Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 7, No.2, April 2025, pp. 0250201-01 ~ 0250201-10
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v7i2.856

Analysis of the Effectiveness of Component Maintenance on PT.XYZ Water Pump Machines through the Life Cycle Cost (LCC) Approach

Ahmad Zidane Albany*, Joumil Aidil Saifuddin

Faculty of Engineering UPN "Veteran" East Java, Jl. Raya Rungkut Madya No. 1, Gunung Anyar, Surabaya

*zdnalbany@gmail.com

Abstract. Machine maintenance is an important factor in supporting a manufacturing process that is competitive in the market. Therefore, every company must carry out regular machine maintenance to ensure the machine operates optimally. The aim of this research is to identify damage that may occur to the pump engine and analyze pump maintenance costs which include the cost of repairing or replacing components. The method used in this research is the Life Cycle Cost (LCC) method. The research results show that the maintenance interval for each Bearing component is 1044 hours, Shaft 64 hours, Impeller 76 hours, Gasket 91 hours, Rotor 103 hours, and Bearing Housing 110 hours. The optimal total cost usage at the age of 3 years is IDR. 3,129,542,106/year with the optimal number of mechanics, namely 3 people, previously there were 5 people.

Keywords: Costs, maintenance intervals, maintenance optimization, life cycle costs, distribution pumps,

(Received 2024-07-19, Accepted 2024-08-23, Available Online by 2025-03-03)

1. Introduction

In the current era of global competition in industry 4.0, technological developments are progressing very rapidly rapidly, especially in the manufacturing sector. Where the use of technology is something that exists cannot be avoided [1]. Therefore, a system is needed operations in the production process, a good and appropriate machine care and maintenance system thereby increasing the effectiveness of equipment and minimizing losses incurred [2]. In production activities, machine maintenance plays an important role in maintaining company productivity [3]. Most companies decide to use machines as the main tool in carrying out the production process, with the hope that the amount of production can increase and be able to meet all market demand. Improvement efforts in industry, seen from an equipment perspective, are to increase the effectiveness of machines or equipment as optimally as possible [4]. The availability of clean water has a very important role in improving the health and welfare of the Indonesian people [5]. In realizing clean water services, PT. XYZ are present which have a strategic function of providing drinking water or at least clean water to the community. However, the provision of water for the people of Indonesia is still faced with problems that until now have not been fully resolved [6]. The problem of pump damage in PT. XYZ is often a crucial issue that affects the distribution of clean water to the community. This damage can be caused by various factors, such as the age of the equipment, lack of regular maintenance, and usage that exceeds the design capacity. In addition, non-ideal environmental conditions, such as the presence of solid particles in water or unstable electrical fluctuations, can also accelerate pump damage. The impact of these breakdowns is significant, resulting in disruptions to clean water supply that can be disruptive to the community, degrade service quality, and potentially cause financial losses to the PT. XYZ [7]. Therefore, early identification and periodic maintenance are essential to ensure pump operational reliability and continuity of adequate clean water services.

Component replacement in pumping machinery is usually required based on several root cause criteria that must be considered to maintain optimal performance and system reliability. The first criterion is component age and wear, where parts such as impellers, seals, and bearings experience material degradation over time and use. The second criterion is mechanical damage that can result from extreme operational conditions, such as excessive vibration, misalignment, or overloading that causes cracks or deformation in components. The third criterion includes pumped water quality issues, where the presence of abrasive particles, corrosion, or chemical contaminants can accelerate the deterioration of pump components. In addition, regular inspections that identify early signs of wear, such as decreased efficiency, abnormal sounds, or leaks, are also an important basis for performing component replacement before further damage occurs. Through careful monitoring and timely replacement of components, the reliability and longevity of pump machinery can be better assured.

Maintenance can be defined as an activity to maintain or maintain factory facilities or equipment and make repairs or adjustments or replacements as needed so that there is a satisfactory state of production operations in accordance with what was planned [8]. With this maintenance activity, the production machinery / equipment can be used according to plan and does not experience damage during a certain period of time that has been planned to be achieved [9]. After knowing the meaning of maintenance from several experts, it can be concluded that maintenance is an activity to maintain or maintain facilities or equipment so that they can continue to work and are always in a ready-to-use state [10].

Maintenance costs are costs that include all activities involved in maintaining system equipment in working order for it to be kept to a minimum to be more adequate [11]. In other terminology, maintenance costs are costs incurred to maintain the function of capital goods throughout their economic life. This means that maintenance costs do not increase the economic life of a capital item. Examples of maintenance costs are building maintenance costs, tool maintenance costs, vehicle maintenance costs and so on [12]. Planned maintenance consists of three forms of implementation [13]. Preventive maintenance costs consist of costs arising from equipment inspection and adjustment activities, replacement or repair of components, and loss of production time caused by these activities. Meanwhile, corrective maintenance costs are costs that arise when equipment is damaged or inoperable, which include loss of production time, maintenance implementation costs or equipment replacement costs [14].

Life Cycle Cost (LCC) is a management technique used to identify and monitor product costs over its life cycle. The life cycle includes all stages, from product design and purchase of raw materials to delivery and service of finished products [15]. LCC can be explained as an economic assessment in determining design alternatives by taking into account all significant costs over the specified building life of each alternative, expressed in equivalent dollar values [16]. Each cost element is formulated in the form of variables that reflect the relationship between maintenance and related resource provision activities [17].

According to Buyung et al. (2020) the LCC method has many unexpected variables, one way to estimate is to look back and estimate the results into the future (forecast) [18]. A concept of modeling the calculation of costs from the start-up stage to the dismantling of an asset from a project as a tool for making decisions on an analysis study and calculation of the total costs that exist during its life cycle [19]. LCC has been used in various research subjects such as the impact of alternative energy, food production, production process improvement, development projects, and machinery procurement projects [20]. The Life Cycle Cost (LCC) approach has emerged as one method that can assist PT. XYZ in managing costs and improving the effectiveness of component replacement in pumping machinery. This approach considers the total cost over the life cycle of a product, from planning, procurement, operation, to maintenance and disposal. By accounting for operational costs and hidden costs that may arise from environmentally unfriendly manufacturing practices, Life Cycle Cost (LCC) analysis can assist the PT. XYZ in making more economically sustainable decisions. In addition, it can also provide a better understanding of the environmental impacts of the PT. XYZ operations.

Thus, this study aims to analyze the effectiveness of using the Life Cycle Cost (LCC) approach in the replacement of components in PT. XYZ pumping machines, in the hope that it can make a significant contribution to the management and maintenance of clean water distribution systems so as to improve their overall operational performance while reducing negative impacts on the environment and society.

2. Methods

The method used in this research is the Life Cycle Cost method. The Life Cycle Cost method is a method that considers all costs that will be incurred during the life of a product, work or service. In this research there are two variables, namely the dependent variable and the independent variable. The dependent variable in this research is the cost of pump machine maintenance. The dependent variables in this research are machine data, machine components, machine sub-components, machine breakdown time, machine component prices, and standard company maintenance costs. The limitation of this LCC method is the difficulty of predicting costs for the future, without considering environmental impacts. The following are the problem solving steps (flowchart) which can be seen as follows:

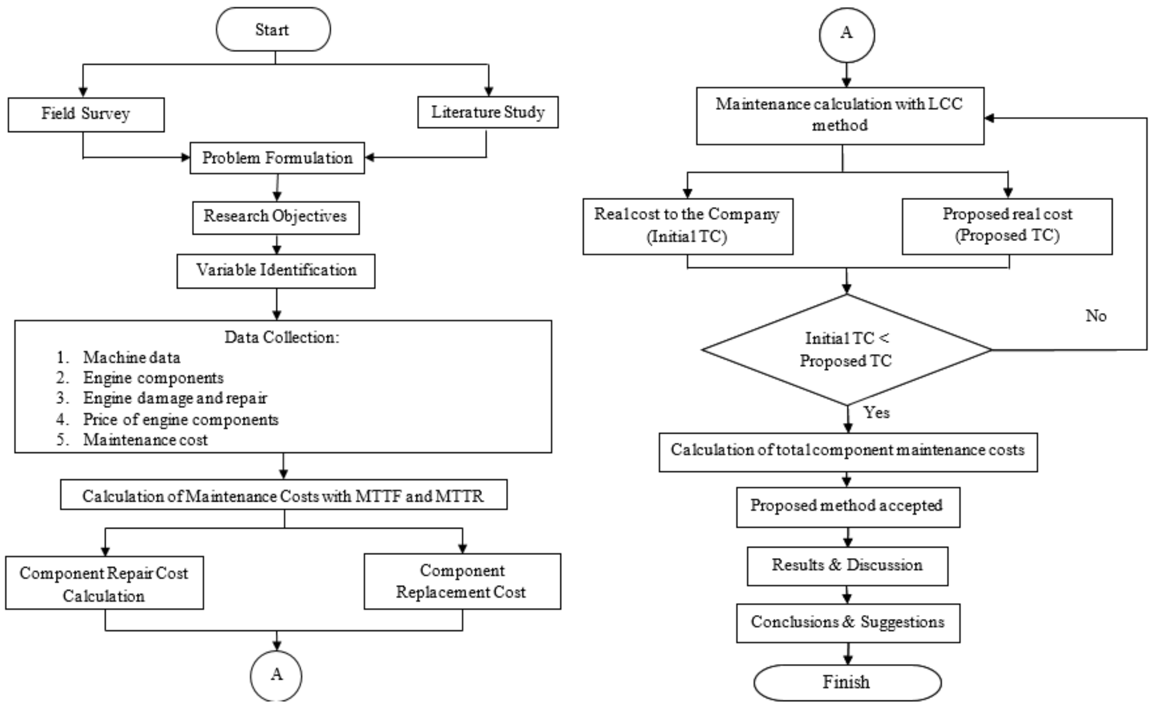

Figure 1. Flowchart

3. Results and Discussion

The data that will be used in this study is the last year in the form of data on damage time and repair time. The following is the data for the last year from January 2023 - December 2023:

Table 1. Distribution Pump Machine Downtime Data

Date of Breakdown	Machine Name	Component Name	Downtime (minutes)
5/1/2023	Pump	*Bearing*	87
23/1/2023	Pump	*Impeller*	43
1/2/2023	Pump	*Gaskets*	95
17/2/2023	Pump	*Rotor*	139
26/2/2023	Pump	*Shaft*	121
13/3/2023	Pump	*Bearing Housing*	79
27/3/2023	Pump	*Impeller*	40
29/4/2023	Pump	*Bearing*	81
6/5/2023	Pump	*Gaskets*	98
19/5/2023	Pump	*Impeller*	45
25/5/2023	Pump	*Rotor*	133
30/5/2023	Pump	*Shaft*	127
20/6/2023	Pump	*Bearing*	85
18/7/2023	Pump	*Bearing Housing*	77
9/8/2023	Pump	*Shaft*	125
21/8/2023	Pump	*Impeller*	44
7/9/2023	Pump	*Gaskets*	97
17/9/2023	Pump	*Bearing*	86
20/9/2023	Pump	*Rotor*	136
26/10/2023	Pump	*Shaft*	124
11/11/2023	Pump	*Bearing Housing*	72
4/12/2023	Pump	*Bearing*	80
23/12/2023	Pump	*Shaft*	129
24/12/2023	Pump	*Impeller*	48

Table 2. MTTF and MTTR Time Data of Distribution Pump Machine

Component	MTTF (Hour)	MTTR (Hour)
Bearing	2005,68	84,15
Shaft	2054,76	125,78
Impeller	2019,35	44,03
Gaskets	2628,88	96,69
Rotor	2586,64	136,41
Bearing Housing	2929,74	76,56

The maintenance carried out by the company is in the form of preventive maintenance. Based on information data from the company, the cost of component maintenance reaches ± Rp. 5,000,000,000 / year which includes labor costs, energy costs, maintenance costs and others in 1 year.

1. Determination of Time to Failure Distribution and Reliability Parameters

Determining the average data between damage (MTTF) is necessary to know the distribution used for the data. Manual calculation of the average value between damage to distribution pump machines is 592.71 hours.

2. Determination of Time to Repair Distribution and Reliability Parameters

Determining the average repair time (MTTR) data is necessary to know the distribution used for the data. Manual calculations obtained the average value of distribution pump engine repair time data, namely 23.48 hours.

3. Life Cycle Cost Method Calculation

A. Sustaining Cost Calculation

Sustaining cost is the sum of annual operating cost, annual maintenance cost, and annual shortage cost. The following is a calculation to determine the value of sustaining cost:

- Annual Operating Cost

  Labor cost = mechanic cost x 12 months x number of mechanics
  = Rp. 5.500.000 x 12 months x 5 mechanics = Rp. 330.000.0000

  Energy cost = electricity price/kWh x operating house x power usage
  = Rp. 2.245kWh x 5760 x 150 = Rp. 1.939.680.000

  The above calculation is the operating cost value in year 1, to calculate operating costs in the next 10 years, inflation data for 2023 is used at 3.42% for energy costs and a 5% salary increase each year according to company policy.

Table 3. Annual Operating Cost

Age (n)	Labor Cost	Energy Cost	Operating Cost
1	Rp 198.000.000	Rp 1.939.680.000	Rp 2.137.680.000
2	Rp 207.900.000	Rp 2.036.664.000	Rp 2.244.564.000
3	Rp 218.295.000	Rp 2.138.497.200	Rp 2.356.792.200
4	Rp 229.209.750	Rp 2.245.422.060	Rp 2.474.631.810
5	Rp 240.670.238	Rp 2.357.693.163	Rp 2.598.363.401
6	Rp 252.703.749	Rp 2.475.577.821	Rp 2.728.281.571
7	Rp 265.338.937	Rp 2.599.356.712	Rp 2.864.695.649
8	Rp 278.605.884	Rp 2.729.324.548	Rp 3.007.930.432
9	Rp 292.536.178	Rp 2.865.790.775	Rp 3.158.326.953
10	Rp 307.162.987	Rp 3.009.080.314	Rp 3.316.243.301

- Maintenance Cost

  Maintenance costs can be calculated by labor costs, component replacement costs, and consumption costs. Labor costs are different for each M or the number of mechanics. For M = 3 conditioned as many as 3 mechanics and M = 5 conditioned as many as 5 mechanics. In determining the number of mechanics, data is needed on the level of salary increase each year by 5% according to company policy. The following is an example of maintenance cost calculation in year 1:

  Maintenance cost = labor cost + component replacement cost + consumption cost
  = Rp. 330.000.000 + Rp. 106.180.000 + Rp. 3.000.000
  = Rp. 439.180.000

Table 4. Annual Maintenance Cost

Age (n)	Number of Mechanics	
	3	5
1	Rp 307.180.000	Rp 439.180.000
2	Rp 317.080.000	Rp 455.680.000
3	Rp 327.475.000	Rp 473.005.000
4	Rp 338.389.750	Rp 491.196.250
5	Rp 349.850.238	Rp 510.297.063
6	Rp 361.883.749	Rp 530.352.916
7	Rp 374.518.937	Rp 551.411.561
8	Rp 387.785.884	Rp 573.523.139
9	Rp 401.716.178	Rp 596.740.296
10	Rp 416.342.987	Rp 621.118.311

- Shortage Cost

  The probability calculation is done to determine how many possibilities there are for a machine to fail so that it can be estimated that the number of mechanics needs to be prepared. Shortage cost is the cost incurred when customer demand is not fulfilled due to insufficient or unavailable material inventory in the warehouse. Shortage cost is influenced by unmet demand and very high shortage costs. Shortage cost is obtained from the result of multiplying the estimated machine not repaired by the number of potential loss/hours due to machine damage. The potential loss/hour data is Rp. 28,080,000. The following is an example of shortage cost calculation in year 1:

Cs = Potential loss/hour
Cs = Rp. 28.080.000
E(s) = 0,0686444
SC = Rp. 28.080.000 x 0,0686444 = Rp. 1.927.535

Table 5. Annual Shortage Cost

Age (n)	Number of Mechanics 3		5	
1	Rp	1.927.535	Rp	1.138.832
2	Rp	2.139.008	Rp	1.261.795
3	Rp	2.374.637	Rp	1.398.387
4	Rp	2.637.383	Rp	1.550.193
5	Rp	2.930.608	Rp	1.718.999
6	Rp	3.258.136	Rp	1.906.822
7	Rp	3.624.326	Rp	2.115.937
8	Rp	4.034.153	Rp	2.348.923
9	Rp	4.493.304	Rp	2.608.700
10	Rp	5.008.285	Rp	2.898.585

- Sustaining Cost Calculation

  An example of the calculation of sustaining cost in year 1 is as follows:

  Sustaining cost = annual operating cost + annual maintenance cost + annual shortage cost
  = Rp. 2.137.680.000 + Rp. 307.180.000 + Rp. 1.927.535
  = Rp. 2.446.787.535

Table 6. Sustaining Cost

Age (n)	Number of Mechanics 3	5
1	Rp 2.446.787.535	Rp 2.709.998.832
2	Rp 2.563.783.008	Rp 2.840.105.795
3	Rp 2.686.641.837	Rp 2.976.725.587
4	Rp 2.815.658.943	Rp 3.120.184.753
5	Rp 2.951.144.246	Rp 3.270.826.287
6	Rp 3.093.423.456	Rp 3.429.010.474
7	Rp 3.242.838.912	Rp 3.595.115.772
8	Rp 3.399.750.468	Rp 3.769.539.750
9	Rp 3.564.536.435	Rp 3.952.700.068
10	Rp 3.737.594.572	Rp 4.145.035.522

B. Acquicition Cost Calculation

Acquisition cost is the sum of annual purchasing cost and annual population cost. The following is a calculation to determine the value of acquisition cost:

- Annual Purchasing Cost

  Annual purchasing cost is the total cost incurred by a company or organization to purchase raw materials, products, or other goods for one year. The loan interest rate assumption is 6% based on interest rates by National Banks in Indonesia in 2023. The price of one unit of distribution pump machine is Rp. 540,978,480, for the value of (A|P ,i, n) obtained from the compounding interest table. The following is an example of the annual purchasing cost calculation in year 1:

  Annual purchasing cost = Rp. 540.978.480 x (A|P ,i, n)
  = Rp. 540.978.480 x 1,06 = Rp. 573.437.189

Table 7. Annual Purchasing Cost

Age (n)	Unit price	(A|P ,6%, n)	Annual Purchasing Cost
1	Rp. 540.978.480	1,06	Rp 573.437.189
2	Rp. 540.978.480	0,54544	Rp 295.071.302
3	Rp. 540.978.480	0,37411	Rp 202.385.459
4	Rp. 540.978.480	0,28859	Rp 156.120.980
5	Rp. 540.978.480	0,23740	Rp 128.428.291
6	Rp. 540.978.480	0,20336	Rp 110.013.384
7	Rp. 540.978.480	0,17914	Rp 96.910.885
8	Rp. 540.978.480	0,16104	Rp 87.119.174
9	Rp. 540.978.480	0,14702	Rp 79.534.656
10	Rp. 540.978.480	0,13587	Rp 73.502.746

- Annual Population Cost

Population cost is the amount of cost that must be incurred in each period due to ownership of a device or machine. The population cost value is obtained from the annual equivalent cost per unit multiplied by the number of units of a device. To get the equivalent cost, namely by calculating the difference between the purchasing cost value and the book value. The following is an example of calculating the annual population cost in year 1:

Annual purchasing cost = Rp. 573.437.189
Annual equivalent cost = Rp. 35.163.601
Population cost = Annual purchasing cost + Annual equivalent cost
= Rp. 573.437.189 + Rp. 35.163.601 = Rp. 608.600.790

Table 8. Annual Population Cost

n	Annual Purchasing Cost	Annual Equivalent Cost	Annual Population Cost
1	Rp 573.437.189	Rp 35.163.601	Rp 608.600.790
2	Rp 295.071.302	Rp 36.327.841	Rp 331.399.143
3	Rp 202.385.459	Rp 38.129.351	Rp 240.514.810
4	Rp 156.120.980	Rp 39.926.278	Rp 196.047.258
5	Rp 128.428.291	Rp 41.586.544	Rp 170.014.835
6	Rp 110.013.384	Rp 43.129.453	Rp 153.142.836
7	Rp 96.910.885	Rp 44.506.801	Rp 141.417.685
8	Rp 87.119.174	Rp 45.729.941	Rp 132.849.116
9	Rp 79.534.656	Rp 46.796.121	Rp 126.330.777
10	Rp 73.502.746	Rp 47.752.394	Rp 121.255.140

- Acquicition Cost Calculation

Acquisition cost calculations based on total annual purchasing costs and total annual population costs can be seen in the calculations below:

Example of acquicition cost calculation in year 1

Acquicition cost = Annual purchasing cost + Annual population cost
= Rp. 573.437.189 + Rp. 608.600.790 = Rp. 1.182.037.979

Table 9. Acquicition Cost

n	Annual Purchasing Cost	Annual Population Cost	Acquicition Cost
1	Rp 573.437.189	Rp 608.600.790	Rp 1.182.037.979
2	Rp 295.071.302	Rp 331.399.143	Rp 626.470.445
3	Rp 202.385.459	Rp 240.514.810	Rp 442.900.269
4	Rp 156.120.980	Rp 196.047.258	Rp 352.168.237
5	Rp 128.428.291	Rp 170.014.835	Rp 298.443.126
6	Rp 110.013.384	Rp 153.142.836	Rp 263.156.220
7	Rp 96.910.885	Rp 141.417.685	Rp 238.328.570
8	Rp 87.119.174	Rp 132.849.116	Rp 219.968.290
9	Rp 79.534.656	Rp 126.330.777	Rp 205.865.433
10	Rp 73.502.746	Rp 121.255.140	Rp 194.757.886

C. Total Cost Based on Life Cycle Cost (LCC) Method

Total life cycle cost is the calculation of total cost from the initial purchase cost to the end of the machine life. LCC is obtained from summing up the total sustaining cost which consists of operating cost, maintenance cost, shortage cost, and acquisition cost which consists of purchasing cost and population cost. The results of the overall LCC can be seen in the table below:

An example of calculating the total life cycle cost of year 1 with the number of M = 5 is as follows:

Total LCC = Sustaining Cost + Acquicition Cost
= Rp. 2.709.998.832 + Rp. 1.182.037.979
= Rp. 3.892.036.811

Table 10. Determination of Machine Life, Number of Mechanics, and Total Costs

Age	Number of Mechanics	
(n)	3	5
1	Rp 3.628.825.514	Rp 3.892.036.811
2	Rp 3.190.253.453	Rp 3.466.576.240
3	Rp 3.129.542.106	Rp 3.419.625.856
4	Rp 3.167.827.180	Rp 3.472.352.990
5	Rp 3.249.587.372	Rp 3.569.269.413
6	Rp 3.356.579.676	Rp 3.692.166.694
7	Rp 3.481.167.482	Rp 3.833.444.342
8	Rp 3.619.718.758	Rp 3.989.508.040
9	Rp 3.770.401.868	Rp 4.158.565.501
10	Rp 3.932.352.458	Rp 4.339.793.408

From the table above, it can be seen that the total life cycle cost with the smallest value is at the number of mechanics (M) = 3, year (n) = 3 with a total cost of Rp. 3,129,542,106.

Based on the results of this research, the LCC results have been declared acceptable, as in previous research from Desrina, 2020, that if there are two comparisons of the number of people, the cost value is smaller for the few people, then the research can be accepted, but otherwise the research will be rejected.

4. Conclusion

In this research, Life Cycle Cost (LCC) analysis is used to evaluate the effectiveness of component replacement and repair at PT. XYZ water pump machine. Based on LCC calculations, it was found that the smallest cost value occurred in year 3 with a total of 3 mechanics. The total cost of the proposed method is Rp. 3,129,542,106, so this method is acceptable. The conclusion of this research is that the LCC approach helps identify optimal maintenance and component replacement costs. The suggestion from this research is that future researchers can add related variables and can add 2 machine objects under study.

References

[1] Muhammad Bagus Maulana, & Widyaningrum, D. (2023). Analysis of the Effectiveness of Automatic Lathes Using the OEE and FMEA Methods. Advance Sustainable Science, Engineering and Technology (ASSET), 5, 10.

[2] 2. Dwi Cahyono, S., Handoko, F., & Budiharti, N. (2020). Penerapan Efektivitas Mesin Debarker Menggunakan Overall Equipment Effectiveness (Studi pada PT. Tri Tunggal Laksana Unit Blitar). Jurnal Teknologi Dan Manajemen Industri, 6(2), 12–17. https://doi.org/10.36040/jtmi.v6i2.3012

[3] 3. Timothy Anugrah Sugiarto, & Endang Pudji W. (2023). Analisa Pemeliharaan Mesin Printer Dengan Reliability Centred Maintenance (RCM) II Dan Life Cycle Cost (LCC) Di CV. XYZ. Jurnal Ilmiah Teknik Informatika Dan Komunikasi, 3(2), 144–158. https://doi.org/10.55606/juitik.v3i2.509

[4] Bilianto, B. Y., & Ekawati, Y. (2017). Pengukuran Efektivitas Mesin Menggunakan Overall Equipment Effectiveness Untuk Dasar Usulan Perbaikan. Jurnal Ilmiah Teknik Industri, 15(2), 116. https://doi.org/10.23917/jiti.v15i2.21412. Dwi Cahyono, S., Handoko, F., & Budiharti, N. (2020). Penerapan Efektivitas Mesin Debarker Menggunakan Overall Equipment Effectiveness (Studi pada PT. Tri Tunggal Laksana Unit Blitar). Jurnal Teknologi Dan Manajemen Industri, 6(2), 12–17. https://doi.org/10.36040/jtmi.v6i2.3012

[5] Jiwantoro, A., Argo, B. D., & Nugroho, W. A. (2013). Analisis Efektivitas Mesin Penggiling Tebu dengan Penerapan Total Productive Maintenance (In Press, JKPTB Vol 1 No 2). Jurnal Keteknikan Pertanian Tropis Dan Biosistem, 1(2), 18–28.

[6] F. Wahyudi, “Estimasi Pemeliharaan Jalan Daerah Berdasarkan Program Krms (Kabupaten Road Management System) Dan Lcca (Life Cycle Cost Analysis),” Jurnal Riset Rekayasa Sipil, vol. 3, no.8, pp. 73-78, 2021.

[7] S. Adam, “Pengembangan Model Data Livestream Kuantitas Dan Kontinuitas Air Pdam Berbasis Sistem Informasi Geografis,” Surabaya: Jakad Media Publishing, 2023.

[8] P. Iqbal, “Analisis Perawatan (Maintenance) Mesin Screw Press Di Pabrik Kelapa Sawit Dengan Metode Failure Mode And Effect Analysis,” Jitekh, vol. 1, no. 9, pp. 104-110, 2021.

[9] N. Fikri Nasrulloh, “Analisa Core Issu Pada Mehchine Maintenance Di Satuan Pelatanan (Satpel) Bandung Uptd,” Teknologinusantara, vol. 2, no. 4, pp. 45-59, 2023.

[10] W. Ahmad, “Pemeliharaan Dan Perawatan Pada Pompa Ipam Ngangel 1,” Jurnal Teknologi Dan Manajemen Sistem Industri, vol. 1, no. 2, pp. 7-12, 2022.

[11] P. Nicco, “Perbandingan Efisiensi Energi Solar Water Heater (Swh) Dan Electric Water Heater (Ewh) Dalam Skala Rumah Tangga Menggunakan Life Cycle Cost(Lcc),” Jurnal Artesis, vol. 1, no. 6, pp. 62-68, 2023.

[12] T. Hani, “Penghitungan Unit Cost (Uc) Dan Penyusunan Tarif Rumah Sakit Dengan Metode Double Distribution (Dd),” Sleman: Deepublish, 2020.

[13] N. Muslih, “Manfaat Perlunya Manajemen Perawatan,” in Buletin Utama Teknik, 2021, pp. 248-252.

[14] N. Eka, “Analisis Umur Mesin Dan Total Biaya Pada Mesin Press Menggunakan Metode Life Cycle Cost Di Pt. Xyz,” Jurnal Manajemen Industri Dan Teknologi, vol. 3, no. 11, pp. 128-140, 2020.

[15] A. Zaenal, “Akuntansi Manajemen,” Sleman: Deepublish, 2020.

[16] P. Grace, “Analisis Life Cycle Cost Pada Pembangunan Gedung,” Jurnal Sipil Statik, vol. 1, no. 43, pp.549-556, 2020.

[17] N. Winda, “Engineering Asset Management (Pengantar Manajemen Aset Industri Berbasis Iso 55000),” Jakarta: Universitas Islam Indonesia, 2020.

[18] R. Buyung, “ Life Cycle Cost (Lcc) Pada Proyek Pembangunan Gedung Akuntansi Universitas

Negeri Manado," Jurnal Sipil Statik, vol. 1, no. 51, pp. 1527-1536, 2020.
[19] A. Firman, "Penjadwalan Preventive Maintenancepada Mesin Mixing Dalam Produksi Brick Batu Tahan Api Dengan Menggunakan Metode Age Replacement Pada Pt. Loka Refractories Wira Jatim," Jurnal Manajemeen Industri Dan Teknologi, vol. 1, no. 14, pp. 144-155, 2021.
[20] Y. Desrina, "Life Cycle Assessment Dan Life Cycle Cost Untuk Serat Kenaf," Jurnal Rekayasa Sistem Industri, vol. 1, no. 18, pp. 213-224, 2020.