Vol. 5 No.1
ISBN: 978-623-7144-28-1

ANALYSIS AND SIMULATION OF RELIABILITY IMPROVEMENT IN GEAR PUMP MACHINE USING LIFE CYCLE COST METHOD IN XYZ COMPANY

Amelia Putri Oktaviani[1*], Judi Alhilman[2], Endang Budiasih[3]

[1] Telkom University
[2] Telkom University
[3] Telkom University

Abstract. Gear pump machine 51-98P01 is a machine that is available at XYZ company, which functions as a transportation machine for raw materials from one production process. Because of its function, if there is a downtime occurs on the machine, production process will stop operating because the raw material cannot be flowed. Those problems caused a large amount of expenses that company should pay because late of production. Downtime occurs due to several factors, such as failure to components on the machine, age that has exceeded the optimal age limit, and the number of maintenance crew that is not optimal. To solve the problems, the Life Cycle Cost (LCC) method is used to determine the optimum age of the machine and the optimal number of maintenance crew using the Life Cycle Cost (LCC) method. In addition, a calculation of the proposed maintenance time interval is also carried out to achieve a certain reliability value using a simulation of reliability improvement to see the effect of reliability on the total LCC. Based on data processing using the LCC method, it is known that LCC in 2018 is Rp1,333,195,316 while the optimum LCC is Rp.690,180,267 with optimal machine life of six years and the number of crew maintenance is one person. Simulation of reliability improvement that carried out on the gear pump machine components shows a decrease of total LCC of the machine.

Keywords: Downtime, Failure Cost Life Cycle Cost, Maintenance Crew, Reliability

1. INTRODUCTION

Production companies have several supporting factors in carrying out the process, one of which is a machine (Handoko, 2003). The role of the machine is as technology used to simplify the production process, especially production on a large scale. Based on this role, a reliable machine is needed to support the production process to run without obstacles. Machine reliability is important because it can affect low maintenance costs and reduce corporate losses (L. Y. Waghmode & Patil, 2016). Things that can be done to maintain machine reliability is to do machine maintenance. Machine maintenance in the company, according to Moubray in Fraser (Fraser, 2014), has a positive effect on reliability, availability, and maintainability and can help minimize the time and costs incurred by the company.

XYZ company is a company engaged in the manufacture of polymer yarn and produce products, namely chips and polyester yarn. The production process begins with stage polymerization in the polymer department. The polymerization stage is the initial stage in the production process that processes chemical liquids as the basic ingredients of the chip. After the chemical liquid has been processed, the liquid will be flowed in the process of making yarn chips, namely spinning and then the texture-giving process will be carried out on each type of yarn with different specifications (texturizing). The process of moving material or raw materials from one department to another is done using a gear pump. The role of the gear pump machine is very important because if there is damage to the machine, the next production process will stop because the chemical liquid contained

* Corresponding Author, Email: ameliaaputrio22@gmail.com

in the polymer department cannot be supplied by the machine, causing a loss of costs. The following is a graph of the downtime frequency of eight gear pump machines in the period 2014 to 2018

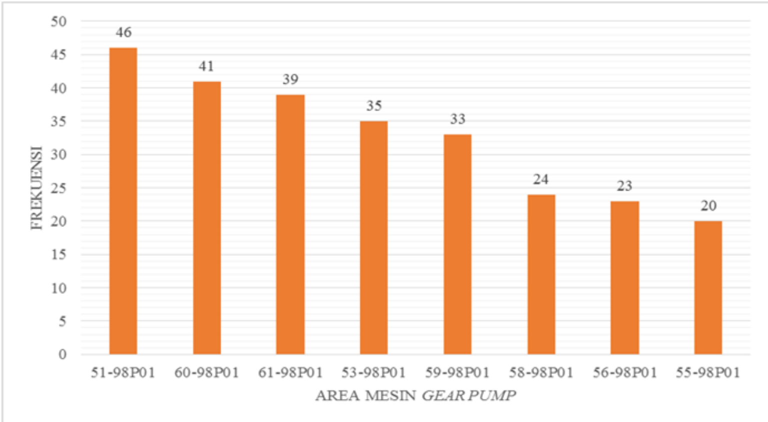

Fig. 1: *Downtime Machine Frequency For XYZ Company 2014-2018*

The method used in this study is the Life Cycle Cost (LCC) method. This method is used as the right method to determine some output in the form of determining the number of the maintenance crew to perform operator optimization on the gear pump machine, knowing the age of the machine so that it can be replaced by the machine, and knowing the machine LCC. In addition, reliability analysis is used to determine the time intervals that must be done by the company based on the reliability index of each component (Patil, Kothavale, Waghmode, & Joshi, 2016). In this study, the calculation of the proposed treatment time interval was calculated to achieve reliability values with a limit of 70%, 80%, and 90% using a simulation of increasing reliability. After the reliability analysis is determined, a simulation of increasing reliability is carried out to determine the maintenance interval that must be done to achieve a certain reliability value and to find out the total LCC that can be minimized.

2. MATERIAL METHOD

2.1. Maintenance

Maintenance is an activity carried out so that a damaged component or system will be returned or repaired in a certain condition for a certain period of time. Maintenance management is a term used to describe activities that ensure that assets operate on the conditions needed and that maintenance is carried out to achieve continuous improvement in reliability, maintainability, and availability (Milje, 2011). The main purpose of maintenance management is to maximize factory availability or equipment and the reliability of these assets to achieve operational / business objectives (Velmurugan & Dhingra, 2015). Other objectives of maintenance are as follows (Alhilman, Saedudin, Atmaji, & Suryabrata, 2015) :

a. Extends the useful life of an asset
b. Ensuring the operational readiness of all equipment needed in emergency activities
c. Ensuring the safety of workers using facilities

Vol. 5 No.1
ISBN: 978-623-7144-28-1

2.2. Life Cycle Cost

The term Life Cycle Cost (LCC), which has appeared in the literature since 1965, according to BS Dhillon (Javad Seif Masoud Rabbani, 2014) refers to an approach to estimating the overall cost of a piece of equipment released to consumers during a period of time determined which means that from the consumer's point of view, equipment life cycle costs include purchase and total cost of ownership (total ownership costs). The purpose of the life cycle cost method can also ensure a realistic choice of one or several maintenance policies with related activities, which maximize the expected value if based on cost minimization and output maximization (Marais, 2013). The application of reliability in the LCC by Rezvanizaniani (Rezvanizaniani, Barabady, Valibeigloo, Asghari, & Kumar U, 2012) focuses on collecting and analyzing data on failure periods in a certain period in a railroad company in Iran. This study uses wheel components on trains as the biggest cause of damage to determine reliability functions. Reliability of each type of wheel is identified during different time intervals to determine when the right time to carry out maintenance. In addition, Enparantza et al. (Enparantza, Revilla, Azkarate, & Zendoia, 2010) discuss LCC calculations and machine tool management systems to predict LCC in the phase design. Waghmode and Patil (Patil et al., 2016) apply the relationship between reliability and maintenance time to optimize LCC from a band saw cutting machine. The results show that the total LCC is reduced by 22% because the failure cost variable on the machine decreases due to increased reliability.

Determination of LCC can be done by various methods such as those carried out by Waghmode et al., (L. Waghmode, Sahasrabudhe, & Kulkarni, 2010) Waghmode et.al presented modeling to estimate the LCC of a pump using the activity based costing method. LCC is also used by Judi Alhilman et al (Alhilman, Atmaji, & Athari, 2017) to estimate the life time of equipment, optimal costs for maintenance, and the optimal number of maintenance crews at the Base Transceiver Station (BTS). Various studies above reveal how the relationship between reliability and LCC. It was found in several studies that reliability analysis for each component of a equipment or machine made the reliability approach more accurate. Therefore, it was proposed to conduct a reliability analysis of the gear pump machine at the component level to determine the reliability of each component to determine the optimal LCC.

Vol. 5 No.1
ISBN: 978-623-7144-28-1

3. RESULT AND DISCUSSION

3.1. Conceptual Moder

The research began with the object of research, namely gear pump 51-98P01. The machine breaks down the component to determine the component MTTF value. In addition, MTTF and MTTR machines were also determined. The next step is quantitative measurement using the Life Cycle Cost (LCC) method. Next is to do a simulation of increasing reliability to determine the proposed failure cost and support cost and calculate the total LCC again to produce the proposed total LCC after increasing reliability. The result of increasing other reliability is the maintenance time interval that the company must do to achieve certain reliability values.

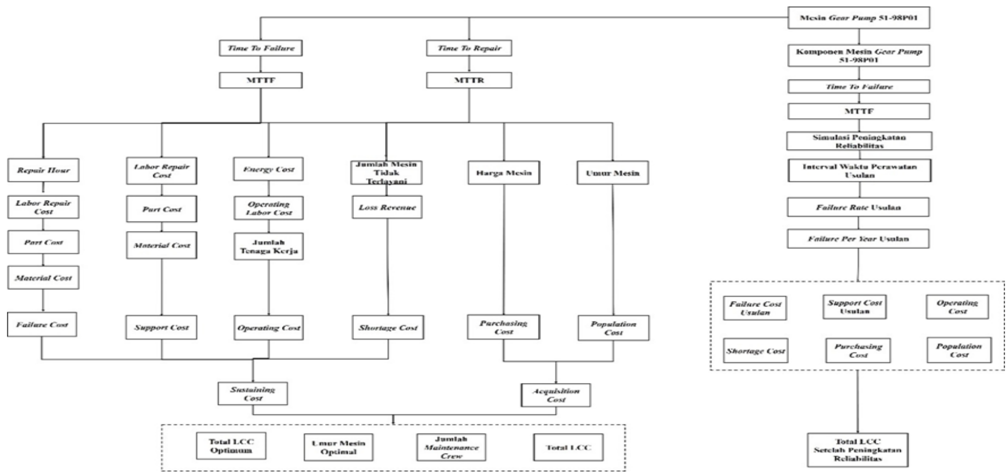

Fig. 2: Conceptual Model

3.2. Life Cycle Cost Calculation

Data collection for the calculation of Life Cycle Cost (LCC) is carried out in the spinning department with the object of research gear pump 51-98P01. The choice of gear pump machine 51-98P01 is based on the largest frequency of downtime from the same eight machines in different areas, which is 46 times downtime. The data needed for this research are data time to failure (TTF) machine, data time to repair (TTR) machine, data time to failure (TTF) component, maintenance technician wage data, material cost data, machine price and component data machine, and loss revenue data. The next step is to determine the distribution for TTF machines and components and machine TTR. This distribution test is used to determine the pattern of damage that occurs in the gear pump machine 51-98P01. Tests carried out with the Anderson Darling (AD) test on the Minitab 17 software are limited to testing normal distribution, exponential distribution, and Weibull distribution. After determining the distribution, the calculation of Mean Time To Failure (MTTF) and Mean Time To Repair (MTTR) is calculated. The following is the result of calculating MTTF and MTTR for gear pump 51-98P01.

Vol. 5 No.1
ISBN: 978-623-7144-28-1

Table. 1: Mean Time To Failure

Chosen Distribution	**Parameter**		***Mean Time To Failure***
Weibull	ß	2,5155	919,2370
	η	1035,8759	

Table. 2: Mean Time To Repair

Chosen Distribution	**Parameter**		***Mean Time To Repair***
Eksponensial	µ	2,53511	2,53511

a. Operating Cost

Operating costs are costs incurred by the company when the machine is operating in the production process. Operating cost is obtained from the sum of two cost variables, namely energy cost and operating labor cost. Energy costs are derived from the multiplication of the number of workdays of the machine, the use of electricity when operating the machine in one day, and electricity tariffs while the operating labor cost is obtained from the multiplication of the number of workers with labor salaries. Operating costs are calculated in 2018 so that to find out the costs in previous years a single present value calculation was used with the assumption of an annual increase of 3.20% obtained from the inflation rate in 2018 based on Bank Indonesia. Figure 3 shows the results of the gear pump 51-98P01 operating cost in graphical form.

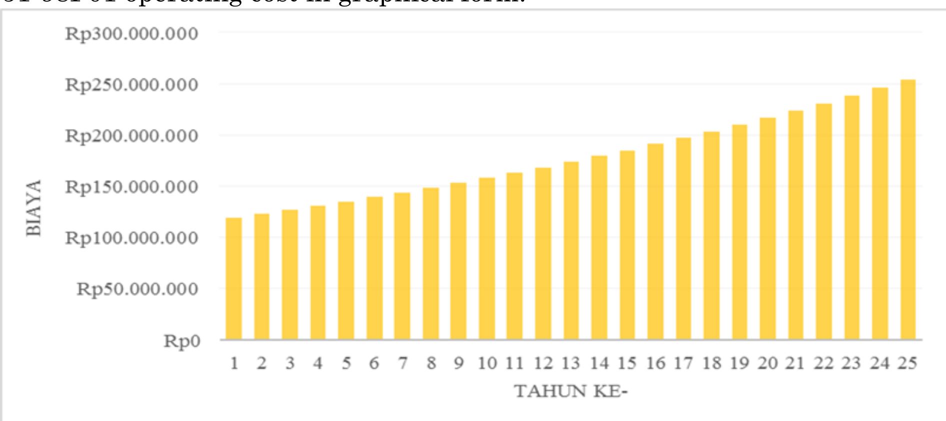

Fig. 3: Operating Cost

Vol. 5 No.1
ISBN: 978-623-7144-28-1

b. Failure Cost

Failure costs are costs associated with corrective maintenance activities. Calculation of failure cost is the sum of labor costs, part costs, equipment costs and consumable costs. Labor cost is a calculation obtained from labor repair cost per hour multiplication with repair hour and failure rate of each component. Failure rate per year each component is obtained from multiplication between component failure rates with operating pump gear hour 51-98P01. Failure costs are calculated in 2018 so that to determine the costs in previous years a single present value calculation is used with the assumption of an annual increase of 3.20% which is obtained from the inflation rate in 2018 according to Bank Indonesia. Calculation of failure cost is done by the number of different maintenance crew to compare the costs incurred. Figure 4 shows the gear pump machine failure cost 51-98P01 in graphical form.

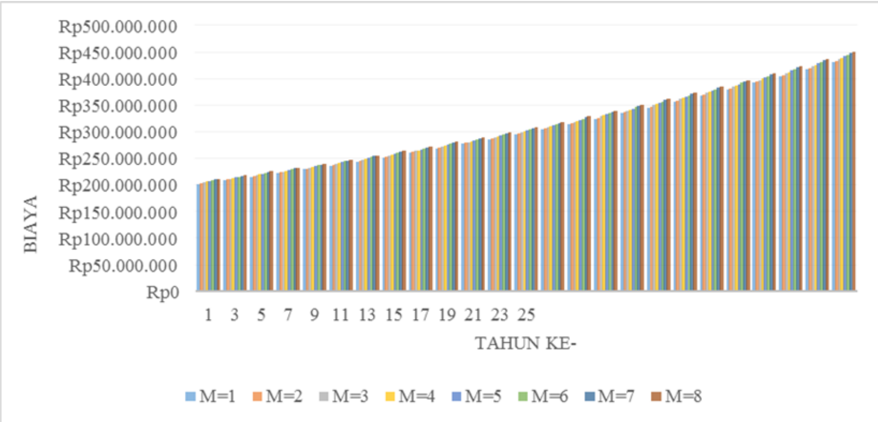

Fig. 4: Failure Cost

Vol. 5 No.1
ISBN: 978-623-7144-28-1

c. Support Cost

Support costs are costs associated with preventive maintenance activities. Calculation of support cost is the sum of labor costs per year, preventive maintenance costs, equipment costs and consumable costs. Support costs are calculated in 2018 so that to find out the costs in previous years used a single present value calculation with the assumption of an annual increase of 3.20% obtained from the average inflation in 2018 according to Bank Indonesia. Calculation of support costs is done by the number of different maintenance crew to compare the costs incurred.

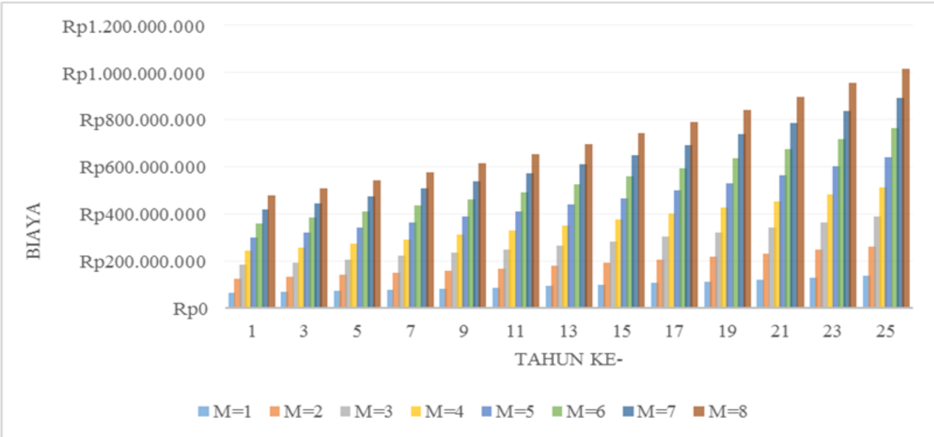

Fig. 5: Support Cost

d. Shortage Cost

Shortage costs are costs incurred by the company due to lack of components due to the lack of maintenance crew or technicians to repair damaged components. Shortage cost calculations are obtained from the results of multiplying loss revenue with machine estimates that are not fixed. The shortage cost value is assumed to increase by 3.20% per year based on the average inflation rate that occurred in 2018.

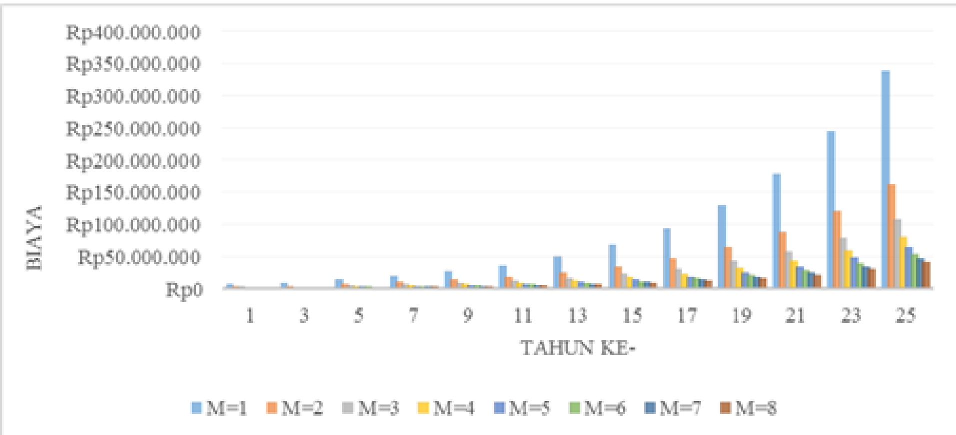

Fig. 6: Shortage Cost

Vol. 5 No.1
ISBN: 978-623-7144-28-1

e. Acquisition Cost

Acquisition Cost is a cost incurred by the company at the time of the initial purchase of a machine or equipment. Acqusition cost is the sum of the purchasing cost and population cost. Based on the graph of acquisition cost, it can be seen that the acquisition cost of the gear pump 51-98P01 has decreased from year to year

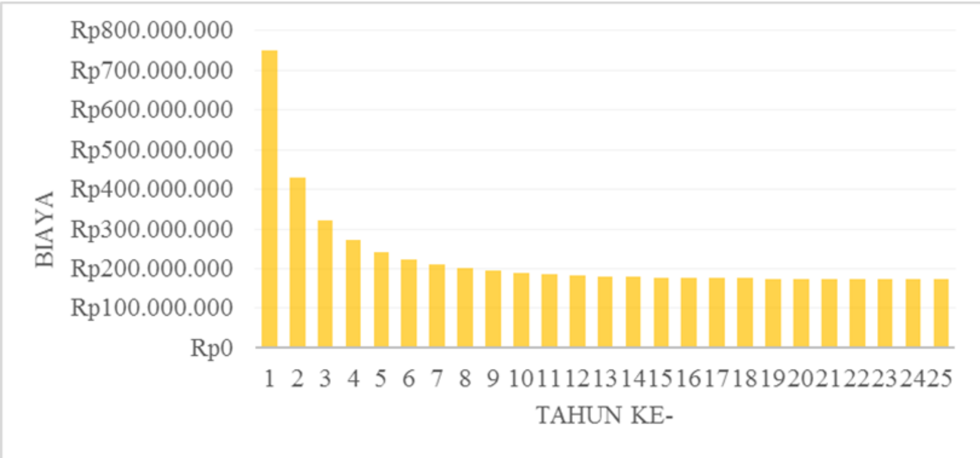

Fig. 7: Acquisition Cost

f. Total Life Cycle Cost

Total life cycle cost (LCC) is the overall cost of the system from the start of the purchase of the machine, the operation of the machine, to the end of the system from the machine. Total LCC is obtained from the sum of sustaining costs and acquisition costs. The total LCC value is used to determine the optimal machine age and the optimal number of maintenance crew. The following is a graph of the total LCC for year 1 to year 25 with the number of crew maintenance of one to eight.

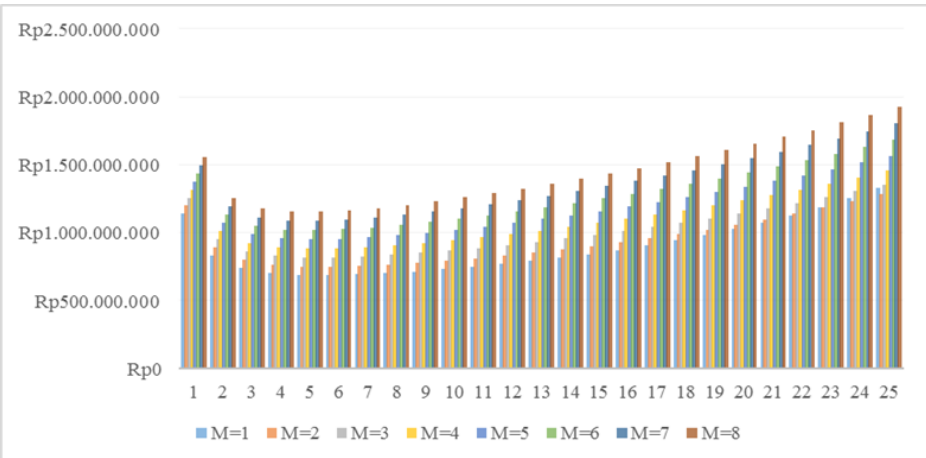

Fig. 8: Total Life Cycle Cost

Vol. 5 No.1
ISBN: 978-623-7144-28-1

3.3. Simulation of Reliability Improvement

Simulation of increasing reliability for each component is done to find out whether increased reliability can affect the total LCC. Therefore, a simulation of two cost variables that form LCC is carried out, namely failure cost and support cost by focusing on changes in maintenance time intervals that affect the number of machine component failures in one year. Simulation of increased reliability is carried out with minimum reliability values of 70%, 80%, and 90%. The following is the result of calculating the simulation of increasing reliability for failure costs and support costs.

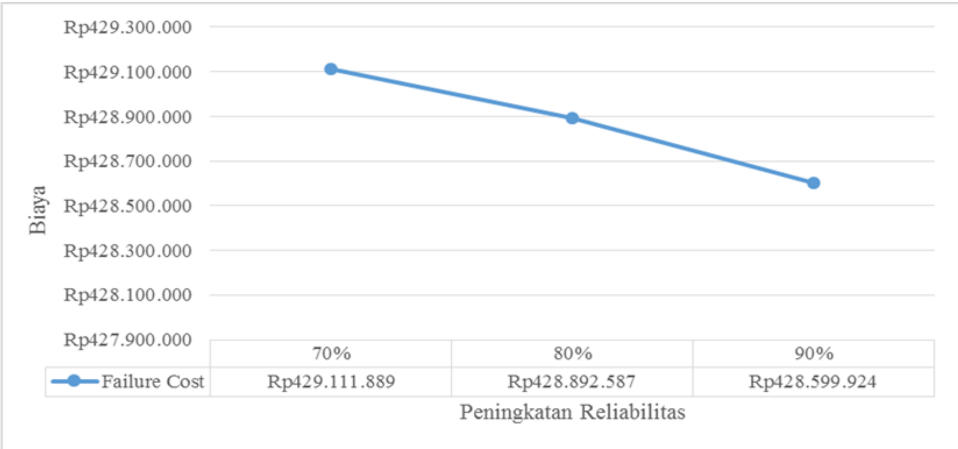

Fig. 9: Improvement Failure Cost

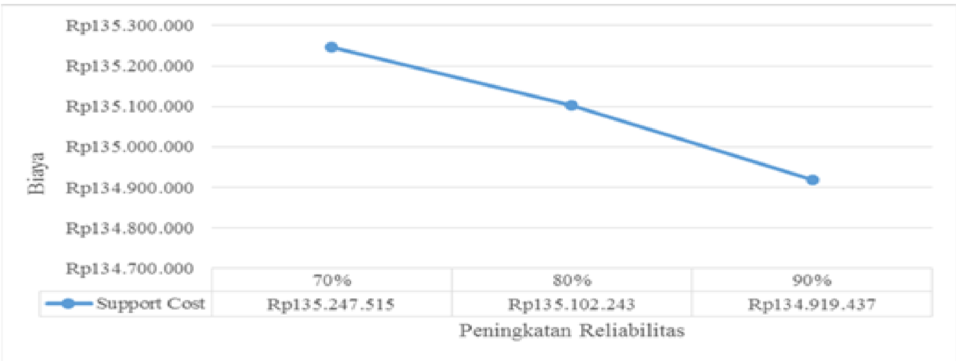

Fig. 10: Improvement Support Cost

Based on the graph, it can be concluded that the greater the reliability value, the smaller the costs that must be incurred for the failure of a machine. In this study, the variable that can be minimized is failure cost and support cost. Increased reliability can occur because the maintenance interval is getting smaller. The more often a component is treated, the possibility of component damage will be smaller. This can be seen in the table below regarding the time intervals that must be done to achieve the minimum reliability value for each component.

Vol. 5 No.1
ISBN: 978-623-7144-28-1

Table. 3: Proposed Maintenance Interval

No	**Component**	**Reliability**	**Maintenance Interval Time With Minimum Reliability (in hour)**		
			0,7	**0,8**	**0,9**
1	Ball bearing 3305 ATN 9	0,140	2082	1611	1067
2	Ball bearing 6308	0,140	2082	1611	1067
3	Ball bearing 6308 2RS	0,140	2082	1611	1067
4	Ball bearing 6312 2RS	0,140	2082	1611	1067
5	Bearing Left	0,231	2860	2200	1358
6	Bearing Left 70-4 VX/TR	0,231	2860	2200	1358
7	Bearing Right	0,231	2860	2200	1358
8	Bearing Right 70-4 VX/TR	0,231	2860	2200	1358
9	Drive shaft	0,281	3415	2625	1721
10	Drive Shaft Rekondisi	0,332	2980	2114	1220
11	Gasket spiral wound DN 25 PN 40	0,297	3146	2347	1467
12	Gear wheel Z-111	0,309	2067	1432	795
13	Gear wheel Z-29	0,309	2067	1432	795
14	Gear wheel Z-60	0,309	2067	1432	795
15	Gearbox cyclo CNHM 6165-17	0,316	3162	2318	1408
16	Gearbox unit C61	0,379	4891	3794	2525
17	Journal cross joint	0,348	5250	4344	3207
18	Karet coupling 112	0,300	3119	2317	1439
19	Needle bearing NKI 45/25	0,300	3757	2907	1927
20	Oil seal 50 x 72 x 8	0,300	3757	2907	1927
21	Oil Seal 60 x 75 x 8	0,300	3757	2907	1927

Vol. 5 No.1
ISBN: 978-623-7144-28-1

22	Pinion shaft Z-14	0,445	6464	5497	4240
23	Rooler bearing NJ 307 ECJ	0,249	1738	1243	726
24	Rooler bearing NUP 205 ECP	0,249	1738	1243	726
25	Shaft AB 55	0,364	3435	2093	946
26	Short shaft	0,364	3435	2093	946
27	Short Shaft Rekondisi	0,432	6138	5091	3771
28	Texron 221	0,235	2633	1996	1281
29	Shell Omalla 150	0,432	6172	5142	3837
30	Energrease LS2	0,431	5820	4569	3100
31	Texron 220	0,236	1743	1258	745

To find out the difference in cost between the total existing LCC and the total LCC after the simulation increases in reliability, a comparison analysis of the existing LCC with the proposed LCC is proposed to increase the reliability value. The total LCC obtained for increasing reliability is 70%, 80%, and 90% respectively are Rp1,330,826,047, Rp1,334,461,472, and Rp1,329,986,003. The following is a graph of the total LCC comparison between the total existing LCC and the total LCC after increasing reliability by 70%, 80%, and 90%.

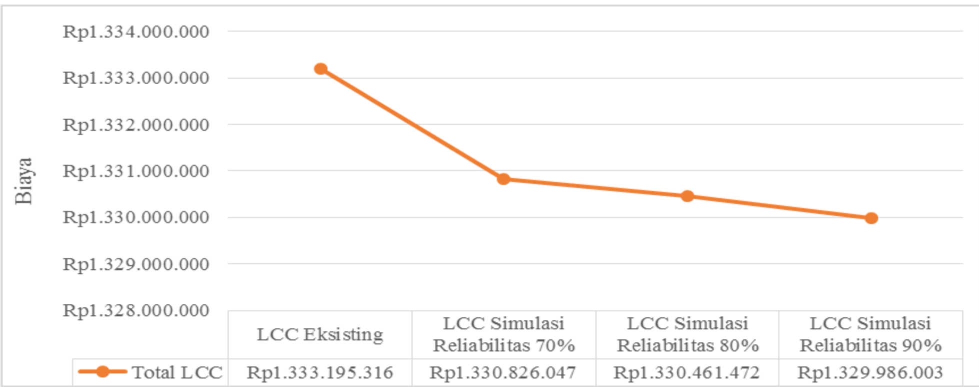

Fig. 11:Time Comparison of Existing LCC with Proposed LCC Increased Reliability

Vol. 5 No.1
ISBN: 978-623-7144-28-1

4. CONCLUSIONS

a) Based on the calculation results using the Life Cycle Cost (LCC) method, the total LCC on the gear pump machine 51-98P01 in 2018 is Rp1,333,195,316. The cost variable that most influences the total LCC on the machine is failure cost.
b) Based on the results of the LCC calculation, the optimal age of the gear pump machine 51-98P01 is six years and the number of maintenance crew as many as one person with the optimum gear pump 51-98P01 LCC is Rp. 690,180,267.
c) Increased reliability can affect the total LCC machine gear pump 51-98P01. Variables that are influenced by reliability are failure costs and support costs which are characterized by a reduction in total LCC along with an increase in reliability in machine components. By using LCC for 2018, the total LCC obtained for increasing reliability by 70% is Rp1,330,826,047, an increase in reliability of 80% is Rp1,330,461,472, and an increase in reliability of 90% is Rp1,329,986,003

5. REFERENCE

Alhilman, J., Atmaji, F. T. D., & Athari, N. (2017). Software application for maintenance system: A combination of maintenance methods in printing industry. 5th International Conference on Information and Communication Technology (ICoIC7). https://doi.org/https://doi.org/10.1109/ICoICT.2017.8074719

Alhilman, J., Saedudin, R. R., Atmaji, F. T. D., & Suryabrata, A. G. (2015). LCC application for estimating total maintenance crew and optimal age of BTS component. In 2015 3rd International Conference on Information and Communication Technology (ICoICT) (pp. 543–547). IEEE. https://doi.org/10.1109/ICoICT.2015.7231483

Enparantza, R., Revilla, O., Azkarate, A., & Zendoia, J. (2010). A life cycle cost calculation and management system for machine tools. 13th CIRP International Conference on Life Cycle Engineering.

Fraser, K. (2014). Facilities management : the strategic selection of a maintenance system. https://doi.org/10.1108/JFM-02-2013-0010

Handoko, T. H. (2003). Manajemen (Edisi 2). BPFE Yogyakarta.

Javad Seif Masoud Rabbani. (2014). Component Based Life Cycle Costing In Replacement Decisions. Journal of Quality in Maintenance Engineering, 20(4), 436–452. https://doi.org/http://doi.org/10.1108/JQME-08-2013-0053

Marais, K. B. (2013). Value Maximizing Maintenance Policies Under General Repair. Reliability Engineering and System Safety, 119, 76–87.

Milje, R. (2011). Engineering methodology for selecting Condition Based Maintenance.

Patil, R. B., Kothavale, B. S., Waghmode, L. Y., & Joshi, S. G. (2016). Reliability analysis of CNC turning center based on the assessment of trends in maintenance data - a case study.

Rezvanizaniani, S., Barabady, J., Valibeigloo, M., Asghari, M., & Kumar U. (2012). Reliability analysis of the rolling stock industry: A case study. International Journal of PerformabilityEngineering.

Vol. 5 No.1
ISBN: 978-623-7144-28-1

Velmurugan, R., & Dhingra, T. (2015). Maintenance strategy selection and its impact in maintenance function A conceptual framework. https://doi.org/10.1108/IJOPM-01-2014-0028

Waghmode, L., Sahasrabudhe, A., & Kulkarni, P. (2010). Life Cycle Cost Modeling of Pumps Using an Activity Based Costing Methodology. Journal of Mechanical Design, 132(12), 121006. https://doi.org/10.1115/1.4002970

Waghmode, L. Y., & Patil, R. B. (2016). Reliability analysis and life cycle cost optimization: a case study from Indian industry. International Journal of Quality & Reliability Management, 33(3), 414–429. https://doi.org/10.1108/IJQRM-11-2014-0184