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Inventory Control Policy for Farm-Out Parts at Cold Section Module CT 7 Engine with Periodic Review (R, s, S) and (R, S) to Minimize Total Inventory Cost

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***Abstract*— This paper discusses how to determine the parts inventory used in aircraft engine and industrial machine at maintenance service industry, which is the number of parts are not as many as manufacture industry, but it may involve in late deliveries. The importance of inventory also occurs in maintenance service industry of aircraft engines and industrial machines such as in PT. XYZ. The problem encountered by one of the engines that have the highest delay handled by this company is a CT7 engine with a contribution of 68 percent of the total engine received. Delivery delay due to repair process stall caused by unavailability or lack of farm out part in the stock room. ADI-CV analysis and ABC analysis is used to determine the demand characteristic and demand classification. Periodic review approach is used to determine interval review, reorder point and maximum inventory level. Interval review for farm out parts of the periodic review (R, s, S) and (R, S) is every three months. Reorder point for item A is two units and for item B and C is one unit. Total inventory cost decreased is by 61 percent from current condition.**

Keywords—Inventory planning; Periodic review; ADI-CV Analysis; ABC Analysis

I. INTRODUCTION

A. Background

PT. XYZ is a maintenance service company to maintain aircraft engines and industrial machines owned by Indonesia. There are three work scopes done by this company they are inspection, repair, and overhaul. The process sequence of engines maintenance involves several activities there are material procurement, the stock of material, processing, capacity, and labor, in case of problems appear on one activity, and it may inhibit the next activity that can lead to late delivery to customers.

There are several types of engines handled by this company; the most common one type CT 7. The root cause of lateness for this type is the availability of material with the contribution of 68%, it is caused by several factors, but the most is the unavailability or lack of farm out parts in the stock room. In recent condition, this company does not use any method to manage the material.

According to the problem occur, to prevent repair process lateness, it is important to control the spare part inventory at overhaul work scope on cold section module of CT 7 engine by determining the optimum ordering lot size. Therefore, it is needing to classify the part based on importance level and critical level by using ADI-CV analysis to determine the demand characteristic and ABC analysis to determine demand classification according to a critical level.

There are several studies that discuss inventory policies for spare parts, such as research conducted by [1] and [2] which studied about joint optimization of spare parts inventory and preventive maintenance, and for aircraft spare part studied by [3] and [4]

B. Problem Formulation

How to determine inventory policy for farm out part with periodic review method (R, s, S) and (R, S) which minimizing total inventory cost.

C. Research Objective

1. To determine inventory policy for part farm out with periodic review method (R,s,S) and (R,S) in PT. XYZ.
2. To minimize the inventory cost with periodic review method (R, s, S) and (R,S) in PT. XYZ

II. THEORETICAL BACKGROUND

There are two categories of accessories parts regarding to consumption pattern, which is continuous and intermittent. The characteristic of continuous demand is the demand or consumption appears every period so that this part has property as fast-moving part. Otherwise, the characteristic of intermittent demand is the demand or consumption not appears every period so that this part has property as slow-moving part. The materials which have intermittent pattern

can be classified into intermittent demand, erratic demand, lumpy demand and slow-moving [3].

Intermittent demand is the demand with random characters or many periods without request. Erratic demand is the demand with indeterminate pattern and characterized by a high variation of demand size per period. Lumpy demand is the patterns with zero requests are randomly generated over a long period of time. Slow moving is the character with less variation between requirement and demand.

The problem of inventory policy can be solved with two kinds of review systems, which is periodic review and continuous review. The periodic review or P model related to the determination of the amount of stock and safety stock that must be provided. Otherwise, the continuous review or Q model has fixed purchase interval and lot size depending on needs. Periodic review system is divided into two types they are (R, S) and (R, s, S) [5].

The calculation of items with periodic review system (R, s, S) determines three parameters, the first parameter is the reorder point (s), which is the point where the order must be reordered when it has reached the point of reorder point. The second parameter is the maximum inventory level (S), it is the maximum limit point of the inventory might be stored. At the time when part of the inventory drops until it reaches the reorder point as it satisfies the demand, then at that time it will be placed to refill the inventory to the maximum limit of S. However, during the periodic review, reservations will only be made at interval review (R). Thus, the frequency of purchase can be minimized with the aim of minimizing holding costs and ordering costs.

According to Scraft (1960) in [5], based on general assumptions about patterns of demand and costs, the periodic review inventory system (R, s, S) can result in a lower total replenishment, storage and backorder cost than other systems. The inventory model (R, s, S) is claimed to be effective when it is used to manage of inventory policies for slow moving as well as fast moving in [6]. According to [5], the periodic review inventory system (R, s, S) is similar to continuous review (s, S), the difference is only in decision-making in replenishment, to wait for review time to order. The use of methods with algorithms (R, s, S) has been widely developed, due to the complexity in analyzing exact sciences.

III. RESEARCH METHOD

The research methodology was based on a practice-based research. Conceptual method for this research is presented as a flow chart in figure 1.

The problem-solving steps are as follows:

1. ADI-CV analysis to determine demand characteristic using formula from [3].
   a. Calculate ADI using formula as follows:

$$\text{ADI} = \frac{\sum_{i=1}^{N} ti}{N} \quad (1)$$

   Where N stands for number of periods without zero demand

   b. Calculate CV using formula as follows:

$$CV = \frac{\frac{\sqrt{\sum_{i=1}^{N}(\varepsilon i - \varepsilon)2}}{N}}{\varepsilon} \quad (2)$$

$$\varepsilon = \frac{\sum_{i=1}^{N} \varepsilon_i}{N} \quad (3)$$

   Where N stands for total number of periods

2. Distribution test using Kolmogorov-Smirnov test.
3. Part classification using ABC analysis.
4. Calculate periodic review (R, s, S) parameters for item A as follows [5]:
   a. Calculate average demand during review period as follow

$$\hat{x}_R = R \, x \, D \quad (4)$$

   b. Calculate average demand during review period and lead time as follow

$$\hat{x}_{R+L} = (R + L) \, x \, D \quad (5)$$

   c. Calculate holding cost during review period (r)
   d. Calculate order quantity

$$Q_p = 1.3 \, \hat{x}_R^{0.494} \left(\frac{A}{vr}\right)^{0.506} \left(1 + \frac{\sigma_{R+L}^2}{\hat{x}_R^2}\right)^{0.116} \quad (6)$$

   e. Calculate Z

$$z = \sqrt{\frac{Q_p \, x \, r}{\sigma_{R+L} \, x \, B_3}} \quad (7)$$

   f. Calculate maximum point

$$s_p = 0.973 \, \hat{x}_{R+L} + \sigma_{R+L} \left(\frac{0.183}{z} + 1.063 - 2.192(z)\right) \quad (8)$$

   g. $\frac{Q_p}{\hat{x}_R} > 1.5$?
      - If yes; reorder point (s) = s_p , maximum inventory (S) = $s_p + Q_p$
      - If not; calculate normal variable, find safety factor (k), calculate minimum point (s_o); reorder point (s) = min (s_p, s_o); maximum inventory (S) = min ($s_p + Q_p$, s_o).

5. Calculate periodic review (R, S) parameters for item B and C, as follows:
   a. Calculate average demand during the review period $(\hat{x}_R)$ and average demand during the review period and lead time $(\hat{x}_{R+L})$.
   b. Calculate holding cost during the review period.
   c. Calculate order quantity (Q_p).

d. Define z.
e. Calculate maximum point (S_p).
f. Calculate normal variable to shortage expectation per replenishment cycle ($G_u(k)$).

$$G_u(k) = \frac{Q}{\sigma_L}\left(\frac{r}{B_3 + r}\right) \quad (9)$$

g. Find safety factor (k) using approximation and excel [TM] functions as follows:

$$k = \frac{a_0 + a_1 z + a_2 z^2 + a_3 z^3}{b_0 + b_1 z + b_2 z^2 + b_3 z^3 + b_4 z^4} \quad (10)$$

h. Calculate maximum inventory (S), as follows:

$$S = \hat{x}_L + k\sigma_L \quad (11)$$

6. Calculate total inventory cost.

$$TIC = H + C + BO \quad (12)$$

Where H stands for holding cost; C stands for ordering cost and BO stands for backorder cost.

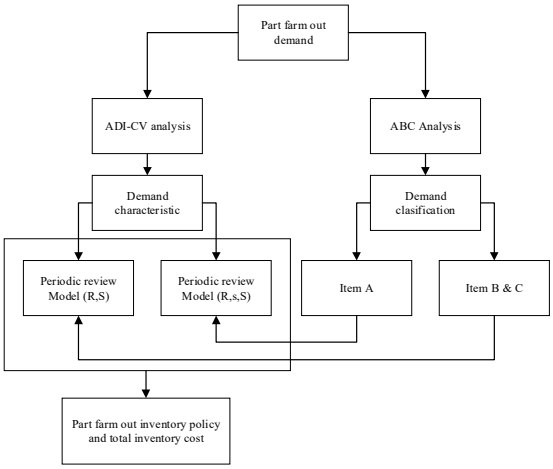

Fig. 1. Conceptual method

IV. Result and Discussion

According to problem-solving steps, the result of this research are as follows;

A. ADI-CV Analysis

Classification process according to demand pattern for farm out part is used to determine the demand characteristics of the part regarding the demand frequency and the number of material demand variation. Parameters used for classification are Average Demand Interval (ADI) and Coefficient Of Variation (CV). The ADI-CV analysis results for the whole part are as follows:

TABLE I. ADI-CV Result

No	Part Name	ADI	CV	Demand characteristic
1	Blade Disk Stg.#1 Compr.SB72-0444	14	0.9636	*Lumpy*
2	Blade-Disk-Stage 2 Compressor	14	0.9636	*Lumpy*
3	Blade-Disk-Stage 3 & 4 Compressor R	14	0.9636	*Lumpy*
4	Seal Outer Balance Piston	14	0.9636	*Lumpy*
5	Seal,Comp Discharge Stationary Air	1.625	0.2619	*Intermittent*
6	Seal,Comp Discharge Stationary	1.5	0.6547	*Lumpy*
7	Blade Disk Stg 3 & 4 Compressor Rtr	4	0.6547	*Lumpy*
8	Blade Disk Stg.#1 Compr.	2	0.6547	*Lumpy*
9	Blade Disk Stg 2 Compressor	2	0.6547	*Lumpy*
10	Swirl Plate	14	0.9636	*Lumpy*
11	Seal Outer Balance Piston	2.167	0.3350	*Intermittent*
12	Obp - Seal	14	0.9636	*Lumpy*

Table I shows that 83% of farm out part has a CV score above 0.49, meanwhile for ADI parameters the whole farm out part has scored above 1.32, it can be concluded that 83% of farm out part has demand characteristics of lumpy demand type and 17% of farm out part has demand characteristics of intermittent demand type. The part that has ADI score less than 1.32 using continuous review systems and the part that has ADI score greater than 1.32 using periodic review system. This is because the long intervals between demands, so the review system does not need to be done continuously [1]. It can be concluded, that all of farm out part can use the periodic review system.

B. Distribution Test

The best data to use in a study has a normal distribution, if the test results of data are not normally distributed, then it must be approached with another approach. In this study, using Kolmogorov-Smirnov test.

According to the test, demand of farm out part is on Asymp. Sig. has a score greater than 0.05 means accept H_0 and reject H_1. The tests result on all farm out parts, using the Kolmogorov-Smirnov test, are all Poisson distributed.

C. Part Farm Out Classification

Farm out part on the cold sections CT7 module has a vary number of demand and repair prices. Categorizing farm out parts based on the importance and absorption of funds needs to be done so the use of funds becomes effective and efficient. Therefore, PT. XYZ requires the classification of the farm-outs part to be under control. ABC analysis will classify farm out parts by sorting the interest of the part based on the absorption amount of funds for 42 months.

Farm out parts of item category A absorbed about 57% of the total capital spent to provide 42 months of stock and the number of parts in this category is 2 pieces out of a total of 12 parts. Whereas for item category B, it absorbed about 27% of all capital spent to provide 42 months of inventory and 4 parts of total 12 parts in this category. As for the item category C, it absorbs about 16% of all capital spent to provide 42 months of inventory and the number of parts in this category is 6 pieces out of a total of 12 parts.

There are different treatments in determining the inventory policy of each category. For item in category A it is better to use the calculation of periodic review method (R, s, S). Characteristics of this method, which uses three parameters, namely review interval (R), reorder point (s), and maximum inventory level (S). With a known review interval time of 3.5 months, other parameters should be calculated, such as reorder point, maximum inventory level, and total inventory. For an item in category B and item C, use the calculation of periodic review method (R, S). Characteristics of this method, it uses 2 parameters, the review interval (R) and the maximum inventory level (S). Review interval is used is similar to item A, only item B, and item C will make an order if it enters the time interval review and fulfill its inventory up to maximum inventory. The following is the result of categorization after the ABC analysis.

TABLE II. PART FARM OUT CLASSIFICATION BASED ON ABC ANALYSIS

No	Part name	Part percentage	Cumulative part percentage	Category
1	Seal,Comp Discharge Stationary Air	8%	8%	A
2	Seal Outer Balance Piston (G05)	8%	17%	A
3	Seal,Comp Discharge Stationary	8%	25%	B
4	Blade Disk Stg.#1 Compr.	8%	33%	B
5	Blade Disk Stg 3 & 4 Compressor Rtr	8%	42%	B
6	Blade Disk Stg 2 Compressor	8%	50%	B
7	Blade Disk Stg.#1 Compr.Sb72-0444	8%	58%	C
8	Blade-Disk-Stage 3 & 4 Compressor R	8%	67%	C
9	Blade-Disk-Stage 2 Compressor	8%	75%	C
10	Seal Outer Balance Piston (G03)	8%	83%	C
11	Obp - Seal	8%	92%	C
12	Swirl Plate	8%	100%	C

Table II shows that the ABC analysis results may affect the inventory policy to be determined by the firm. Each category has a different inventory policy. Category A has a higher interest than category B and category C.

D. Periodic Review (R, s, S)

Calculation of periodic review method (R, s, S) is specific to items in category A. Based on the calculation of ABC analysis, there are two items of farm-out parts included in category A, which is Seal Comp Discharge Stationary Air and Seal Outer Balance Piston (G05). According to calculation steps of items in category A, the result shown in Table III

TABLE III. PARAMETER (R, S, S) RESULT FOR ITEM A

Part Name	R	s	S
Seal Comp Discharge Stationary Air	3	2	3
Seal Outer Balance Piston (G05)	3	2	3

According to Table III, it can be concluded that the reorder point for the Seal Comp Discharge Stationary Air for the proposed condition is 2 units, with a maximum inventory level of 3 units. This indicates that during the review period, if the inventory level is less than 2 units, then the reservation will be made directly to increase inventory so that the inventory level is as high as 3 units.

The use of periodic review methods (R, s, S) and (R, S), is considered to be more effective, since the replenishment time will be performed at the same time, with varying numbers and types of farm out parts. Thus, it can be possible the order of several parts made in the same purchase order (PO), so that the ordering cost can be minimized.

The purpose of calculating interval review (R) is to determine order interval constantly, reorder point (s) or minimum level is to determine minimum limits for reordering, while maximum level (S) is to set a maximum stock limit on inventory stock room. With this condition, the activity of material procurement is more effective because some several types of parts are ordered on the same purchase order. This causes a positive effect by reducing the total cost of inventories. In addition, ordering farm out parts at the same time for some inventory items has an opportunity to save backorder costs.

E. Periodic Review (R, S)

The following data in Table IV is the result of the calculation for the items in category B and item C.

TABLE IV. PARAMETER (R, S) RESULT FOR ITEM B AND C

Part Name	R	S
Seal,Comp Discharge Stationary	3	1
Blade Disk Stg.#1 Compr.	3	1
Blade Disk Stg 3 & 4 Compressor Rtr	3	1
Blade Disk Stg 2 Compressor	3	1
Blade Disk Stg.#1 Compr.Sb72-0444	3	1
Blade-Disk-Stage 3 & 4 Compressor R	3	1
Blade-Disk-Stage 2 Compressor	3	1
Seal Outer Balance Piston (G03)	3	1
Obp – Seal	3	1
Swirl Plate	3	1

For example, the maximum inventory level for Seal, Comp Discharge Stationary, is 1 unit. This indicates that during the

review period, if the inventory level is less than 1 unit, then the reservation will be made directly to increase inventory, so the inventory level is as high as 1 unit.

F. Total Inventory Cost

After performing an overall comparison of cost parameters at the time of actual conditions and proposed conditions, total inventory costs decreased is by 61%. The actual condition of inventory cost is Rp 974,237,862, - and for the proposed condition is Rp 383,817,082, -. This proves that using periodic review inventory policies (R, s, S) and (R, S) can minimize total inventory costs.

V. CONCLUSION

This paper proposes a policy for farm-out parts, that is able to minimize total inventory cost. Interval review for farm-out parts of the periodic review (R, s, S) and (R, S) is every three months. Reorder point for item A is two units and for item B and C is one unit. Total inventory cost decreased by 61 percent from current condition

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