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Raw Material Ordering Quantity for Wiring Harness Using Economic Order Quantity Method Considering Warehouse Capacity

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Abstract. This research aims to determine the optimal ordering quantity of bus wiring harness raw materials by taking into account warehouse capacity constraints and procurement efficiency. The main challenges encountered by the company include stock shortages resulting from sudden demand increases and limited storage space, which consequently cause production delays and hinder the fulfilment of customer demand targets. The methodology applied involves the probabilistic Economic Order Quantity (EOQ) model to establish the optimal order quantity, in conjunction with the Lagrange Multiplier approach to facilitate the simultaneous ordering of various types of raw materials, thereby minimizing the total inventory cost. The data utilized in this study comprise historical demand, ordering cost, holding cost, warehouse capacity, and the targeted service level. The findings of this research are expected to reduce the risk of stock shortages, lower total inventory cost, and enhance the efficiency of production processes.

1 Introduction

Inventory includes various goods and materials used in production and distribution. The inventory system evolves according to needs, ranging from simple methods when inventory is small to complex ones as products grow and develop [1]. Periodic evaluation of the inventory system is very important to achieve goals and leverage efficiency during economic growth [2].

The company is facing issues with controlling raw material inventory due to a surge in demand and warehouse limitations, resulting in restricted order quantities. This condition risks causing stock shortages that disrupt production and the fulfilment of demand. Therefore, the optimal order timing and quantity must be determined to minimize the risk of overstocking or stockouts and to keep inventory costs under control [3].

Probabilistic Economic Order Quantity (EOQ) differs from the deterministic model, in which demand can be known with certainty [4]. Probabilistic deals with demand uncertainty that fluctuates according to consumer needs. Although uncertain, these fluctuations still follow certain patterns that can be predicted through the mean, the degree of dispersion, and the shape of their distribution. Lagrange Multiplier method is used to determine the

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minimum value of a function subject to certain constraints [2]. Constraints such as limited capital or physical space often act as factors that prevent achieving truly optimal solutions.

2 Methodology

Multi-Item Economic Order Quantity (EOQ) is used to determine the optimal order quantity to minimize total inventory costs, particularly storage and ordering costs [4]. The required data are demand (*D*), purchase price (*p*), ordering cost (*A*), holding cost (*h*), and stockout cost (*Cu*). The company is currently trying to prevent stock shortages. Therefore, the order quantity (Qi) each time is kept as minimal as possible with the aim of reducing the total inventory costs overall.

$$Q_i = D_i \sqrt{\frac{2A}{\sum_{i=1}^{N} h_i D_i}} \quad (1)$$

The order interval (T) indicates how frequently orders should be placed to meet production requirements and consumer demand.

$$T = \sqrt{\frac{2A}{\sum_{i=1}^{N} h_i D_i}} \quad (2)$$

Total cost (TC) in inventory management aims to identify the total costs that a company must bear in the process of managing inventory thoroughly and efficiently.

$$TC = \sum_{i=1}^{N} D_i P_i + \frac{A}{T} + \frac{1}{2} \sum_{i=1}^{N} h_i T D_i \quad (3)$$

Inventory system calculations based on company policy are carried out by considering demand, ordering intervals, and the quantity of purchases made at present. The cost components considered are purchasing costs, ordering costs, and storage costs.

Lagrange Multiplier method is an approach used in inventory management that considers various constraints, one of which is the limitation of warehouse space [4]. In this section, the Q calculation is performed using the EOQ method, which does not consider storage space limitations.

$$Q_i = \sqrt{\frac{2.C.R_i}{F.P_i}} \quad (4)$$

Next, the Q value is calculated using the Lagrange Multiplier method, taking into account the warehouse space constraints.

$$Q_i = \sqrt{\frac{2.C.R_i}{F.P_i + 2\lambda w_i}} \quad (5)$$

C = ordering cost

R_i = demand

F = holding cost per unit

P_i = price per unit

λ = *Lagrange multiplier indicating storage capacity constraint*

w_i = storage requirements for each item unit

To determine the warehouse requirements for storing raw materials, it is necessary to calculate the volume for each raw material using the formula:

$$Volume\ per\ Unit\ \left(m^3\right) = \pi \times radius^2 \times\ tube\ requirements \quad (6)$$

3 Result and Discussion

Currently, the company produces five types of products that use wiring harness raw materials. Demand over 6 months and the required cost components can be seen in Tables 1 and 2.

Table 1. Product Demand Over 6 Months.

Product	Tube Size (mm)	Demand (m)
Product A	10	14202
Product B	13	11340
Product C	15	38318
Product D	19	34080
Product E	22	36140

Table 2. Cost Components.

Product	p (Rp)	A (Rp)	h (Rp)	C_u (Rp)
Product A	15000	715000	2361	72000
Product B	18000	715000	2375	54000
Product C	25000	715000	2409	55000
Product D	27000	715000	2418	40500
Product E	32000	715000	2442	26000

The number of raw material orders for each type of product is calculated using formula (1) with the results shown in Table 3. The calculation for product A is as follows:

$$Q_i = D_i \sqrt{\frac{2A}{\sum_{i=1}^{N} h_i D_i}}$$

$$= 14202 \sqrt{\frac{2 \times 715000}{(2361 \times 6) \times 14202) + (2375 \times 6) \times 11340) + (2409 \times 6) \times 38318) + (2418 \times 6) \times 34080) + (2442 \times 6) \times 36140)}} = 386\ meter$$

Table 3. Number of Orders.

Product	Qi (meter)
Product A	386
Product B	308
Product C	1041

Product D	926
Product E	982

The calculation of the reorder period and total cost using the probabilistic EOQ method is as follows:

$$T = \sqrt{\frac{2A}{\sum_{i=1}^{N} h_i D_i}} = 0.02714\, month = 4\, day$$

$$TC = \sum_{i=1}^{N} D_i P_i + \frac{A}{T} + \frac{1}{2} \sum_{i=1}^{N} h_i T D_i = Rp\, 3,502,226,885$$

Inventory system calculations based on company policy are conducted to compare the total inventory costs incurred between the implementation of the probabilistic EOQ model and the model that complies with the company's internal policy. Table 4 shows the results of the inventory system calculations based on the policies implemented by the company.

Table 4. Current Condition Total Cost Calculation.

Product	Demand (meter)	Order Frequency	Qi (meter)	Total Cost (Rp)
Product A	14202	45	316	261,991,020
Product B	11340	45	252	249,762,826
Product C	38318	45	852	1,036,302,072
Product D	34080	45	758	993,580,862
Product E	36140	45	804	1,232,837,315
TOTAL				**3,774,474,094**

The optimal purchase quantity without constraints using the Lagrange Multiplier method is shown in Table 5. The calculation for product A is as follows:

$$Q_i = \sqrt{\frac{2.C.R_i}{F.P_i}} = \sqrt{\frac{2 \times 14.202 \times 715.000}{0,0575 \times 90.000}} = 1981\, meter$$

Table 5. Optimal Purchase Quantity Without Constraints.

Product	Qi (meter)
Product A	1981
Product B	1252
Product C	1650
Product D	1401
Product E	1185

The Lagrange Multiplier calculation for optimal purchases with warehouse capacity constraints is shown in Table 6. The calculation for product A is as follows:

$$Q_i = \sqrt{\frac{2.C.R_i}{F.P_i + 2\lambda w_i}} = \sqrt{\frac{2 \times 715.000 \times 14.202}{90.000 \times (0,00575 + 2 \times 0,129)}} = 845\, meter$$

Table 6. Optimal Purchase Quantity With Constraints.

Product	Qi (meter)

Product A	845
Product B	534
Product C	704
Product D	597
Product E	505

The warehouse currently available measures 8x5 meters. The available warehouse space can only be used for 20 m² because 10 m² is allocated for the aisle. The warehouse stores an average of 13,106 meters of raw materials, with the packaging size of raw materials for Products A and B being 28x28x49 cm, while other products use packaging sized 58x58x30 cm. The layout of raw material warehouse is shown in Figure 1.

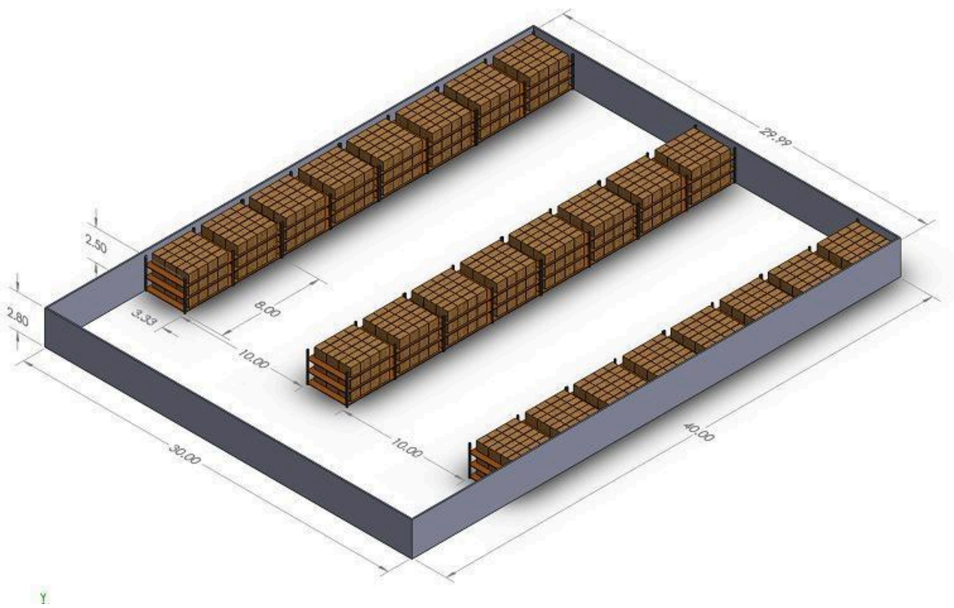

Figure 1. Layout of Raw Material Warehouse

Volume per unit of raw material for each type of raw material is shown in Table 7. The required warehouse space for storing raw materials based on the calculation results of the optimal purchase quantity, both without constraints and with constraints, can be seen in Table 8.

Table 7. Raw Material Volume Per Unit.

Product	Tube's Requirement (m)	Tube Size (m)	Radius (m)	Volume per unit (m^3)
Product A	6	0,010	0,005	0,00047
Product B	10	0,013	0,0065	0,00133
Product C	14	0,015	0,0075	0,00248
Product D	16	0,019	0,0095	0,00453

Product E	20	0,022	0,011	0,00760

Table 8. Calculation of Lagrange Multipliers for Warehouse Requirements.

Product	Qi without Obstacles (m)	Qi with Obstacles (m)	Warehouse Requirements without Obstacles (m^3)	Warehouse Requirements with Obstacles (m^3)	Warehouse Area Availability (m^3)
Product A	1981	845	0.933	0.398	20.000
Product B	1252	534	1.661	0.708	
Product C	1650	704	4.080	1.740	
Product D	1401	597	6.351	2.709	
Product E	1185	505	9.005	3.841	
TOTAL			**22.030**	**9.396**	

4 Conclusion

The calculation results show the optimal order quantities for each product as 1041 m, 982 m, 926 m, 386 m, and 308 m, with an ordering frequency of approximately every 4 days. The application of the Probabilistic EOQ method has been proven to reduce total inventory costs to Rp 3,502,226,885, which is more efficient compared to the previous policy that required Rp 3,756,561,668. In addition, the warehouse capacity of 20 m^3 is still ample for use under the EOQ method policy.

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