014	5:58:00	18/10/2014	6:15:00	18/10/2014	6:38:00	18/10/2014	6:38:00	988.133	0.283	0.383
30/10/2014	23:29:00	30/10/2014	23:41:00	31/10/2014	0:43:00	31/10/2014	0:29:00	304.850	0.200	1.033
17/11/2014	9:14:00	17/11/2014	9:30:00	17/11/2014	10:00:00	17/11/2014	10:00:00	416.750	0.267	0.500
01/12/2014	14:05:00	01/12/2014	14:25:00	01/12/2014	14:50:00	01/12/2014	14:50:00	340.083	0.333	0.417
25/12/2014	9:24:00	25/12/2014	9:39:00	25/12/2014	10:06:00	25/12/2014	10:06:00	570.567	0.250	0.450
11/01/2015	20:55:00	11//01/2015	21:09:00	11/01/2015	21:30:00	11/01/2015	21:30:00	418.817	0.233	0.350
09/02/2015	11:01:00	09/02/2015	11:20:00	09/02/2015	11:45:00	09/02/2015	11:45:00	685.517	0.317	0.417
14/03/2015	1:00:00	14/03/2015	1:17:00	14/03/2015	1:40:00	14/03/2015	1:40:00	781.250	0.283	0.383
21/06/2015	6:00:00	21/06/2015	7:30:00	21/06/2015	8:20:00	21/06/2015	8:20:00	2380.333	1.500	0.833
19/08/2015	2:40:00	19/08/2015	2:55:00	19/08/2015	3:26:00	19/08/2015	3:26:00	1410.333	0.250	0.517
04/09/2015	21:45:00	04/09/2015	22:00:00	04/09/2015	22:30:00	04/09/2015	22:30:00	402.317	0.250	0.500
25/10/2015	12:45:00	25/10/2015	13:00:00	25/10/2015	13:35:00	25/10/2015	13:35:00	1214.250	0.250	0.583
10/11/2015	15:35:00	10/11/2015	15:50:00	10/11/2015	16:15:00	10/11/2015	16:15:00	386	0.250	0.417
18/11/2015	3:28:00	18/11/2015	5:00:00	18/11/2015	6:00:00	18/11/2015	6:00:00	179.217	1.533	1
30/11/2015	11:02:00	30/11/2015	11:15:00	30/11/2015	13:20:00	30/11/2015	13:20:00	293.033	0.217	2.083
28/12/2015	13:20:00	28/12/2015	13:37:00	28/12/2015	14:00:00	28/12/2015	14:00:00	672	0.283	0.383
18/03/2016	10:45:00	18/03/2016	11:00:00	18/03/2016	11:35:00	18/03/2016	11:35:00	1940.750	0.250	0.583
07/05/2016	16:29:00	07/05/2016	16:45:00	07/05/2016	17:40:00	07/05/2016	17:40:00	1204.900	0.267	0.917
20/05/2016	3:16:00	20/05/2016	3:40:00	20/05/2016	4:05:00	20/05/2016	4:05:00	297.600	0.400	0.417
18/06/2016	8:46:00	18/06/2016	15:50:00	18/06/2016	16:30:00	18/06/2016	16:30:00	700.683	7.067	0.667

Table 5 Failure Data of Cutter Ply 1 for Replacement Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
22/02/2014	13:00:00	22/02/2014	13:40:00	22/02/2014	14:25:00	22/02/2014	14:25:00	0	0.667	0.750
11/04/2014	19:42:00	11/04/2014	20:20:00	11/04/2014	21:00:00	11/04/2014	21:00:00	1157.283	0.633	0.667
21/07/2014	6:40:00	21/07/2014	7:15:00	21/07/2014	8:10:00	21/07/2014	8:10:00	2409.667	0.583	0.917
20/10/2014	13:39:00	20/10/2014	14:20:00	20/10/2014	15:10:00	20/10/2014	15:10:00	2189.483	0.683	0.833
21/11/2014	0:40:00	21/11/2014	1:17:00	21/11/2014	1:50:00	21/11/2014	1:50:00	753.500	0.617	0.550
22/01/2015	19:30:00	22/01/2015	20:01:00	22/01/2015	20:35:00	22/01/2015	20:35:00	1505.667	0.517	0.567
20/06/2015	6:00:00	20/06/2015	6:55:00	20/06/2015	7:45:00	20/06/2015	7:45:00	3561.417	0.917	0.833
15/09/2015	5:46:00	15/09/2015	6:07:00	15/09/2015	6:56:00	15/09/2015	6:56:00	2086.183	0.350	0.817
28/11/2015	21:58:00	28/11/2015	22:37:00	28/11/2015	23:15:00	28/11/2015	23:15:00	1791.033	0.650	0.633
07/03/2016	0:38:00	07/03/2016	7:40:00	07/03/2016	8:10:00	07/03/2016	8:10:00	2377.383	7.033	0.500
28/06/2016	7:22:00	28/06/2016	8:06:00	28/06/2016	10:35:00	28/05/2016	10:35:00	2711.200	0.733	2.483

Table 6 Failure Data of Sensor Machine for Setting/adjustment Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
12/01/2014	15:06:00	12/01/2014	15:25:00	12/01/2014	16:10:00	12/01/2014	16:10:00	0	0.317	0.750
19/07/2014	20:36:00	19/07/2014	20:54:00	19/07/2014	21:25:00	19/07/2014	21:25:00	4516.433	0.300	0.517
21/08/2014	0:45:00	21/08/2014	1:05:00	21/08/2014	1:35:00	21/08/2014	1:35:00	771.333	0.333	0.500
18/09/2014	19:14:00	18/09/2014	19:40:00	18/09/2014	20:35:00	18/09/2014	20:35:00	689.650	0.433	0.917
08/11/2014	1:52:00	08/11/2014	2:10:00	08/11/2014	2:30:00	08/11/2014	2:30:00	1205.283	0.300	0.333

Table 6 Failure Data of Sensor Machine for Setting/adjustment Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
19/01/2015	3:44:00	19/01/2015	4:00:00	19/01/2015	4:37:00	19/01/2015	5:37:00	1729.233	0.267	0.617
01/04/2015	0:53:00	01/04/2015	1:15:00	01/04/2015	1:47:00	01/04/2015	1:47:00	1723.267	0.367	0.533
25/07/2015	1:27:00	25/07/2015	1:40:00	25/07/2015	2:00:00	25/07/2015	2:00:00	2759.667	0.217	0.333
28/09/2015	1:10:00	28/09/2015	1:30:00	28/09/2015	2:06:00	28/09/2015	2:06:00	1559.167	0.333	0.600
04/11/2015	13:17:00	04/11/2015	13:55:00	04/11/2015	15:18:00	04/11/2015	15:18:00	899.183	0.633	1.383
13/01/2016	15:17:00	13/01/2016	15:36:00	13/01/2016	16:00:00	13/01/2016	16:00:00	1679.983	0.317	0.400
12/05/2016	18:50:00	12/05/2016	19:05:00	12/05/2016	19:30:00	12/05/2016	19:30:00	2882.833	0.250	0.417

Table 7 Failure Data of Sensor Machine for Repairing Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
16/03/2014	17:50:00	16/03/2014	18:40:00	16/03/2014	20:41:00	16/03/2014	20:41:00	0	0.833	2.017
18/05/2014	1:30:00	18/05/2014	2:30:00	18/05/2014	3:33:00	18/05/2014	3:33:00	1492.82	1	1.050
20/07/2014	14:28:00	20/07/2014	14:55:00	20/07/2014	15:49:00	20/07/2014	15:49:00	1522.92	0.450	0.900
23/10/2014	19:35:00	23/10/2014	20:05:00	23/10/2014	21:00:00	23/10/2014	21:00:00	2283.77	0.500	0.917
11/01/2015	14:54:00	11/01/2015	15:20:00	11/01/2015	16:20:00	11/01/2015	16:20:00	1913.90	0.433	1
22/04/2015	0:14:00	22/04/2015	1:05:00	22/04/2015	2:46:00	22/04/2015	2:46:00	2407.90	0.850	1.683
28/06/2015	10:05:00	28/06/2015	10:42:00	28/06/2015	11:34:00	28/06/2015	11:34:00	1615.32	0.617	0.867
01/09/2015	6:09:00	01/09/2015	6:35:00	01/09/2015	7:31:00	01/09/2015	7:31:00	1554.58	0.433	0.933
05/11/2015	8:36:00	05/11/2015	9:12:00	05/11/2015	11:23:00	05/11/2015	11:23:00	1561.08	0.600	2.183

Table 7 Failure Data of Sensor Machine for Repairing Activity (Cont'd)

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
17/12/2015	9:22:00	17/12/2015	10:00:00	17/12/2015	11:27:00	17/12/2015	11:27:00	1005.98	0.633	1.450
10/03/2016	9:44:00	10/03/2016	10:08:00	10/03/2016	11:44:00	10/03/2016	11:44:00	2014.28	0.400	1.600
15/06/2016	11:35:00	15/06/2016	12:15:00	15/06/2016	13:42:00	15/06/2016	13:42:00	2327.85	0.667	1.450

Table 8 Failure Data of Cutter Ply 3 for Setting/adjustment Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
14/02/2014	23:23:00	14/02/2014	23:40:00	14/02/2014	0:02:00	14/02/2014	0:02:00	0	0.2833	0.367
25/05/2014	21:00:00	25/05/2014	21:20:00	25/05/2014	21:49:00	25/05/2014	21:49:00	2396.967	0.3333	0.483
28/08/2014	2:52:00	28/08/2014	3:15:00	28/08/2014	3:41:00	28/08/2014	3:41:00	2261.050	0.3833	0.433
31/01/2015	17:16:00	31/01/2015	17:40:00	31/01/2015	18:13:00	31/01/2015	18:13:00	3757.583	0.4000	0.550
08/06/2015	0:51:00	08/06/2015	1:17:00	08/06/2015	2:00:00	08/06/2015	2:00:00	3054.633	0.4333	0.717
12/12/2015	20:00:00	12/12/2015	20:23:00	12/12/2015	21:20:00	12/12/2015	21:20:00	4506	0.3833	0.950

Table 8 Failure Data of Cutter Ply 3 for Repairing Activity

Stop Machine		TTR Start		TTR Finish		Start Production				
Day	Time	Day	Time	Day	Time	Day	Time	TBF (hours)	Waiting Time (hours)	TTR (hours)
23/01/2014	22:45:00	23/01/2014	23:15:00	23/01/2014	0:05:00	23/01/2014	0:05:00	0	0.500	0.833
28/03/2014	15:13:00	28/03/2014	15:44:00	28/03/2014	16:37:00	28/03/2014	16:37:00	1527.133	0.517	0.883
29/06/2014	1:08:00	29/06/2014	1:32:00	29/06/2014	2:31:00	29/06/2014	2:31:00	2216.517	0.400	0.983
08/10/2014	15:14:00	08/10/2014	16:00:00	08/10/2014	17:08:00	08/10/2014	17:08:00	2436.717	0.767	1.133
19/01/2015	2:00:00	19/01/2015	2:37:00	19/01/2015	3:51:00	19/01/2015	3:51:00	2456.867	0.617	1.233
29/04/2015	6:13:00	29/04/2015	7:00:00	29/04/2015	8:22:00	29/04/2015	8:22:00	2402.367	0.783	1.367
13/09/2015	11:04:00	13/09/2015	12:13:00	13/09/2015	13:30:00	13/09/2015	13:30:00	3290.700	1.150	1.283
12/12/2015	7:35:00	12/12/2015	10:01:00	12/12/2015	11:43:00	12/12/2015	11:43:00	2154.083	2.433	1.700
04/02/2016	17:30:00	04/02/2016	18:15:00	04/02/2016	19:20:00	04/02/2016	19:20:00	1301.783	0.750	1.083
05/05/2016	1:56:00	05/05/2016	2:45:00	05/05/2016	3:51:00	05/05/2016	3:51:00	2166.600	0.817	1.100

Appendix 3 Goodness of Fit and index of fit Test Result for TBF and TTF

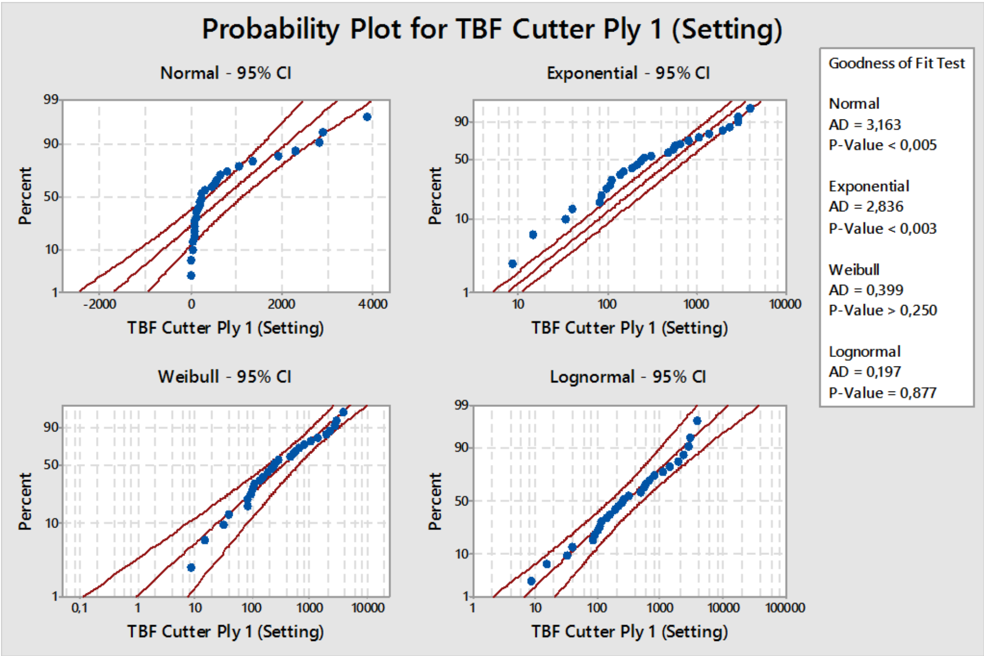

Figure 1 Goodness of Fit Test for Time Between Failure (TBF) Cutter ply 1 (Setting/adjustment)

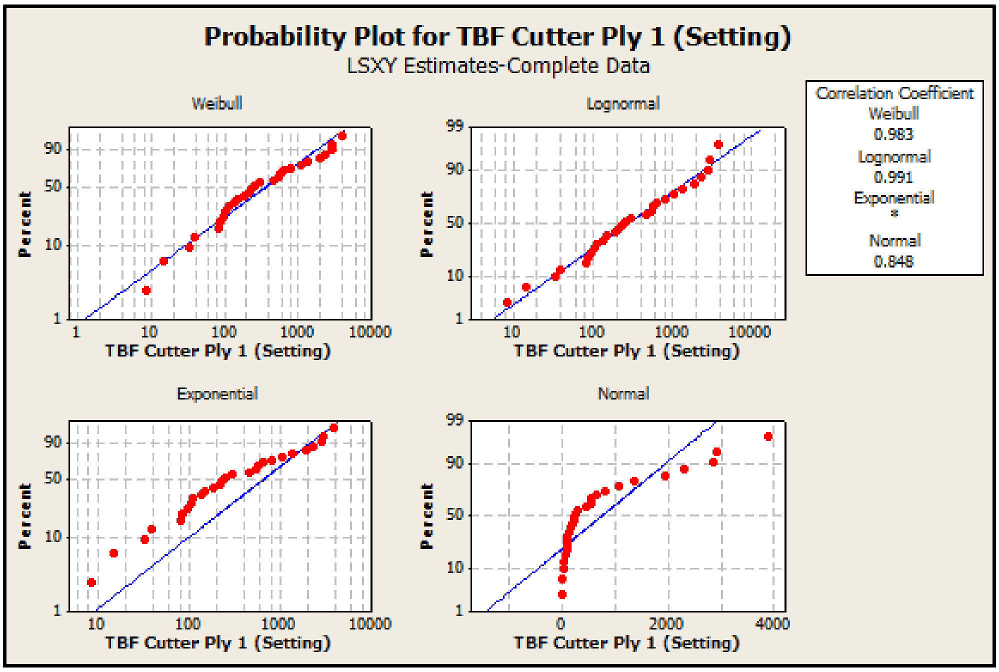

Figure 2 Index of Fit Test for Time Between Failure (TBF) Cutter ply 1 (Setting/adjustment)

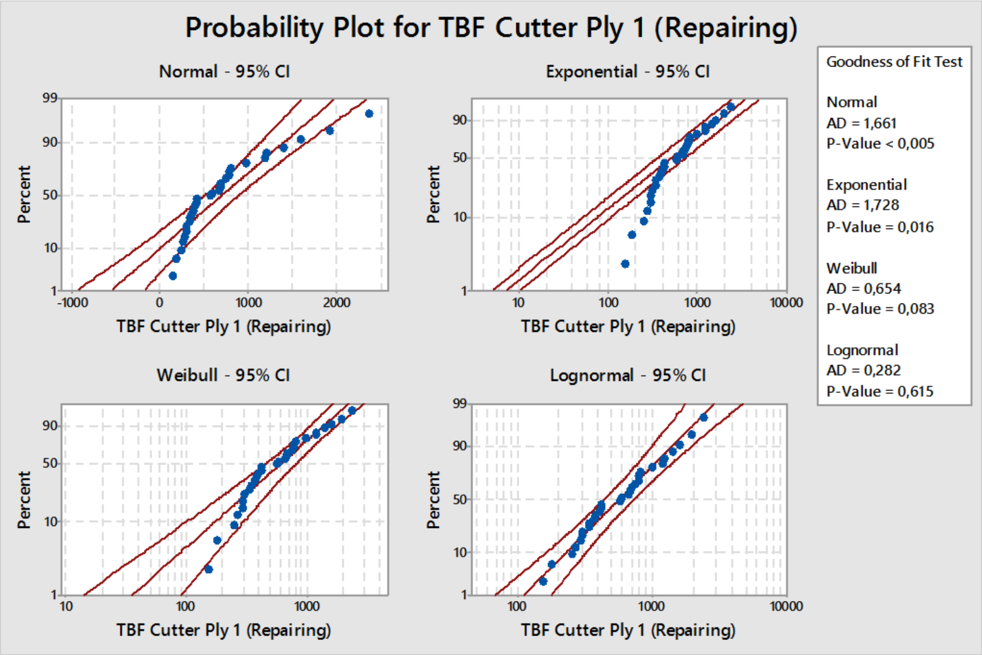

Figure 3 Goodness of Fit Test for Time Between Failure (TBF) Cutter ply 1 (Repairing)

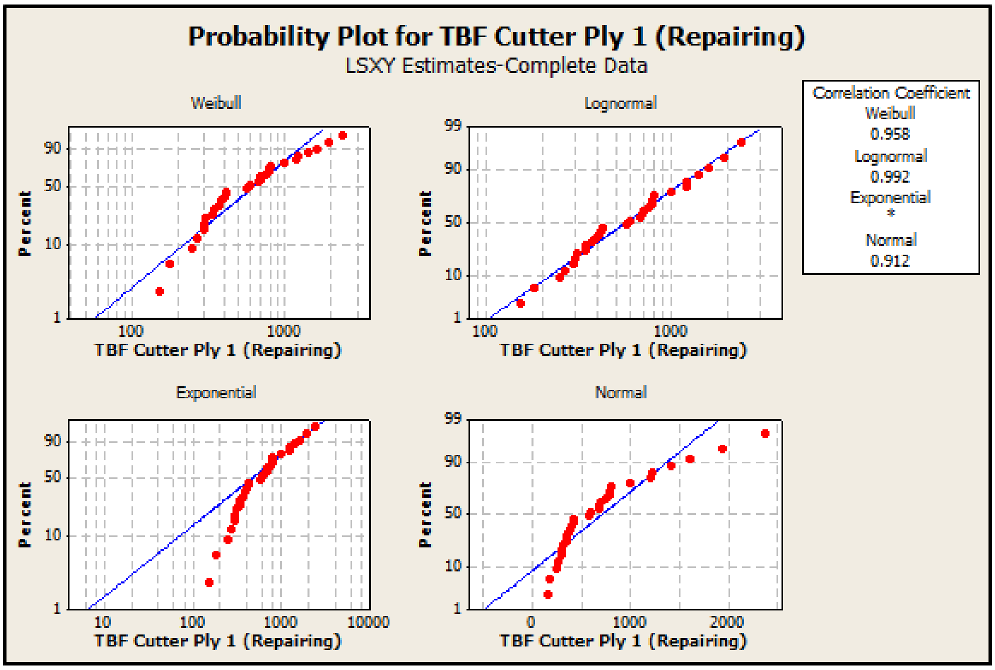

Figure 4 Index of Fit Test for Time Between Failure (TBF) Cutter ply 1 (Repairing)

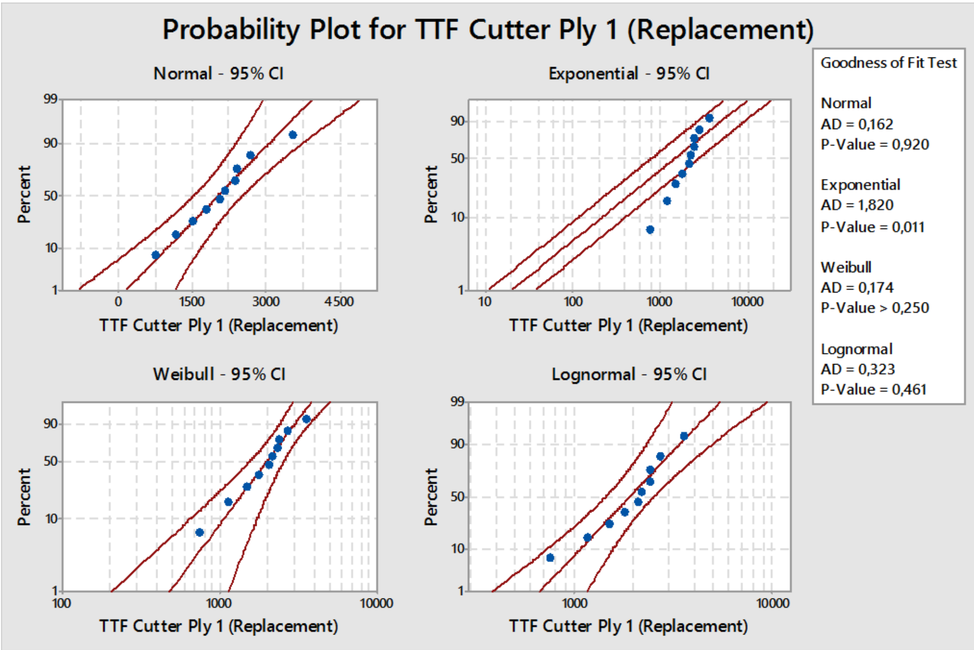

Figure 5 Goodness of Fit Test for Time To Failure (TTF) Cutter ply 1 (Replacement)

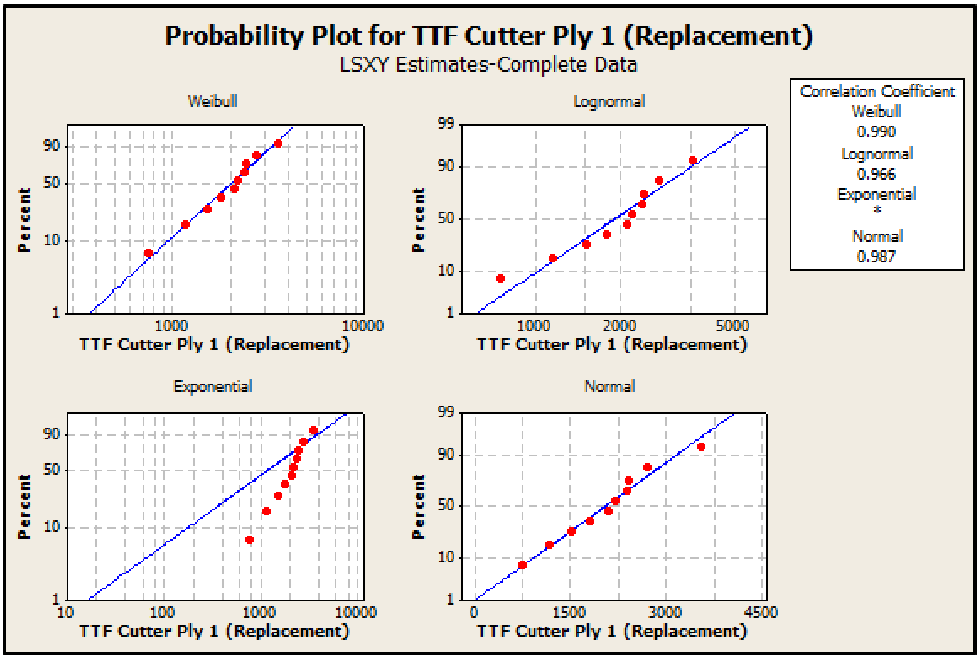

Figure 6 Index of Fit Test for Time To Failure (TTF) Cutter ply 1 (Replacement)

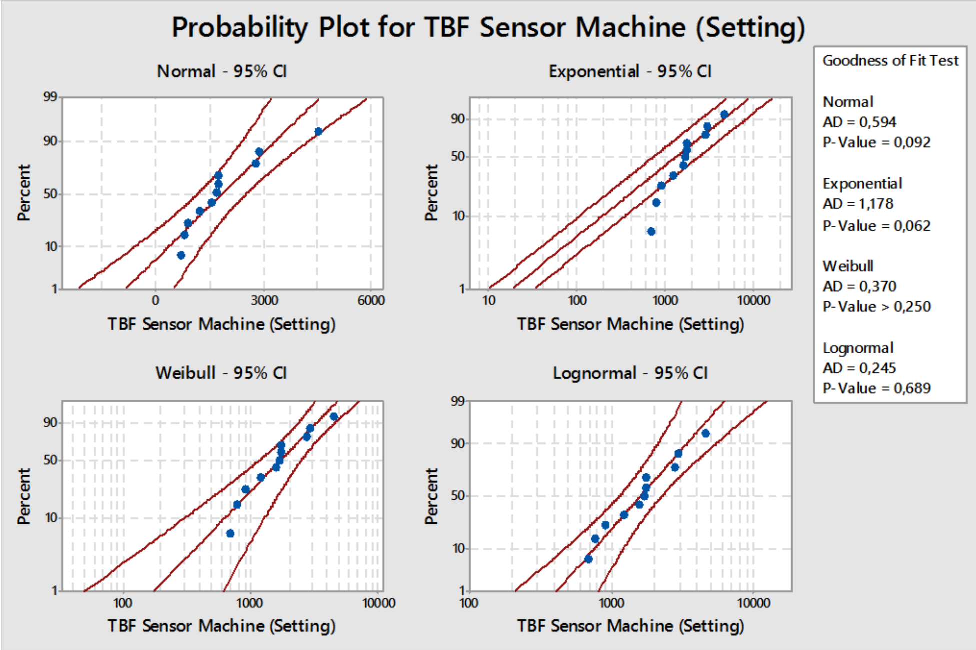

Figure 7 Goodness of Fit Test for Time Between Failure (TBF) Sensor Machine (Setting/adjustment)

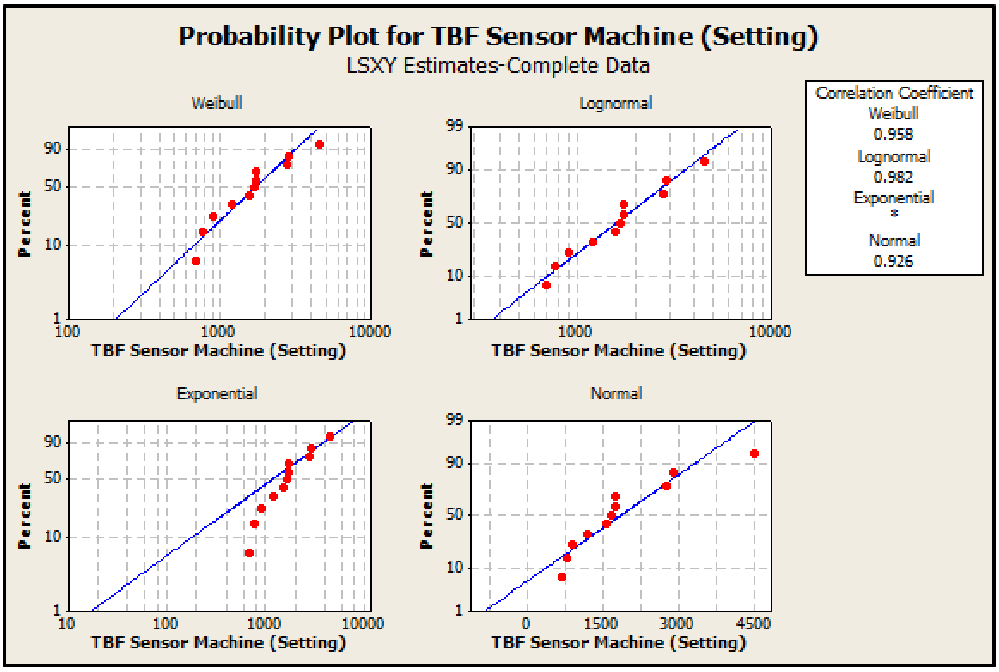

Figure 8 Index of Fit Test for Time Between Failure (TBF) Sensor Machine (Setting/adjustment)

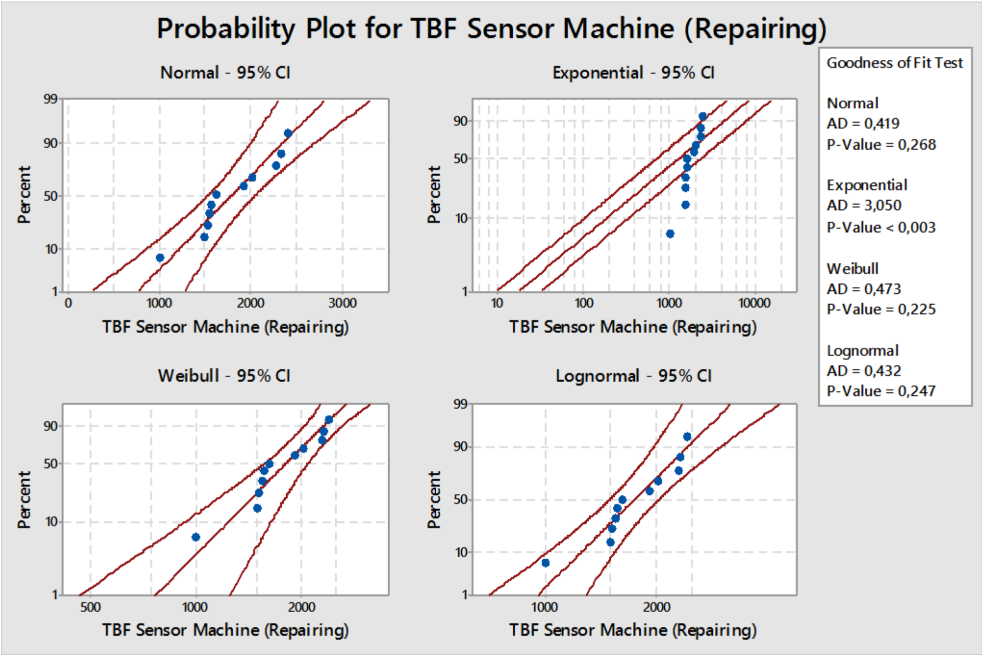

Figure 9 Goodness of Fit Test for Time Between Failure (TBF) Sensor Machine (Repairing)

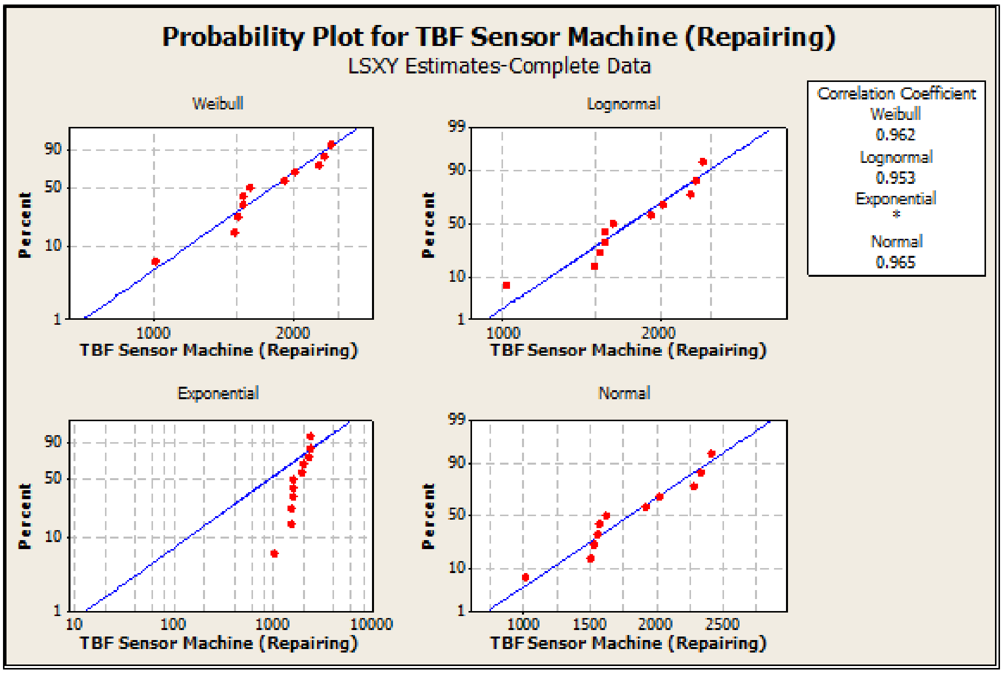

Figure 10 Index of Fit Test for Time Between Failure (TBF) Sensor Machine (Repairing)

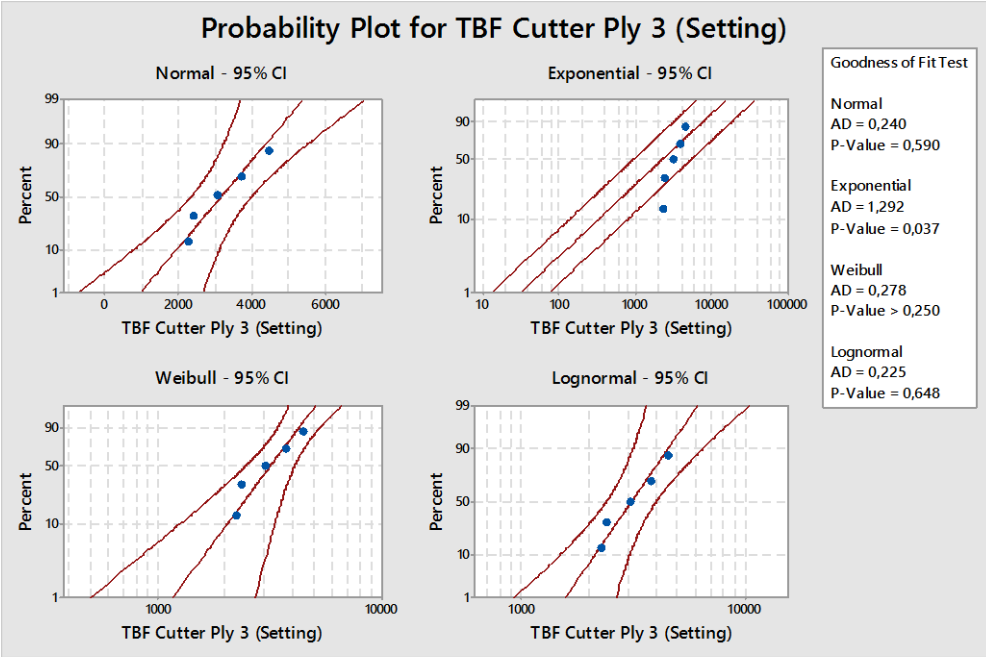

Figure 11 Goodness of Fit Test for Time Between Failure (TBF) Cutter Ply 3 (Setting/adjustment)

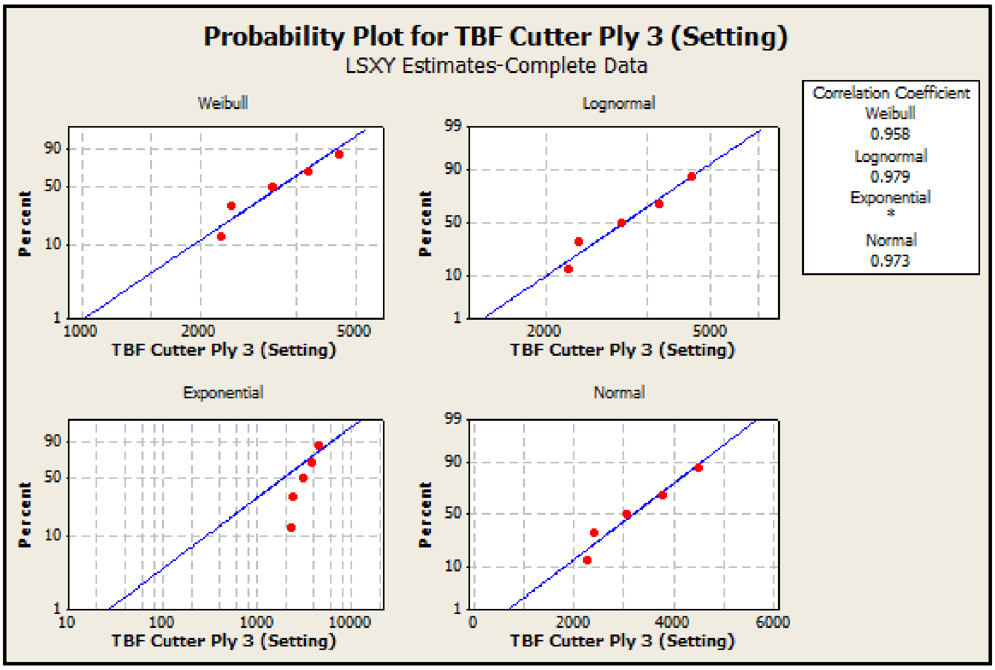

Figure 12 Index of Fit Test for Time Between Failure (TBF) Cutter Ply 3 (Setting/adjustment)

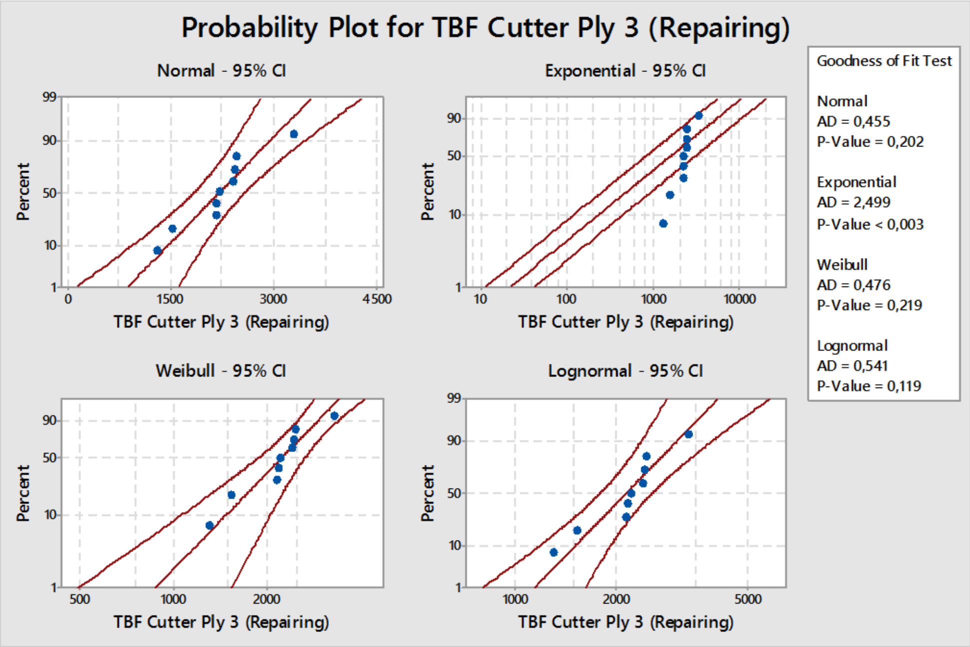

Figure 13 Goodness of Fit Test for Time Between Failure (TBF) Cutter Ply 3 (Repairing)

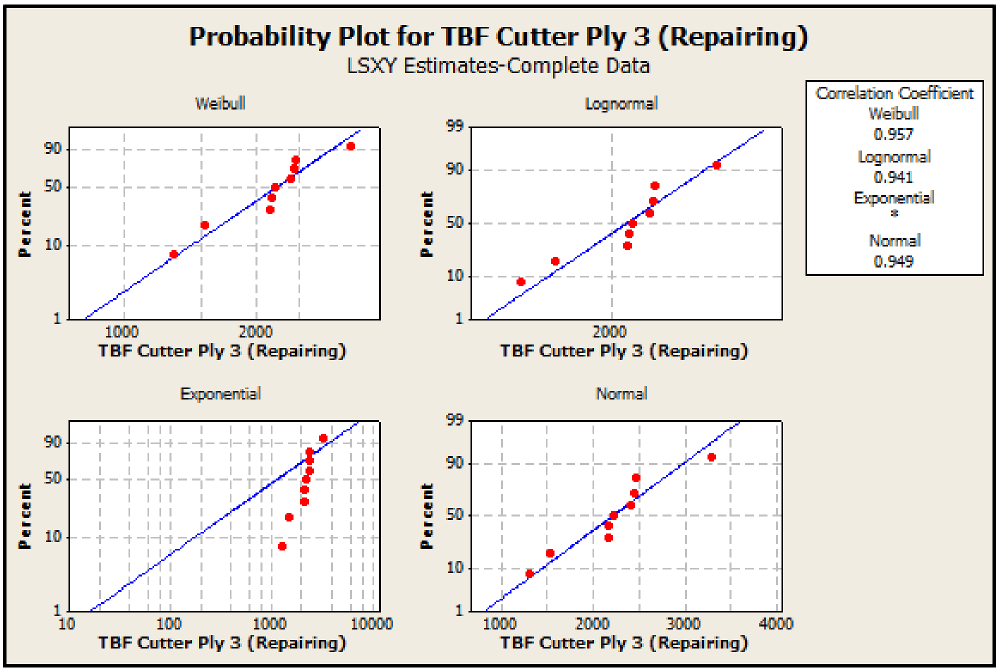

Figure 14 Index of Fit Test for Time Between Failure (TBF) Cutter Ply 3 (Repairing)

Appendix 4 Goodness of Fit and index of fit Test Result for Time To Repair

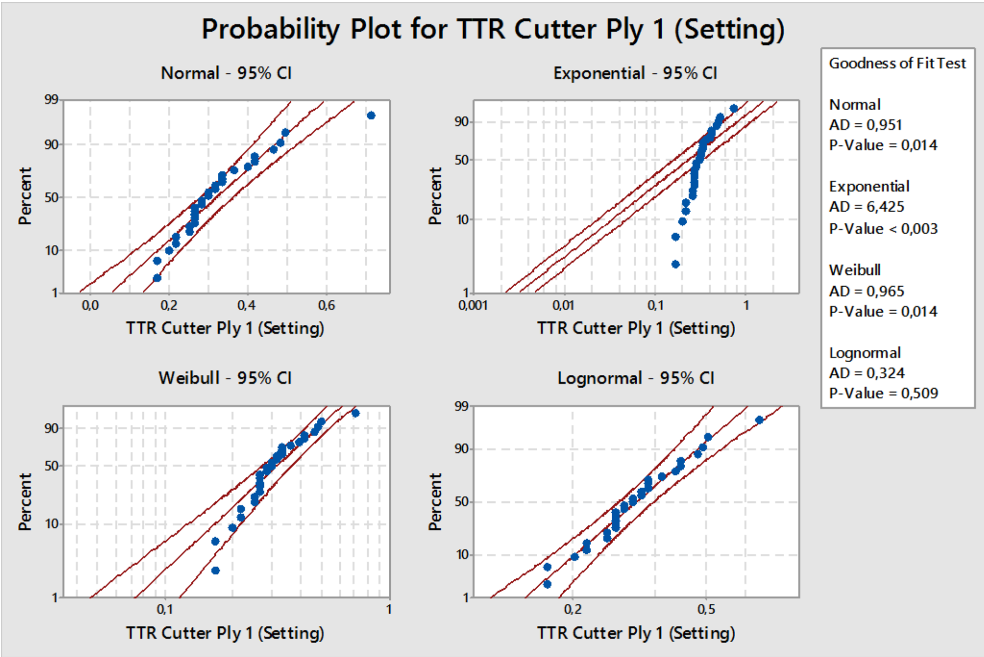

Figure 15 Goodness of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Setting/adjustment)

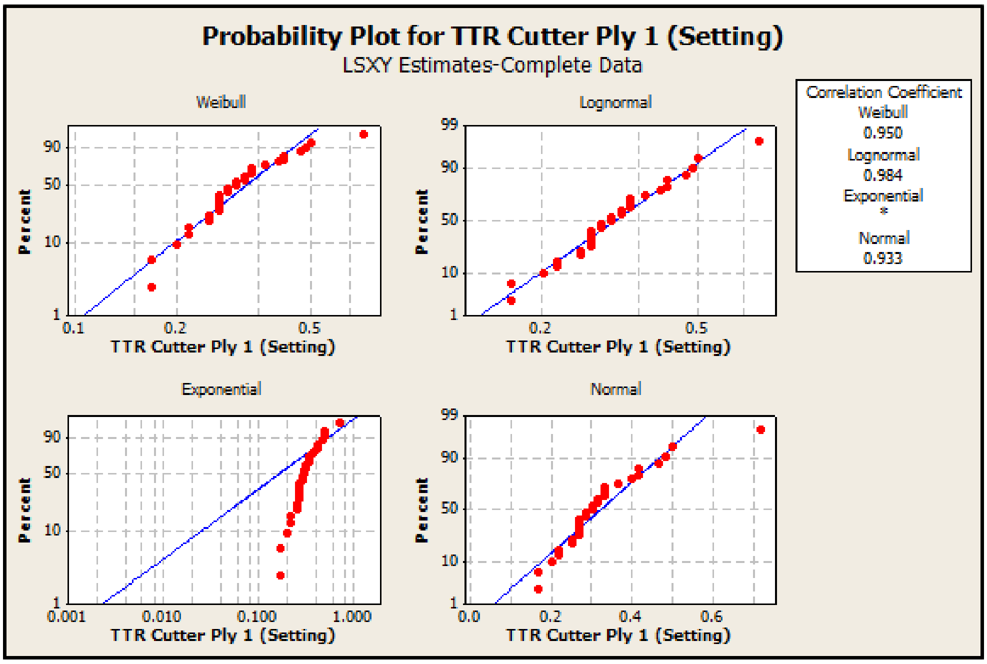

Figure 16 Index of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Setting/adjustment)

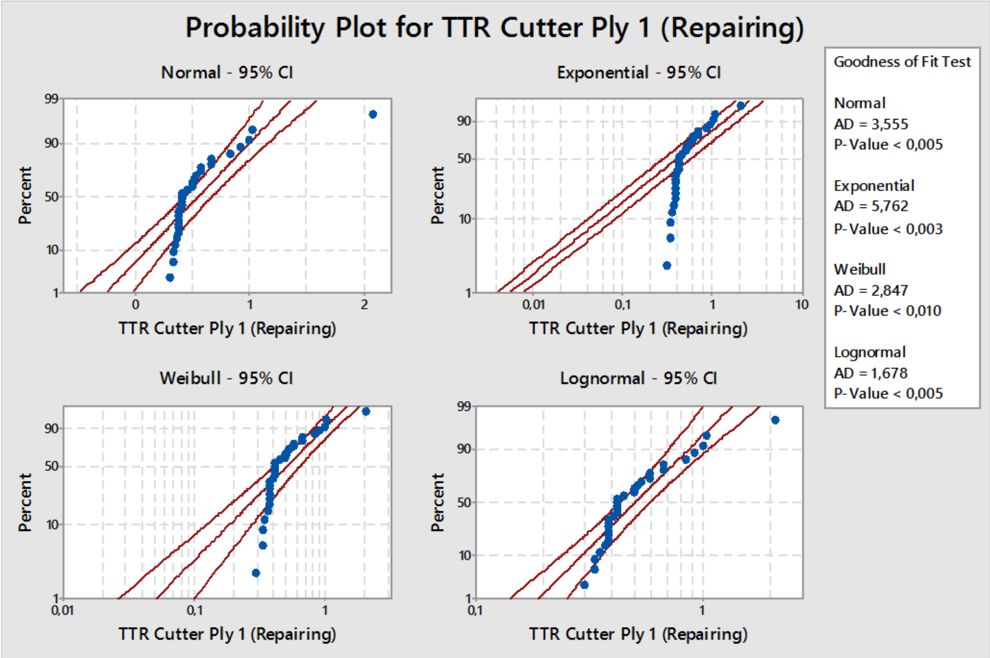

Figure 17 Goodness of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Repairing)

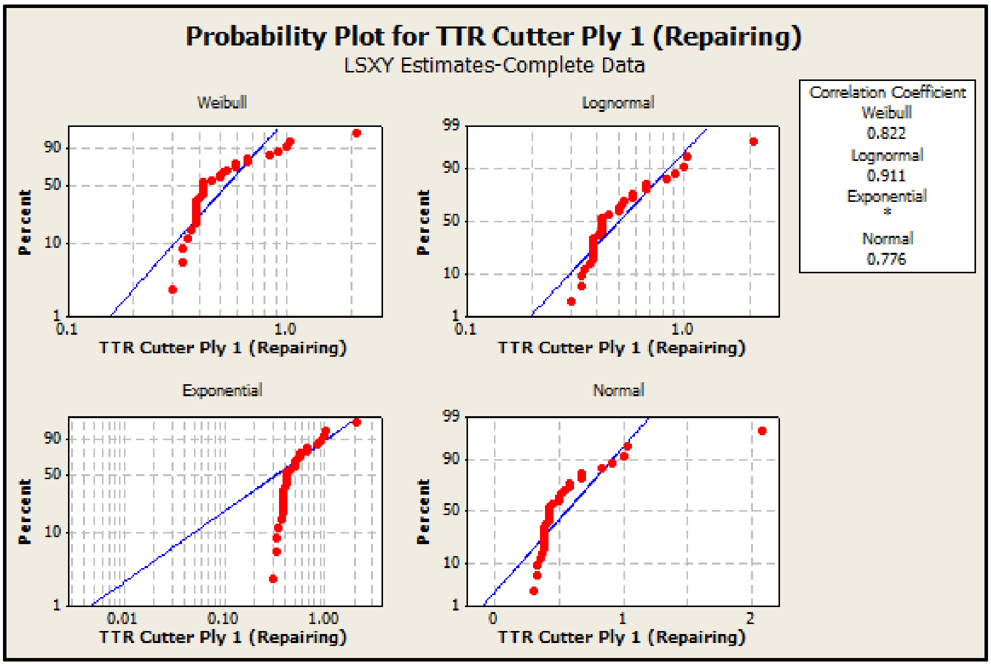

Figure 18 Index of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Repairing)

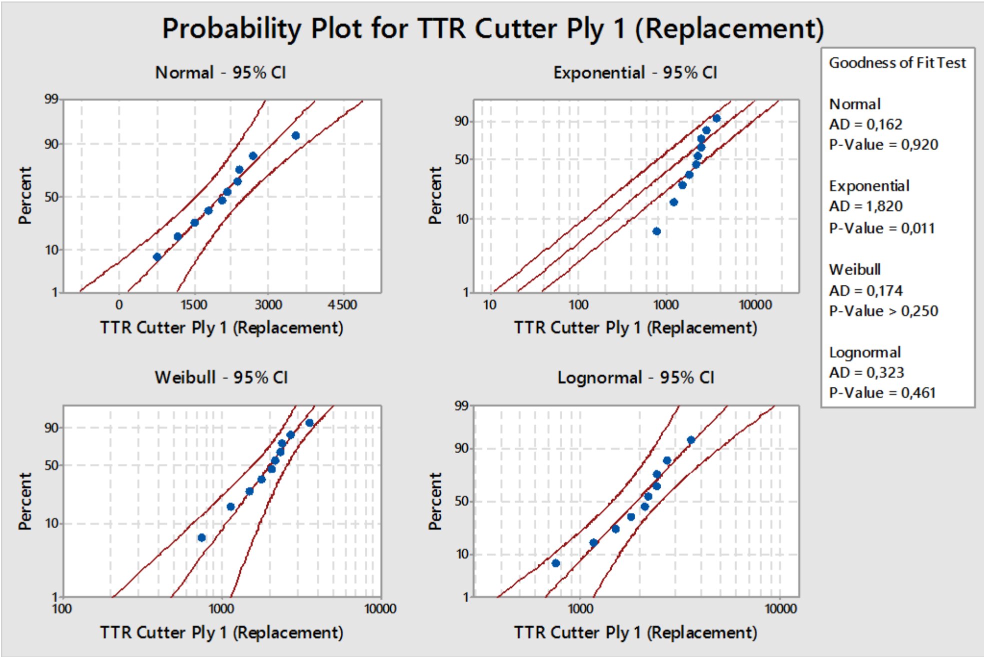

Figure 19 Goodness of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Replacement)

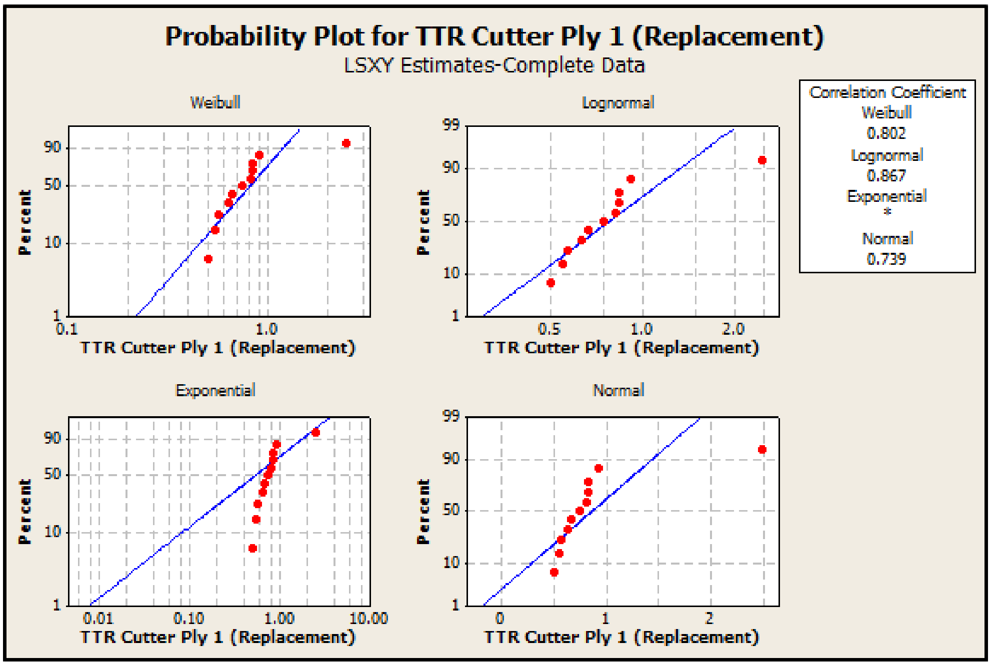

Figure 20 Index of Fit Test for Time To Repair (TTR) Cutter Ply 1 (Replacement)

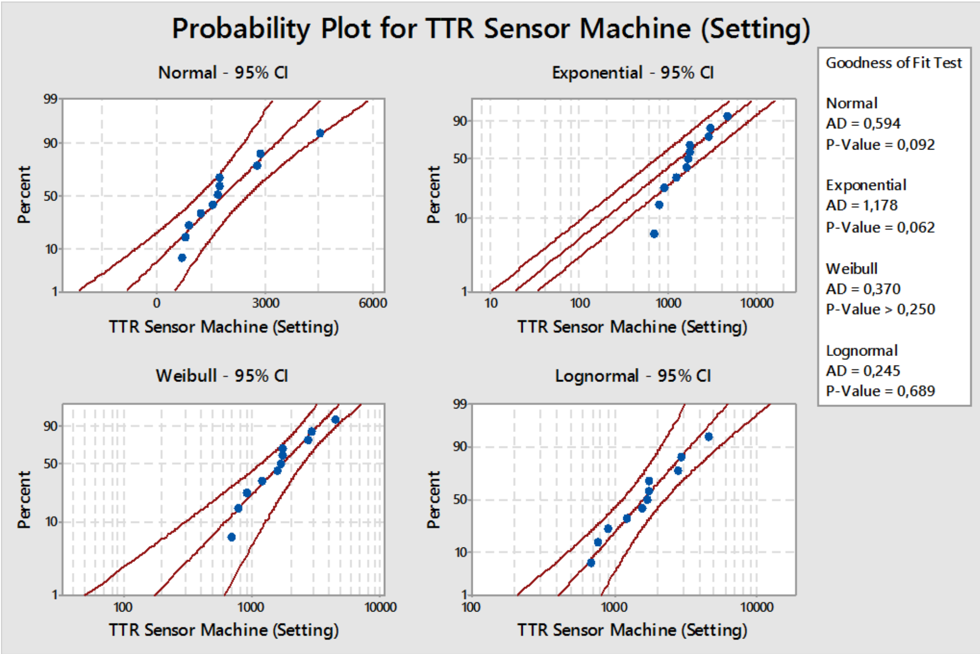

Figure 21 Goodness of Fit Test for Time To Repair (TTR) Sensor Machine (Setting/adjustment)

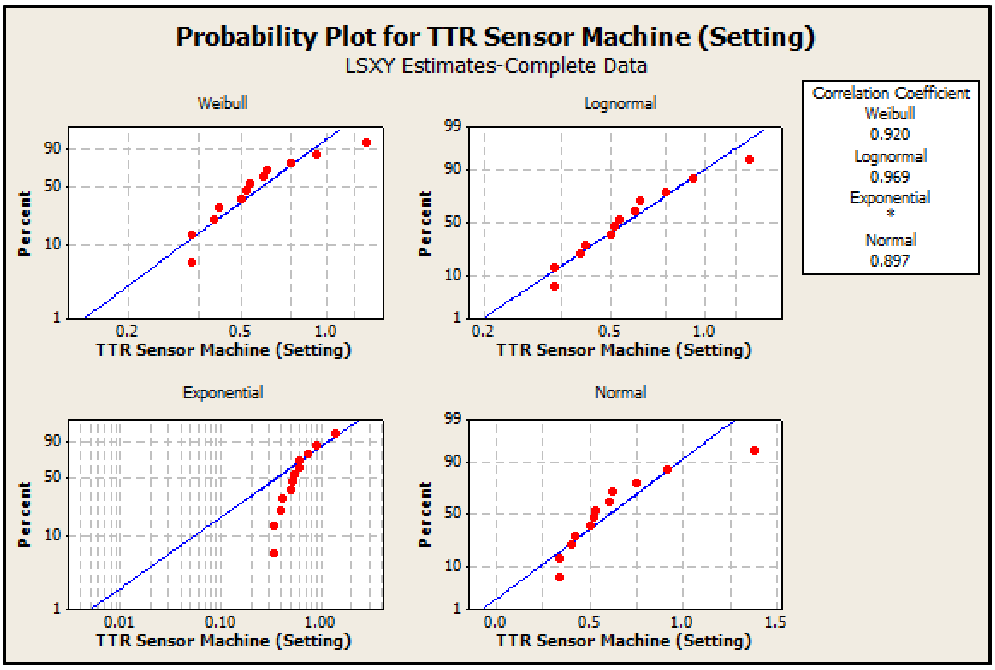

Figure 22 Index of Fit Test for Time To Repair (TTR) Sensor Machine (Setting/adjustment)

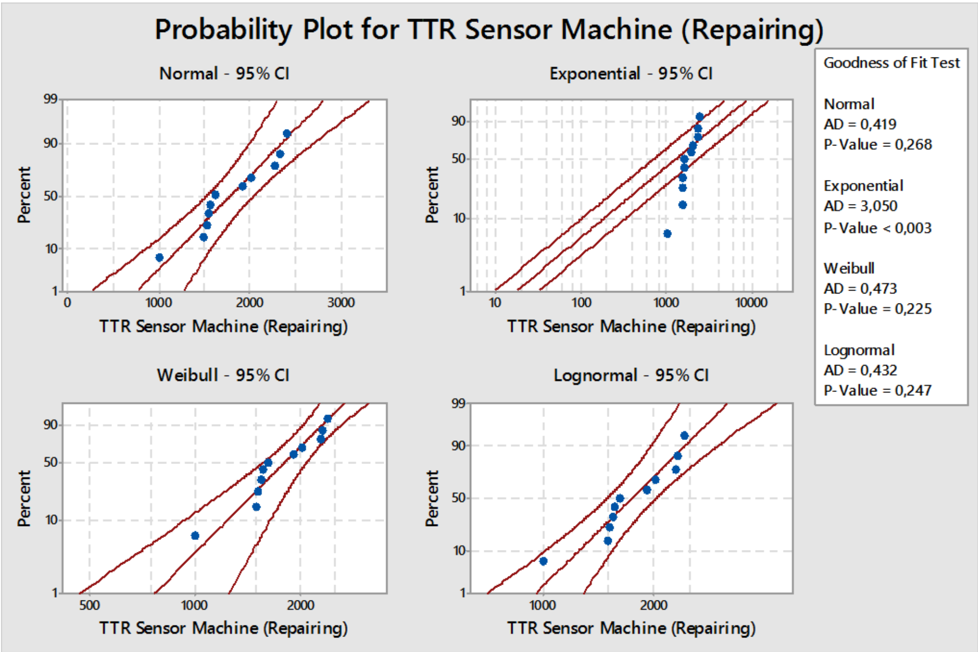

Figure 23 Goodness of Fit Test for Time To Repair (TTR) Sensor Machine (Repairing)

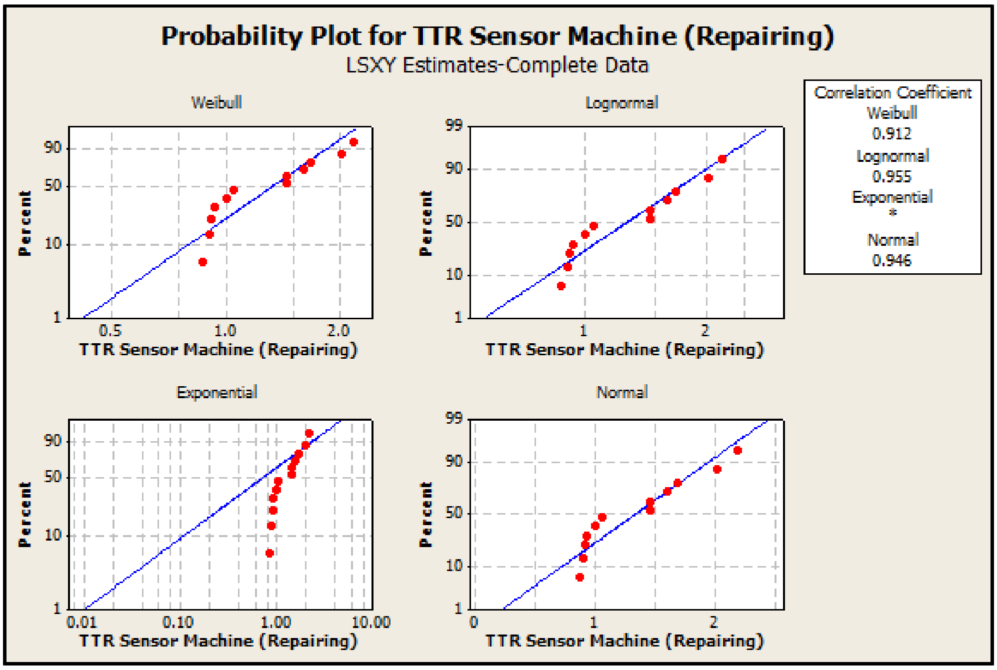

Figure 24 Index of Fit Test for Time To Repair (TTR) Sensor Machine (Repairing)

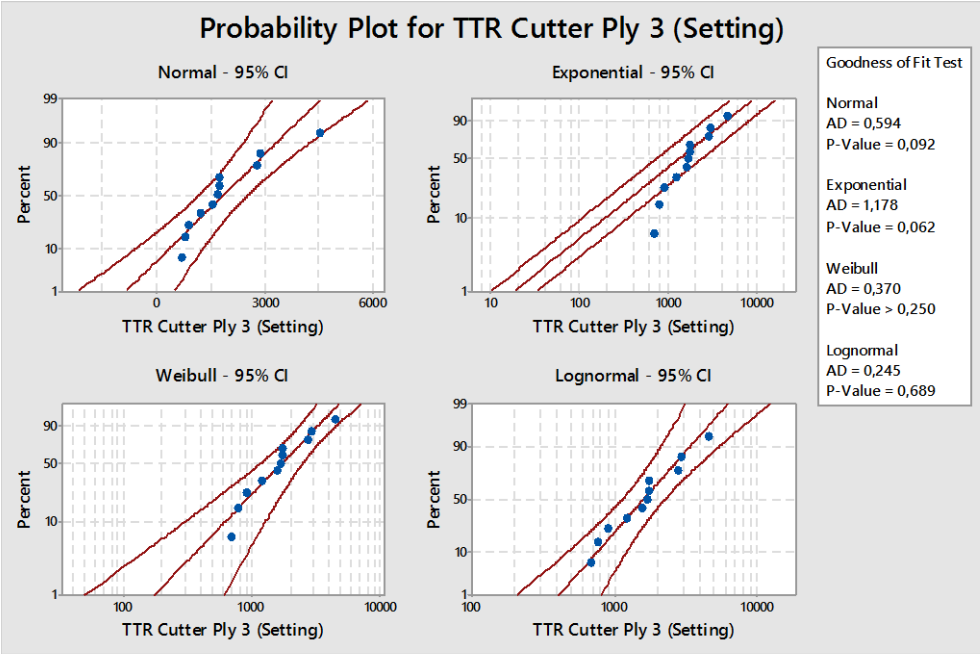

Figure 25 Goodness of Fit Test for Time To Repair (TTR) Cutter Ply 3 (Setting/adjustment)

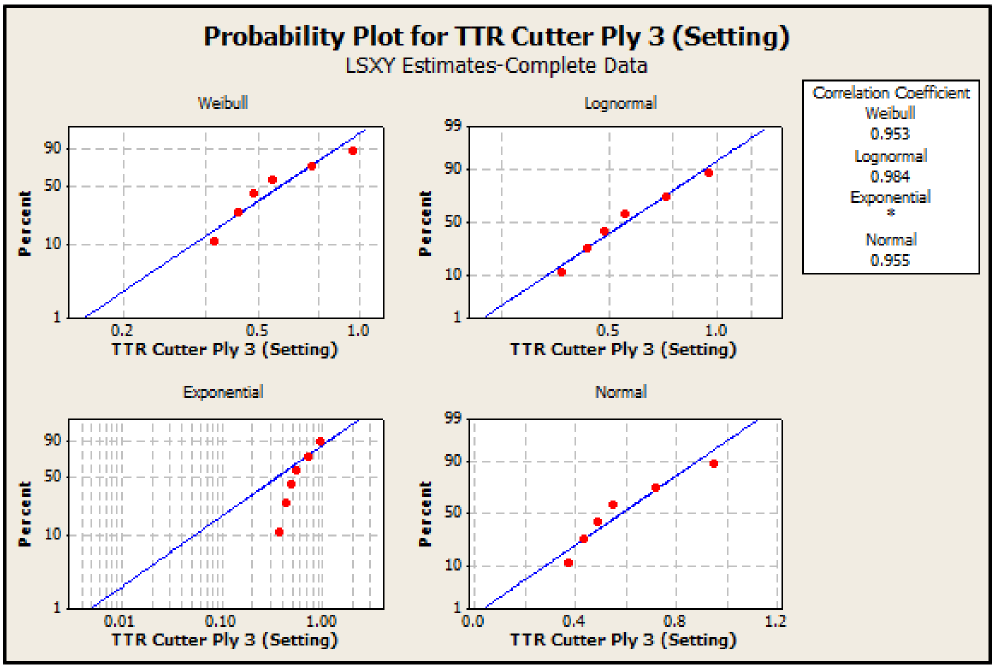

Figure 26 Index of Fit Test for Time To Repair (TTR) Cutter Ply 3 (Setting/adjustment)

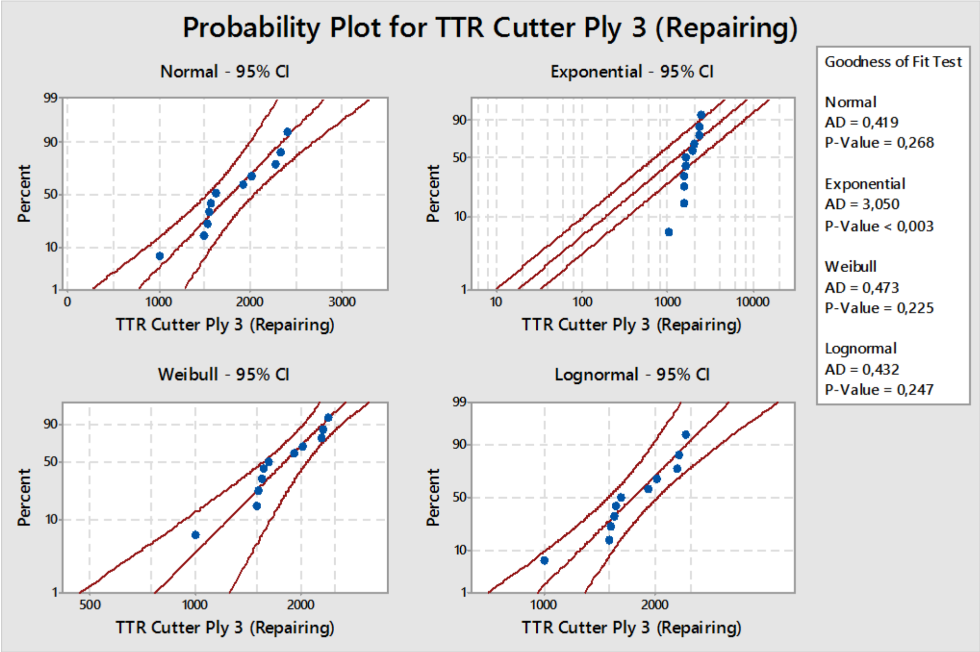

Figure 27 Goodness of Fit Test for Time To Repair (TTR) Cutter Ply 3 (Repairing)

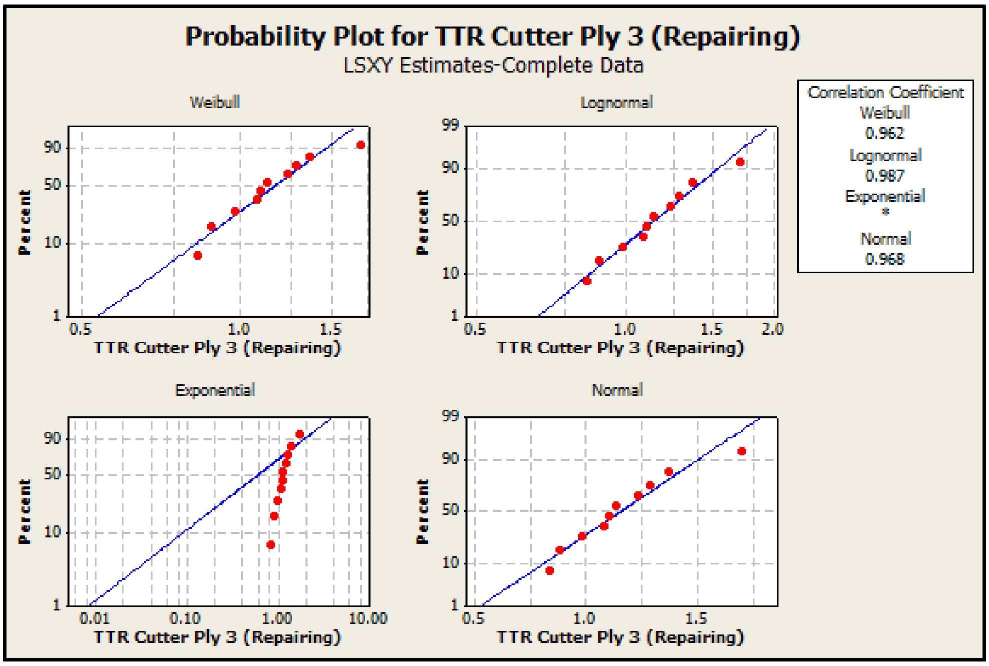

Figure 28 Index of Fit Test for Time To Repair (TTR) Cutter Ply 3 (Repairing)

Appendix 5 Proposed Preventive Maintenance Schedule from June 2016 Until June 2017

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

August 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

September 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

October 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

November 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

December 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

January 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

February 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

Figure 29 Preventive Maintenance Schedule (Scenario 1 : Reliability 65%)

March 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

April 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

May 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

June 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Note :

- CP 1 (Setting)
- CP 1 (Reparing)
- CP 1 (Replacement)
- SM (Repairing)
- CP 3 (Repairing)
- CP 1 (Repairing) + SM(Setting)
- CP 1 (Setting) + SM (Setting)
- CP 1 (Setting)+ SM (Repairing)
- CP 1 (Setting(+ cp 3 (Setting)
- CP 3 (Setting)
- CP 1 (Setting) + CP 3 (Repairing)
- CP 1 (Repairing) + CP 3 (Repairing)

Figure 29 Preventive Maintenance Schedule (Scenario 1 : Reliability 65%) Cont'd

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

August 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

September 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

October 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

November 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

December 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

January 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

February 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

Figure 30 Preventive Maintenance Schedule (Scenario 2 : Reliability 75%)

March 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

April 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

May 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

June 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Note :

- CP 1 (Setting)
- CP 1 (Reparing)
- CP 1 (Replacement)
- SM (Repairing)
- CP 3 (Repairing)
- CP 1 (Repairing) + SM(Setting)
- CP 1 (Setting) + SM (Setting)
- CP 1 (Setting)+ SM (Repairing)
- CP 1 (Setting(+ cp 3 (Setting)
- CP 3 (Setting)
- CP 1 (Setting) + CP 3 (Repairing)
- CP 1 (Repairing) + CP 3 (Repairing)

Figure 30 Preventive Maintenance Schedule (Scenario 2 : Reliability 75%) Cont'd

June 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

July 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

August 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

September

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

October 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

November

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

December 2016

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

January 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

February 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

Figure 31 Preventive Maintenance Schedule (Scenario 3 : Reliability 85%)

March 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

April 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

May 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

June 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Note :

- CP 1 (Setting)
- CP 1 (Reparing)
- CP 1 (Replacement)
- SM (Repairing)
- CP 3 (Repairing)
- SM (Setting)
- CP 1 (Setting) + SM (Setting)
- CP 1 (Setting)+ SM (Repairing)
- CP 1 (Setting) + cp 3 (Setting)
- CP 1 (Setting) + CP 3 (Repairing)
- CP 1 (Repairing) + CP 3 (Repairing)
- CP 1 (Replacement) + SM(Repairing)
- CP 1 (Repairing) + SM (setting) + CP 3 (Setting)

Figure 31 Preventive Maintenance Schedule (Scenario 3 : Reliability 85%) Cont'd

Appendix 6 Preventive Maintenance Checksheet

Table 9 Preventive Maintenance Checksheet (Scenario 1)

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Repair setting machine	15 June 2016				
2	Setting/adjustment cutter ply 1	18 June 2016				
3	Setting/adjustment cutter ply 1	24 June 2016				
4	Replace cutter ply 1	28 June 2016				
5	Repair cutter ply 1	5 July 2016				
6	Setting/adjustment sensor machine					
7	Setting/adjustment cutter ply 1	12 July 2016				
8	Repair cutter ply 3					
9	Setting/adjustment cutter ply 1	18 July 2016				
10	Repair cutter ply 1	22 July 2016				
11	Setting/adjustment cutter ply 1	24 July 2016				
12	Setting/adjustment cutter ply 1	30 July 2016				
13	Setting/adjustment cutter ply 3					
14	Setting/adjustment cutter ply 1	5 August 2016				
15	Repair cutter ply 1	8 August 2016				
16	Setting/adjustment cutter ply 1	11 August 2016				
17	Setting/adjustment cutter ply 1	17 August 2016				
18	Repair sensor machine	21 August 2016				
19	Setting/adjustment cutter ply 1	23 August 2016				
20	Repair sensor machine	25 August 2016				
21	Setting/adjustment cutter ply 1	29 August 2016				
22	Setting/adjustment sensor machine					
23	Replace cutter ply 1	2 September 2016				
24	Repairing cutter ply 1	10 September 2016				
25	Setting/adjustment cutter ply 1	16 September 2016				
26	Repair cutter ply 3					
27	Setting/adjustment cutter ply 1	22 Septembr 2016				
28	Repair cutter ply 1	28 September 2016				
29	Setting/adjustment cutter ply 1	4 October 2016				
30	Setting/adjustment cutter ply 1	10 October 2016				
31	Repair cutter ply 1	15 October 2016				
32	Setting/adjustment cutter ply 1	22 October 2016				
33	Setting/adjustment sensor machine					
34	Setting/adjustment cutter ply 1	28 October 2016				
35	Repair sensor machine					
36	Repair cutter ply 1	1 November 2016				
37	Setting/adjustment cutter ply 1	3 November 2016				

Table 9 Preventive Maintenance Checksheet (Scenario 1)

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
38	Replace cutter ply 1	7 November 2016				
39	Setting/adjustment cutter ply 1	15 November 2016				
40	Repair cutter ply 1	18 November 2016				
41	Setting/adjustment cutter ply 1	21 November 2016				
42	Repair cutter ply 3					
43	Setting/adjustment cutter ply 3	24 November 2016				
44	Setting/adjustment cutter ply 1	27 November 2016				
45	Setting/adjustment cutter ply 1	3 December 2016				
46	Repair cutter ply 1	5 December 2016				
47	Setting/adjustment cutter ply 1	9 December 2016				
48	Setting/adjustment cutter ply 1	15 December 2016				
49	Setting/adjustment sensor machine					
50	Repair cutter ply 1	21 December 2016				
51	Setting/adjustment cutter ply 1	27 December 2016				
52	Setting/adjustment cutter ply 1	2 January 2017				
53	Repair sensor machine					
54	Replace cutter ply 1	12 January 2017				
55	Setting/adjustment cutter ply 1	20 January 2017				
56	Repair cutter ply 3	28 January 2017				
57	Setting/adjustment cutter ply 1	1 February 2017				
58	Setting/adjustment cutter ply 1	7 february 2017				
59	Setting/adjustment sensor machine					
60	Repair cutter ply 1	11 February 2017				
61	Setting/adjustment cutter ply 1	13 February 2017				
62	Setting/adjustment cutter ply 1	19 February 2017				
63	Setting/adjustment cutter ply 1	25 February 2017				
64	Repair cutter ply 1	28 February 2017				
65	Setting/adjustment cutter ply 1	3 March 2017				
66	Setting/adjustment cutter ply 1	9 March 2017				
67	Repair sensor machine					
68	Setting/adjustment cutter ply 1	15 March 2017				
69	Replace cutter ply 1	19 March 2017				
70	Setting/adjustment cutter ply 1	21 March 2017				
71	Setting/adjustment cutter ply 3					
72	Setting/adjustment cutter ply 1	27 March 2017				
73	Repair cutter ply 1	2 April 2017				
74	Setting/adjustment sensor machine					
75	Repair cutter ply 3	5 April 2017				
76	Setting/adjustment cutter ply 1	8 April 2017				

Table 9 Preventive Maintenance Checksheet (Scenario 1)

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
77	Setting/adjustment cutter ply 1	14 April 2017				
78	Repair cutter ply 1	20 April 2017				
79	Setting/adjustment cutter ply 1	26 April 2017				
80	Setting/adjustment cutter ply 1	2 May 2017				
81	Repair cutter ply 1	8 May 2017				
82	Setting/adjustment cutter ply 1	14 May 2017				
83	Repair sensor machine	16 May 2017				
84	Setting/adjustment cutter ply 1	20 May 2017				
85	Replace cutter ply 1	24 May 2017				
86	Setting/adjustment sensor machine	26 May 2017				
87	Setting/adjustment cutter ply 1					
88	Setting/adjustment cutter ply 1	1 June 2017				
89	Setting/adjustment cutter ply 1	7 June 2017				
90	Repair cutter ply 1	10 June 2017				
91	Repair cutter ply 3					
92	Setting/adjustment cutter ply 1	13 June 2017				
93	Setting/adjustment cutter ply 1	19 June 2017				
94	Repair cutter ply 1	27 June 2017				

Table 10 Preventive Maintenance Checksheet (Scenario 2)

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Setting/adjustment cutter ply 1	12 June 2016				
2	Setting/adjustment cutter ply 1	15 June 2016				
3	Repair cutter ply 1	18 June 2016				
4	Setting/adjustment cutter ply 1	21 June 2016				
5	Setting/adjustment cutter ply 1	24 June 2016				
6	Setting/adjustment cutter ply 1	27 June 2016				
7	Setting/adjustment sensor machine					
8	Setting/adjustment cutter ply 1	30 June 2016				
9	Repair cutter ply 1	3 July 2016				
10	Setting/adjustment cutter ply 1	6 July 2016				
11	Repair cutter ply 3	9 July 2016				
12	Setting/adjustment cutter ply 1	12 July 2016				
13	Setting/adjustment cutter ply 3					

Table 10 Preventive Maintenance Checksheet (Scenario 2) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
14	Repair cutter ply 1	15 July 2016				
15	Setting/adjustment cutter ply 1	21 July 2016				
16	Setting/adjustment cutter ply 1	24 July 2016				
17	Setting/adjustment cutter ply 1	27 July 2016				
18	Repair cutter ply 1	30 July 2016				
19	Setting/adjustment cutter ply 1	2 August 2016				
20	Setting/adjustment cutter ply 1	5 August 2016				
21	Setting/adjustment cutter ply 1	8 August 2016				
22	Setting/adjustment cutter ply 1	11 August 2016				
23	Setting/adjustment sensor machine					
24	Repair cutter ply 1	14 August 2016				
25	Setting/adjustment cutter ply 1	17 August 2016				
26	Repair sensor machine					
27	Setting/adjustment cutter ply 1	20 August 2016				
28	Replace cutter ply 1	26 August 2016				
29	Setting/adjustment cutter ply 1	1 September 2016				
30	Setting/adjustment cutter ply 1	4 September 2016				
31	Setting/adjustment cutter ply 1	7 September 2016				
32	Repair cutter ply 3					
33	Repair cutter ply 1	10 September 2016				
34	Setting/adjustment cutter ply 1	13 September 2016				
35	Setting/adjustment cutter ply 1	16 September 2016				
36	Setting/adjustment cutter ply 1	19 September 2016				
37	Setting/adjustment cutter ply 1	22 September 2016				
38	Setting/adjustment cutter ply 1	28 September 2016				
39	Setting/adjustment cutter ply 1	1 October 2016				
40	Setting/adjustment cutter ply 1	4 October 2016				
41	Repair cutter ply 1	7 October 2016				
42	Setting/adjustment cutter ply 1	10 October 2016				
43	Setting/adjustment cutter ply 1	13 October 2016				
44	Setting/adjustment cutter ply 1	16 October 2016				
45	Repair sensor machine					
46	Setting/adjustment cutter ply 1	19 October 2016				
47	Setting/adjustment cutter ply 1	25 October 2016				
48	Setting/adjustment cutter ply 1	28 October 2016				
49	Setting/adjustment cutter ply 3					
50	Setting/adjustment cutter ply 1	31 October 2016				
51	Setting/adjustment cutter ply 1	3 November 2016				

Table 10 Preventive Maintenance Checksheet (Scenario 2) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
52	Repair cutter ply 1	6 November 2016				
53	Repair cutter ply 3					
54	Setting/adjustment cutter ply 1	9 November 2016				
55	Setting/adjustment sensor machine					
56	Setting/adjustment cutter ply 1	12 November 2016				
57	Setting/adjustment cutter ply 1	15 November 2016				
58	Setting/adjustment cutter ply 1	18 November 2016				
59	Setting/adjustment cutter ply 1	21 November 2016				
60	Setting/adjustment cutter ply 1	24 November 2016				
61	Setting/adjustment cutter ply 1	27 November 2016				
62	Setting/adjustment cutter ply 1	30 November 2016				
63	Repair cutter ply 1	3 December 2016				
64	Setting/adjustment cutter ply 1	6 December 2016				
65	Setting/adjustment cutter ply 1	9 December 2016				
66	Setting/adjustment cutter ply 1	12 December 2016				
67	Setting/adjustment cutter ply 1	15 December 2016				
68	Setting/adjustment cutter ply 1	18 December 2016				
69	Repair sensor machine					
70	Replace cutter ply 1	21 December 2016				
71	Setting/adjustment cutter ply 1	24 December 2016				
72	Setting/adjustment sensor machine					
73	Setting/adjustment cutter ply 1	27 December 2016				
74	Setting/adjustment cutter ply 1	30 December 2016				
75	Setting/adjustment cutter ply 1	2 January 2017				
76	Repair cutter ply 3					
77	Setting/adjustment cutter ply 1	5 January 2017				
78	Setting/adjustment cutter ply 1	8 January 2017				
79	Setting/adjustment cutter ply 1	11 January 2017				
80	Repair cutter ply 1	14 January 2017				
81	Setting/adjustment cutter ply 1	20 January 2017				
82	Setting/adjustment cutter ply 1	23 January 2017				
83	Setting/adjustment cutter ply 1	26 January 2017				
84	Repair cutter ply 1	29 January 2017				
85	Setting/adjustment cutter ply 1	1 February 2017				
86	Setting/adjustment cutter ply 1	4 February 2017				
87	Setting/adjustment cutter ply 1	7 February 2017				
88	Setting/adjustment sensor machine					
89	Repair cutter ply 1	10 February 2017				

Table 10 Preventive Maintenance Checksheet (Scenario 2) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
90	Setting/adjustment cutter ply 1	13 February 2017				
91	Setting/adjustment cutter ply 3					
92	Replace cutter ply 1	16 February 2017				
93	Repairing sensor machine	19 February 2017				
94	Setting/adjustment cutter ply 1	22 February 2017				
95	Setting/adjustment cutter ply 1	25 February 2017				
96	Setting/adjustment cutter ply 1	28 February 2017				
97	Repair cutter ply 3					
98	Setting/adjustment cutter ply 1	3 March 2017				
99	Setting/adjustment cutter ply 1	6 March 2017				
100	Setting/adjustment cutter ply 1	9 March 2017				
101	Repair cutter ply 1	12 March 2017				
102	Setting/adjustment cutter ply 1	15 March 2017				
103	Setting/adjustment cutter ply 1	18 March 2017				
104	Setting/adjustment cutter ply 1	21 March 2017				
105	Repair cutter ply 1	24 March 2017				
106	Setting/adjustment sensor machine					
107	Setting/adjustment cutter ply 1	27 March 2017				
108	Setting/adjustment cutter ply 1	30 March 2017				
109	Setting/adjustment cutter ply 1	2 April 2017				
110	Setting/adjustment cutter ply 1	5 April 2017				
111	Repair cutter ply 1	8 April 2017				
112	Setting/adjustment cutter ply 1	11 April 2017				
113	Setting/adjustment cutter ply 1	14 April 2017				
114	Replace cutter ply 1	17 April 2017				
115	Repair sensor machine	20 April 2017				
116	Setting/adjustment cutter ply 1					
117	Repairing cutter ply 3	23 April 2017				
118	Setting/adjustment cutter ply 1	26 April 2017				
119	Setting/adjustment cutter ply 1	29 April 2017				
120	Setting/adjustment cutter ply 1	1 May 2017				
121	Setting/adjustment cutter ply 1	4 May 2017				
122	Repair cutter ply 1	7 May 2017				
123	Setting/adjustment sensor machine					
124	Setting/adjustment cutter ply 1	10 May 2017				
125	Setting/adjustment cutter ply 1	13 May 2017				
126	Setting/adjustment cutter ply 1	16 May 2017				
127	Repair cutter ply 1	19 May 2017				
128	Setting/adjustment cutter ply 1	22 May 2017				

Table 10 Preventive Maintenance Checksheet (Scenario 2) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
129	Setting/adjustment cutter ply 1	25 May 2017				
130	Setting/adjustment cutter ply 1	28 May 2017				
131	Setting/adjustment cutter ply 1	31 May 2017				
132	Setting/adjustment cutter ply 3					
133	Repair cutter ply 1	3 June 2017				
134	Setting/adjustment cutter ply 1	6 June 2017				
135	Setting/adjustment cutter ply 1	9 June 2017				
136	Setting/adjustment cutter ply 1	12 June 2017				
137	Replace cutter ply 1	15 June 2017				
138	Repair cutter ply 3	18 June 2017				
139	Setting/adjustment cutter ply 3	21 June 2017				
140	Repair sensor machine					
141	Setting/adjustment cutter ply 1	24 June 2017				
142	Setting/adjustment cutter ply 1	27 June 2017				
143	Setting/adjustment cutter ply 1	30 June 2017				

Table 11 Preventive Maintenance Checksheet (Scenario 3)

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
1	Setting/adjust cutter ply 1	2 June 2016				
2	Setting/adjust cutter ply 1	4 June 2016				
3	Setting/adjust cutter ply 1	6 June 2016				
4	Setting/adjust cutter ply 1	8 June 2016				
5	Setting/adjust cutter ply 1	10 June 2016				
6	Repair cutter ply 1					
7	Setting/adjust cutter ply 1	12 June 2016				
8	Setting/adjust cutter ply 1	14 June 2016				
9	Setting/adjust cutter ply 1	16 June 2016				
10	Setting/adjust sensor machine	18 June 2016				
11	Repair cutter ply 1					
12	Setting/adjust cutter ply 1	20 June 2016				
13	Setting/adjust cutter ply 1	22 June 2016				
14	Repair cutter ply 1					
15	Setting/adjust cutter ply 1	24 June 2016				
16	Setting/adjust cutter ply 1	24 June 2016				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
17	Setting/adjust cutter ply 1	26 June 2016				
18	Setting/adjust cutter ply 1	28 June 2016				
19	Repair cutter ply 1	30 June 2016				
20	Repair cutter ply 3					
21	Setting/adjust cutter ply 1	2 July 2016				
22	Setting/adjust cutter ply 1	4 July 2016				
23	Setting/adjust cutter ply 1	6 July 2016				
24	Setting/adjust cutter ply 1	8 July 2016				
25	Repair cutter ply 1	10 July 2016				
26	Setting/adjust cutter ply 1	12 July 2016				
27	Setting/adjust cutter ply 1	14 July 2016				
28	Setting/adjust cutter ply 1	16 July 2016				
29	Setting/adjust cutter ply 1	18 July 2016				
30	Setting/adjust cutter ply 1	20 July 2016				
31	Repair cutter ply 1	22 July 2016				
32	Setting/adjust cutter ply 1	24 July 2016				
33	Setting/adjust sensor machine					
34	Setting/adjust cutter ply 1	26 July 2016				
35	Setting/adjust cutter ply 1	28 July 2016				
36	Setting/adjust cutter ply 1	30 July 2016				
37	Repair cutter ply 1	1 August 2016				
38	Setting/adjust cutter ply 1	5 August 2016				
39	Setting/adjust cutter ply 1	7 August 2016				
40	Setting/adjust cutter ply 1	9 August 2016				
41	Repair sensor machine					
42	Setting/adjust cutter ply 1	11 August 2016				
43	Setting/adjust cutter ply 1	13 August 2016				
44	Setting/adjust cutter ply 1	15 August 2016				
45	Replace cutter ply 1	17 August 2016				
46	Setting/adjust cutter ply 1	19 August 2016				
47	Setting/adjust cutter ply 1	21 August 2016				
48	Repair cutter ply 1	23 August 2016				
49	Setting/adjust cutter ply 1	25 August 2016				
50	Repair cutter ply 3					
51	Setting/adjust cutter ply 1	27 August 2016				
52	Setting/adjust cutter ply 1	29 August 2016				
53	Setting/adjust cutter ply 1	31 August 2016				
54	Setting/adjust cutter ply 1	02-Sep-16				
55	Repair cutter ply 1	04-Sep-16				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
56	Setting/adjust cutter ply 1	06-Sep-16				
57	Setting/adjust cutter ply 1	08-Sep-16				
58	Setting/adjust cutter ply 1	10-Sep-16				
59	Setting/adjust cutter ply 1	12-Sep-16				
60	Repair cutter ply 1	14-Sep-16				
61	Setting/adjust cutter ply 1	16-Sep-16				
62	Setting/adjust cutter ply 1	18-Sep-16				
63	Setting/adjust cutter ply 1	20-Sep-16				
64	Setting/adjust cutter ply 1	22-Sep-16				
65	Setting/adjust cutter ply 1	24-Sep-16				
66	Repair cutter ply 1	26-Sep-16				
67	Setting/adjust cutter ply 1	28-Sep-16				
68	Setting/adjust cutter ply 3					
69	Setting/adjust cutter ply 1	30-Sep-16				
70	Setting/adjust cutter ply 1	2 October 2016				
71	Setting/adjust cutter ply 1	4 October 2016				
72	Replace cutter ply 1	6 October 2016				
73	Repair sensor machine					
74	Setting/adjust cutter ply 1	8 October 2016				
75	Setting/adjust sensor machine					
76	Setting/adjust cutter ply 1	10 October 2016				
77	Setting/adjust cutter ply 1	12 October 2016				
78	Setting/adjust cutter ply 1	14 October 2016				
79	Repair cutter ply 1	16 October 2016				
80	Setting/adjust cutter ply 1	18 October 2016				
81	Setting/adjust cutter ply 1	20 October 2016				
82	Repair cutter ply 3					
83	Setting/adjust cutter ply 1	22 October 2016				
84	Setting/adjust cutter ply 1	24 October 2016				
85	Setting/adjust cutter ply 1	26 October 2016				
86	Repair cutter ply 1	28 October 2016				
87	Setting/adjust cutter ply 1	30 October 2016				
88	Setting/adjust cutter ply 1	01-Nov-16				
89	Setting/adjust cutter ply 1	03-Nov-16				
90	Setting/adjust cutter ply 1	05-Nov-16				
91	Repair cutter ply 1	07-Nov-16				
92	Setting/adjust cutter ply 1	09-Nov-16				
93	Setting/adjust cutter ply 1	11-Nov-16				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
94	Setting/adjust cutter ply 1	13-Nov-16				
95	Setting/adjust sensor machine					
96	Setting/adjust cutter ply 1	15-Nov-16				
97	Setting/adjust cutter ply 1	17-Nov-16				
98	Repair cutter ply 1	19-Nov-16				
99	Setting/adjust cutter ply 1	21-Nov-16				
100	Setting/adjust cutter ply 1	23-Nov-16				
101	Replace cutter ply 1	25-Nov-16				
102	Setting/adjust cutter ply 1	27-Nov-16				
103	Setting/adjust sensor machine	29-Nov-16				
104	Setting/adjust cutter ply 1	2 December 2016				
105	Setting/adjust cutter ply 1	4 December 2016				
106	Setting/adjust cutter ply 1	6 December 2016				
107	Setting/adjust cutter ply 1	8 December 2016				
108	Repair cutter ply 1	10 December 2016				
109	Setting/adjust cutter ply 1	12 December 2016				
110	Setting/adjust cutter ply 1	14 December 2016				
111	Repair cutter ply 3					
112	Setting/adjust cutter ply 1	16 December 2016				
113	Setting/adjust cutter ply 1	18 December 2016				
114	Setting/adjust cutter ply 1	20 December 2016				
115	Setting/adjust sensor machine					
116	Repair cutter ply 1	22 December 2016				
117	Setting/adjust cutter ply 1	24 December 2016				
118	Setting/adjust cutter ply 1	26 December 2016				
119	Setting/adjust cutter ply 1	28 December 2016				
120	Setting/adjust cutter ply 1	30 December 2016				
121	Repair cutter ply 1	1 January 2017				
122	Setting/adjust cutter ply 1	3 January 2017				
123	Setting/adjust cutter ply 3					
124	Setting/adjust cutter ply 1	5 January 2017				
125	Setting/adjust cutter ply 1	7 January 2017				
126	Setting/adjust cutter ply 1	9 January 2017				
127	Setting/adjust cutter ply 1	11 January 2017				
128	Replace cutter ply 1	13 January 2017				
129	Setting/adjust cutter ply 1	15 January 2017				
130	Setting/adjust cutter ply 1	17 January 2017				
131	Setting/adjust cutter ply 1	19 January 2017				
132	Setting/adjust cutter ply 1	21 January 2017				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
133	Repair cutter ply 1	23 January 2017				
134	Setting/adjust cutter ply 1	25 January 2017				
135	Repair sensor machine					
136	Setting/adjust cutter ply 1	27 January 2017				
137	Setting/adjust sensor machine					
138	Setting/adjust cutter ply 1	29 January 2017				
139	Setting/adjust cutter ply 1	31 January 2017				
140	Setting/adjust cutter ply 1	2 February 2017				
141	Repair cutter ply 1	4 February 2017				
142	Setting/adjust cutter ply 1	6 February 2017				
143	Setting/adjust cutter ply 1	8 February 2017				
144	Repair cutter ply 3					
145	Setting/adjust cutter ply 1	10 February 2017				
146	Setting/adjust cutter ply 1	12 February 2017				
147	Repair cutter ply 1	14 February 2017				
148	Setting/adjust cutter ply 1	16 February 2017				
149	Setting/adjust cutter ply 1	18 February 2017				
150	Setting/adjust cutter ply 1	20 February 2017				
151	Setting/adjust cutter ply 1	22 February 2017				
152	Setting/adjust cutter ply 1	24 February 2017				
153	Repair cutter ply 1	26 February 2017				
154	Setting/adjust cutter ply 1	28 February 2017				
155	Setting/adjust cutter ply 1	2 March 2017				
156	Setting/adjust cutter ply 1	4 March 2017				
157	Setting/adjust sensor machine					
158	Setting/adjust cutter ply 1	6 March 2017				
159	Replace cutter ply 1	8 March 2017				
160	Setting/adjust cutter ply 1	10 March 2017				
161	Setting/adjust cutter ply 1	12 March 2017				
162	Setting/adjust cutter ply 1	14 March 2017				
163	Setting/adjust cutter ply 1	16 March 2017				
164	Setting/adjust cutter ply 1	18 March 2017				
165	Repair cutter ply 1	20 March 2017				
166	Setting/adjust cutter ply 1	22 March 2017				
167	Repair sensor machine					
168	Setting/adjust cutter ply 1	24 March 2017				
169	Setting/adjust cutter ply 1	26 March 2017				
170	Setting/adjust cutter ply 1	28 March 2017				
171	Repair cutter ply 1	30 March 2017				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
172	Setting/adjust cutter ply 1	02-Apr-17				
173	Setting/adjust cutter ply 1	04-Apr-17				
174	Setting/adjust cutter ply 1	06-Apr-17				
175	Repair cutter ply 3					
176	Setting/adjust cutter ply 1	08-Apr-17				
177	Repair cutter ply 1	10-Apr-17				
178	Setting/adjust sensor machine					
179	Setting/adjust cutter ply 3					
180	Setting/adjust cutter ply 1	12-Apr-17				
181	Setting/adjust cutter ply 1	14-Apr-17				
182	Setting/adjust cutter ply 1	16-Apr-17				
183	Setting/adjust cutter ply 1	18-Apr-17				
184	Setting/adjust cutter ply 1	20-Apr-17				
185	Replace cutter ply 1	22-Apr-17				
186	Setting/adjust cutter ply 1	24-Apr-17				
187	Setting/adjust cutter ply 1	26-Apr-17				
188	Setting/adjust cutter ply 1	28-Apr-17				
189	Setting/adjust cutter ply 1	30-Apr-17				
190	Setting/adjust cutter ply 1	1 May 2017				
191	Repair cutter ply 1	3 May 2017				
192	Setting/adjust cutter ply 1	5 May 2017				
193	Setting/adjust cutter ply 1	7 May 2017				
194	Setting/adjust cutter ply 1	9 May 2017				
195	Setting/adjust cutter ply 1	11 May 2017				
196	Repair cutter ply 1	13 May 2017				
197	Setting/adjust cutter ply 1	15 May 2017				
198	Setting/adjust cutter ply 1	17 May 2017				
199	Repair sensor machine					
200	Setting/adjust cutter ply 1	19 May 2017				
201	Setting/adjust cutter ply 1	21 May 2017				
202	Setting/adjust cutter ply 1	23 May 2017				
203	Repair cutter ply 1	25 May 2017				
204	Setting/adjust cutter ply 1	27 May 2017				
205	Setting/adjust cutter ply 1	29 May 2017				
206	Setting/adjust cutter ply 1	31 May 2017				
207	Setting/adjust cutter ply 1	2 June 2017				
208	Repair cutter ply 3					
209	Repair cutter ply 1	4 June 2017				

Table 11 Preventive Maintenance Checksheet (Scenario 3) Cont'd

Preventive Maintenance Schedule						
Tire Building Machine (TBM) Samson 1						
No	Maintenance Activity	Service Date	Time		Check	Note
			Start PM	Finish PM		
210	Setting/adjust cutter ply 1	6 June 2017				
211	Setting/adjust cutter ply 1	8 June 2017				
212	Setting/adjust cutter ply 1	10 June 2017				
213	Setting/adjust cutter ply 1	12 June 2017				
214	Setting/adjust cutter ply 1	14 June 2017				
215	Replace cutter ply 1	16 June 2017				
216	Setting/adjust cutter ply 1	18 June 2017				
217	Setting/adjust cutter ply 1	20 June 2017				
218	Setting/adjust cutter ply 1	22 June 2017				
219	Setting/adjust cutter ply 1	24 June 2017				
220	Setting/adjust sensor machine	24 June 2017				
221	Repair cutter ply 1	26 June 2017				
222	Setting/adjust cutter ply 1	28 June 2017				
223	Setting/adjust cutter ply 1	30 June 2017				