Economic Order Quantity Inventory Considering Perishable Factor in Product, Delay in Payment, All-Unit Discount, and Product Return

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Abstract— The inventory existence of the company is a waste but still needed to maintain service level. For drug industry companies, especially pharmaceutical installations, the expiration factor is a factor that needs to be considered because drugs have an expiration date. Previous research has an inventory model that considers product expiration factors, permissible payment delays, and price discounts. The developed study provides a solution to the loss of expiry costs by adding a return factor. This research aims to create a deterministic inventory model that considers expiration factors, permissible delay in payment, discounts and product returns. The result of the developed model can minimize the total cost of inventory by 3.37 % with the predefined parameters compared to the previous model, which has not considered the return factor.

Index Terms—economic order quantity, perishable product, permissible delay in payment, all unit discount, product return

I. INTRODUCTION

Inventory is considered a waste cost because it does not provide added value to the product but provides added costs. However, the stock is also something companies need to maintain the level of service to consumers. Good inventory can undoubtedly reduce costs and ensure demand fulfilment. Therefore, the company must have a policy to determine the optimum number of bookings and order time [1].

The development of the model carried out is related to the case of consumer products such as food, medicines and others. The pharmaceutical installations selling medicines have four factors that must be considered in controlling their inventory. These factors include the possibility of drugs being damaged due to an expiration period ([2] and [3]). It is also the possibility of paying for goods within a grace period given after the goods are received, the chance of discounts in the purchase of medicines, and the possibility of returning damaged medication if they are under the supplier's requirements. The expiration period is the time limit for the use of an item. It has been regulated in Ref. [4] that business actors are prohibited from trading damaged goods or damaged products are prohibited from being traded. In this case, the expired goods will be considered damaged [5]. In conducting procurement, the company will also try to find suppliers who provide leeway for payment time. The leeway of payment time in question is the provision of more time by the supplier to the company to pay off the goods that have been received [6]. It means that the company can obtain the proceeds from the sale

of the product in advance. It also uses the sale proceeds to pay for the goods purchased from the supplier. Or in other words, the supplier gives the company a capital loan. Usually, companies are not charged additional fees as long as they can pay before the payment time allowance is reached. Still, if it passes the payment time allowance, the company may be charged additional fees in the form of fines.

Generally, suppliers also provide discounts if the company makes a large purchase, so it is expected that the company will buy in large quantities. This discount can reduce the total cost of inventory, where discounts can be divided into two groups: discounts on the overall price of goods (all unit discounts) and incremental discounts [7]. In addition, usually, drug suppliers also provide a policy of returning goods that have been damaged (past the expiration period). It can be done if they meet the supplier's requirements [8]. It can reduce the total cost of inventory by lowering the cost of damage [9]. This study aims to develop a deterministic inventory model by considering product expiration factors, payment time allowances, all unit discounts and returns, to accommodate the situation of the inventory model in pharmaceutical installations.

II. METHOD

This research was conducted in several steps as follows. This research begins with previous studies, problem formulation, and determination of research objectives and benefits. The next step is to conduct a literature study to study earlier models as the basis for model development. The research continued with the development of the model.

The development of the model was carried out using Ref. [10] as a reference model that has paid attention to product expiration factors, payment time allowances and all unit discounts. This model was then further developed by adding a return factor taken from the research of Ref. [8]. Once the model is created, then the model will be validated. Model validation is carried out in 2 ways, namely verification and trial. Model verification is a way of checking the equations used in the model by checking the left and correct side equations. Model trials are carried out by entering secondary data from the reference research and hypothetical data to see if the model can produce the minimum total cost and cost components of inventory. The final stage is conclusions and suggestions. Conclusions are the result of answers obtained

from the objectives of this study based on the results of model development and trials.

III. RESULTS AND DISCUSSION

A. Model Development

This developed model can result in two scenarios of payment time leeway factors. The first scenario is a condition where a good product is sold out before it reaches the leeway of payment time. Scenario 2 is a condition where a good product will be sold out after the payment time allowance is reached. Figures 1 and 2 are an overview of the model descriptions in each scenario.



Fig. 1. Scenario 1.



Fig. 2. Scenario 2.

This developed model is aimed at minimizing the total cost of inventory and is expressed as follows.

Total Inventory Cost = Purchase Cost + Booking Fee + Storage Cost + Cost of Cons + COst of Demage + Fine Cost - Interest Gain + Cost of Return)

The explanation and components of the costs that affect the total cost of availability are as follows.

Purchase Cost

This cost is the cost of purchasing goods from suppliers.

$$P_{i} = \begin{cases} P_{0} \text{ untuk } R_{0} \leq Q \leq R_{1} \\ P_{1} \text{ untuk } R_{1} \leq Q \leq R_{2} \\ P_{j} \text{ untuk } R_{i} \leq Q \leq R_{j} \end{cases}$$
, where
$$P_{j} < P_{j+1} = 0, 1, 2, 3, \dots \text{ for each unit so that the purchase cost for a year is:}$$
$$C_{p} = D \times P_{i} \qquad (1)$$

Booking Fee

This cost is the cost of ordering goods from suppliers. The message for a year is:

$$C_o = S x \frac{1}{T} \tag{2}$$

Storage Costs

Storage costs will only be incurred in period t_1 because, in period t_2 , all damaged (non-refundable) products will be destroyed, so the storage costs in a year are:

$$C_s = \frac{DTP_i h(2\theta - \theta^2)}{2} \tag{3}$$

Cost of Cons

This cost arises as a result of damaged goods. The cost of the shortage in a year is:

$$C_{so} = \frac{DTU(1-\theta)^2}{2} \tag{4}$$

Cost of Damage

This cost arises as a result of damaged goods. The cost of the shortage in a year is:

$$C_{kd} = P_i \left(D(1-\theta) - \left(\left[\frac{D(1-\theta)}{s} \right] s \right) \right)$$
(5)

Fine Fees

These costs arise because the company exceeds the time limit and only appears when it experiences scenario 2. The cost of a year's fine is:

$$C_c = \frac{P_i I_c (DT\theta - Dt_3)}{2} x \left(\theta - \right)_T^{t_3}$$
(6)

Interest Gains

Profit Interest is the interest earned by the company by depositing it into the bank and taken at the moment when the leeway of the payment time is reached. Two scenarios in the model cause two different formulations for interest gain.

Scenario 1

$$C_{d} = \frac{DT\theta^{2}P_{i}I_{d}}{2} + D - \theta P_{i}I_{d}t_{3}DT\theta^{2}P_{i}I_{d} \qquad (7)$$
Scenario 2

$$C_{d} = \frac{Dt_{3}^{2}P_{i}I_{d}}{2T} \qquad (8)$$

Cost of Return

The cost of returning for a year is:

$$C_r = \frac{F_r \, x \, S_r}{T} \tag{9}$$

To obtain the minimum total inventory cost, a decrease in the formulation of the entire inventory cost to T $\left(\frac{\delta z}{\delta T}=0\right)$ can be obtained so that the formulation of the optimum order time can be obtained. There are two scenarios in the formulation of T.

10)

$$T = \sqrt{\frac{2(S)+2(F_r S_r)}{DP_i h(2\theta-\theta^2)+DU(1-\theta)^2 - D\theta^2 P_i I_d + 2(D\theta^2 P_i I_d)}}$$
Scenario 2
(

$$T = \sqrt{\frac{2S + Dt_3^2 P_l l_c - Dt_3^2 P_l l_d + 2F_r S_r}{DP_l h(2\theta - \theta^2) + DU(1 - \theta)^2 - D\theta^2 P_l l_c}}$$
(11)

To facilitate understanding of the formulation, here is an explanation of the notation used:

- D: Demand in one planning horizon
- Q: Optimum number of orders per one-time message
- P_i: Purchase cost per unit of product (Rp/unit)
- S: Order fee per one message (Rp/unit)
- h: Fraction of storage costs per unit per year
- w: number of refundable lots (lots)
- s: number of products per one lot (units/lots)
- F_r : Product return frequency
- S_r : The cost of returning the product on a planning horizon
- C_p : Purchase costs in one planning horizon
- C_o : Booking fee in one planning horizon
- C_s : Storage costs in one planning horizon
- C_{so} : Cost deficiencies in one planning horizon
- C_{kd} : Cost of damage in one planning horizon
- C_c : Cost of fines in one planning horizon
- C_r : Cost returns in one planning horizon
- C_d : Profit interest in one planning horizon
- U: Cost of shortage per unit of product (Rp/unit)
- k: Cost of shortage per unit of product (Rp/unit)
- Q: Rebooking Time (Year)
- t_1 : The period until the undamaged product is exhausted (year)
- t_2 : Product shortage period
- t_3 : The length of time allowance given by the supplier (years)
- l_c : Percentage of profit that can be obtained per IDR invested l_d : Percentage of fines imposed per Rp that have not been paid to
- suppliers
- θ : Product fraction is not damaged
- (1-: Defective product fraction θ)
- Z: Total Inventory cost

There is an algorithm used to obtain the solution of the most minimal total inventory costs, which is described as follows.

- 1. Calculate the optimal order time (T) using equation 10 at each unit level of the purchase price of the goods.
- 2. Calculate t_1 , and check whether T meets the conditions of scenario 1. If the result $t_1 < t_3$, then T is valid.
- 3. If the results t_1 do not match, then use equation 11 to perform the check.
- 4. Calculate t_1 whether it meets the conditions of scenario 2. If $t_1 > t_3$ is appropriate, then T is valid.
- 5. Calculate Q at each unit level of the purchase price of goods
- 6. Compare Q with the interval table. If Q is in the interval R $(R_i \le Q \le R_{i+1})$, when valid, go to step 4
- 7. If Q is invalid, then:
 - a. For Q that is smaller than the R interval, use R_i
 - b. For Q greater than the R interval, use R_{i+1}
- 8. Check whether the product can be returned to the supplier by specifying the number of lots with the equation $w = \frac{Q_{kd}}{s}$, and the result is rounded down.
- 9. Calculate Z on each valid T
- 10. Compare valid Q and T results
- 11. Choose the Q that gives the most Z value

B. Model Trials

After the model formulation is made, model verification is carried out by checking each equation's unit consistency, and all equations driven are consistent in the same units. Furthermore, model trials were carried out using data from several previous studies, namely research [8], [9] and [10], which can be seen on Table 1. The percentage of interest profit and fines are used from [11] and [12]. The contents of Table 2 show the numerical data of the price classification given by the supplier on an all-unit discount basis. After calculating the

value t_1, it is obtained that the data used has a value t_1 of < t_3, indicating that the selected scenario is scenario 2. Further calculations regarding the optimum Q and valid Q in each price range are shown in Table 3.

TABLE I. Parameter Data

No.	Parameters	Value
1	Number of Requests in one year (D)	1770 units
2	Storage cost fraction (h) 0	
2	The fraction of the product is in	0.95
3	good condition (θ)	
4	The period of leeway for payment	0.05
4	time agreed with the supplier (t_3)	
5	Percentage of fines	0.03
6	Percentage of interest from banks	0.01

TABLE II. Discounted Price Range

No.	Parameters	Value	
1	Purchase price of products in the	IDR 9,750	
	amount of 570 units<		
2	Purchase price of products in the	IDR 9,250	
2	amount of 570 - 640 units		
3	Purchase price of products in the	IDR 8,750	
0	amount of 641 - 711 units		
4	Purchase price of products in the	IDR 8,250	
-	amount of 711 units>		
5	Cost per one message	IDR 100,000	
6	Cost per return	IDR 100,000	
7	Shortage costs per unit of product	IDR 6,500	
8	Number of products in one lot	5 units	

TABLE III. Optimum Q Amount in Each Price Range

Price/Unit	Q (Unit)	
IDR 8,250	334	
IDR 8,750	325	
IDR 9,250	316	
IDR 9,750	308	

Based on step 6 of the algorithm that has been created, the optimum Q value of the calculation results is revalidated against the supplier discount policy in Table 2 so that a valid Q is a Q that corresponds to the terms of the order quantity from the supplier presented in Table 4.

	TABLE IV. Q VALID
Price/Unit	Q (Unit)
IDR 8,250	711
IDR 8,750	641
IDR 9,250	571
IDR 9,750	435

From the calculation results of Table 5, several results are presented, such as the total cost of inventory and some variable components obtained based on valid Q in Table 4. From the results of Table 5, it is known that with a price of Rp8,250.00 it can produce the lowest total inventory cost compared to other discounted price ranges. Different results, such as the number of damaged products and the number of products that experience fines, indicate that the more goods purchased, the higher the potential for fines and damage. According to step 8 of the algorithm, there are a number of lots that can be returned. It affects the cost of damage and gives rise to the cost of returns. Table 6 showed the results of calculations on all components of costs that affect the minimum total cost of inventory on this model. In this study, with the parameter data used, scenario 1 is invalid, so the value of T in scenario 2 is used in the calculation. The results from Table 6 show that the developed model was successfully tested using secondary data in the previous study.

Table 7 is a comparison of the results of the calculation of the cost component between the developed model and the reference model. There are several differences in the cost component due to differences in order time and return factors that were not considered in the study of [9] and [10].

TABLE V.	
DATA PROCESSING RESULT	S

N.	Result -	Purchase Price from Supplier			
NO.		8250	8750	9250	9750
1	Optimal delivery time	0.189	0.183	0.178	0.174
2	Number of products damaged	17	17	16	16
3	Refundable lot amount	3	3	3	3
4	Number of products that can be returned	15	15	15	15
5	Number of non-returnable products	2	2	1	1
6	The amount of product subject to fines	88	84	80	76
7	The optimal number of bookings	711	641	571	435
8	Total inventory costs	Rp16,80 2,374.18	Rp17,73 7,608.22	Rp18,6 71,468. 24	Rp19,604, 065.26

 TABLE VI.

 The result of the Calculation of the Inventory Cost Component

Na	Cost Component	Scenario		
INO.		1	2	
1	Scenario Validation		Valid	
2	Purchase Cost		Rp14,602,500.00	
3	Booking Fee		Rp529,945.80	
4	Storage Costs		Rp1,099,432.72	
5	Cost of Cons	Involid	Rp2,713.72	
6	Cost of Damage	mvand	Rp28,875.00	
7	Fine Fees		Rp11,437.47	
8	Interest Gains		Rp2,476.33	
9	Cost of returns		Rp529,945.80	
10	Total Inventory Cost		Rp16,802,374.18	

TABLE VII.

COMPARATIVE ANALYSIS OF RESULTS WITH REFERENCE MODEL

		Scenario		
No.	Cost Component	Ref. [10]	Research	
			developed	
1	Scenario Validation	Scenario 2 Valid	Scenario 2 Valid	
2	Optimum Ordering	0.133	0 180	
	Time	0.133	0.169	
3	Purchase Cost	Rp 14,602,500.00	Rp14,602,500.00	
4	Booking Fee	Rp750,134.38	Rp529,945.80	
5	Storage Costs	Rp776,713.84	Rp1,099,432.72	
6	Cost of Cons	Rp1,917.16	Rp.2,713.72	

7	Cost of Damage	Rp730.125.00	Rp28.875.00
8	Fine Fees	Rp3,574.77	Rp11,437.47
9	Interest Gains	Rp3,505.23	Rp2,476.33
10	Cost of returns	Rp0.00	Rp529,945.80
11	Total Inventory Cost	Rp16,861,459.92	Rp16,802,374.18

In this study, the optimum order time was more significant than the reference model, which indicates that the frequency of bookings and returns will be less so that the cost of ordering and returns are cheaper. The developed model's storage costs are higher than the reference model. It is because as the reorder time increases, the time the goods are stored will also be longer, increasing storage costs. In the cost of damage, there is a significant difference of 96%. It is due to the return factor considered in this study where damaged products can be returned if they are still in one lot intact.

Further research of the study can be directed to the demand characteristic, considering safety stock to anticipate probabilistic demand [13]. This can be enhanced by also considering the capacity of the warehouse [14]. Another interesting further research is the collaboration between company and the suppliers, where the permissible delay in payment time is analyzed to find the optimum for both sides [15].

IV. CONCLUSION

This study developed a single-item deterministic inventory model that considers product expiration factors, payment time allowances, all unit discounts and returns. The created algorithm also successfully identifies valid model scenarios. The number of damaged products and the number of products subject to fines in various price ranges showed consistent results. This research also succeeded in minimizing reference research. It suggests adding another factor in research such as the expiration date of drugs in the supply chain. It is also a key factor to have a well-managed supply cycle to avoid all types of wastage. Further research can be done by considering the capacity of warehouse and probabilistic demand.

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