International Journal of Research and Applied Technology

4(1)(2024) 75-79

Journal homepage: https://ojs.unikom.ac.id/index.php/injuratech

# Determination of Maintenance Method for Turbine Pump Engine Based on Markov Analysis

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**Abstract.** The purpose of this research is to determine the type of maintenance method that can be applied to the C1107 engine in the company. The C1107 engine is a turbine pump machine used in the manufacture of fertilizers. The main problem discussed in this study is the frequency of damage that occurs in the C1107 engine is quite large, and this will impact the maintenance costs incurred by the company. The types of damage that occurred were categorized into four states, namely good condition, minor, moderate, and high damage. The method used in this research is the Markov analysis method, where, in this method, the value of the transition probability to the steady-state condition will be sought from the transition probability of the failure condition of the CII07 engine used by the company. From the results of the research conducted, it was found that the steady-state status was good, the damage was minor, moderate, and severe, respectively by 11.50, 61.40, 18.70, and 8.40%. The types of maintenance that can be applied are the type of repair maintenance in severe damage conditions and the type of preventive maintenance in moderate damage conditions with a total cost of Rp. 25,042,826. The benefit obtained in this research is to determine the best type of C1107 engine maintenance for the company.

**Keywords:** Turbine Pump Engine, Markov Analysis, Maintenance.

## 1. Introduction

In this study, we calculated maintenance costs based on the damage history of the turbine pump machine in PT X to find the lowest maintenance cost. The method used is Markov analysis. The results of this study will provide the choices of maintenance cost based on the proposal of the type of maintenance. The company is given the option to minimize maintenance costs on the turbine pump machine in the future.

Maintenance is an activity to maintain or repair a facility until it reaches normal conditions or conditions that are acceptable [1]. Achievement in good planning can predict a situation to come, predictable work conditions, achievement of goals according to task choices, can emphasize creativity to plan thoroughly, make policies, procedures, standards, and methods of work implementation, and can achieve the results of supervision by changing the plan according to instructions. Quality in the organization itself is referred to as a procedure or

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company action to ensure high-quality products [2]. Machine failures that occur can cause many business problems, late delivery, poor product quality, loss of good reputation in the product and company, as well as lost profits and opportunities [3]. The importance of planning, according to Gits in Ashayeri et al. (1996), is adequate in the maintenance function must be emphasized by mechanisms and automation, new production systems such as Just in Time (JIP), Not on time, preventive maintenance, and corrective maintenance reduced by continuous maintenance program plan, and spare parts and materials available [4].

The maintenance that has been carried out by the company for the C1107 engine is corrective maintenance at status 4 (P0). It is proposed with corrective maintenance at status 4 and preventive maintenance at status 3 (P1), corrective maintenance at status 3 and 4 and preventative maintenance at status 2 (P2), corrective maintenance at status 4, and preventive maintenance at status 2 and 3 (P3), and corrective maintenance at status 3 and 4 (P4). This classification of damage and conditions in the matrix will form the state of the Markov model, each of which is represented by the probability value of a movement from one state to another [5].

## 2. Method

The method used in this research is the Markov Analysis method. In this method, three main steps can be used to solve a problem [6]. The first step is to determine the probability transition matrix. Then, the next step determines the probability of the transition. In the last step, a steady-state condition will be determined that can be used for the decision-making process [7]. In this study, the Markov Analysis method was used to determine the probability of transitioning from the actual treatment method to the proposed treatment method. After that, it is determined the probability of steady-state conditions for each type of treatment to be converted into maintenance costs. The goal of this research is to determine the exact type of maintenance for the turbine pump engine.

## 3. Results and Discussion

The status transition formed due to the proposed maintenance plan above is determined if corrective maintenance action is taken, the system will go to status 1 (good). However, if preventive maintenance measures are taken, the system will remain or return to its previous state [8]. The following is a table of turbine pump machine status transitions; the turbine pump machine status transition can be seen in Table 1.

**Table 1. Cumulative transition probabilities of turbine pump machine**

| Month | Status | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $P_{11}$ | $P_{12}$ | $P_{13}$ | $P_{14}$ | $P_{22}$ | $P_{23}$ | $P_{24}$ | $P_{33}$ | $P_{34}$ | $P_{41}$ |
| 1 | * | * | * | * | 1/1 | 0 | 0 | 1/1 | 0 | * |
| 2 | 0 | 1/1 | 0 | 0 | 2/3 | 1/3 | 0 | 1/3 | 2/3 | 1/1 |
| 3 | 1/4 | 3/4 | 0 | 0 | 0 | 2/3 | 1/3 | * | * | 13/13 |
| 4 | * | * | * | * | 2/3 | 0 | 1/3 | 1/3 | 2/3 | 1/1 |
| 5 | 2/5 | 1/5 | 1/5 | 1/5 | 0 | 1/1 | 0 | 2/3 | 1/3 | 8/8 |
| 6 | 0 | 1/1 | 0 | 0 | 2/2 | 0 | 0 | * | * | 7/7 |
| 7 | 0 | 0 | 0 | 1/1 | 1/3 | 2/3 | 0 | * | * | 7/7 |
| 8 | 0 | 2/3 | 0 | 1/3 | 3/4 | 0 | 1/4 | 0 | 1/1 | 8/8 |
| 9 | 0 | 1/3 | 1/3 | 1/3 | 2/2 | 0 | 0 | 0 | 1/1 | 8/8 |
| 10 | 1/1 | 0 | 0 | 0 | * | * | * | 0 | 1/1 | 7/7 |
| 11 | * | * | * | * | 3/3 | 0 | 0 | 1/2 | 1/2 | 6/6 |

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| Month | Status | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $P_{11}$ | $P_{12}$ | $P_{13}$ | $P_{14}$ | $P_{22}$ | $P_{23}$ | $P_{24}$ | $P_{33}$ | $P_{34}$ | $P_{41}$ |
| 12 | * | * | * | * | * | * | * | 3/3 | 0 | 7/7 |
| 13 | 1/1 | 0 | 0 | 0 | 1/1 | 0 | 0 | 0 | 1/1 | 2/2 |
| 14 | 2/2 | 0 | 0 | 0 | 4/5 | 1/5 | 0 | * | * | 7/7 |
| 15 | 0 | 1/1 | 0 | 0 | 0 | 3/3 | 0 | 0 | 2/2 | 6/6 |
| 16 | * | * | * | * | 1/1 | 0 | 0 | 0 | 1/1 | 6/6 |
| 17 | 0 | 1/2 | 1/2 | 0 | 1/2 | 0 | 1/2 | 1/1 | 0 | 6/6 |
| 18 | 0 | 3/3 | 0 | 0 | 0 | 1/1 | 0 | 0 | 1/1 | 6/6 |
| 19 | 0 | 0 | 0 | 2/2 | 1/7 | 4/7 | 2/7 | 1/2 | 1/2 | 5/5 |
| 20 | 0 | 0 | 2/2 | 0 | * | * | * | 0 | 1/1 | 7/7 |
| 21 | 0 | 0 | 0 | 1/1 | 4/6 | 1/6 | 1/6 | 0 | 1/1 | 4/4 |
| 22 | 1/2 | 0 | 1/2 | 0 | 1/1 | 0 | 0 | 0 | 2/2 | 7/7 |
| 23 | 1/1 | 0 | 0 | 0 | 2/2 | 0 | 0 | 1/3 | 2/3 | 7/7 |
| 24 | 0 | 1/2 | 0 | 1/2 | * | * | * | 3/3 | 0 | 6/6 |
| **Total** | **0.271** | **0.366** | **0.133** | **0.230** | **0.626** | **0.280** | **0.093** | **0.333** | **0.667** | **1** |

Steady-state transition matrix computation, which has been multiplied by good state [9]. The steady-state results to see the probability of the situation after maintenance has been proposed based on the transition matrix on machine maintenance carried out by the company (P0). Then, it can be seen that the four results of the proposed production facilities plan are expressed in the form of a transition matrix. The followings are Figures 1 – 5, which are the transition matrix of the proposed turbine pump machine.

$$P_0 = \begin{Bmatrix} 0.301 & 0.295 & 0.184 & 0.220 \\ 0 & 0.626 & 0.280 & 0.093 \\ 0 & 0 & 0.333 & 0.667 \\ 0.548 & 0 & 0 & 0 \end{Bmatrix}$$

**Figure 1**. Proposed Transition Matrix ($P_0$) Turbine Pump Machine

$$P_1 = \begin{Bmatrix} 0.271 & 0.366 & 0.133 & 0.230 \\ 0 & 0.626 & 0.280 & 0.093 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{Bmatrix}$$

**Figure 2**. Proposed Transition Matrix ($P_1$) Turbine Pump Machine

$$\begin{Bmatrix} 0.271 & 0.366 & 0.133 & 0.230 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{Bmatrix}$$

**Figure 3**. Proposed Transition Matrix ($P_2$) Turbine Pump Machine

$$P_3 = \begin{Bmatrix} 0.271 & 0.366 & 0.133 & 0.230 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{Bmatrix}$$

**Figure 4**. Proposed Transition Matrix ($P_3$) Turbine Pump Machine

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$$P_4 = \begin{Bmatrix} 0.085 & 0.366 & 0.133 & 0.230 \\ 0 & 0.626 & 0.280 & 0.093 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{Bmatrix}$$

**Figure 5**. Proposed Transition Matrix ($P_4$) Turbine Pump Machine

The results of the proposed steady-state transition matrix are shown in Table 2.

**Table 2. Proposed Steady State Transition Matrix**

| Maintenance Activity | Probability | | | |
|---|---|---|---|---|
| | Good | Minor Damage | Moderate Damage | Heavy Damage |
| $P_0$ | 0.301 | 0.295 | 0.184 | 0.220 |
| $P_1$ | 0.115 | 0.614 | 0.187 | 0.084 |
| $P_2$ | 0.578 | 0.212 | 0.077 | 0.133 |
| $P_3$ | 0.537 | 0.268 | 0.072 | 0.123 |
| $P_4$ | 0.369 | 0.361 | 0.151 | 0.119 |

The expected average cost is obtained from the comparison of the expected average cost of maintenance carried out by the company ($P_0$). The cumulative expected average cost is shown in Table 3.

**Table 3. Expected Average Cost**

| Machine | Costs | | | | |
|---|---|---|---|---|---|
| | $P_0$ | $P_1$ | $P_2$ | $P_3$ | $P_4$ |
| Turbine Pump Machine | Rp 53.090.840 | Rp 25.042.826 | Rp 56.184.087 | Rp 38.511.564 | Rp 65.079.678 |

From the table above, it can be seen that the optimal type of maintenance is to carry out preventive maintenance compared to corrective maintenance. The cost of maintenance can still be minimized if the company implements preventive maintenance activities [10].

## 4. Conclusion

This type of maintenance with the lowest cost used the Markov method, namely proposed maintenance, corrective maintenance at status 4, and preventive maintenance at status 3 ($P_1$), which is the lowest expected average cost of maintenance. In the steady-state probability, if the turbine pump machine is not being maintained, the probability value of the machine will remain in good condition at 11.50%, minor damage conditions are 61.40%, moderate damage conditions are 18.70%, and heavy damage is 8.40%. Maintenance costs for $P_1$ maintenance are Rp. 25,042,826.

## References

[1] Ben-Daya, M., Duffuaa, S. O., Raouf, A., Knezevic, J., and Ait-Kadi, D. (Eds.). 2009. *Handbook of maintenance management and engineering* (7). London: Springer London.

[2] Anthara, I. M. A., Robecca, J., and Lubis, M. L. 2020. Improvement of System Production Based on Analysis of Quality Control. In *IOP Conference Series: Materials Science and Engineering*, 879(1), p. 012175. IOP Publishing.

[3] Sianturi, G., Riyanto, A., and Maulana, R. 2020. Maintenance Strategy Selection in Spinning Mills Industry Using Fuzzy AHP. In *IOP Conference Series: Materials Science and Engineering*, 879(1), p. 012171. IOP Publishing.

[4] Ashayeri, J., Teelen, A., and Selenj, W. 1996. A production and maintenance planning model for the process industry. *International journal of production research*, 34(12), pp.3311-3326.

[5] Fleming, 2012, Theory of Markov Processes, *Technometrics*, 5.

[6] Frederick S. H., and Gerald J. L., 2001, Introduction To Operator Research, Ed. 7, Mc Graw-Hill Higher Education, Avenue of the Americas.

[7] Molenaar, D., Oberski, D., Vermunt, J., and De Boeck, P. 2016. Hidden Markov item response theory models for responses and response times. *Multivariate Behavioral Research*, 51(5), pp. 606-626.

[8] Swanson, L. 2001. Linking maintenance strategies to performance. *International journal of production economics*, 70(3), pp.237-244.

[9] Mathew, C. G., Ramanathan, N. H., and Arabhip, R. 2017. A study on the effectiveness of Markov Analysis-A tool for Human Resource supply forecasting. *International Journal of Engineering Trends and Technology IJETT*, 149, pp.244-249.

[10] Fore, S., and Msipha, A. 2010. Preventive maintenance using reliability centred maintenance (RCM): A case study of a ferrochrome manufacturing company. *South African Journal of Industrial Engineering*, *21*(1), 207-234.