

An Inventory System For Packaging Material Under The Probabilistic Demand Using Joint Replenishment Method At Cocoa Company

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Abstract—Company XYZ is a company in the cocoa industry, located in Bandung. Currently, Company XYZ has a problem with the inventory control system of their packaging materials because there is only one supplier. Variation of lead time and high stocks result in packaging materials that pile up in the warehouse. The purpose of this research to minimize the cost of total inventory, this system consists of three stages. First, determining the demand for packaging material and testing the distribution of demand, classification using ABC analysis and testing distribution of lead time. Second, determine the economic order interval and order quantity, safety stock and reorder point. Third, calculate the total inventory cost. Sensitivity analysis is performed to see the effect of the change of variable parameter input of ordering cost and holding cost to total inventory cost. Sensitivity analysis is performed with a range of 5% to 25%. Based on research that has been done, actual inventory system in this company is not efficient because the actual policy is still not optimal. It can be seen from the number of overstocks that generate high embedded costs, then the actual policy in Company XYZ need improvement. From the total 25 SKUs of material packaging, Inventory system proposed in this paper can save 83.24% that is Rp171,342,981,-. The proposed system that considers the variation of lead time has improved inventory performance.

Keywords— *joint replenishment, economic order interval, economic order quantity, safety stock, reorder point, Inventor Turnover (ITO)*

I. INTRODUCTION

Company XYZ is a company runs in the cocoa industry located in Bandung. Company XYZ will send their product to customer, the amount of packaging material inventory will impact on customer satisfaction, calculating the optimum safety stock and determining the right reorder point will result in high customer satisfaction and can minimize total inventory cost. Since the packaging is a dependent goods to finished goods, from the Figure 1 the demand listed is a demand based on the sale of finished goods. Demand, beginning inventory, and ending inventory that contained in the Figure 1 is the sum of all packaging SKUs.

When compared between the numbers of safety stock and ending inventory looks very much the amount of excess inventory and this condition causes overstock and lead to high inventory cost resulting in the company loss. In Aug-17 the number of overstock for the entire SKU reaches 382.194

pcs. Companies need to improve policies for their inventory packaging material.

The number of embedded cost is quite high, in Aug-17 the cost reaching Rp22,882,306,996. The embedded cost is obtained from the gap between ending inventory and safety stock in Figure 1 which is multiplied by the price of the packaging material of each SKU.

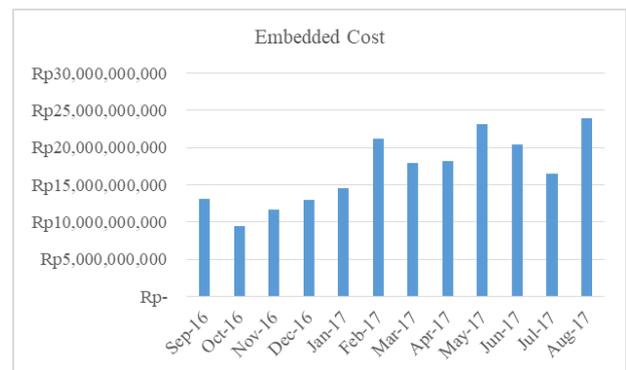


Fig. 1. Embedded cost in the period

II. LITERATURE

A. Inventory

According to reference [1] inventory is idle resources whose existence awaits further process. Further process here may be production activities on manufacturing systems, marketing activities on distribution systems, or consumption activities in household systems, offices, and so on.

B. Inventory Cost

Inventory costs incurred as a result of inventories over a given time horizon. The components in the cost of inventory are:

- Purchasing Cost
- Procurement Cost
- Holding Cost
- Shortage Cost
- Systemic Cost

C. Inventory Turnover (ITO)

According to reference [8] in addition to both cost performance measures and service levels, in the business system often used inventory turnover as a measure of capital effectiveness and inventory management system capabilities to create profit. The ITO can be measured from:

$$ITO = \frac{V_p}{V_T} \quad (1)$$

Where:

V_p : Annual sales volume

V_T : Yearly average inventory volume

D. Distribution Test

Test distribution used to test the distribution of demand packaging material and lead time. The test was performed using One-sample Kolmogorov-Smirnov. After doing the testing it is proved that the data is normally distributed because p value > 0.05

E. ABC Analysis

The principle of ABC analysis is to classify the types of goods based on the level of annual investment absorbed in the provision of inventory for each type of goods. ABC classification is using principle 80-20 or Pareto law which about 80% of the total supply of materials representing 20% of the material in the inventory. ABC analysis is used to determine investment decisions and can be applied to companies with different types of materials and different values.

F. Probabilistic Model

According to reference [13] parameters in this model such as demand, lead time, inventory costs are varies in the real condition. The use of probabilistic model is because if using a deterministic model is not sensitive to such things. The equation used to determine the total inventory cost is using equations Economic Order Interval (EOI)-Multiple Items. The economic order interval can be obtained by minimizing the total annual cost. Neglecting stock out cost, the formulation is:

1. Total annual cost for an order interval of T years

$$TC(T) = \sum_{i=1}^n P_i R_i + \frac{C+nc}{T} + \frac{TF}{2} \sum_{i=1}^n P_i R_i \quad (2)$$

2. Economic order interval in years

$$T^* = \sqrt{\frac{2(C+nc)}{F \sum_{i=1}^n P_i R_i}} \quad (3)$$

3. Maximum inventory each item

$$E_i = \frac{R_i T}{N} + \frac{R_i L}{N} = \frac{R_i(T+L)}{N} \quad (4)$$

If lead time is normally distributed, then the formulation used for reorder point optimization is:

$$B = \bar{M} + Z_\sigma = D\bar{L} + ZD\sigma_L \quad (5)$$

G. Joint Replenishment Method

Determination of Economic Order Interval (T^*) and Optimal Order Quantity (Q^*) packaging material the proposed system by using joint replenishment method step to determination T^* and Q^* are as follows:

1. Determine the annual demand per SKU by using the equation:

$$P_i R_i \quad (6)$$

2. Calculate total annual demand for all SKU

3. Determination of Economic Order Interval (EOI) by using the equation:

$$T^* = \sqrt{\frac{2(C+nc)}{F \sum_{i=1}^n P_i R_i}} \quad (7)$$

With:

$$F = \frac{\text{Holding Cost per year}}{\text{Total Asset}} \quad (8)$$

4. Determine optimal order quantity for all SKU by using the equation:

$$Q^* = R_i \times T^* \quad (9)$$

5. Calculate ordering cost by using the equation:

$$TC_p = \frac{C+nc}{T^*} \quad (10)$$

6. Calculate holding cost by using the equation:

$$TC_s = \frac{T^* F}{2} \sum_{i=1}^n P_i R_i \quad (11)$$

7. Calculate total inventory cost for all SKU by using the equation:

$$TC = TC_p + TC_s \quad (12)$$

Next to determine the Safety Stock (SS) and Reorder Point (B) for the proposed system are as follows:

1. Determine Safety Stock (SS) for each SKU by using the equation:

$$SS = ZD\sigma_L \quad (13)$$

2. Determine Reorder Point (B) for each SKU by using the equation:

$$B = \bar{M} + Z_\sigma = D\bar{L} + ZD\sigma_L \quad (14)$$

Notation:

P_i : Price per unit

R_i : Total requirement

T^* : Economic Order Interval in year

C : Order cost for the joint order

n : Total number of joint order items

c : Order cost associated with each individual item

F : Annual holding cost as a fraction of purchase cost

Q^* : Optimal Order Quantity

TC_p : Ordering cost

T : Order interval in years

m : Number of annual orders

TC_s : Holding cost

TC : Total inventory cost

SS : Safety stock

- B : Reorder point
 D : Rate constant demand per period
 \bar{L} : Average lead time in the period
 σ : Standard deviation or demand during lead time
 σ_L : Standard deviation of lead time

III. RESULTS AND ANALYSIS

A. Results

From the total SKU packaging material amounting to 12 for Class A and B, each SKU has lead time data. Each SKU has its own ordering frequency in each month after testing the data distribution, the distribution of lead time is normal distribution for all 12 SKUs. Here is the example of determination of Economic Order Interval (T^*) and Optimal Order Quantity (Q^*) packaging material for the proposed system by using joint replenishment method.

SKU	: H-202
Description	: Plastic bag PE, Sealed gusset, C. Butter, 390/700 x 680 x 0.1 mm 25 kg
Unit	: Pcs
Class	: A
Total requirement (R_i)	: 918,474 Pcs
Price per unit (P_i)	: Rp 72,808,-
Ordering cost (C)	: Rp 250,000,-
Fraction of holding cost (F)	: 0.014990

Table 1 Holding cost

Holding Cost	
Electricity Cost	Rp 250,928,063
Facility Cost	Rp 1,619,173,333
Labor Costs	Rp 771,272,346
Total Cost (Per Year)	Rp 2,641,373,743
Total Asset	Rp 176,204,192,130
Fraction of Holding Cost	0.014990414

Fraction of holding cost (F) can be found by dividing total cost of holding cost for one year with total assets. Total assets are all packaging materials purchased for one year multiplied by the price of each SKU packaging material. So, the result for fraction of holding cost is 0.014990.

Step to determination T^* and Q^* are as follows:

Step 1: Calculate annual demand

$$P_i R_i = \text{Rp } 72,808 \times 918,474 \text{ Pcs} = \text{Rp } 66,872,755,604$$

Step 2: Calculate total annual demand = Rp 158,900,270,549

Step 3: Determination of Economic Order Interval (EOI)

$$T^* = \sqrt{\frac{2(C + nc)}{F \sum_{i=1}^n P_i R_i}}$$

$$T^* = \sqrt{\frac{2(\text{Rp}250,000 + (0))}{0,0149 \times 158,900,270,549}}$$

$$= 0.01448 \text{ years} = 5.28 \text{ days}$$

Step 4: Determination of Optimal Order Quantity

$$Q^* = R_i \times T^*$$

$$= 918,474 \text{ Pcs} \times 0.01448$$

$$= 13,307 \text{ Pcs per order}$$

Step 5: Calculate ordering cost

$$TC_p = \frac{C + nc}{T^*}$$

$$TC_p = \frac{\text{Rp}250,000 + 0}{0.0149} = \text{Rp } 17,255,364$$

Step 6: Calculate holding cost

$$TC_s = \frac{T^* F \sum_{i=1}^n P_i R_i}{2}$$

$$TC_s = \frac{0.01448 \times 0.0149}{2} \times \text{Rp } 158,900,270,549 = \text{Rp } 17,255.364$$

Step 7: Calculate total inventory cost

$$TC = TC_p + TC_s$$

$$= \text{Rp } 17,289,156 + \text{Rp } 17,289,156$$

$$= \text{Rp } 34,596,311$$

Next to determine the Safety Stock (SS) and Reorder Point (B) for the proposed system are as follows:

$$\bar{L} = 102.0732 \text{ days} = 0.2796 \text{ years}$$

$$\sigma_L = 55.0434 \text{ days} = 0.1508 \text{ years}$$

$$SS = ZD\sigma_L$$

$$= 1.29 \times 918,474 \text{ Pcs} \times 0.1508$$

$$= 17,867 \text{ Pcs}$$

$$B = \bar{M} + Z_\sigma = D\bar{L} + ZD\sigma_L$$

$$= (918,474 \text{ Pcs} \times 0.2796) + 17,8677 \text{ Pcs}$$

$$= 435,531 \text{ Pcs}$$

B. Analysis

Table 2 Cost comparison between existing and proposed inventory system

Component of Inventory System	Actual Inventory System	Proposed Inventory System
Ordering Cost	Rp 116,750,000	Rp 17,255,364
Holding Cost	Rp 89,103,710	Rp 17,255,364
Total Inventory Cost	Rp 205,853,710	Rp 34,510,729
Save	Rp 171,342,981	
% Save	83,24%	

In Table 2 it can be seen the comparison between the total inventory cost of existing inventory system with the proposed inventory system, seen from the total inventory cost is reduced and the proposed system saves Rp171,342,981 or 83,24% in percentage.

According to reference [12] sensitivity analysis is the stages of the modeling system to validate the inventory model to be built or developed. Two important issues in the sensitivity analysis are as follows:

1. Find response of optimal solutions generated to changes in the input values
2. Find out how the big error occurs (loss profits or savings)

Sensitivity analysis is performed to see the effect of the change of variable parameter input of ordering cost and holding cost to total inventory cost. Sensitivity analysis is performed with a range of 25% decrease to 25% increase

Sensitivity Analysis of Ordering Cost

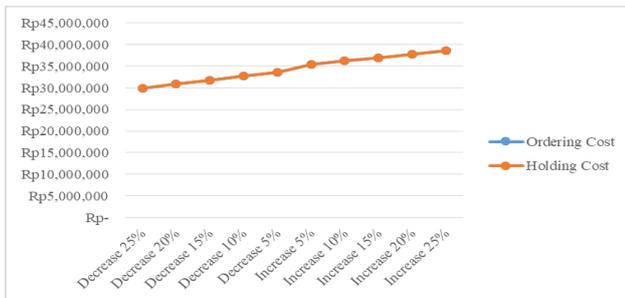


Fig. 1. Sensitivity Analysis

Parameters used to perform sensitivity analysis are ordering cost and holding cost. This is because there is a possibility that the value of the parameter changes volatile either decrease or increase. Ordering cost and holding cost are the constituent components of total inventory cost. The increase and decrease of the parameters is assumed to vary from 5% to 25%. It can be concluded from Figure 4 that the proposed solution is optimal because if ordering cost has increased then it is sensitive total inventory cost. And Figure 4 also shows that the total cost of inventory is influenced by the holding cost. This is because the more packaging material stored in the warehouse the greater the holding cost. Ordering cost and holding cost have the same value.

IV. CONCLUSIONS

Based on the research objectives that have been formulated, it can be obtained the inventory policy with the parameters generated in the form of intervals between reservations, reorder point, the amount of safety stock, as well as the results of savings made to the total cost of inventory of the proposed policy. This policy is based on the outcomes of the Joint Replenishment method for overstock cases. Inventory policy is exemplified in SKU H-202, and the result of the calculation is as follows:

1. In the calculation using Joint Replenishment method, the economic order interval is 0.0144 or about 5 days.

2. Based on the calculation of total inventory cost in one year using proposed system for the entire packaging material save Rp171,342,981 or equal to 83.24%. The number of safety stock based on the calculation of proposed system for SKU H-202 is 178,677 Pcs. Reorder point on SKU H-202 by using probabilistic model that is in the form of unit that is equal to 435,531 unit. Order is made if it has reached the reorder point.

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