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Inventory Control of Vaccine Products in Pharmaceutical Company Using the Economic Order Quantity Model and Monte Carlo Simulation

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Abstract

Health is a basic need in human life. People spend a lot of money to maintain their health. One of the preventive health service options is to vaccinate. Indonesia is a country that can produce its own vaccines with its local pharmaceutical companies. The company faces stiff competition in today's rapidly growing market. Therefore, evaluation and assessment are needed to measure the progress of the company's development. One useful assessment is a company's financial review. Inventory control ensures that the planned approach can minimize costs without disrupting the production process. This research simulates data of demand and analyzes the inventory control based on simulated data. The object used in this research is the inventory of products of pharmaceutical companies. The data used is secondary data such as data of product quantity sold per period, purchasing cost, order cost, holding cost, shortage cost, and lead time. The method used for inventory control is Economic Order Quantity (EOQ) model and Monte Carlo simulation. The simulation results on the monthly demand for vaccine products show that the total demand for one year is 3,394,805 vials for Vaccine A, 1,320,900 vials for Vaccine B and 107.345 for Vaccine C. Based on simulated data processing, calculations using the probabilistic EOQ model result in total inventory costs of Rp 456,918,008,386.14 for Vaccine A, Rp 218,292,795,949.34 for Vaccine B, and Rp 9,177,930,319.05 for Vaccine C.

Keywords: Inventory control, economic order quantity, monte carlo simulation, vaccine

1. Introduction

Vaccination is one of the preventive health service options. Indonesia is a country that can produce its own vaccines with its local pharmaceutical companies. The company faces stiff competition in today's rapidly growing market. Therefore, evaluation and assessment are needed to measure the progress of the company's development. One useful assessment is a review of the company's finances so it is important to minimize costs incurred in the production process (Dwipayana, 2020)

The arrival of consumers and the number of demands is random. This will be a challenge for the company because they have to adjust to the number of uncertain requests. The company need to control inventory in order to maintain a balance between consumers' trust and holding costs. An inventory model is needed to determine the number of orders and inventory costs to increase profits.

Research with the EOQ model and Monte Carlo simulation has been carried out before. As in the study by Assis *et al.* (2019) which calculates the Economic Disposal Quantity (EDQ) for retail businesses to minimize waste products so that not a lot of money is wasted. Dedrizaldi *et al.* (2019) conducted research to analyze mineral water supply planning using the Monte Carlo method. Data processing using Monte Carlo simulation results in forecasting the number of requests in 2018. Research by Ramadan *et al.* (2020) processed shoe sales data using a probabilistic EOQ model and Monte Carlo simulation to calculating a lower total inventory cost in the future.

Based on the ideas that have been described, this research will carry out the implementation EOQ Model for inventory control of vaccine product in pharmaceutical companies. This study uses the same method as the research previously mentioned. The factors that distinguish this research from previous studies are the type of EOQ model and the data used. This study applies the probabilistic Economic Order Quantity Model and Monte Carlo Simulation to generate optimal order quantity and calculate inventory cost.

2. Inventory Control Theory Concept

Inventory is an idle resource to meet future demands which waits for further process, such as production, distribution, or marketing activities (Bahagia, 2006). Common problems in inventory control originate from incidents faced by suppliers in the business, industrial or other fields. This problem needs to be clearly defined and differentiated between real problems based on facts or objective data and problems that are still presumptive. Inventory control must maintain its reliability and durability from time to time while facing the uncertainty of supply flow (Almaktoom, 2017). Inventory control ensures that a planned approach minimizes costs without disrupting the production and sales process. This is done by determining the number of items that must be ordered and when to place an order.

Inventory costs are defined as all costs required to ensure the availability of products owned. These costs include purchasing costs (C_p), ordering costs (C_o), holding costs (C_h), and shortage costs (C_s). The expenditures made for inventory are used to measure operational performance.

a) Purchasing cost (C_p) is cost incurred when buying goods. Purchasing costs can be calculated using the following equation.

$$C_p = PD \tag{1}$$

b) Ordering cost (C_o) is cost for the process of ordering goods. This fee is usually assumed to be fixed for each order. Ordering costs arise in the activities of checking inventory before ordering, determining suppliers, and so on. The ordering cost can be obtained using the following equation.

$$C_o = \frac{D}{q}A \tag{2}$$

c) Holding cost (C_h) includes all costs related to the storage of goods owned. These costs include warehouse rental, depreciation and damage costs, administrative costs, insurance costs, expiration costs, and others. be calculated using the following equation.

$$C_h = H\left(\frac{q}{2} + S_s\right) \tag{3}$$

d) Shortage cost (C_s) can be measured based on the quantity that cannot be fulfilled, the time of fulfillment, as well as the cost of emergency procurement. The shortage cost is the multiplication of the expected inventory shortage during the lead time with the shortage cost per unit which can be written as follows.

$$C_s = \frac{KDE}{q} \tag{4}$$

2.1. Probabilistic Economic Order Quantity

Economic Order Quantity (EOQ) is the most economical number of items in each purchase. An economic state is achieved when ordering costs and carrying costs are in balance. The value of EOQ is strongly influenced by the characteristics and level of demand for products. Therefore, EOQ Model is classified into two models, namely deterministic EOQ model and probabilistic EOQ model.

The Deterministic EOQ is a model in which the system parameters are assumed to be always the same or constant, while the probabilistic EOQ is a model in which the system parameters cannot be known with certainty. This model relies on probabilistic lead times and requests. The following are the assumptions used in the probabilistic EOQ model.

a) The demand is probabilistic with an average demand D and a standard deviation with a normal distribution pattern.
b) Constant order lot size per unit time and orders are made when inventory reaches the reorder point.
c) Products ordered will come simultaneously with a constant lead time.
d) Price of the products is constant and are not affected by the number of products purchased.
e) Ordering cost is constant each period and holding costs are proportional to the number of items stored.
f) Shortage cost is proportional to the number of items that cannot be fulfilled.

Probabilistic EOQ model is a method that is used to determine when an order will be done and the quantity of goods in each order to minimize value of total cost. The following are steps to determine EOQ.

a) Calculate the economic order quantity (q)

$$q_o = \sqrt{\frac{2DA}{H}} \tag{5}$$

b) Calculate standard deviation of demand (S)

$$S = \sqrt{\frac{\sum_{t=1}^{n}(D_t - D)^2}{n}} \tag{6}$$

c) Calculate the probability of stockout (α)

$$\alpha = \frac{H \times q_o}{K \times D} \tag{7}$$

d) Determine safety stock (S_s)

$$S_s = zS \tag{8}$$

e) Determine reorder point (R)

$$R = DL + S_s \tag{9}$$

f) Calculate expected stockouts (E)

$$E = S[f(z) - z\Psi(z)] \tag{10}$$

g) Redetermine the economic order quantity (q_o^*)

$$q_o^* = \sqrt{\frac{2D(A+KE)}{H}} \tag{11}$$

After obtaining q_o^* , the next step performs iteration at step (3), (4), (5), (6) and (7) until q_o^* is same. The last step aster getting the new economic order quantity is calculating the total cost of inventory using the following equation.

$$C_t = (PD) + \left(\frac{D}{q}A\right) + H\left(\frac{q}{2} + S_S\right) + \left(\frac{KDE}{q}\right) \tag{12}$$

2.2. Monte Carlo Simulation

Monte Carlo is a type of probabilistic simulation that estimates the solution by taking samples from a random process. Monte Carlo simulation involves determining the probabilistic distribution of the variables, then taking a random sample to obtain the data. According to Heizer *et al.* (2017), there are four steps to perform a simulation, namely:

a) Setting up a probability distribution for important variables.
b) Building a cumulative probability distribution for each variable.
c) Establishing an interval of random numbers for each variable.
d) Generating random numbers.

3. Materials and Methods

3.1. Materials

The materials used in this study is inventory control data for vaccine products in pharmaceutical company. The data used is secondary data including the number of products sold per month, purchasing cost, ordering cost, holding cost, shortage cost, and lead time of the types of vaccine products with the highest sales.

3.2. Methods

The following are steps on this study:

a) Identify the problems of inventory control of vaccine products in pharmaceutical companies.
b) Conduct literature studies or material studies through books, journals, essays, and other scientific articles.

c) Collect inventory control data for vaccine products at pharmaceutical companies including the number of products sold per month, purchasing cost, ordering cost, holding cost, storage cost, and lead time.
d) Determine the assumptions used in the probabilistic Economic Order Quantity (EOQ) model.
e) Define the variables involved in the inventory control model.
f) Formulate a Monte Carlo simulation and probabilistic EOQ model with the Python programming language.
g) Generate random numbers from pharmaceutical company vaccine product inventory data using Monte Carlo simulation.
h) Calculate the economic order quantity based on simulated data.
i) Calculate the standard deviation of demand.
j) Initiate the value of $i = 1$ to iterate on the probabilistic EOQ model.
k) Perform iterations to determine the probability of stockout, safety stocks, reorder point, expected stockouts, and EOQ.
l) Step 11 is repeated until a fixed EOQ value is obtained. The EOQ value in the last iteration is used as the optimal solution.
m) Calculate the optimal total cost of inventory.
n) Summarize the results of the research and the interpretations obtained.

4. Results and Discussion

4.1. Monte Carlo Simulation Results

The following table is the simulated data of demand of vaccine products as Table 1.

Table 1: Simulated Data of Demand

No	Demand		
	Vaccine A (vial)	Vaccine B (vial)	Vaccine C (vial)
1	169.692	548.450	26.303
2	6.578	345.000	7.630
3	90.101	80.000	7.630
4	409.681	250.050	8.171
5	457.440	0	0
6	692.907	900	8.171
7	262.531	0	4.446
8	244.425	0	0
9	472.661	80.000	27.574
10	262.531	0	8.171
11	114	12.500	99
12	326.144	4.000	9.150
Total	3.394.805	1.320.900	107.345

4.2. Calculation with Probabilistic EOQ Model

The data of costs that is needed consist of purchasing cost (P), ordering cost (A), holding cost (H), and shortage cost (K) are shown in Table 2.

Table 2: Data of Costs

No	Vaccine	Purchasing Cost (IDR)	Ordering Cost (IDR)	Holding Cost (IDR)	Shortage Cost (IDR)
1	Vaccine A	133,606.56	180,000.00	4,676.23	6,680.33
2	Vaccine B	163,139.28	180,000.00	5,709.87	8,156.96
3	Vaccine C	84,688.28	180,000.00	2,964.09	4,234.41

Meanwhile, the data of lead time is shown in Table 3.

Table 3: Data of Lead Time

Product	Per-Month	Per-Year
Vaccines	3	0.25

Based on the data above, the total of supply cost from demand of vaccine can be determined with probabilistic EOQ model. After calculating the value of optimal order measure with several iteration, the following is a summary of calculation result of q_o, α, S_s, R, and E for Vaccine A as Table 4.

Table 4: Calculation of q_o, α, S_s, R, and E for Vaccine A

i	q_o	α	S_s	R	E	q_o^*
1	16,167	0.00333	531,840	1,380,542	1,449	119,649
2	119,649	0.02467	385,325	1,234,027	7,837	276,181
3	276,181	0.05695	309,912	1,158,614	14,889	380,364
4	380,364	0.07843	277,525	1,126,227	19,012	429,730
5	429,730	0.08861	264,520	1,113,222	20,895	450,479
6	450,479	0.09289	259,386	1,108,088	21,436	456,266
7	456,266	0.09408	257,986	1,106,688	21,696	459,022
8	459,022	0.09465	257,323	1,106,025	21,696	459,022
9	459,022	0.09465	257,323	1,106,025	21,696	459,022

Based on Table 4 shows that the number of q_o in several iteration have been done to obtain same value. The value of optimal demand (q_o) is 459,022 vials. Therefore, the total inventory cost using probabilistic EOQ model is IDR 456,918,008,386.14.

Meanwhile, the calculation result of q_o, α, S_s, R, and E for Vaccine B is shown in Table 5.

Table 5: Calculation of q_o, α, S_s, R, and E for Vaccine B

i	q_o	α	S_s	R	E	q_o^*
1	9,126	0.00484	441,821	772,046	1,738	81,502
2	81,502	0.04319	292,825	623,050	10,598	200,201
3	200,201	0.10609	213,040	543,265	20,627	279,159
4	279,159	0.14794	178,503	508,728	25,959	313,134
5	313,134	0.16594	165,696	495,921	27,945	324,882
6	324,882	0.17217	161,480	491,705	28,825	329,953
7	329,953	0.17485	159,690	489,915	29,124	331,659
8	331,659	0.17576	159,092	489,317	29,124	331,659
9	331,659	0.17576	159,092	489,317	29,124	331,659

Based on Table 5 shows that the number of q_o in several iteration have been done to obtain same value. The value of optimal demand (q_o) is 331,659 vials. Therefore, the total inventory cost using probabilistic EOQ model is IDR 218,292,795,949.34.

Lastly, the calculation result of q_o, α, S_s, R, and E for Vaccine C is shown in Table 6.

Table 6: Calculation of q_o, α, S_s, R, and E for Vaccine C

i	q_o	α	S_s	R	E	q_o^*
1	3,611	0.02355	17,311	44,148	335	10,761
2	10,761	0.07017	12,856	39,693	779	15,874
3	15,874	0.10351	11,001	37,838	1,030	18,137
4	18,137	0.11827	10,320	37,157	1,134	18,996
5	18,996	0.12387	10,078	36,915	1,173	19,308
6	19,308	0.12591	9,992	36,829	1,186	19,411
7	19,411	0.12658	9,963	36,800	1,186	19,411
8	19,411	0.12658	9,963	36,800	1,186	19,411

Based on Table 6 shows that the number of q_o in several iteration have been done to obtain same value. The value of optimal demand (q_o) is 19,411 vials. Therefore, the total inventory cost using probabilistic EOQ model is IDR 9,177,930,319.05.

5. Conclusion

Based on the results of Monte Carlo Simulation and the calculation with probabilistic EOQ model of vaccine product inventory control, the conclusions are obtained:

a) Monte Carlo simulation on the three types of vaccines with the highest sales in pharmaceutical companies managed to estimate the monthly demand for vaccine products for one year. The number of requests for Vaccine A products was 3,394,805 vials, the total requests for Vaccine B products were 1,320,900 vials, and the total requests for Vaccine C products were 107,345 vials.
b) Inventory control planning using the probabilistic EOQ model on simulation data shows that the number of economical purchases of vaccine A is 459,022 vials with a reorder point of 1,106,025 vials and a safety stock of 257,323 vials. The economic purchases of vaccine B are 331,659 vials with reorder points of 489,317 vials and safety stock of 159,092 vials. Meanwhile, the number of economic purchases of vaccine C was 19.411 vials with reorder points of 36.800 vials and safety stock of 9,963 vials.
c) The total cost of supplies issued in one year is IDR 456,918,008,386.14 for Vaccine A, IDR 218,292,795,949.34 for Vaccine B, and IDR 9,177,930,319.05 for Vaccine C.

References

Almaktoom, A. T. (2017). Stochastic Reliability Measurement and Design Optimization of an Inventory Management System. *Complexity*, 2017.

Assis, R., Marques, P. C., Santos, J. O., & Vidal, R. (2019). Economic Disposal Quantity of Leftovers Kept in Storage: A Monte Carlo Simulation Method. *Open Engineering*, *9*(1), 522-529.

Bahagia, S. N. (2006). *Inventory System*. Bandung: ITB Publisher.

Dedrizaldi, D., Masdupi, E., & Linda, M. R. (2019). Analysis of Mineral Water Supply Planning with The Monte Carlo Method Approach at PT. Agrimitra Utama Persada. *Jurnal Kajian Manajemen dan Wirausaha*, *1*(1), 388-396.

Dwipayana, I. D. A. P. (2020). Efforts in securing vaccine for covid-19 outbreak in Indonesia. *Health Notions*, *4*(10), 313-317.

Heizer, J., Render, B., & Munson, C. (2017). *Operations Management: Sustainability and Supply Chain Management*. (12). United States of America: Pearson Education, Inc.

Ramadan, H., Gio, P. U., & Rosmaini, E. (2020). Monte Carlo Simulation Approach to Determine the Optimal Solution of Probabilistic Supply Cost. *Journal of Research in Mathematics Trends and Technology*, *2*(1), 1-6.