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Safety Stock, Warehouse Capacity, and Return of Goods in Inventory Model Development

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***Abstract*— The increasing level of competition between companies, companies are required to be able to manage their inventory system optimally. In the pharmacy supply system, it is important to consider the uncertainty factor because the demand for medicines depends on the uncertain nature of the disease, besides that there is an expiration factor that must be considered because medicines must have an expiration date. To solve the problem of expiration, the supplier usually provides a return policy in accordance with the specified conditions. In addition, pharmacies also have limitations on warehouse capacity that must be considered. To solve the problem of limited warehouse capacity in this study, an approach to the requirements of the Karush Kuhn-Tucker method was used. From the developed model, two ordering times are obtained, namely and which will be compared to get the optimal ordering time. From the analysis of the model, it is found that the more characteristic considerations in an inventory system, the greater the total inventory cost.**

***Index Terms*—limited warehouse capacity, multi-item, perishable, probabilistic, return of goods**

I. Introduction

As time goes by, competition between companies is growing by leaps and bounds. Every company is required to be able to meet the needs of consumers by providing quality goods at competitive prices and also the fastest possible delivery time. On the other hand, companies are also required to be able to manage their inventory system wisely to achieve optimal performance [1].

Pharmacies as one of the units in the pharmaceutical industry provide a variety of drugs ranging from over-the-counter drugs to limited-sale drugs that can be purchased directly by the public. With so many variations of drugs, pharmacies should have a strategy in determining the amount of inventory that optimal [2]. To determine the optimal amount of inventory in the pharmaceutical industry, it is necessary to consider the characteristics of drugs and how they are handled so that they can reduce the cost of inventory that must be incurred by the company.

In a pharmacy, the presence of supplies is an important thing that needs to be considered because the inventory is in the form of medicines and has special characteristics. Medicines are one of the products that cannot be ascertained the level of demand because the demand for medicines is very dependent on the presence of diseases, where diseases are unpredictable. In addition, medicines are products that have an expiration rate so special handling is needed to handle them to maintain product quality and safety [3]. One of the policies provided by *suppliers* to deal with expiration problems is to return products [4]. The product return policy provided must of course be in accordance with the terms and conditions that have been determined by the *supplier.*

In the real case, no industry has unlimited warehouse capacity, as well as in pharmacies. The warehouse capacity at each pharmacy is significantly limited. The limitations in warehouse capacity will limit the quantity of drug orders, causing *tradeoffs* when pharmacies also must always meet drug demand to maintain their service level. There have been several studies that have looked at the limitations of warehouses in their inventory systems [5]-[9]. Meanwhile, there are several studies considered probabilistic demand which need safety stock in the models ([10]-[12]). Also, some studies considered multi-item characteristic ([13]-[15]) that also applied in Pharmacies inventory policy.

This research will develop a multi-item probabilistic inventory model considering expiration periods, returns on goods and warehouse capacity constraints. The approach used to solve obstacles in the limitations of warehouse capacity in this study uses an approach to the requirements of the calculus or linear inequality method, namely the Kuhn-Tucker condition method. Thus, it is hoped that this model can help related companies to deal with similar problems.

II. Methods

This study developed a multi-item probabilistic inventory model by taking into account the expiration and return factors of goods referring to the research of Ref. [2] with the addition of restrictions on warehouse capacity referring to the research of Ref. [3].

This research consists of ten main stages in its development starting with literature studies, namely previous research that became a reference model in this study. Furthermore, the formulation of the problems to be developed in this study and the determination of the objectives and benefits of the research continued with determining the limitations of the problems in the study. Then the development of a model is carried out which is continued by collecting data in a secondary manner which is then processed in data processing. After that, an analysis is carried out and ends with the drawing of conclusions and suggestions for further research. The research process can be seen in Fig. 1.

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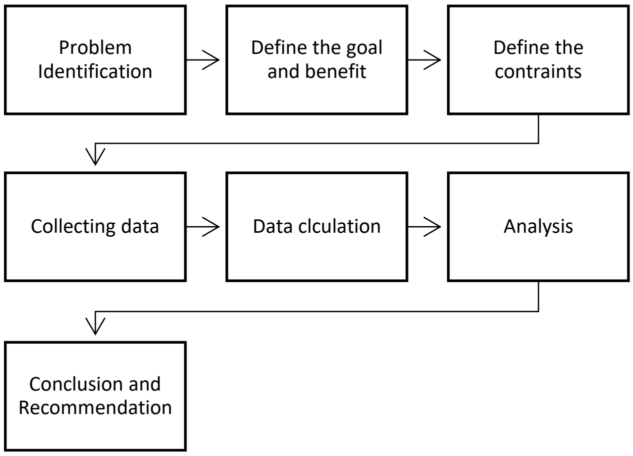

Fig. 1. Research flowchart.

III. RESULT AND DISCUSSION

A. Notation

The notation used in the development of this model is as follows.

T = Planning period (year)
T^* = Optimal order time (year)
T_{gudang} =Order time based on warehouse capacity (year)
T_{joint} = Combined order time (year)
t_i = Small cycle of inventory period for the i-th type of goods (years)
t_{1_i} = The storage period of the i-th type of goods before expiration (year)
t_{2_i} = The occurrence of the shortage period of the i-th type of goods (year)
θ_i = Fraction of good goods for the i-th type of goods (0 < θ_i < 1)
1 - θ_i = Fraction of goods to expire for the i-th type of goods (0 < 1 - < 1)θ_i
Q_i = The optimal order quantity for the i-th type of goods (units)
Q_{ki} = Number of items to expire for the i-th type of goods (units)
D_i = Total demand for the *i-th* type of goods during one planning period (units/year)
S_i = Standard deviation of demand for the i-th type of goods during one planning period (units/year)
m_i = Total product quantity for one lot for the i-th type of goods (units/lots)
w_i = Number of lots returned for the i-th type of goods (lots)
v_i = Volume of one unit product for the i-th type of goods (unit of volume)
X_r = Return frequency
P_i = Purchase cost for one unit for the i-th type of goods (IDR/unit)
A = Ordering cost for one order with a *joint order* policy (IDR/order)
H_i = Storage cost for one unit for the i-th type of goods during retention period (IDR/units/period)
C_{u_i} = Shortage cost for one unit for the i-th type of goods (IDR/units)
K = Return cost for one return (IDR/return)
α = Possible occurrence of inventory shortages for the i-th type of goods (%)
Z_{α_i} = Value of z at normal distribution for the α rate for the i-th type of goods
$f_{Z_{\alpha_i}}$ = Value of ordinate evacuation for the i-th type of goods
$\varphi_{Z_{\alpha_i}}$ = Partial expected value for the i-th type of goods
L = Lead time for all types of goods (years)
N_i = Expected amount of inventory shortage for the i-th type of goods (units)
N_{T_i} = Expected amount of inventory shortage for the i-th type of goods during the planning period (units)
ss_i = Total of safety stock for the i-th type of goods (unit)
W = Total available warehouse capacity (unit volume)
O_b = Total of purchase cost for one planning period (IDR)
O_p = Total of ordering cost for one planning period (IDR)
O_s = Total of storage cost for one planning period (IDR)
O_k = Total of deficiency cost for one planning period (IDR)
O_{kd} = Total of expiration cost for one planning period (IDR)
O_r = Total of return cost for one planning period (IDR)
O_T = Total of inventory cost for one planning period (IDR)

In one planning period (T) there is a small cycle of the inventory period (t_i) consisting of the period of the storage of the product before expiration (t_{1_i}) and the period of occurrence of a shortage of goods (t_{2_i})where the length of time of the small cycle of the inventory period is equal to the optimal ordering time (T^*). The optimal order time length is the division between the optimal order quantity (Q_i) and the demand in a planning period (D_i). The number of goods to expire is obtained from the optimal number of orders for goods multiplied by the fraction of goods to expire (1 - θ_i).

B. Model Assumptions

The model developed in this study uses several assumptions because there are several factors that cannot be controlled by the author and to avoid misunderstandings. The following are the assumptions used in this study.

- The demand rate of each product is simple probabilistic with average demand (D) and standard deviation (S) known and normally distributed.
- Cost minimization is carried out for each product that comes from the same supplier (single supplier).
- The design time (L) for each product is the same because it comes from the same supplier.
- The product ordering policy is carried out jointly (joint order).
- The expiration period of each product is known with certainty.
- The t_{1_i} expired product review period is carried out at the end of the period.
- Products that have expired can be returned provided that the product is intact per lot.

- The size of the number of products in one lot is constant and is known for sure at the beginning of the planning period.
- The existence of expired goods and the return of expired goods has consequences for two cost components, namely expiration costs and shortage costs. Consequences on expired costs: The company will suffer losses due to non-returnable goods because it does not meet the return requirements so that there is an expiration cost of each product whose cost is equal to the purchase price (P_i). Consequences on the cost of shortages: The presence of expired goods that cannot be returned causes the availability of goods to be reduced so that it is not enough to meet the incoming demand.
- Returned products will be replaced with the same product with a longer expiration period directly without any lead time.
- The cost of return (O_k) occurs at the time of the frequency of returns.
- The shortage of goods during one planning period is considered lost sales.
- The cost of shortage per unit is equal to the profit obtained from each item or the difference between the selling price to the consumer and the purchase price to the consumer.
- The warehouse capacity is limited, and the area of the warehouse capacity is known with certainty.

C. Model Development

In this study, a model development was carried out that refers to the inventory model that has been developed by Ref. [2] and a factor of warehouse capacity limitations will be added based on the reference model that has been developed in the study [3]. The previously developed inventory model [2] is a simple probabilistic inventory model so that the inventory model in this study will also use a simple probabilistic inventory model. In addition, it is also used the characteristics of multi-item products with single suppliers and orders are carried out simultaneously using the joint order policy.

There are six components that make up the total inventory cost in this developed inventory model. These cost components include purchase costs, ordering costs, storage costs, shortage costs, expiration costs and return fees. So that the total inventory cost can be formulated as follows:

$$O_T = O_b + O_p + O_s + O_k + O_{kd} + O_r \quad (1)$$

Purchase cost is a cost obtained from the purchase price of goods per unit (which is multiplied by the number of requests for the P_i)*i-th* type of goods in one year (. D_i)The formulation of the cost of purchase can be formulated as follows.

$$O_b = \sum_{i=1}^{n} P_i \times D_i \quad (2)$$

The booking fee is a fee obtained from the booking fee per one message multiplied by the booking cycle in one year $\left(\frac{D_i}{Q_i}\right)$. The order fee is affected by the joint order policy so that the order fee used is the order fee with the joint order policy ()A. The formulation of the ordering fee can be formulated as follows.

$$O_p = \frac{A}{T^*} \quad (3)$$

Storage costs are costs derived from storage costs for the i-th type of goods within each retention period (, the average of goods stored in each retention period and storage cycle in one year. The average of goods stored in each retention period can be obtained by subtracting the average number of goods stored in one cycle by the average number of expired goods that cannot be returned or can be formulated into $H_i)\left(\frac{D_i}{Q_i}\right)\frac{1}{2}Q_iT^* - \left(\frac{1}{2}(Q_{ki} - w_im_i)t_{2_i}\right)$, where $w_i \approx \frac{Q_i(1-\theta_i)}{m_i}$. Then the storage costs can be formulated as follows.

$$O_s = \sum_{i=1}^{n}\left(\frac{H_i\left(\left(D_iT^*(1-(1-\theta_i)^2)\right)+(w_im_i(1-\theta_i))+2\,ss_i\right)}{2}\right) \quad (4)$$

The cost of shortage is a cost that is influenced by two factors, namely the probabilistic nature and the number of expired goods. The cost of shortages in one planning period can be obtained from the multiplication between the costs of shortages per unit (C_{u_i}) with the expectation of inventory shortages of the i-th type of goods during one planning period (N_{T_i}) which is added by the multiplication between the costs of the shortage of the i-th type of goods (C_{u_i}), the average shortage of goods due to expired goods cannot be returned for each period of time of shortage (t_{2_i}) and the number of the cycles of shortages for one planning horizon $\left(\frac{D_i}{Q_i}\right)$. Hence the final formulation is as follows.

$$O_k = \sum_{i=1}^{n}\left(\frac{c_{u_i}((T^{*2}D_i(1-\theta_i)^2)-(T^*w_im_i(1-\theta_i))+(2N_i))}{2T^*}\right) \quad (5)$$

Expired costs are costs that must be incurred because the product has passed its service life or expired and is non-refundable. The expiration fee can be obtained from the multiplication between the purchase price of the i-th product (P_i) with the number of products that have expired, the length of expiration time for each period (t_{2_i}) and many cycles of shortages in one planning period. The formulation of expired costs is as follows.

$$O_{kd} = \sum_{i=1}^{n} P_i \times (((T^*D_i + ss_i(1-\theta_i)^2) - (w_im_i(1-\theta_i)))) \quad (6)$$

The cost of return can be obtained from the frequency of returns (X_r) which is multiplied by the cost per once return (K). The frequency of returns can be obtained by the following formulations.

$$X_r = \begin{cases} 0, if\ there\ is\ no\ product\ return \\ 1, if\ there\ is\ a\ product\ return \end{cases} \quad (7)$$

Expired products that will be returned will be reviewed after the period ends, so that in one year there will be t_{i_1} as many expired product reviews $N = \frac{D}{Q}$. The cost-of-return formulation can be formulated as follows.

$$O_r = K \times \sum_{i=1}^{N} X_r \quad (8)$$

The total inventory cost consists of six cost elements namely purchase costs (O_b), ordering costs (O_p), storage costs (O_s), shortage costs (O_k), expiration costs (O_{kd}) and return costs (O_r) where the six elements can be obtained from equations (2), (3), (4), (5), (6) and (8). So that the total inventory cost can be formulated as follows.

$$O_T = \sum_{i=1}^{n} P_i D_i + \frac{A}{T^*} + \sum_{i=1}^{n}\left(\frac{H_i\left(\left(D_i T^*(1-(1-\theta_i)^2)\right)+(w_i m_i(1-\theta_i))+2\,ss_i\right)}{2}\right) + \sum_{i=1}^{n}\left(\frac{cu_i\left(\left({T^*}^2 D_i(1-\theta_i)^2\right)-(T^* w_i m_i(1-\theta_i))+(2N_i)\right)}{2T^*}\right) + \sum_{i=1}^{n} P_i \times (((T^* D_i + ss_i(1-\theta_i)^2) - (w_i m_i(1-\theta_i)))) + K \times \sum_{i=1}^{N} X_r \quad (9)$$

The ordering decision in this study was taken based on the combined order time for all types of goods which provides the optimum total cost because it has more than one type of goods. In addition, with the consideration of warehouse capacity constraints, a model development will be carried out using an approach to the requirements of the *Karush-Kuhn-Tucker Method.* The optimal order time is obtained from the comparison between the combined order time (T_{joint}) and the combined order time based on warehouse capacity (T_{gudang}). The combined ordering time can be formulatedas follows.

$$T_{joint} = \sqrt{\frac{(A+\sum_{i=1}^{n} Cu_i N_i + K\,X_r)}{\sum_{i=1}^{n}\left(\frac{H_i D_i\left(1-(1-\theta_i)^2\right)}{2}\right)+\sum_{i=1}^{n}\left(\frac{cu_i D_i(1-\theta_i)^2}{2}\right)+\sum_{i=1}^{n} P_i D_i(1-\theta_i)^2}} \quad (10)$$

As for the combined ordering time based on warehouse capacity, it can be formulated as follows.

$$T_{warehouse} = \frac{W}{\sum_{i=1}^{n} v_i D_i} \quad (11)$$

D. *Algorithm*

To obtain the optimum value must be generated the value of T for the optimum value () using the following algorithm:$O_T O_T T^*$

- Determine the value T_{gudang} using equation (11).
- Determine the value T_{joint}using equation (10).
- If $T_{gudang} \geq T_{joint}$ then there is no warehouse capacity constraint and the value T^* is T_{joint}. If $T_{gudang} < T_{joint}$, then the value T^* is T_{gudang}.
- Calculate the optimal number of bookings (Q^*) using the value T^*.
- Calculate the amount of safety reserves (ss_i).
- Calculate the number of product lots to be returned.(w_i)
- Calculate the total inventory cost (O_T) using equation (9).

E. *Model Trials*

The analysis was carried out by comparing the ordering time obtained from the development of the model in this study with the reference model used, namely the model developed in Budiyono's research [2]. Here are the types of inventory models to be analyzed.

- Availability Modeln 1: Research model [2] is a *multi-item* probabilistic inventory model taking into account expiration and return factors.
- Inventory Model 2: The research model developed in this study is a multi-item probabilistic inventory model taking into account expiration factors, returns of goods and limited warehouse capacity.

The data used in this study refer to the study [2] and some additional data refer to the study [3] and some assumptions added. The data taken from the study [2] is product data and product cost components consisting of 3 types of products, namely Cefotaxim, Cefrodaxil and Ringer Lactate. Meanwhile, the data taken from the study [3] is additional data that supports the application of the model with warehouse capacity constraints, namely warehouse capacity and unit volume per product. Table I shows the product information.

TABLE I
PRODUCT DATA AND PRODUCT INVENTORY ELEMENTS

No.	Product Type	Inventory Elements	Value
1	Cefotaxim	Demand expectations (unit/year) (D_i)	852
		Standard Deviation (unit/ year) (S_i)	182.0539
		The timing of the preparation (year) (L)	0.0054795
		Demand expectations were not met (N_i)	0.03318
		Fraction of good goods (θ_i)	0.95
		Z values in the normal distribution table	3.1
		Quantity quantity of products per lot (units) (m_i)	2
		Volume per unit of product (unit volume) (v_i)	2
2	Cefradoxil	Demand expectations (unit/year) (D_i)	770
		Standard Deviation (unit/ year) (S_i)	136.6535
		The timing of the preapration (year) (L)	0.0054795
		Demand expectations were not met (N_i)	0.0249
		Fraction of good goods (θ_i)	0.95
		Z values in the normal distribution table	3.1
		Quantity quantity of products per lot (units) (m_i)	2
		Volume per unit of product (unit volume) (v_i)	2
3	Ringer Lactate	Demand expectations (unit/year) (D_i)	2189
		Standard Deviation (unit/ year) (S_i)	985.6986
		The timing of the preparation (year) (L)	0.0054796
		Demand expectations were not met (N_i)	0.912
		Fraction of good goods (θ_i)	0.95
		Z values in the normal distribution table	2.5
		Quantity quantity of products per lot (units) (m_i)	10
		Volume per unit of product (unit volume) (v_i)	2

There are 5 components of product costs taken from the study [2] which consist of purchase costs, ordering fees, storage costs, shortage costs and return fees. For expired costs, purchase cost data is used because the expired product that is not returned will be destroyed. Table II shows the product cost component.

TABLE II
PRODUCT COST COMPONENT DATA (IDR)

Cost Element	Cefotaxim	Cefradoxil	Ringer Lactate
Purchase cost per unit (P_i)	6,600	8,800	5,000
The combined message cost per message (A)	5,000	5,000	5,000
The cost of savings per unit per period (H_i)	330	330	250
The cost of shortages per unit (C_{u_i})	7,650	7,650	10,120
The cost of returning goods per period (k)	0	0	0

Basically, both inventory models have the same cost components, namely the purchase cost component, ordering cost, storage cost, shortage cost, expiration cost and return cost. However, in this study, development has been carried out for several cost components, namely storage costs, shortage costs and expiration costs.

TABLE III
ANALYSIS COMPARISON OF COMPONENTS OF INVENTORY COSTS

Cost Component	Inventory Model 1	Inventory Model 2
Purchase Cost	IDR 23,344,200	IDR 23,344,200
Booking Fee	IDR 31,562	IDR 76,220
Storage Costs	IDR 156,798	IDR 105,621
Cost of Cons	IDR 67,847	IDR 149,534
Expiry Fees	IDR 3,685	IDR 6,028
Return Fee	IDR 0	IDR 0
Total Cost	IDR 23,604,056	IDR 23,681,603

Based on Table III, it can be seen that the total inventory costs generated in the inventory model 2 taking into account the warehouse capacity are greater than IDR 77,547 or 0.3% of the inventory model 1 which does not take into account warehouse capacity.

The message cost generated by inventory model 1 is smaller than the message cost on inventory model 2 because in inventory model 1 the optimal order time is longer compared to inventory model 2 so that the order cycles produced are fewer. In addition, in the inventory model 2 there are constraints on warehouse capacity that limit the number of orders so that the order cycle will be carried out more than the inventory model 1.

The cost of storage has been developed on the inventory model 2 taking into account the number of expired goods that cannot be returned so that after the *review* of expired goods, non-refundable goods are no longer stored but destroyed, as stated in the inventory model 1 the formulation of the cost of savings has not considered this. In addition, the storage capacity on the inventory model 2 is limited so that the number of orders is less and results in smaller storage costs than the inventory model 1.

In the inventory model 2, a formulation of shortage costs against the factor of expired goods has been developed where the shortage cost is only applied to expired goods that cannot be returned because the returnable expired goods will be replaced with similar goods, while in the inventory model 1 the shortage cost is applied to all expired goods. Inventory model 2 has a shorter optimal ordering time than inventory model 1 because it is limited to warehouse capacity so that the shortage cycle occurs longer and results in greater shortage costs.

In the inventory model 2, the development of the expiry cost formulation is carried out where the number of lots of returnable goods is calculated separately before the calculation is carried out on the formulation of expiry costs, so that the number of lots of goods that can be returned is a positive integer while in the inventory model 1 the number of lots of returnable goods is calculated directly in the expiry cost formulation. Because the number of orders on inventory model 2 is less compared to inventory model 1, the expired goods that meet the whole lot will be less, so the destroyed goods will be more or in other words, will result in greater expiration costs.

Because the return of the drug is assumed to be able to be done at the same time as the arrival of the order, the amount of the return fee is IDR 0.00. See Table IV for the comparative analysis.

TABLE IV
COMPARATIVE ANALYSIS OF OPTIMAL BOOKING TIME SCENARIOS

Booking Scenarios	Inventory Model 1	Inventory Model 2
Q Product 1	136	56
Q Product 2	123	51
Q Product 3	348	144
Order Time Based on Warehouse Capacity	-	0.0656
Combined Booking Time	0.1586	0.3807
Optimal Ordering Time	0.1586	0.0656
Booking Fee	IDR 31.562	IDR 76.220
Storage Costs	IDR 156.798	IDR 105.621

In inventory model 1, the number of product orders is greater than in inventory model 2 because the optimal order time distance in inventory model 1 is longer than in inventory model 2 this is due to inventory model 1 which has unlimited warehouse capacity while inventory model 2 is limited with warehouse capacity.

In terms of cost, inventory model 1 has fewer ordering costs than both inventory models 2 because inventory model 2 has a shorter optimal ordering time so that the order cycle is carried out more frequently and results in greater order costs. As for the cost of storage, the inventory model 1 the number of product orders per message is more so that the average item stored in one storage cycle is more and causes the resulting storage costs to be greater than the inventory model 2.

IV. CONCLUSION

This study succeeded in creating a *multi-item* probabilistic inventory model by taking into account expiration factors, returns of goods and limitations of warehouse capacity. Based on the results of the analysis, it was found that a model developed by considering limitations in warehouse capacity resulted in greater total costs than the reference inventory model which did not pay attention to limitations in warehouse capacity so that it could be concluded that the more characteristic considerations in an inventory system, the greater the total inventory costs. For companies that have the characteristics of a multi-item probabilistic inventory system with consideration of expiration factors, returns of goods and limited warehouse capacity can minimize total inventory costs by seeking sufficient warehouse capacity for the optimal order amount so that it can achieve optimal inventory costs. For the next research, you can consider the optimal return time interval because this study uses the assumption of returning goods directly without a lead time so that it has not considered the optimal return time interval.

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