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Development of a Multi-Item Inventory Model by Considering Perishable and Return of Goods in a Hospital Pharmacy

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***Abstract*—In determining an inventory's quantity, some factors need to be considered. The factors to be considered in the pharmaceutical industry are the fluctuating demand factor (diseases are unpredictable) and the perishable factors. The purpose of this paper is to propose a probabilistic inventory model by considering perishable and return of goods. Compared to the previous models, the developed model has lower inventory costs when compared to the model not considering the return of goods and higher inventory costs when compared to the model that considers deterministic demand patterns. The sensitivity analysis was done to see the behavior of the total cost, component costs, and time to order. The parameters to be changed for the sensitivity test were a fraction of good condition goods, holding costs per unit per period, and ordering cost per unit per period. The analysis showed that total cost, based on joint order, is sensitive to the fraction of good condition products. In general, the model was perceived as able to describe the behavior of the model components.**

***Index Terms*—multi-item inventory, perishable, probabilistic, return of goods**

I. INTRODUCTION

THE effective management of materials is crucial to the performance of many business organizations [1]. The existence of an inventory in company activities can be seen as a waste, but its existence cannot be avoided [2]. Determining the number of inventory to be stored is the main problem. This is related to the inventory cost that should be kept as low as possible while keeping a relatively good service level. The problem becomes more complicated for perishable goods where the goods will expire if they are not used until a certain period [3].

In a study by Ref. [4], the control of medicine inventory in a hospital pharmacy has yet to include probabilistic demand in its consideration, as it only added 10-30% of extra supply from the previous number. This creates an excess in stock, which leads to many of those expiring before being used. Expired medicines cannot be sold and must be exterminated, which means the hospital will incur losses. To avoid this problem, hospitals usually can return medicines to their supplier, given that the whole lot remains untouched.

Ref. [3] researched the Economic Order Quantity (EOQ) inventory model by considering the return of goods. Then, Ref. [5] developed a model for multi-item products. The paper about the Economic Order Quantity Inventory Model considers perishable and return of goods with Hadley Within the method [4]. However, the demand pattern in the three previous research is still deterministic, which can be further developed to overcome probabilistic demand. Ref. [6] researched the multi-item probabilistic inventory model with perishable factor and purchase bonus factor. Ref. [7] researched a multi-item probabilistic model that considers expiration factor, all unit discount policy, and warehouse capacity constraints, but both did not consider the return of goods factor.

The purpose of this paper is to propose a probabilistic inventory model by considering perishable and return of goods. This inventory model is expected to deal with more realistic inventory problems in hospital pharmacies.

II. RESEARCH METHODS

The mathematical model in this paper was developed by giving the following notations and assumptions.

Notations:

- $\mathbf{D_i}$: Number of demand for the type-I goods in a planning horizon (unit/year)
- $\mathbf{S_i}$: Standard deviation of demand for the type i goods in a planning horizon (unit/year)
- $\mathbf{T}$: Planning period (year)
- $\mathbf{T^*}$: Time between goods ordering from one cycle to the next cycle (year)
- $\mathbf{Q_i}$: Optimal order quantity for the type I goods (unit)
- $\mathbf{Q_{ki}}$: Optimal order quantity after purchase bonus for the type i goods (unit)
- $\mathbf{P_i}$: Purchasing cost of each unit for the type i goods (Rp/unit)
- $\mathbf{A}$: Ordering cost for each order with joint order policy (Rp/order)
- $\mathbf{H_i}$: Holding cost of each unit of each holding period for the type-i goods (Rp/unit/period)
- $\mathbf{C_{ui}}$: Stockout cost of each unit for the type-i goods (Rp/unit)
- $\mathbf{K}$: Cost of a return (Rp/return)
- n : Number of goods types managed in inventory system (type)
- $\mathbf{Z_{\alpha i}}$: The z value of the standard normal distribution for the type-i goods
- N_i : Expectation of inventory shortage for the type i goods
- ss_i : Number of safety stock for the type i goods (unit)
- t_i : Small cycle of holding period for the type I goods (year)

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t_{1i} : Holding period before the goods expire for the type i goods (year)
t_{2i} : Inventory shortage period for the type i goods (year)
θ_i : Fraction of good condition goods for the type-i goods ($0 < \theta i < 1$)
$1-\theta_i$: Fraction of goods that will expire for the type i goods ($0 < 1 - \theta i < 1$)
L : Lead time for all goods (year)
w_i : Number of lot return goods for type i goods (lot)
m_i : Number of quantity per lot (unit/lot)
X_r : Return Frequencies
O_b : Total purchasing cost in a planning horizon (R_p)
O_p : Total ordering cost in a planning horizon (R_p)
O_s : Total holding cost in a planning horizon (R_p)
O_k : Total stockout cost in a planning horizon (R_p)
O_{kd} : Total expired cost in a planning horizon (R_p)
O_T : Total inventory cost in a planning horizon (R_p)

Assumptions:

a. The existence of expired goods has consequences on two cost components, namely stockout cost and expired cost (the consequence of stockout cost is inventory shortage, and the consequence of expired cost is losses from selling goods at a lower price than the purchase price).
b. All expired goods will be sold at the end of the $t1i$ period simultaneously, so there are no expired goods left during the $t2i$ period.
c. All expired goods are not sold to the customer, but to special parties, so the selling price of the expired goods will always be the same as the purchase price.
d. Purchase of three types of goods (Cefadroxil, Cefotaxime, and Ringer Laktat) applying a return of goods policy must be made in lot units.
e. Stockout cost for each unit is assumed to be equal to the profit earned from each item or the difference between the customer's selling price and the supplier's purchase price.
f. Stockout cost due to expired goods and probabilistic demand pattern is considered the same.
g. The fraction of good condition goods for each item is assumed to be 95%.
h. All goods are ordered from the same supplier (single supplier).
i. Expired Drugs will be returned and replaced with the same drug for a more extended period of perishable.
j. The number of units per lot (mi) is not calculated, but the value is known.
k. Return costs (k) incurred when there is returned

III. RESULTS AND DISCUSSION

A. Model Formulation

This inventory model aims to determine the optimal order amount and order cycle length to minimize the total cost. This research referred to and combined the two previous models. Probabilistic demand and perishable factor refer to Ref. [6], and the return of goods factor refers to Ref. [3]. There are five cost components, namely purchasing cost, ordering cost, holding cost, stockout cost, expired cost, and return cost.

Purchasing Cost

The purchasing cost is the cost spent to buy goods or materials. Purchasing cost equation is a multiplication of purchasing cost of each unit with purchased goods demand.

$$\text{Ob} = \sum_{i=1}^{n} P_i D_i$$

Ordering Cost

Ordering costs are incurred to order goods or materials from the suppliers. In this research, joint order policy is used so that all goods will be ordered simultaneously. There is only one supplier for all goods in this research. The ordering cost equation is obtained by multiplying the ordering cost for each order with order frequency in a planning horizon.

$$\text{Op} = \sum_{i=1}^{n} \frac{A}{T*}$$

Holding Cost

Holding cost is the cost incurred when the goods are stored. Because this research's demand pattern is probabilistic, a safety stock should be added to the equation.

$$\text{OS} = \sum_{i=1}^{n} \frac{H_i\left(T^*D_i + T^*D_i\theta_i(1-\Theta_i)\right) + 2\,\text{ss}_i}{2}$$

In Ref. [1], an equation calculates the number of safety stocks needed based on a simple probabilistic inventory model.

$$ss_i = Z\alpha S_i\sqrt{L}.$$

Stockout Cost

Stockout cost occurs when there are no goods left (shortage), and the company cannot fulfill the demand from the customer. In this research, stockout cost is assumed to be the same as the profit of each good. In this research, stockout cost is the combination of the cost that occurred due to inventory shortage and probabilistic demand pattern.

Expired Cost

Expired cost occurs when the goods expire and cannot be returned. The expired goods cannot return when the number of expired goods does not match with units per lot (mi) in one lot (wi) of goods.

$$O_{kd} = \sum_{i=1}^{n} P_i\left(T^*D_i + ss_i(1-\theta_i)^2 - \left(\left\lfloor\frac{T^*D_i\,(1-\theta_i)^2}{m_i}\right\rfloor m_i\right)\right)$$

Returned Cost

Returned cost is the cost that occurred when the goods expired and can return because it matched with the term of lot return.

$$O_r = \text{K} \times X_r$$

Total inventory cost is the sum of the equation

$$O_T = \sum_{i=1}^{n} P_iD_i + \frac{A}{T^*}$$

$$+\sum_{i=1}^{n}\left(\frac{H_i\left(T^*D_i + T^*D_i\theta_i(1-\Theta_i)\right) + 2\,ss_i}{2}\right)$$
$$+\sum_{i=1}^{n}\left(\frac{C_{u_i}D_i(1-\Theta_i)^2T^{*2} + 2N_i}{2T^*}\right)$$
$$+\sum_{i=1}^{n}P_i\left(T^*D_i + ss_i(1-\theta_i)^2 - \left(\left\lceil\frac{T^*D_i\,(1-\theta_i)^2}{m_i}\right\rceil m_i\right)\right)$$
$$+K\times X_r$$

To optimize the value of time between goods ordered from one cycle to the next cycle ($T*$), we should calculate the derivation of the equation.

$$(T^*) = \sqrt{\frac{A + \sum_{i=1}^{n} C_{u_i}N_i}{\sum_{i=1}^{n}\left(\frac{H_i\left(D_i\Theta_i + D_i\theta_i(1-\Theta_i)\right)}{2}\right) + \sum_{i=1}^{n}\left(\frac{C_{u_i}D_i(1-\Theta_i)^2}{2}\right) + \sum_{i=1}^{n}P_i\left(D_i\,(1-\theta_i)^2 - \left(\left(\left\lceil\frac{D_i\,(1-\theta_i)}{m_i}\right\rceil m_i\right)\right)\right)}}$$

Based on the explanation above, there are several procedures or algorithms to calculate total inventory cost as follows:

1. Calculate the amount of time between goods ordered from one cycle to the next cycle (T *).
2. Calculate the number of purchased goods quantity order quantity units for each item (Q*).
3. Calculate the number of safety stocks needed for each item.
4. Calculate the amount of total inventory cost (OT)

B. Numerical Example

In this section, a numerical example is provided to illustrate how the above model works. The model above is given the values of the following variables and parameters. Table I shows the data of product and inventory elements.

TABLE I.
DATA OF PRODUCTS AND INVENTORY ELEMENT

No	Type of Goods	Element Inventory	Value
1	Cefotaxim	(D_i)	852
		(S_i)	182.0539
		(L)	0.0054795
		(N_i)	0.03318
		(θ_i)	0.95
		(Z_α)	3.1
2	Cefradoxil	(D_i)	770
		(S_i)	136.6535
		(L)	0.0054795
		(N_i)	0.0249
		(θ_i)	0.95
		(Z_α)	3.1
3	Ringer Laktat	(D_i)	2189
		(S_i)	985.6986
		(L)	0.0054796
		(N_i)	0.912
		(θ_i)	0.95
		(Z_α)	2.5

Table II shows the data of the cost component of products for each type of goods.

TABLE II.
DATA OF COST COMPONENT OF PRODUCTS

No	Type of Goods	Element Cost	Value
1	Cefotaxim	P_i	Rp 6,600
		A	Rp 5,000
		H_i	Rp 330
		C_{u_i}	Rp 7,650
		K	Rp -
2	Cefradoxil	P_i	Rp 8,800
		A	Rp 5,000
		H_i	Rp 330
		C_{u_i}	Rp 7,650
		K	Rp -
3	Ringer Laktat	P_i	Rp 5,000
		A	Rp 5,000
		H_i	Rp 250
		C_{u_i}	Rp 0.120
		K	Rp -

Following the previous solution procedure, the results for the time between the goods ordering inventory model and optimal order quantity are obtained. The resulting time between goods (T*) is 0.06264 years. Then, Table III shows the result of optimal order quantity and safety stock for each good.

TABLE III.
RESULT OPTIMAL ORDER QUANTITY AND SAFETY STOCK

Good Type	Q*	ssi
Cefotaxim	53	42
Cefradoxil	48	30
Ringer Laktat	137	183

The total Inventory cost per type unit of goods used in Microsoft Excel can be calculated.

There are differences between the cost components of both models. The return factor has not been considered in the previous 1st model [6] see Appendix 1. The probabilistic factor does not exist in the previous 2nd model [4]. The total cost of inventory from developing the model in this research is in the middle or higher than the previous 2nd model and lower than the previous 1st model because of the differences in the results decision variable. Ordering costs in the previous model [6] and developed model are lower than in the previous 2nd model [5] because the joint order policy made optimal time ordering goods simultaneously, so the frequency of ordering cost can be lower. Holding costs in the previous 1st model [6] and development model are higher than in the previous 2nd model [5] because this research is probabilistic, so there is safety stock in this model. Stockout costs in the developed model and previous 1st model are higher than the previous 2nd model because of incurred costs from perishable goods and expected inventory shortage. Perishable cost in the previous 1st model [6] is higher than the previous 2nd model [5] and develop model because the result of the time of ordering goods (T*) is longer and was not considering the deduction return of goods. If we use the developed model, the planning of the inventory model will be considered probabilistic, which means this model will cover the volatile demand and give the time of goods is shorter because considering the quantity has a period of a perishable and limited number of lots returned.

Furthermore, because the time of ordering goods in the developed model will be shorter, it can make deduction optimal for order quantity and make holding cost shorter too. If we compare, the time of ordering goods is longer in the previous 1st model and the second one, but in the development model will incur added cost in ordering cost, holding cost for safety stock, stockout cost because of probabilistic demand.

C. Sensitivity Analysis

Sensitivity analysis of inventory models with perishable and returns performed on the value of the fraction of suitable condition, ordering cost, holding cost, and demand. Sensitivity analysis to see changes in the values of total cost inventory. Sensitivity analysis with different parameters in a fraction of good is shown in Appendix 2.

From Appendix 2, if a fraction of good condition increases while the total cost inventory decreases. From that, we know that this model is sensitive to the fraction of suitable conditions. It is because increases in the fraction of good condition increase the number of perishable quantities and directly affect stockout cost and perishable cost. From Appendix 3, if ordering goods increases by 30%, then the total cost inventory will be increased by 0.05%. From that, we know that this model was not significantly sensitive to changing ordering costs. It is because ordering only costs affects the horizon time, not the quantity of product. From Appendix 4, if the holding cost increases by 30%, then the total cost of inventory will be increased by 0.25%. From that, we know that this model is sensitive to the changing holding costs. It is because increases in the holding cost increase the holding cost per unit product, even if the number of orders is decreased.

IV. CONCLUSION

This paper has developed a multi-item probabilistic inventory model that considers perishable and returned goods. With this model, a company has an alternative inventory model, specifically in perishable inventory and return goods policy. Goods expiration and return should be considered by a company, especially for a pharmacy company, because this factor can affect total inventory cost. Perishable factor causes higher total inventory cost consequently. On the other hand, a return policy can reduce purchasing costs. The developed model can be applied to the actual situation. Perishable and return factors can also be appropriately applied in this developed model, indicated by higher total inventory cost when compared to the models that consider deterministic demand patterns and lower inventory cost when compared to the model that was not considered with return of goods. This model offers a more comprehensive inventory model to help decision-makers determine inventory policy. Moreover, this paper can give a contribution to the inventory discipline. Further research can be done in case products have a different expiry date, and considering by interval time, the return of goods will determine the optimal time for returning the goods.

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APPENDIX 1. TOTAL INVENTORY COST

Cost Component	Type of Goods	Previous Model 1	Previous Model 2	Develop Model
O_b	CT	Rp 5,623,200.00	Rp 5,623,200.00	Rp 5,623,200.00
	CF	Rp 6,776,000.00	Rp 6,776,000.00	Rp 6,776,000.00
	RL	Rp 10,945,000.00	Rp 10,945,000.00	Rp 10,945,000.00
	Total	Rp 23,344,200.00	Rp 23,344,200.00	Rp 23,344,200.00
O_p	CT		Rp 26,134.97	
	CF	Rp 32,646.00	Rp 28,153.52	Rp 79,819.00
	RL		Rp 36,241.72	
	Total	Rp 32,646.00	Rp 90,530.21	Rp 79,819.00
O_s	CT	Rp 35,337.00	Rp 24,951.44	Rp 22,644.00
	CF	Rp 39,520.00	Rp 27,540.74	Rp 24,225.00
	RL	Rp 87,554.00	Rp 34,809.61	Rp 62,848.00
	Total	Rp 162,411.00	Rp 87,301.79	Rp 109,717.00
O_k	CT	Rp 4,562.00	Rp 937.04	Rp 4,562.00
	CF	Rp 2,632.00	Rp 814.82	Rp 2,632.00
	RL	Rp 49,071.00	Rp 1,370.86	Rp 149,071.00
	Total	Rp 69,189.00	Rp 3,152.69	Rp 156,265.00
O_{kd}	CT	Rp 45,185.00	Rp 0	Rp 924.03
	CF	Rp 53,980.00	Rp 814.82	Rp 1,103.88
	RL	Rp 90,824.00	Rp 1,192.05	Rp 1,857.34
	Total	Rp 189,989.00	Rp 2,006.87	Rp 3,885.00
O_r	CT	-	Rp 0	Rp 0
	CF	-	Rp 0	Rp 0
	RL	-	Rp 0	Rp 0
	Total	-	Rp 0	Rp 0

APPENDIX 2. SENSITIVITY ANALYSIS FOR THE FRACTION OF GOOD CONDITION

Type of	Fraction of good condition			
Criteria	95%	85%	70%	45%
T^* (years)	0.06264	0.05935	0.05401	0.04387
T^* (days)	23	21	20	16
O_p	Rp 79,819.00	Rp 83,033.00	Rp 91,584.00	Rp 113,974.00
O_s	Rp 109,717.00	Rp 107,602.00	Rp 102,244.00	Rp 91,108.00
O_k	Rp 156,265.00	Rp 184,298.00	Rp 257,640.00	Rp 439,047.00
O_{kd}	Rp 3,885.00	Rp 33,614.00	Rp 95,500.00	Rp 25,232.00
O_T	Rp 23,693,886.00	Rp 23,750,733.00	Rp 23,891,168.00	Rp 24,013,561.00

APPENDIX 3. SENSITIVITY ANALYSIS FOR THE ORDERING COST

Type of Criteria	**Condition 1 (Rp 3,500.00)**	**Condition 2 (Rp 5,000.00)**	**Condition 3 (Rp 6,500.00)**
T^* (years)	0.0593	0.0626	0.0658
T^* (days)	21.6602	22.8643	24.0081
O_p	Rp 58,979.00	Rp 79,819.00	Rp 98,821.00
O_s	Rp 107,796.00	Rp 109,717.00	Rp 111,541.00
O_k	Rp 164,672.00	Rp 156,265.00	Rp 149,074.00
O_{kd}	Rp 3,681.00	Rp 3,885.00	Rp 4,080.00
O_T	Rp 23,679,328.00	Rp 23,693,886.00	Rp 23,707,715.00

APPENDIX 4. SENSITIVITY ANALYSIS FOR THE HOLDING COST

Type of Criteria	**Kondisi 1 (-30%)**	**Kondisi 2**	**Kondisi 3 (+30%)**
T^* (years)	0.0745	0.0626	0.0551
T^* (days)	27	23	20