Inventory policy for multi item products by short expiration period

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Abstract. Inventory planning is an important part in the industry. For industries that produce products with short expiration period, such as the food industry, product expiration period is an important factor that cannot be released in determining the inventory model. Small and Medium Enterprises (SMEs) in the food industry produce the product has a short expiration period of 3 days. Products that have exceeded the expiration period will be returned to the industry and will bear the product expiration costs. The SMEs obtain the expiration costs of IDR 1,518,800 with a total expired product of 600 units. SMEs have not considered multi-item inventory systems. Order policy conducted by single order system. Therefore, efforts should be made to reduce the quantity of expired products, and find out the optimal order quantity and time of ordering goods together (joint order). The optimal order quantity planned with the EOQ method. The result indicate that optimal quantity of orders on lapis legit as many as 60 units, 30 units of Caramel, 54 units of Sponge cake, 6 units of Brownies and 108 units of Bika Ambon, frequency of delivery 28 times in a month with a total inventory cost of IDR 4,548,044.

1. Introduction
Inventory is an asset that includes goods belonging to a company with the intention to sell within a normal business period or goods still in the production process or raw material inventory that is still waiting to be used in a production process [1]. The existence of inventory in the company is an essential thing and unavoidable, but its presence is usually known as a waste. Therefore, inventory control is an important thing to do in order to obtain product demand optimally [2]. Inventory managers are expected to ensure the stock of items required by their company is available at the right time, and in the right quantity [3]. Applications of optimal control theory to management science, in general, and to production planning is proven. Naturally, the optimal control theory, optimal control techniques applied to production planning problems and the other problem [4].

Food supply chains have become globalised and consumers are demanding availability of fresh products in retail of the past decades. However, seasonal production means that the producers must source the products from multiple climate regions over the year. Sourcing from each of these regions
requires a specifically designed supply chain to supply consumers with fresh products in high quality to minimize cost and product waste [5][6].

Real world seen that it is often experience problem to estimate the model parameters accurately. The cost and demand parameter values used in models are at best an approximation to their actual values. The policy computed using the approximated parameters referred to as approximated policy, cannot be optimal. The true values of the model’s parameters are needed so that the optimal policy can be computed. Clearly, if another policy is used, the realized cost will be greater than the cost of the true optimal policy [7]. The most important analysis of inventory control is the EOQ calculation, and one of the most important results applied in operations management. The first reference to the work is conducted by Harris (1915), but the calculation is often credited to Wilson (1934) who independently duplicated the work and marketed the results [8].

The multi-product newsvendor problem with capacity constraints is a classical production/inventory management problem, which was firstly studied by Hadley and Whitin (1963). Due to the difficulty for solving large-scale problems with multiple constraints, many works focus on the singly constrained problems, and develop exact solution methods for some special cases, and approximate solution methods for general problems [9].

Previous research conducted by Bin Zhang namely Optimal Policy and Simple Algorithm for a Deteriorated Multi-Item EOQ Problem discuss the deteriorated multi-item economic order quantity (EOQ) problem as an object in the literature, but the algorithms used in the literature are limited. In this paper, we explore and observe the optimal policy of this inventory problem by analyzing the structural properties of the model, and introducing a simple algorithm to solve the optimal solution to this problem. Numerical results are reported to show the efficiency of the proposed method [10].

Another study conducted by Junfeng et al. to compared total inventory cost of these two policies in the application of blood plasma inventory in an effort to select the most appropriate policy given budget constraints. Its consider three cases, which cover almost all situations; results across all three cases point to the fact that when a higher budget is provided continuous review policy is appropriate, whereas periodic review policy seems to yield smaller costs for lower budget conditions [11]. Another study was conducted by Ashok and Dharamvir to determine the junction of ordering cost curve and carrying cost line using EOQ [12]. However, this study is done to determine the optimal order quantity so that the expiration costs can be reduced.

2. Methodology

The study was conducted at one of the SMEs engaged in the food industry with the research object used is a perishable product. SMEs is engaged in food production is cake, with a short expiration period of 3 days for all types of products, then on the 4th day the product will be returned. The study was conducted by collecting data needed to analyze the problems in SMEs, as the formulation of the problem found is the quantity of expiration and costs spent on perishable products, so that the optimum quantity of orders determination in the inventory model using the model economic order quantity (EOQ). EOQ is a model to find the optimal order quantities and minimize total inventory costs [13]. The order policy is carried out by means of a joint order. The data needed in this study are as follows: quantity and cost of products ordered, quantity and cost of products stored, quantity of expired product, selling price of product and price when the product will expire. The algorithm to obtain an optimal order quantity by considering an expired product, by using a joint order policy is

1. Calculation of interval time ($T^*$) or product order time from first order to next order using interval time formula

$$T^* = \frac{T}{n} \tag{1}$$

Where:

$T^*$ = The time between product order from one cycle to the next cycle

$n$ = Delivery frequency

$T$ = Planning cycle
2. Calculation of optimum order quantity \( Q \) and good product fraction \( \Theta \) and damage rate of each product type at each time interval. Using \( Q_l = D_l x T^* \) and 
\[
\Theta_l = \frac{Q_l-\text{Qex}_l}{Q_l} = 1- \frac{\text{Qex}_l}{Q_l} 
\]
Where:
\( D_l \) = Demand quantity for items of to-1 type in one planning period
\( \Theta_l \) = Good product fraction for product type to-1 \((0<\Theta_l<1)\)
\( Q_l \) = Optimum quantity of orders for product type to-1
\( \text{Qex}_l \) = Quantity of expired products for product type to-1

3. Calculation of expiration cost \( (C_{\text{EXP}}) \) on each product for each time interval.
\[
C_{\text{EXP}} = \sum_{l=1}^{n} (D_l(P_l-J_l)(1-\Theta_l)) 
\]
Where:
\( C_{\text{EXP}} \) = Expiration cost
\( P_l \) = Purchase cost per unit of products for product type to-1
\( J_l \) = Sell cost per unit at each product at time \( t_l \)

4. Calculation of order cost \( (C_O) \) at each time interval by using a joint order policy, each product is given a load of 1/5 from total order cost.
\[
C_O = \frac{S^*}{T^*} 
\]
Where:
\( C_O \) = Order cost
\( S^* \) = Order cost for each time an order is submitted if a joint order policy is made

5. Calculation of saving cost \( (C_H) \) on each product for each time interval.
\[
C_H = \sum_{l=1}^{n} \left( \frac{P_l x h_l x \Theta_l \left( \left( (D_lT^*) - (D_lT^*) (1-\Theta_l) \right) \right)}{2} \right) 
\]
Where:
\( C_H \) = Saving cost
\( h_l \) = Fraction of saving cost products per unit per planning period for product type to-1

6. Calculation of storage cost or pinalty cost \( (C_P) \) on each product for each time interval
\[
C_P = \sum_{l=1}^{n} \left( \text{Cex}_l x \frac{D_lT^*(1-\Theta_l)^2}{2} \right) 
\]
Where:
\( C_P \) = Shortage cost
\( \text{Cex}_l \) = Shortage cost per unit per unit time

7. Calculation of total inventory cost at each product using formula
\[
\text{TIC} = C_{\text{EXP}} + C_O + C_H + C_P 
\]
\[
\text{TIC} = \frac{S^*}{T^*} + \sum_{l=1}^{n} \left( \frac{P_l x h_l x \Theta_l \left( \left( (D_lT^*) - (D_lT^*) (1-\Theta_l) \right) \right)}{2} + \text{Cex}_l x \frac{D_lT^*(1-\Theta_l)^2}{2} + \sum_{l=1}^{n} (D_l(P_l-J_l)(1-\Theta_l)) \right) 
\]

8. Select the \( T^* \) value provides the minimum total inventory cost with the optimum order quantity.
3. Result and discussion

3.1. System characteristic
Small and Medium Enterprises engaged in the food manufacturing, producing bikaambon cake products, Sponge Cake, caramel, lapis legit and brownies. The product has a short expiration period of 3 days for all types of products, then on the 4th day the product will be returned by the agent to the SMEs. Products expired and returned to the manufacturer will be sold for animal feed.

3.2. Optimum quantity of orders \((Q_l)\) to each type product
The optimum quantity of orders for a company is when the company is capable to minimize the occurrence of out of stock and it does not hamper the production process and is capable to save inventory costs, where the optimum quantity of orders is obtained from the total multiplication of time intervals between product order from one cycle to the next with the demand quantity in one planning period to obtain the optimum quantity of orders for each product can be seen in Table 1 that calculated using equation (1) and (2).

| Product Name   | Optimum Order Quantity \(Q_l\) (unit) |
|----------------|-------------------------------------|
| Lapis Legit    | 60                                  |
| Caramel        | 30                                  |
| Sponge Cake    | 54                                  |
| Brownies       | 6                                   |
| Bika Ambon     | 108                                 |

Table 1. The optimum quantity of orders at each product.

Inventory model can be seen in Figure 1.

![Inventory model](image)

\[ T = 1 \text{ month} \]

Figure 1. Inventory model.

3.3. Determination of individual order policy using joint order
Policy determination can be done in two ways, namely the individual order policy (single order) and the policy of joint order. Single order policy means the company makes an order for each type of products separately and does not affect to each other between products, while the joint order policy means the company makes an order together for all types of products. The problem faced by SMEs to implement a joint order policy is when the company must submit an order of products together so that
the total cost of inventory is a minimum. The following below is a results comparison of the costs and the total quantity for each order policy can be seen in Table 2 that calculated using equation (1) until (8).

| Product      | Individual Order | Joint Order |
|--------------|------------------|-------------|
|              | T*   | Ql (unit) | TIC (IDR) | T*   | Ql (unit) | TIC (IDR) |
| Lapis Legit  | 0.036 | 60       | 889,991,43 | 0.036 | 60       | 889,991,43 |
| Caramel      | 0.036 | 30       | 646,647,38 | 0.036 | 30       | 646,647,37 |
| Sponge Cake  | 0.036 | 54       | 732,122,50 | 0.036 | 54       | 732,122,50 |
| Brownies     | 0.036 | 6        | 807,888,50 | 0.036 | 6        | 807,888,50 |
| Bika Ambon   | 0.033 | 101      | 1,435,168,20 | 0.036 | 108      | 1,471,394,50 |
| Total        | 251   |          | 4,511,818,01 | Total | 258      | 4,548,044,30 |

From Table 2, it is found that on a single order total inventory cost is cheaper than a joint order, but on a single order order, the order costs spent is high where the customer is charged for IDR 80,000 / order and an order of 4 more products, then there is an additional cost of IDR 320,000 so that the total cost becomes IDR 4,831,818,01, whereas in a joint order the customer only needs to place one order at a time for all five products, while for the optimum order quantity (Ql) obtained on joint order is greater than the quantity of single order.

3.4. Total inventory cost
The total inventory cost for one type of item by considering the expiration factor and for multi-item products is the sum of the purchase costs, order costs, saving costs, shortage costs, and expiration costs. The five cost components are still used for inventory problems with many types of products, but the difference can be seen in the order cost if the company carried out a joint order policy. For a graph of total inventory costs can be seen in Figure 2.
Then the minimum inventory cost is obtained at the time between the first delivery and the next delivery for 1,07 days or for 25.71 hours which is equal to $T^* = 0.036$ with a total inventory cost of IDR 4,548,044,304, which is at the time of 28 times the delivery frequency.

3.5. Comparison of actual inventory cost, previous and proposed research

SMEs use the single item inventory model with a single order policy. Comparison of total inventory costs on actual and proposed can be seen in Table 3.

| Actual Total Inventory Cost | Proposed Total Inventory Cost | Previous Research of Total Inventory Cost |
|-----------------------------|------------------------------|------------------------------------------|
| IDR 13,453,130              | IDR 4,548,044                | IDR 4,726,954                            |

The total actual inventory costs obtained of IDR 13,453,130 while the total proposed inventory costs obtained of IDR 4,548,044,304 so that the total inventory costs decrease by 63%, it can be seen that the total proposed inventory costs are cheaper than the total actual inventory costs, this is caused by differences with multi item products, consider the joint order policy. Previous studies with a total inventory cost of IDR 4,726,954, it was different when compared with the total cost of the proposed inventory due to differences in the methods and sources of data used.

4. Conclusion

The expiration period of perishable products (decrease in value after a certain time), is an important factor that cannot be released in the supply model determination of food industry. The inventory model used in this study is the EOQ model for multi-item products using a joint order policy so that an optimal quantity of orders are obtained in Lapis legit as many as 60 units, Caramel as many as 30 units, Sponge Cake at as many as 54 units, Brownies as many as 6 units and 108 units of Bika Ambon.

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