The optimisation of fresh apple inventory by using a multi-supplier Basnet-Leung model (Case study in X Supermarket, Indonesia)

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Abstract. Apple, as one of the fresh fruit commodities, needs specific treatment in material handling to keep the freshness of the product from farm to the consumers. One of the critical processes to maintain the quality of the product is the inventory system. Inventory is one of the significant cost components in the production system. Therefore, the inventory system must be controlled to propose the optimal inventory level at the minimum cost. The objective of this paper is to minimise the inventory costs of fresh apple inventory in one of supermarket in Indonesia by using a multi-supplier Basnet-Leung formulation model since the retailer replenishes his inventory from several suppliers. This model allows the system to apply multi-products, multi-periods lot sizing and multi-suppliers. The result shows by comparing the costs components between the existing company inventory system and the proposed Basnet-Leung inventory system; the total cost is reduced up to 40.26%. It results in the total saving in purchasing cost, ordering cost, and holding cost up to 43.20%, 1.17%, and 44.31% respectively. To sum up, controlling the inventory level by using Basnet-Leung model will result in a more effective way of purchasing management.

1. Introduction

Apple is one of the fresh agricultural products available throughout the year in the market and has a short shelf life. As a perishable product, apple needs specific treatment in material handling to ensure the quality of the product when it reaches the customers. In reality, the demand in the market fluctuates and custom. To anticipate the uncertainty condition, inventory planning and control plays the main role in maintaining the availability in the market while keeping the quality of the product. Inventory control is the action in the business system to control the amount of inventory periodically to meet the demand and minimise the total cost [1]. Inventory needs to be maintained effectively to facilitate the efficient production process and material flows.

One of the strategies to keep the continuity of the material in the company is by applying a multi-supplier system. This system is more reliable in eliminating the disturbances in supply while fulfilling the demand and gives more benefits in reducing the holding cost as well as shortage cost [2]. Supermarket X is one of the stores which applies a multi-supplier system in fulfilling the stocks. This store sells fresh agricultural products, including fresh apple. It utilises the anticipation inventory system in maintaining the apple stock in the store. The anticipation inventory system allows accumulating stocks to use in future demand and deal with the demand fluctuation [3]. This system applies the demand forecasting based on historical data to predict future demand. Currently, this store has multi suppliers of fresh apple to ensure the continuity and the availability of the fresh apple in the market. As a theory, by applying multi-supplier, the lead time and inventory level decreased. Therefore, the holding cost and shortage cost can be minimised. However, it can result in the increasing of the fixed ordering cost. Also, overstock mostly occurred in the store. As a result, they have to sell to the reseller at a lower price to
minimise the number of rotten products in the store. Therefore, a thorough analysis is critical to identify whether this system gives the more economically trade-off in term of the total inventory costs [4].

Dealing with multi suppliers, Basnet and Leung [5] proposed multi-products, multi-suppliers, and a multi-period inventory lot-sizing scenario. They applied the mixed integer programming formulation to the model. This model tries to minimise the purchasing cost of the products, the ordering cost for the suppliers, and the holding cost for remaining inventory in each period [6]. This model is applicable to solve the inventory problems in Supermarket X to minimise the total inventory costs. Thus, this paper presents a case study to determine the lot size of fresh apple inventory for each different suppliers by using multi-period lot sizing with supplier selection problem (MLSSP) by Basnet and Leung [5]. The research questions for this paper are: (1) how is the efficiency level of inventory costs in Supermarket X compared to Basnet and Leung model? (2) how to minimise the total inventory cost by using Basnet and Leung model?

2. Methods

The data that have been used in this research are purchasing cost, ordering cost, holding cost, and lead time for each supplier. The objective of this research to minimise the total inventory cost in Supermarket X by using multi-period lot sizing with supplier selection problem (MLSSP). Firstly, the actual inventory cost in the company is calculated as follow: The formulation of the model as follows:

\[
\sum_{i} \sum_{j} P_{ij} X_{ij} + \sum_{j} O_{j} Y_{j} + \sum_{i} \sum_{t} H_{i}(t_{it} - L_{i}) D_{it}
\]

Then, the result of the actual inventory cost will be compared to the total inventory cost by implementing Basnet-Leung model. The proposed total inventory costs will be calculated as follow:

\[
\begin{align*}
\min & \quad \sum_{i} \sum_{j} \sum_{t} P_{ij} X_{ijt} + \sum_{j} \sum_{t} O_{j} Y_{jt} + \sum_{i} \sum_{t} H_{i} \left( \sum_{j} \sum_{k=1}^{t} X_{ijk} - \sum_{k=1}^{t} D_{ik} \right) \\
\text{s.t.} & \quad R_{it} = \sum_{j} X_{ijt} - \sum_{k=1}^{t} D_{ikt} \geq 0 \text{ for all } i \text{ and } t, \\
& \quad \left( \sum_{k=1}^{t} D_{ik} \right) Y_{it} - X_{ijt} \geq 0 \text{ for all } i,j, \text{ and } t, \\
& \quad Y_{jt} = 0 \text{ or } 1 \text{ for all } j \text{ and } t, \\
& \quad X_{ijt} \geq 0 \text{ for all } i,j, \text{ and } t,
\end{align*}
\]

Where:

\begin{align*}
P_{ij} & = \text{ purchase price of product } i \text{ from supplier } j \\
X_{ijt} & = \text{ number of product } i \text{ ordered from supplier } j \text{ in period } t \\
O_{j} & = \text{ ordering cost for supplier } j \\
Y_{jt} & = 1 \text{ if an order is placed on supplier } j \text{ in time period } t, \text{ 0 otherwise} \\
H_{i} & = \text{ holding cost of product } i \text{ per period} \\
D_{it} & = \text{ demand of product } i \text{ in period } t \\
L_{i} & = \text{ lead time of product } i \\
i & = 1, \ldots, I \text{ index of products} \\
j & = 1, \ldots, J \text{ index of suppliers} \\
t & = 1, \ldots, T \text{ index of time periods}
\end{align*}

3. Results and Discussion

In fulfilling the demand of fresh apple, Supermarket X has a partnership with seven suppliers which have fluctuation in term of availability and price. The partnership with multi-suppliers provides the benefits in dealing with the resource limitation [7]. The inventory level of fresh apple in Supermarket X is shown in Table 1. It can be seen that the selling quantity fluctuates. The lowest demand is in period 11, while the highest demand is in period 13. It depends on the quality of the products and the season.
The inventory level correlates with inventory cost. To calculate the inventory cost, there are three costs involved, which are purchasing cost, ordering cost, and holding cost. The purchasing cost is the price charged per by the supplier for the unit order [8]. It calculated based on the quantity order and the price of the product per unit. The purchasing cost fluctuates from IDR 25,000 to IDR 33,000. The ordering cost associated with the fixed cost in replenishment the order [9]. It covers administration costs, such as transaction cost and transportation cost. The ordering cost per order is varied from IDR 125,000 to IDR 130,000. The holding cost associated with the cost incurred in keeping the material in the storage, including opportunity cost, product defect cost, and storage cost [10]. It fluctuates based on product price, product quantity, and duration of the product in the storage. This store determines the total holding cost is 24% of the lowest product price/period, which consist are 15% opportunity cost, 3% product defect cost, and 6% storage cost. The holding cost per unit/period fluctuations from IDR 240 to IDR 304,60.

3.1. The calculation of total inventory costs by using the existing system

Based on the data in Table 1, the total inventory cost per period can be calculated. Firstly, the inventory costs from the existing condition are calculated by using the equation (1). The result of the existing inventory costs can be seen in Table 2.

| Period | Total order | Selling quantity End customer | Re-seller | Broken stock | End inventory | Period | Total order | Selling quantity End customer | Re-seller | Broken stock | End inventory |
|--------|-------------|-------------------------------|-----------|--------------|---------------|--------|-------------|-------------------------------|-----------|--------------|---------------|
| 1      | 75          | 22.69                         | 10.5      | 2            | 39.81         | 14     | 20          | 25.62                         | 39        | 2            | 33.58         |
| 2      | 19          | 32.45                         | 9         | 0.8          | 16.56         | 15     | 116         | 48.83                         | 48        | 4.7          | 48.05         |
| 3      | 59          | 24.99                         | 12        | 5.2          | 33.37         | 16     | 152         | 33.34                         | 38.8      | 8.9          | 119.01        |
| 4      | 89          | 35.87                         | 13        | 7.2          | 66.3          | 17     | 39          | 55.66                         | 29.5      | 3.07         | 69.78         |
| 5      | 0           | 27.66                         | 9         | 9.2          | 20.44         | 18     | 71          | 32.24                         | 28.6      | 5.1          | 74.84         |
| 6      | 60          | 28.97                         | 29        | 3.09         | 19.38         | 19     | 16          | 34.21                         | 33.8      | 5.7          | 17.13         |
| 7      | 64          | 29.87                         | 18        | 6.7          | 28.81         | 20     | 46          | 41.25                         | 17.8      | 0.7          | 3.38          |
| 8      | 95          | 35.23                         | 38        | 3            | 47.58         | 21     | 117         | 35.3                          | 39        | 6.7          | 39.38         |
| 9      | 136         | 48.95                         | 29.5      | 2            | 103.13        | 22     | 117         | 29.58                         | 48        | 4.01         | 74.79         |
| 10     | 40          | 27.54                         | 38        | 6.7          | 70.89         | 23     | 58          | 27.73                         | 18        | 0.8          | 86.26         |
| 11     | 40          | 20.89                         | 9.2       | 0.8          | 80            | 24     | 76          | 40.31                         | 38        | 1.8          | 82.15         |
| 12     | 96          | 33.33                         | 43.8      | 0.8          | 98.07         | 25     | 20          | 26.44                         | 29.5      | 1.7          | 44.51         |
| 13     | 78          | 57.79                         | 29        | 9.08         | 80.2          | 26     | 77          | 28.72                         | 38        | 5           | 49.79         |

### Table 1. The inventory level of fresh apple in Supermarket X

| Period | Total order | Selling quantity End customer | Re-seller | Broken stock | End inventory | Period | Total order | Selling quantity End customer | Re-seller | Broken stock | End inventory |
|--------|-------------|-------------------------------|-----------|--------------|---------------|--------|-------------|-------------------------------|-----------|--------------|---------------|
| 1      | 2,047,500   | 380,000                       | 168,210   | 2,595,710    |               | 14     | 560,000     | 125,000                       | 77,550    | 762,550      |
| 2      | 513,000     | 125,000                       | 47,348    | 685,348      |               | 15     | 3,248,000   | 125,000                       | 479,776   | 3,852,776    |
| 3      | 1,554,000   | 125,000                       | 184,080   | 1,863,080    |               | 16     | 4,256,000   | 125,000                       | 550,088   | 4,931,088    |
| 4      | 2,314,000   | 250,000                       | 576,720   | 3,140,720    |               | 17     | 1,170,000   | 125,000                       | 140,388   | 1,435,388    |
| 5      | 0           | 0                             | 0         | 0            | 18            |        | 2,130,000   | 125,000                       | 275,239   | 2,530,239    |
| 6      | 1,580,000   | 255,000                       | 244,800   | 2,079,800    |               | 19     | 496,000     | 125,000                       | 39,874    | 660,874      |
| 7      | 1,684,000   | 377,000                       | 168,960   | 2,229,960    |               | 20     | 1,380,000   | 125,000                       | 331,172   | 1,836,172    |
| 8      | 2,535,000   | 250,000                       | 567,785   | 3,352,785    |               | 21     | 3,510,000   | 125,000                       | 226,781   | 3,861,781    |
| 9      | 3,536,000   | 375,000                       | 376,666   | 4,287,666    |               | 22     | 3,510,000   | 125,000                       | 259,178   | 3,894,178    |
| 10     | 1,100,000   | 255,000                       | 189,392   | 1,544,392    |               | 23     | 1,914,000   | 125,000                       | 371,003   | 2,410,003    |
| 11     | 1,120,000   | 125,000                       | 103,400   | 1,348,400    |               | 24     | 2,508,000   | 125,000                       | 208,346   | 2,841,346    |
| 12     | 2,688,000   | 125,000                       | 446,688   | 3,259,688    |               | 25     | 660,000     | 125,000                       | 73,104    | 858,104      |
| 13     | 2,204,000   | 255,000                       | 293,779   | 2,752,779    |               | 26     | 2,541,000   | 125,000                       | 304,905   | 2,970,905    |
Based on the result, it can be seen that the highest total cost occurs in period 16. The highest cost component is purchasing costs since the total unit products ordered is high. It results in the high holding cost since it depends on the number of stored unit and duration. Holding cost correlates with the purchasing cost [11]. It is a function of the purchasing cost. Furthermore, the total ordering cost depends on the number of suppliers that handle the order and the frequency of orders per period. On the other hand, the lowest total cost (non-zero value) in period 19 since it has the lowest purchased unit and stored unit. By using the existing inventory system, the total inventory costs for twenty-six periods is IDR 62,240,732 that consist of purchasing cost IDR 50,758,500; ordering cost is IDR 4,777,000; and holding cost is IDR 6,705,232. It can be seen that the most dominant component in the total inventory costs is purchasing cost (81.55%).

3.2. The calculation of total inventory costs by using Basnet-Leung Model

The next step is calculating the total inventory costs by using the Basnet-Leung model. The constraints of this model are all requirements have to be fulfilled in the same period, and no shortage/back ordered allowed [5]. Therefore, this model focuses on how to optimise the order while minimising the total costs. By using this model, the allocation of order for each supplier has changed compared to the existing model. The proposed model allocates the order to the combination of suppliers who gives the lowest cost. The comparison of the allocation order for both models can be seen in Table 3, while the total inventory costs by using Basnet-Leung model can be seen in Table 4.

| No | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|----|------------|------------|------------|------------|------------|------------|
| 1  | 15         | 20         | 27.69      | 40         | 0          | 0          |
| 2  | 19         | 37.45      | 0          | 0          | 0          | 0          |
| 3  | 20         | 29.98      | 19         | 0          | 20         | 0          |
| 4  | 30         | 0          | 59         | 40.87      | 0          | 0          |
| 5  | 0          | 0          | 0          | 0          | 0          | 0          |
| 6  | 40         | 33.97      | 0          | 0          | 0          | 0          |
| 7  | 30         | 34.87      | 0          | 0          | 0          | 20         |
| 8  | 69         | 0          | 8.05       | 0          | 8.05       | 0          |
| 9  | 76         | 30.8       | 0          | 0          | 0          | 40         |
| 10 | 20         | 32.54      | 0          | 0          | 0          | 20         |
| 11 | 40         | 25.89      | 0          | 0          | 0          | 0          |
| 12 | 96         | 38.33      | 0          | 0          | 0          | 0          |
| 13 | 58         | 0          | 0          | 12.56      | 0          | 12.56      |
| 14 | 20         | 30.64      | 0          | 0          | 0          | 0          |
| 15 | 116        | 53.83      | 0          | 0          | 0          | 0          |
| 16 | 152        | 38.34      | 0          | 0          | 0          | 0          |
| 17 | 39         | 60.66      | 0          | 0          | 0          | 0          |
| 18 | 71         | 37.24      | 0          | 0          | 0          | 0          |
| 19 | 0          | 39.21      | 16         | 0          | 0          | 0          |
| 20 | 46         | 46.25      | 0          | 0          | 0          | 0          |
| 21 | 117        | 40.3       | 0          | 0          | 0          | 0          |
| 22 | 117        | 34.58      | 0          | 0          | 0          | 0          |
| 23 | 58         | 32.73      | 0          | 0          | 0          | 0          |
| 24 | 76         | 45.31      | 0          | 0          | 0          | 0          |
| 25 | 20         | 31.44      | 0          | 0          | 0          | 0          |
| 26 | 77         | 33.72      | 0          | 0          | 0          | 0          |
Table 4. Total inventory costs by using Basnet-Leung model (in IDR)

| Period | Purchasing cost | Ordering cost | Holding cost | Total cost | Period | Purchasing cost | Ordering cost | Holding cost | Total cost |
|--------|----------------|--------------|--------------|------------|--------|----------------|--------------|--------------|------------|
| 1      | 747,630        | 125,000      | 98,207       | 970,837    | 14     | 857,360        | 125,000      | 110,504     | 1,092,864  |
| 2      | 1,011,150      | 125,000      | 132,823      | 1,268,973  | 15     | 1,507,240      | 125,000      | 187,568     | 1,819,808  |
| 3      | 779,940        | 125,000      | 100,766      | 1,005,706  | 16     | 1,073,520      | 125,000      | 133,594     | 1,332,114  |
| 4      | 1,062,620      | 125,000      | 132,237      | 1,268,973  | 17     | 1,819,800      | 125,000      | 226,464     | 2,171,264  |
| 5      | 849,160        | 150,000      | 110,439      | 1,070,638  | 18     | 1,117,200      | 125,000      | 139,029     | 1,381,229  |
| 6      | 883,220        | 125,000      | 114,139      | 1,111,508  | 19     | 1,176,300      | 125,000      | 151,288     | 1,452,588  |
| 7      | 906,620        | 125,000      | 117,163      | 1,148,946  | 20     | 1,387,500      | 125,000      | 172,688     | 1,685,188  |
| 8      | 1,037,934      | 662,000      | 132,582      | 1,832,516  | 21     | 1,209,000      | 125,000      | 150,472     | 1,484,472  |
| 9      | 1,348,750      | 250,000      | 187,986      | 1,786,736  | 22     | 1,037,400      | 125,000      | 129,115     | 1,291,515  |
| 10     | 878,580        | 125,000      | 113,384      | 1,116,964  | 23     | 1,080,090      | 125,000      | 122,207     | 1,327,297  |
| 11     | 724,920        | 125,000      | 226,602      | 1,076,522  | 24     | 1,495,230      | 125,000      | 169,178     | 1,789,408  |
| 12     | 1,073,240      | 125,000      | 110,504      | 1,308,758  | 25     | 1,037,520      | 125,000      | 117,391     | 1,279,911  |
| 13     | 1,613,703      | 657,000      | 226,602      | 2,497,305  | 26     | 1,112,760      | 125,000      | 125,904     | 1,363,664  |

The result of the calculation by using Basnet-Leung model shows that supplier A still becomes the main supplier of Supermarket X. This model is able to move the order to the supplier who offers the largest saving. This model results in the reduction of the total quantity order up to 44.76% from 1742kg to 962.21kg. This proposed model determines the quantity order based on the forecast demand to minimise the excess inventory in the warehouse. Within this model, the purchasing and ordering costs, as well as the carrying inventory, can be minimised. The comparison of the component of the inventory costs can be seen in Figure 1.

![Figure 1. The comparison of the inventory costs](image)

This model results in the decreasing of the total holding cost up to 44.31%. In this model, 5kg safety stock has been considered in the inventory system as the anticipation stock. Safety stock is a tactical strategy to deal with demand variability [12]. Moreover, it has an impact on the total purchasing cost, which declines up to 43.20%. However, the total ordering cost only slightly decreases up to 1.17% since the number of the order does not change significantly. Overall, all of these costs bring an impact to the efficiency of total inventory cost, which can give the company saving up to 40.26%.

4. Conclusions
Basnet-Leung model is one of the effective models to determine the lot size, which involves multi-supplier and multi-periods. This model aims to minimise the total inventory costs, which include purchasing cost, holding cost, and ordering cost. The comparison of the existing model and Basnet-Leung model shows that the proposed model has higher cost efficiency. It reduces the purchasing cost,
holding cost, and ordering cost up to 43.20%, 44.31%, and 1.17% respectively. Overall, it offers a saving of the total inventory cost to the company up to 40.26% and reduce the total quantity order up to 44.76%. Although this model provides the solution with cost efficiency, some constraints need to be considered, such as the availability of the stock in the suppliers and quantity discount. These limitations open the gap for further research to enhance the current model.

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