Policy Analysis on Spare Part Inventory of Critical Asset with Life Cycle Cost Approach

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Abstract. Life Cycle Cost (LCC) is a method which is used to calculate all costs over the use’s period that can be seen from the economic aspect to determine the alternative design. This method is also used to help for making a decision. The purpose of this research is to design a strategy to assist companies for making decisions in purchasing and inventory of critical parts engine based on the lowest cost. The result of this research is the company's current strategy of breakdown maintenance costs Rp. 508,574,008.40 for one year of production. Meanwhile the results of the proposal strategy are preventive maintenance with Monte Carlo simulation tool to predict the amount of parts and when the inventory parts of the engine need to be replaced. The proposal strategy costs Rp. 786,968,691.40 for three years of production. So, it can be concluded that by using LCC calculation with Monte Carlo simulation tool, it can help the decision maker to determine the minimum cost in long term period.

1. Introduction

Most of research in the area of maintenance management or asset management deal with the designing maintenance strategy, maintenance scheduling, or any issue on maintenance optimization. Maintenance management includes not only the asset to maintain but also include other maintenance resources to manage, such as information, people, material, and spare parts. However, research in improving organizational performance by analyzing the policy on critical spare part inventory by applying Life Cycle Cost Model (LCC) is very limited [1]. In this research, the issue is discussed as well as a case study in a sugar milling company in Indonesia. The company produces approximately 3,500 tons of white sugar per day or about 10% of the sugar demand in Indonesia. Unfortunately, the country lack 50% of the supply of this commodity and should depend on import. The worse is the price of the imported commodity is cheaper than production cost in Indonesia [2]. This circumstance is a challenge for Indonesian researcher to assist the industry to reduce the cost to make so that the commodity can compete with the imported product. The cost to make may consists of asset related cost presented in LCC hence the cost reduction of cost components in LCC lead to the reduction of the cost to make.
This research is an advanced research on [3] that discusses about the design of maintenance strategy for critical asset in the same organization as this research is conducted. In [3], reliability centered maintenance (RCM) is applied to determine the critical asset and the maintenance strategy. However, there is no discussion about the policy related to the inventory of the critical asset as well as the discussion about the cost related to the maintenance policy. The result of the research shows that one of the critical assets in the company is milling station. The failure data in this station has been collected and presented in Figure 1.

![Failure Data of the Milling Station](image)

**Figure 1.** The Failure Data of the Milling Station

It is estimated that the failure happened in 2017 is approximately 59 times with maximum failure time is almost 4 hours. It generates a huge financial lost from the opportunity lost and the setup cost. It is argued that to reduce the cost of failure cannot be done only by designing the maintenance policy and scheduling, but it should be further to designing the inventory policy related to the provision and inventory of the components. This research proposes an optimum policy to manage spare part inventory for the critical spare part based on the lowest life cycle cost.

2. Review of Literature

According to [4], Life Cycle Cost (LCC) is a useful method to calculate the whole cost during the period of use of an asset. It is seen from the economic aspect to decide the alternative design associated to asset related policies such as selecting maintenance strategy. The LCC is useful to assist in managing the process continually from the planning or acquisition of asset to the asset disposal and replacement. Thus, in this research, LCC will be applied to design strategy to help the company to make policy related to the provision and inventory of critical spare part based on the lowest cost.

There are researches that explain about LCC and the tool of method which is used to decide the amount of the inventory. Similar research done by [5] presents the application of Life Cycle Costing analysis in Green Building Diamond Building Malaysia. The purpose of this research is to calculate the total cost of the life cycle on a building when applying eco-friendly concept during the predetermined period. The approach used in the research is the present worth of the variables cost included into the calculation of LCC such as initial cost, operational-maintenance operational, replacement cost, energy cost and the cycle’s ages. The pre-determined period for the present worth
analysis is ten years. The result is selecting optimum construction cost by applying green building concept.

The modeling of LCC with dynamics cost is presented by Bengtsson and Kurdve in [6]. The purpose of the research is to use LCC or the total cost of ownership that has been used on the manufacturing tools in the company in Sweden. The method used in this research involves life cycle cost and life cycle profit (LCP). The result reveals the aspect that is used to design and to plan the tools using LCC is a man-time operation, the using of energy, the cost of maintenance and repair, downtime cost, process liquid and chemical substance. Some of which is raising along with the maintenance ages and it should be considerable. It gives the implication on the tool design to be easier to maintenance and easier to clean and easier to use. Another research on implementation of LCC is a research by Armendariz-Lopez, et al. [7]. It uses LCC life cycle cost (LCC) of photovoltaic technology in the commercial building in Baja California, Mexico. The purpose of this research is to identify the geometric orientation that gives LCC the best to photovoltaic multi-crystal module, to supply electric energy to the commercial building in the three locations in Baja California, Mexico.

The LCC includes the cost of electric energy consumption and estimation of solar source. The estimation of production energy from array photovoltaic and the budget of this research results that silicon multi-crystal photovoltaic cell is the alternative infestation that is appropriate when it is installed in commercial buildings with the highest utilization cost (3,17) and the return of the shortest infestation (13,2 years). Other applications of LCC are presented by [8, 9].

The purpose of research is to identify the geometric orientation that gives LCC the best to photovoltaic multi-crystal module, to supply electric energy to the commercial building in the three locations in Baja California, Mexico.

3. Research Method

The approach used in this research is total cost comparison between current inventory strategy and proposed maintenance strategy. The strategy with the lowest total cost will be selected. The LCC model used in this research is the LCC model proposed in [1] as shown in Eq. 1. In this study, thenLCC is used to select maintenance strategy with lowest LCC related with inventory of the critical spare part.

\[
LCC = \sum [C_m, MTBF, MTTR, m, t + s, t + F, + A, C_n, m + \\
\sum F_{n+}, + \sum F_{n+}, + n, F_{n+}, + T_n, C_n + \\
(n_3, L + + \sum F_{n+}, + \sum n_3, F_{n+}, + + \sum n_3, A, L ) + \\
[ n_3, F_{n+}, + \sum (n_3, C_n), + ] + F_{n+} + \sum (n_3, C_n) + + (n_3, C_n) + + \\
\frac{1}{\gamma^2 A} \frac{L}{L} m, t + s, t ] 1 + \pi^H 1 + r^H \] 

.................Eq. 1
4. Result and Discussion

The LCC model used in this research includes the calculating of the maintenance cost, stoppage loss and total cost of purchasing and inventory. The total cost is used to compare the current maintenance strategy and the proposed maintenance strategy. The current maintenance strategy applied in the factory is corrective maintenance and preventive maintenance is selected as the proposed strategy. In this case study, the selected cost components considered to calculate the total cost for maintenance consists of (1) Maintenance cost, (2) stoppage lost, and (3) purchasing and inventory cost. The total cost model used in this research is derived from the LCC in [1], and presented in Eq. 2, Eq. 3, Eq. 4 and Eq. 5.

\[ TC = CM + CSL + CPI \]  

\[ KL = \sum_{V} PQ \ MNL, O + KNL, O + \sum_{U} Q \ MSL, T + KSL, T \]  

\[ CSL = nd. FSL + Td. CS \]  

\[ CPI = F_i + (np. C_p) + (nc. C_i) + ((ni + nc/184). C_{inv}) \]

Where:
- \( F_{SM} \) : fixed cost of scheduled maintenance
- \( C_{SM} \) : total variable cost for every scheduled maintenance performed
- \( F_{UM} \) : fixed cost of unscheduled maintenance
- \( C_{UM} \) : total variable cost for every unscheduled maintenance performed
- \( n_d \) : number of stoppage occurrences
- \( F_{SL} \) : Fixed cost of a unit’s stoppage
- \( T_d \) : amount of time the units fail
- \( C_S \) : opportunity loss per measured time
- \( F_i \) : Fixed purchasing and inventory cost
- \( n_p \) : number of purchases
- \( C_p \) : purchasing cost
- \( n_i \) : number of initial inventories
- \( n_c \) : number of components purchased
- \( C_i \) : cost of a component
- \( C_{inv} \) : inventory cost

4.1. Current Strategy

After collecting the required data and information, the total cost for the current strategy is calculated. The total cost for the current strategy is Rp. 508,574,008.40 that consist of maintenance cost Rp. 29,827,680.00, stoppage loss Rp. 164,860,280.00 and the total cost of purchasing and inventory is Rp.313,895,282.40. Because the current maintenance strategy is corrective, no cost spent for scheduled maintenance. The cost for maintenance mostly from the variable cost of unscheduled maintenance. For the stoppage loss, it is calculated that there are 20 events of stoppage with total failure time is 1010 minutes and the estimated opportunity loss per minute is Rp. 162,228. The total cost for the current strategy is only for one milling season.

4.2. Proposed Strategy

The proposed strategy in this research is preventive maintenance strategy. The bottom line of the replacement preventive maintenance strategy is to replace the critical spare part after a period to avoid the production stoppage caused by the wear and tear of the critical spare part. The main purpose if reducing the opportunity lost because of the production stoppage. Using the same total cost model as the current strategy, the total cost generated by the proposed strategy is also calculated. The total cost for the proposal strategy is Rp. 786,968,691.40 for three milling seasons which consists of purchasing cost Rp. 89,667,159.42, stoppage loss Rp. 532,655,158.00 and the total cost of purchasing and inventory is Rp. 165,646,374.00. It should be noted that the information required to predict the total cost for the proposed strategy is based on the result of the developed Montecarlo model and dedicated for this research. The time period for the Montecarlo is three milling seasons.

The Montecarlo model is used to predict the number of component failure in the period of interest (in this case study is three years). The main assumption of the Montecarlo model is the distribution of the component failure is Exponential distribution. The probability of failure follows an exponential distribution, the equation will be as shown in Eq. 6.

\[ P = 1 - X^{HY} \]
where:
\[ P \] : probability of failure
\[ \lambda \] : exponential distribution parameter
\[ t \] : time

Then, the time-to-failure can be calculated by finding \( t \) as shown in Eq. 7, where \( P \) is a generated random number between 0 and 1.

\[
\frac{t}{\lambda} = -\ln(1-P) \quad \text{Eq. 7}
\]

The total cost for the current maintenance strategy and proposed maintenance strategy represent different period of milling season. The total cost for the current strategy is only for one milling season and for the proposed strategy represents three milling seasons. To fairly compare the total cost for those two strategies, the number of milling seasons should be similar. In this case study, it recommended that to fairly compare the strategies, the total cost for the current strategy will be multiplied by three to represent three milling seasons. It is assumed that the total cost for the current strategy is similar from one season to another. After multiplied by three, the total cost of the current strategy for three milling seasons is Rp 1,525,722,026.00. On the other hand, the total cost for the proposed strategy is Rp 786,968,691.40 for three milling seasons.

5. Conclusion and Recommendation
This research investigates the opportunity arises from applying LCC to assist the decision maker to understand the impact of selecting different maintenance strategy to the policy of purchasing and inventory of the critical spare part. The LCC is capable to serve its purpose in selecting the optimum maintenance strategy based on the lowest cost and its impact to the purchasing and inventory. The result shows that the preventive maintenance strategy as the proposed maintenance strategy generates lower total cost than the corrective maintenance strategy as the current maintenance strategy. The proposed maintenance strategy generates cost for approximately Rp 786,968,691.40 for three milling seasons while the current maintenance strategy is Rp 1,525,722,026.00 for three milling seasons.

The calculation of the total cost is for three milling seasons or multi years, but it has not yet considered the value of money. For the future research, the value of money can be associated into the calculation of the LCC as well as the present worth analysis. Also, other cost components, such as human resource cost, can be included to make the model more feasible.

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