

A Model Development of Perishable Product to Minimize Total Supply Chain Cost on Fresh Food and Frozen Product Sales on The Trains

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Abstract— The inventory system has a function as an act of planning, implementing, controlling the flow and storage of a product and information effectively and efficiently in order to fulfill customer demand. However, there are differences between inventory system policies on non-perishable products and perishable products. In the perishable product, special handling is needed in storage by considering the shelf life and storage time to prevent damage or decay. Accuracy in designing inventories is a suitable solution to reduce the occurrence of expired products and unfulfilled customer demand due to a lost sale. The case study used was in food sales activities on the train. Products sold consist of two categories: fresh food (8 hours) and frozen food (30 days). Travel time for each train is between 8 hours and 14 hours. On each trip, refilling is done at the location specified for each product category and each train. The refilling process aims to reduce the occurrence of food damage and decay during the trip. Thus, this paper will discuss the development of an inventory system model in a perishable product that aims to minimize the total supply chain costs by considering multiproduct, fixed lifetime, and probabilistic lead time.

Keywords—perishable product, inventory, shelf life, lead time, multiproduct

I. INTRODUCTION

The handling system for inventory can be classified according to product categories. Product categories are divided into two types of non-perishable products and perishable products. Perishable products have a direct impact on sales, prices, inventory levels, decay costs, slump costs, logistics costs and product availability that have an impact on profitability. Therefore, many studies consider various factors such as product characteristics, level of competition, internal and external constraints, price impact on demand, product availability, nature of demand, etc. in certain environments.

In the case study, this perishable product is divided into two categories of food are fresh food and frozen food. TABLE I. describes the differences between the two categories of food products based on their respective differentiation criteria. The fresh product has 10 (Stop Keeping Units) SKU and the frozen food has 17 SKUs. In total, the number of SKUs used in the study was 27 SKUs. The SKU is chosen based on the frequency of sales every day. Fig. 1 shows the percentage of product sales for each product on all trains from BDO-SUB. The percentage of sales shows that only 9 SKUs have a percentage above 70%, while the rest only has a percentage below 70%.

This maximum sale is due to the inaccuracy of the company in designing food supplies for each train. This inaccuracy results in waste or outdated or lost sale products. The percentage of the amount of waste or outdated products on each train shown is shown in Fig. 2 and Fig. 3.

TABLE I. CRITERIA FOR FRESH AND FROZEN PRODUCTS

Criteria	Fresh Food	Frozen Food
Product Durability	8 Hours	30 days
Food Presentation	Requires the presentation process first using microwave	Requires the presentation process first using microwave
Storage	Does not require special storage handling process	Requires freezer as storage media
Storage Capacity	100 box	90 box
Packaging	Does not require special packaging process	Requires airtight packaging to maintain the product's durability
Recharging Location in Train Journey	It can only be refilled on a certain area	It can be refilled in all areas

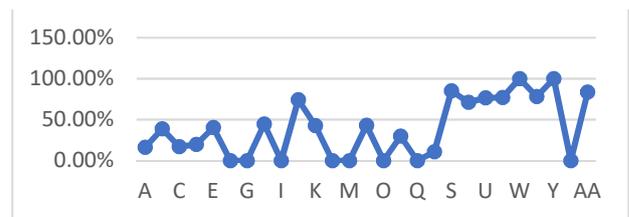


Fig. 1. Percentage of Frozen Food and Fresh Food Sales in Train

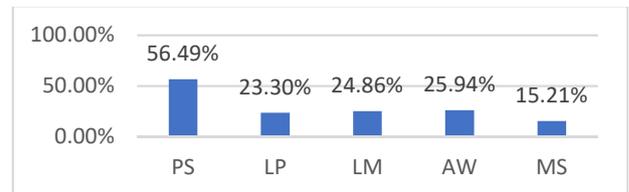


Fig. 2. Percentage of Amount of Waste or Outdated Products

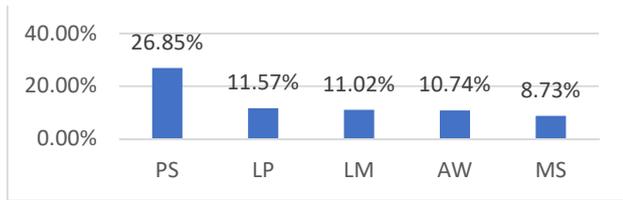


Fig. 3. Percentage of Lost Sale Products

These two incidents of waste or outdated and lost sale can affect the supply chain costs, the number of products wasted due to expiration and products that cannot be ordered by consumers due to the unavailability of the desired product. In addition to these two problems, there are product storage costs, order costs based on order frequency and set-up costs for heating products in the microwave before serving to consumers. This study aims to minimize supply chain costs in food sales activities on trains by considering lead time, lifetime, and multiproduct.

II. RELATED WORKS

The development of the proposed inventory model for perishable products is based on the problems that occur in food sales activities on the train. The basic model in the inventory system for perishable products can be classified into fixed lifetime and random lifetime [1] and [2]. In the case of studies, food products have a fixed lifetime. Fixed lifetime serves to show that the product has a usage age limit. If it passes from the age of use, the product cannot be used and must be disposed of immediately.

The research [3] also shows that the basic inventory model for deterministic demand is used in general conditions, policies that optimize product ordering so as not to suffer damage or deficiency. The basic model used is a simple EOQ model taking into account the lifetime that is denoted by m . Perishable product inventory systems for stochastic models have a fairly complex model that is when the demand is random and the product lifespan exceeds one period. Determining an optimal ordering policy is difficult. This is because it is not possible to get an optimal ordering policy without any damaged products [1].

Development of a perishable product inventory model using several references in previous research (See Fig. 4). The research aims to compare and verify the effectiveness of the existing inventory system (r, Q) for perishable products by considering the fixed lead time and lifetime [4]. In the study consider a continuous review inventory system model (r, Q) that considers constant lead time and lifetime. The model has a purpose to minimize total costs [5]. In the study consider the continuous review inventory system model (r, Q) . However, this research does not discuss perishable products, but non-perishable products. This model considers multi-echelon and multiproduct on lateral transshipment [6]. The research [7], using multi-product and multi-period inventory models (Q, r) to calculate optimal order quantities and optimal reorder points. In this model consider shelflife, budget, storage capacity, and an extra number of products. The approach used for this model is to use GA with local search.

Based on existing references, the differences in this study with the previous research in the case study. The case study has several segments that are used to indicate the time unit in the location that is replenished. Each product category has a different segment. The author uses 24 segments a day for each train. The travel time of each segment is different for each train, travel time of each segment is called the replenishment lead time. This time difference results in a probabilistic lead time.

After making comparisons based on the relevant models and case studies, the development of inventory models in the research aims to minimize supply chain costs by considering probabilistic lead time based on lead time replenishment time, multi products because it uses food types as much as 27 SKUs, and two product categories have a different lifetime.

In this study consider the continuous review inventory system model (r, Q) . A continuous review system shows the state of the inventory system monitored all the time. The importance of a continuous inventory system is shown for two reasons, namely, the inventory control system can automatically trigger orders when the inventory level reaches a predetermined level. Second, the ongoing review model provides a simple approach to complex problems that are difficult to solve with periodic review formulations [3]. The approach used to solve problems from the proposed model is using GA with local search.

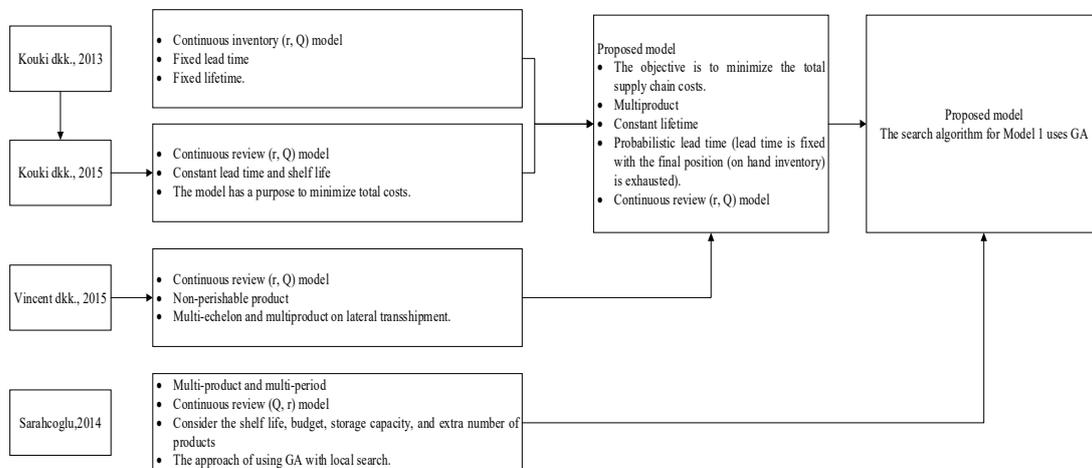


Fig. 4. Development of Inventory Model for Perishable Products

III. RESEARCH METHOD

Model development design used as a proposed model in Figure 5 has the purpose of minimizing the total supply chain cost. The proposed model uses the continuous review (r, Q) inventory method. This chosen method considers sustainable inventory. The selection of this method uses the concept of product order based on quantity if the quantity has reached the reorder point value it needs refilling. Refilling is not only considering quantity but also considering replenishment time. The design phase of the model begins with calculating the optimal value (Q), this Q value is affected by demand, holding cost and order cost. Hold costs are affected by storage and labor costs. The search for r value is influenced by the quantity, lead time, and shelf life. A proposed inventory model with inventory policy (r, Q). The proposed model is solved using a search algorithm (GA).

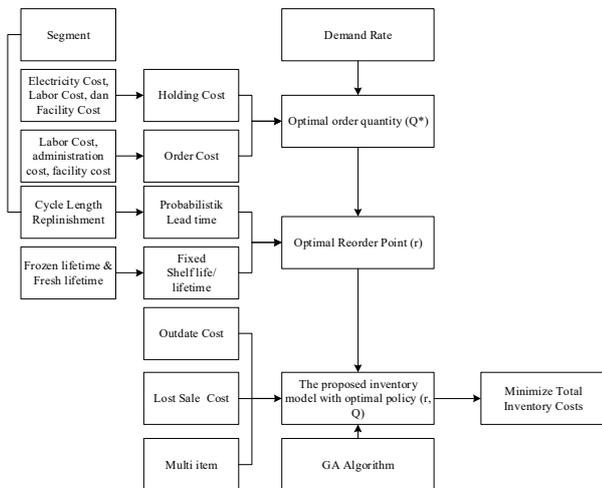


Fig. 5. Model Development Design

Assumption

In the design of this model it is assumed that several conditions are:

- In this study using hypothetical data to determine the demand for each request for each segment or station. The use of hypothetical data is because this study only has aggregate data, namely passenger data for each train every day and food sales data every day.
- The demand data used is stochastic, the number of food requests is based on the number of daily sales. The amount of food ordered every day cannot be ascertained.

Designing mathematical models in accordance with existing problems with the objective function to minimize the total supply chain costs in fresh and frozen food sales in the train. The basic formulation used to minimize supply chain costs is to divide the expected cycle cost with the expected cycle length. Expected cycle costs are cost expectations which consist of order cost (OC), lost sale costs (LQC) and waste costs or outdating costs (WQC). The cycle length consists of the expected time $E[T]$ is the length of the cycle time from the first time replenish to the next replenish. The order cost value OC_k is the order cost for each KA (k). The lost sale LQC_{psk} is a lost sale cost LC multiplied by the

expectation of the quantity of product lost sale $E[LQ_{psk}]$ for each product (p) for each segment (s) in each KA (k). Waste cost or outdating cost WQC_{psk} is the cost incurred due to a product that has exceeded its useful life. Calculation of the division between the expected cycle cost and the expected cycle length of the business plus the saving cost plus the setup fee. The saving cost of HIC_{psk} consists of the cost of storing in each place of listening and employee costs for each train. Setup costs are costs incurred for preparing food by heating it in the microwave for several minutes. This cost is explained if the number of requests can meet consumer demand. Fig. 6 shows inventory control designed for inventory policies.

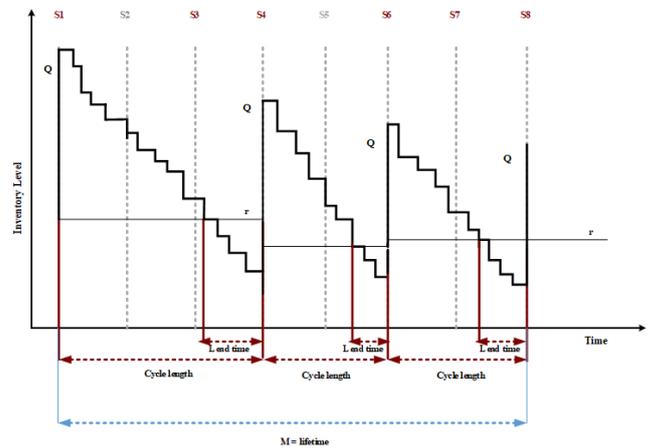


Fig. 6. Inventory Control (r, Q) in case study

Objective Function

$$\text{Minimasi Total Supply Chain Cost} = \frac{\text{Expected Cycle Cost}}{\text{Expected Cycle Length}}$$

$$\text{Min } Z = \sum_{p=1} \sum_{s=1} \sum_{k=1} \frac{OC_k + LQC_{psk} + WQC_{psk}}{E[T]} + HIC_{psk} + SetQC_{psk} \quad (1)$$

$$LQC_{psk} = LC \times E[LQ_{psk}] \quad (2)$$

$$WQC_{psk} = WC \times E[WQ_{psk}] \quad (3)$$

$$HIC_{psk} = (H_{psk} \times I_{psk}) + Labor_k \quad (4)$$

$$SetQC_{psk} = SetC \times Satisfy D_{psk} \quad (5)$$

Constrain

A. Expected Waste Penalty / Outdate Cost

$$E[WQ_{psk}] = \int_0^{r+Q} (r_{psk} + Q_{psk} - d_{m-L}) f_{m-L}(d_{m+L}) dd_{m+L} - \int_0^r (r_{psk} - d_{m-L}) f_{m+L}(d_{m+L}) dd_{m+L} \quad (6)$$

B. Expected Lost Sale Quantity

$$E[LQ_{psk}] = \mu L - r \int_0^r F_L(x) dx_L + \int_{Q-r}^Q F_m(x_m) dx_m - \int_{Q-r}^Q F_L(r - Q + x_m) F_m(x_m) dx_m \quad (7)$$

C. Expected Time

Expected time is an estimated time calculated using $E [T]$ notation. $E [T]$ is obtained from the division between the quantity quantity ordered by Q_{psk} , summed up by the expected loss sale minus the outdated expectation.

$$E[T] = \frac{Q_{psk} + E[LQ_{psk}] - E[WQ_{psk}]}{\mu} \quad (8)$$

$$E[T] - 1 \quad (9)$$

D. Inventory

The inventory delimiter function is used to identify the quantity that is in each echelon and the amount of inventory in each location detail. Calculate the amount of inventory by analyzing the number of products that come out and the number of products entered.

The mathematical formulation used to calculate inventory $E [I_{psk}]$ is the average amount of inventory, namely the number of reorder points added to the quantity quantity ordered with the value of S_n , the value of 0 if it does not meet the requirements, then the number of products that expire. Then added with μ demand rate multiplied by lead time L.

$$I_{psk} = \frac{(r_{psk} + [\sum S_n \times Q_{psk}] - E[WQC_{psk}])}{2} + \frac{\mu L}{2} \quad (10)$$

$$S_n \begin{cases} 1; I_{psk} \leq Rop_{psk} \text{ dan } \sum T_{(s+1)} \leq \sum T_{(s+1)} \\ 0; \text{else} \end{cases} \quad (11)$$

Example calculation, if known $T_{aktual} = 10$, $T_{kl} = 5$, $T_{kl} = 5$, $T_{k2} = 6$, $T_{k8} = 8$. Refilling is not done on R_1 , R_2 is the initial stock value. To find out at the location that restock is needed a calculation based on the specified variable. Replenishment occurs in

$$S_2 = \sum T_{(s-1)} \leq T_{aktual} \leq \sum T_{(s+1)} = 8 \leq 10 \leq 11$$

if the results of the calculation are correct, it is necessary to refill.

E. Storage Capacity

Storage capacity is the maximum amount of capacity in each echelon. This limiter is used to identify the amount of inventory stored in each echelon. Fresh products do not require special storage places such as frozen products stored in the chiller. In frozen products, there is a chiller for each train. The fresh product storage does not require a special storage area on the train. In the existing condition, the storage of this product is only at room temperature. In the sale of fresh products $I_{p18-27k}$ are limited to $STC_{p18-27k}$ as many as 100 for all fresh p products, in segment s, and for each KA k. Frozen products must be stored in a chiller. Each train has two chillers. Each chiller has a maximum capacity that can accommodate as many as 90 products. On the sale of fresh product I_{p1-17k} is limited to STC_{p1-17k} .

$$\sum I_{p1-17k} \leq STC_{p1-17k} \quad (12)$$

$$\sum I_{p18-27k} \leq STC_{p18-27k} \quad (13)$$

F. Satisfy Demand

Satisfied demand is the number of requests received by consumers.

$$\mu_{psk} \leq I_{psk} \quad (14)$$

IV. RESULT

Initial performance is a calculation that is carried out in the initial conditions before applying the calculation model that has been designed. In this condition, performance assesses the total supply chain cost compared to the proposed condition. In the calculation, examples of calculations on KA 5 for one day of departure. The Total departure of 30 days. There are several steps in calculating performance on the initial conditions.

• First Step

The calculation is done by determining and calculating the beginning inventory and stock based on inbound and demand. In the inbound value, use a replenishment quantity and hypothetical demand data.

• Second Step

The calculation is done to calculate satisfy demand, this calculation is done to find out the fulfillment of the request made. In addition, the output in this calculation is used to calculate the total setup costs to warm up the product before serving to consumers.

• Third Step

In this step, calculate the lost sale of the product. to get the value of the lost sale is done by comparing the value of a stock (inventory) with consumer demand. If the demand value is greater than the inventory value, there will be a lost sale of the product.

• Fourth Step

Analyze the occurrence of outdated products. In the case study studied, fresh products only lasted 8 hours.

• Fifth Step

The final step is used to calculate the total supply chain cost by adding up several cost. In the sum of the total costs obtained in the initial conditions for one day of calculation that is equal to Rp. 2,463. 404. 12

The performance of the proposed conditions is a calculation carried out on the proposed conditions. The purpose of the analysis on the performance of this proposal is the same as the purpose of calculating performance in the initial conditions, namely calculating the total supply chain cost compared to the initial conditions. The total departure of 30 days. The steps used to complete the calculation of the performance of this proposal are the same as the

calculation steps taken in the calculation by means of several calculation steps.

- The first step that is done the same as the initial condition is to do calculations that are used to determine and calculate beginning inventory and stock based on the Q proposed results from the calculation using GA and hypothetical demand.
- The calculation is done to calculate satisfy demand, this calculation is done to find out the fulfillment of the request made. In addition, the output in this calculation is used to calculate the total setup costs to warm up the product before serving to consumers.
- In this step, calculate the lost sale of the product. to get the value of a lost sale is done by comparing the value of a stock (inventory) with consumer demand. If the demand value is greater than the inventory value, there will be a lost sale of the product.
- The fourth step is used to analyze the occurrence of outdated products. In the case study studied, fresh products only lasted 8 hours.
- The final step is used to calculate the total supply chain cost by adding up several cost components. In sum, the total costs obtained in the initial conditions for one day of calculation are Rp. 1,572,404.36.

After calculating with the same steps, the initial conditions of using inbound initial conditions and proposed conditions use the inbound Q value of the calculation results of GA, then the total supply chain cost obtained in KA 5 for one day is Rp. 2. 436. 404. 12 for initial conditions and Rp. 1,572,404.36 for proposed conditions. Both results of the total inventory cost indicate that there is a gap of Rp. 863,999, 76. The gap is the ratio of the total supply chain cost between the two conditions. In addition to the comparison of the total supply chain cost, this study compares the comparison results between a lost sale and outdated products in the initial conditions and proposed conditions. Model development can reduce the overall total supply chain cost in the five Bandung departure trains to Surabaya (KA 1, KA 2, KA 3, KA 4, and KA 5) by 26%, the total supply chain cost in the initial condition is IDR 357. 201. 439, 71 and the total supply chain cost in the proposed conditions amounted to Rp.264, 926,443,76.

The value of the lost sale in the initial condition shows a value of 512 products and for an outdated product of 22 products, the value of the lost sale in the proposed condition shows a value of 271 products and for an outdated product of 12 products. This shows that not only can reduce costs but can also reduce the value of lost sale products and outdated products. (See Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11). Each comparison value of the total supply chain cost for each train can be seen in TABLE II.



Fig. 7. Total Supply Chain Cost Comparison KA 1

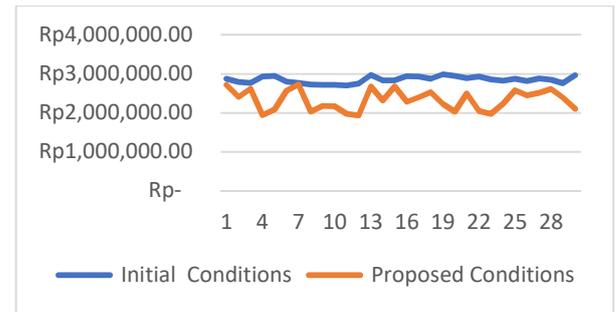


Fig. 8. Total Supply Chain Cost Comparison KA 2



Fig. 9. Total Supply Chain Cost Comparison KA 3



Fig. 10. Total Supply Chain Cost Comparison KA 4

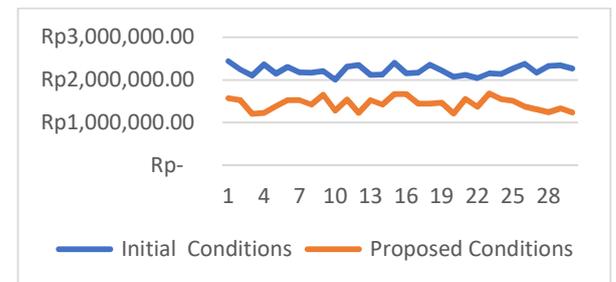


Fig. 11. Total Supply Chain Cost Comparison KA 5

TABLE II. COMPARISON OF TOTAL SUPPLY CHAIN COST FOR EACH TRAIN

	Initial conditions	Proposed Conditions	Percentage Decrease
KA 1	Rp 41,402,669.08	Rp 32,606,561.03	21,25%
KA 2	Rp 85,465,295.01	Rp 69,930,240.72	18,18%
KA 3	Rp 64,455,207.75	Rp 45,447,733.65	27,70%
KA 4	Rp 99,276,434.75	Rp 73,897,464.99	27,34%
KA 5	Rp 66,601,833.12	Rp 43,044,443.36	42,88%

V. CONCLUSION

The development of the proposed model is the development of an inventory model for perishable products. The development of this model can minimize supply chain costs by 26%. This proposed model can reduce lost sales with an average value of each train of 20.6% and can reduce the outdated with an average value of each train as much as 10.6%. Research that can be developed for future research based on existing case studies is the development of models with current case studies by considering multi-echelon and using other solution solving algorithms such as ga and so on.

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