EDITORIAL PREFACE

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Periodic Review Model for Determining Inventory Policy for Aircraft Consumable Spare Parts

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Abstract
This research is conducted to develop inventory policy of aircraft consumable spare parts which are needed on aircraft maintenance activity. In this research, we used periodic review model to determine the optimal policy of aircraft spare parts inventory. By using the periodic review model, we find optimal period of inventory review and maximum level of inventory. The optimal decision is determined based on the minimum total cost. We have classified consumable spare parts using ABC method to categorize them based on their dollar contribution and demand frequency. Therefore in this research, we focus on managing the inventory level for spare parts on class C. The result from this study shows that the proposed periodic review policy result in lower total inventory cost compared the the company policy. The proposed policy gives an average saving 35.38 %.

Keywords: Inventory, Spare Part, Periodic Review, ABC Method.

1. INTRODUCTION
Inventory management is one of key success factors that should be considered by manager to win the business in global competition. In modern business environment, the company needs more significant efforts to reduce the operating cost and also increase customer satisfaction. Inventory has significant role to satisfy the customer demand hence, it becomes important asset for any organization. Therefore, it should be managed effectively and efficiently to minimize total cost and to satisfy the customer’s requirement. In any real condition, inventory management faces barriers in the form of a tradeoff between minimizing total cost and maximizing service level. Therefore, choosing the correct inventory policy that can be applied in industry now becomes essential to management as there are many inventory policies developed by many scholars.

Maintenance plays an important role in airline industries. The aircraft operational daily activities can be affected by the performance of maintenance. Moreover, the performance of maintenance activities can be determined by how the management can provide spare part continuously during maintenance activity. One of the largest aircraft’s MRO company in Indonesia is Garuda Maintenance Facility Aero Asia (GMF). GMF is a company that provides maintenance, repair and
overhaul (MRO) service to airline industries. In this company, maintenance is known as the activity to maintain aircraft which consist of line maintenance, base maintenance and engine maintenance while repair is an activity to improve the broken components in aircraft machine. Further, overhaul is an activity to monitor and give major repair to any object in aircraft, including machine or component.

In aircraft industry, spare parts usually can be classified into three categories. First, rotatable spare part is the category of spare part that can be rotated among any types of aircraft. Second, repairable spare part is spare parts that have a same character as rotatable spare part but having lower price. Third, consumable spare part is the spare parts that can be used once or disposable component. In this research, we focus on managing consumable spare parts due to their magnitude needs in daily MRO activity. Consumable spare parts have higher demand than other spare parts and should be purchased from foreign countries, hence, the replenishment lead time may take a long time. If the spare parts aren’t well managed by management, the daily MRO process will probably be interrupted due to the lack of spare part inventories. Moreover, if management decides to hold more spare parts to guarantee that the needs from daily MRO activity must be satisfied, a high inventory cost may occurs. Therefore, controlling consumable spare part accurately is needed by management to ensure that the daily MRO activities run smoothly.

Some researchers focused on developing inventory model based on deterministic environment. Croston [1], Syntetos and Boylan [3], Syntetos and Boylan [4], Syntetos and Boylan [5] proposed deterministic inventory model for spare parts which considering some forecasting methods. The demand of spare parts are forecasted and then the optimal inventory level can be determined by some formulas.

Strijbosch et al [6] developed another model compound bernoulli method and compound poisson method to determine ordering quantity and reorder point. Teunter and Sani [7] gave their research attention on studying the lumpy product. They used order-up-to policy to determine inventory level which previously employed croston method to forecast the demand. Results from this research indicated that integrating croston method and order-up-to policy results in optimal service level. Chang et al [8] implemented r,r,Q policy to manage semiconductor component by assuming stochastic demand. Furthermore, Porras and Dekker [9] determined spare part inventory level at oil company. They used different reorder points to find optimal inventory level in order to minimize total inventory cost. Smidth-Destombes et al. [10] proposed joint optimization of inventory management and maintenance activity. They proposed a heuristic model to derive the optimal solutions and proved that the proposed model performed better than METRIC model. Kilpi et al.[11] developed cooperative strategies for the availability service of repairable aircraft components and determined the factors that give the contribution to the cooperative strategy. They used simulation model to determine optimal cost and used game theory to test the cooperative strategies. Wong et al. [12] investigated the cost allocation problem in context of repairable spare parts pooling with game theoretic model. The results from this study showed that the cost allocation policy affects the companies in making the decision in inventory management. Even many methods have been implemented in determining spare part inventory level, lack of them considering the utilization of continuous review model in reducing total inventory cost.

In this paper we intend to determine spare part inventory level in order to minimize total inventory cost. In this research, we use periodic review policy to determine optimal periodic review and safety stock. The results from many studies proved that periodic review policy can be applied more easily in managing inventory than continuous review policy. This is because using periodic review, the company has less effort on reviewing the inventory level, hence some costs such as information system cost, labor cost can be significantly reduced. Here, we also intend to continue the work of Aisyati, et al. [13] by proposing periodic review as a policy to manage the spare parts in Class C. Previously, Aisyati, et al [13] used ABC classification system to categorize spare part based on their contribution to dollar volume. They focused on determining the optimal inventory
level on Class A and B by using continuous review model. Periodic review policy review is popular method which is very useful and easy method to implement in many areas of industries.

2. LITERATURE REVIEW

2.1 Periodic Review Model

The periodic review model is one of the inventory policies that reviews physical inventory at specific interval of time and orders the quantity order as many as the maximum level of inventory. Wisner, et al [14]. The safety stock of periodic review model is larger than that of continuous review model. This safety stock is important to meet demand at lead time period (L). One of Periodic Review Model is P model. This model characterize fixed order interval (T) and the quantity order based on the differ of the maximum inventory level (R) and the on hand inventory. We can draw this situation in Figure 1.

\[ O_p = \frac{A}{T} \] \hspace{1cm} (1)

The holding cost per unit time \( O_h \) is determined by multiplying the expected of inventory per year \( m \) and holding cost per unit product per year \( h \). In a cycle, the inventory will be at the level \( s + TD \) at the beginning of the cycle and at the level \( s \) at the end of the cycle, so the expected of inventory is:

\[ m = s + \frac{TD}{2} \] \hspace{1cm} (2)

In case of shortage, inventory backorder can be met then. The backorder allow negative values so the expected value of \( s \) is:

\[
\begin{align*}
  s &= \int_{0}^{\infty} (R-z)f(z) \, dz \\
  &= R - \int_{0}^{\infty} zf(z) \, dz
\end{align*}
\]
If \[ \int_{0}^{\infty} zf(z) \, dz = D(L + T) \]
\[ = D_L + TD \]
so,
\[ s = R - D_L - TD \]  (3)

where,
\[ z \] : Random variable of demand for (T + L) period
\[ f(z) \] : Probability function of demand z
\[ D_L \] : Expected of demand for L period
\[ T \] : Interarrival demand

So, the expected of inventory (m) is:
\[ m = R \cdot D_L - TD + \frac{TD}{2} \]
\[ = R \cdot D_L - TD \]  (4)

By substituting equation (4) into \( O_s \), holding cost (\( O_s \)) can be expressed as:
\[ O_s = \left( R \cdot D_L \cdot \frac{TD}{2} \right) \frac{1}{2} \]  (5)

Shortage can be happened when demand fluctuation is occurred in (T+L) periods. Like Q model, shortage cost can be calculated based on the number of stock out. For one year, shortage cost (\( O_k \)) can be formulated as follow:
\[ O_k = N_T c_u \]  (6)

\( N_T \) can be defined by multiplying the number of cycle per year and the number of stock out in a cycle. \( N_T \) is as follow:
\[ N_T = N \times \frac{1}{T} \]
\[ = \frac{N}{T} \]  (7)

Therefore, the shortage cost can be expressed as:
\[ O_k = \frac{c_u N}{T} \]  (8)
If backorder is permitted to solve shortage problem, then we can substitute equation (1) until (8) to $O_T$ as follow Bahagia [15]:

$$O_T = O_p + O_s + O_k$$

$$O_T = D_p + \frac{A}{T} + h\left(R-D_L + \frac{DT}{2}\right) + \frac{c_u}{T} \int_R^\infty (z-R)f(z) dz$$

$$O_T = D_p + \frac{A}{T} + h\left(R-D_L + \frac{DT}{2}\right) + \frac{c_u}{T} \int_R^\infty (z-R)f(z) dz$$

Decision variable $T$ and $R$ can be found by taking the first partial derivatives of $O_T$ with respect to $T$ and $R$ respectively and equating them to zero.

$$\frac{\partial O_T}{\partial T} = 0$$

$$\frac{\partial O_T}{\partial T} = 0$$

$$\frac{\partial O_T}{\partial R} = 0$$

$$\frac{\partial O_T}{\partial T} = 0$$

$$\frac{\partial O_T}{\partial R} = 0$$

$$\alpha = \int_r^\infty K(z) dz = \frac{Th}{c_u}$$

$$\alpha = \int_r^\infty K(z) dz = \frac{Th}{c_u}$$

Equation (10) and (11) is implicit function, so the optimal solution can not be found analytically. Considering the iterative procedure from Hadley-Within Method, the algorithm to solve the periodic review is as follows:

a. Find value of $T$

$$T = \sqrt{\frac{2A}{Dh}}$$

b. Find $\alpha$ and $R$ value by using equation (11).

$$\alpha = \frac{Th}{c_u}$$

If demand has normal distribution, $R$ value will be including demand in $(T+L)$ period and can be expressed as:

$$R = D(T + L) + z_\alpha \sqrt{T + L}$$
c. Find the \((OT)_0\) value by using equation (9).

d. Repeat step b by changing \(T_0 = T_0 + \Delta T_0\)

   - If new \((OT)_0 > (OT)_0\), then stop to increase \(T_0\). Next, we try decrease iteration \(T_0 = T_0 - \Delta T_0\) until we find \(T' = T_0\) that result minimum value of \(OT_0\).

   - If new \((OT)_0 < (OT)_0\), increasing iteration \(T_0 = T_0 + \Delta T_0\) can be continued and can be stopped when new \((OT)_0 > (OT)_0\). The value of \(T_0\) that result minimum total cost \((OT_0')\) is an optimal interval time \((T'\).

3. RESEARCH METHODOLOGY
In first stage of our research we define spare parts class C from classification to categorize 60 consumable spare parts [13]. There are 36 spare parts in class C presented in Table 1. Secondly, we find all input parameters of spare parts including, the mean of demand per unit time, standard deviation of demand and inventory cost, including holding cost, ordering cost and shortage cost. The mean and standard deviation of demand for selected spare parts is determined from demand data during ten years. Holding cost is determined by considering interarrival demand, expected demand and maximum level of inventory. Shortage cost is determined from the number of cycle per year and the number of stock out in a cycle. The ordering cost is determined by considering cost of each order(A) and order frequency per year. Table 1 presents the input parameters and inventory cost of 36 spare parts studied in this research. The final stage of this research, we determine the optimal interval period and maximum level of inventory by using Hadley-Within algorithm described in previous section.

![FIGURE 2: Research Methodology.](image-url)
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<th>Standard Deviation (unit)</th>
<th>Holding Cost (IDR)</th>
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**TABLE 1**: Input Parameters and Related Inventory Costs of Spare Parts.
4. RESULTS AND DISCUSSIONS

4.1 Input Parameters

In this research, we focus to manage the spare part inventory in class C which consists of 36 spare parts. We can define spare parts in class C in Table 1. From Table 1 we know spare part 4551 have the largest mean and standard deviation of demand. This shows that the spare part is the most needed spare part.

4.2 Determination of Interval Review Period and Maximum Level of Inventory

Interval period ($T$) and maximum level of inventory ($R$) are determined by employing an iterative procedure described in above section. We develop list of program using MATLAB 2009a. The results from MATLAB program are given in table 2. From this table we can see that there are different values of review period for each spare part. Spare parts BV03112-03-33 and 69-41868-3 have the longest review period that is 2.57 year and 2.48 year. Further, spare part 1683 has the shortest review period (0.0893 year). From table 1 we also can see that the maximum inventory levels are determined in a range of 2-285 units. The demand rate is the factor that affecting the quantity of inventory level.

<table>
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<tr>
<th>No</th>
<th>Spare Part</th>
<th>Review Period (year)</th>
<th>Review Period (month)</th>
<th>Maximum Inventory (unit)</th>
<th>Total Cost of Periodic Review (IDR)</th>
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Table 3 shows the benefit of the proposed method in comparison with company policy. The company makes inventory policy that each spare part must be reviewed in same period (three months). Even this policy can be done easily since the manager only has less effort to control the inventory level of all spare parts, this policy may result in not optimal cost. This is because each spare part has different parameters, then the optimal review period and maximum inventory should be determined individually. From this table, one can see that when comparing with company policy, the proposed method which adopting periodic review policy can produce significant amount of saving in average of 35.38%. The largest saving (92.43%) is produced from spare part BACR15BB6D7C. It is also found that there is one spare part which has negative saving, that is spare part 65B10920-171. Moving the policy from company’s policy to proposed policy will reduce the total inventory cost for about IDR 68,091,840 for all spare parts.

5. CONCLUSIONS
In this paper, we focus on determining the optimal review period and maximum inventory level for consumable spare parts by employing periodic review policy. We continue the study of Aisyati et al. (2013) by investigating the optimal inventory level for 36 spare parts in Class C. The results from this study indicate that the periodic review will produce lower total inventory cost compared to the company policy. Moreover, moving from company’s policy to the proposed policy will also result significant amount of saving on average 35.38%. However, one spare part that is spare part 65B10920-171 still produce negative saving, hence further comprehensive investigation should be done to it.

Further study can be done by introducing another demand’s distribution, such as poisson demand or compound poisson demand. This kind of distribution may be suitable with the spare part demand since it is usually modeled as intermittent demand. Another extension can be done by integrating the inventory policy into maintenance activity. Previously, most of maintenance models discuss only maintenance activity and neglecting its relationship with spare part inventory. Integrating both policies in one model may produce some important insights.

6. REFERENCES


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