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# Inventory Optimization Using Consecutive Method and Silver Meal Method for Non-Linear Demand Model: Case Study

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**Abstract-** Inventory is material or good stored to be used to fulfill a specific purpose. Inconstant inventory will affect the inventory cost and products reorder or replenishment. Replenishment was an attempt by the company to hold an ordering to suppliers for the purpose of storing inventory. Therefore we need an analysis to determine the inventory optimization in the form of time and the replenishment quantity so the total inventory cost can be minimized as possible. Calculations for inventory optimization with non-linear demand/sales model can use the consecutive method developed by Wang (2002) and Silver Meal method. The case studies in this study conducted of Malang apples inventory at X Hypermarket. The purposes of this study were to compare the inventory cost of Malang apple at X Hypermarket with the optimization results using the consecutive method and Silver Meal method; determine the quantity and frequency of Malang apple orders at X Hypermarket.

**Index Terms-** consecutive method, non-linear demand, silver meal method

## 1. INTRODUCTION

Inventory is stock managed by the business in anticipation of some future demand (Adeyemi and Salami, 2010) [1]. Provision of supplies meant to face uncertainty, whether it be out of stock, overstock or demand that exceeded forecasts. One way to deal with their out of stock or overstock is to set the time and quantity at the time of the replenishment. Replenishment was an attempt by the company to hold an ordering to suppliers for the purpose of storing inventory.

Companies often get into trouble as a result of the unavailability of materials (inventory), or too many materials piled up in warehouses (Hasian, 2012) [4]. Overstock can lead to the emergence of funds idle, causing holding costs are higher, and the risk of damage to the materials inventories is higher. Out of stock can cause a delay in the materials demand process (sales) can even result in the loss of customers due to the delay of materials (Saputra and Zeplin, 2014)[17].

Calculations for inventory optimization model with non-linear demand / sales could use the consecutive method developed by Wang (2002) [19] and Silver Meal method. The purpose of this study was to compare the cost of inventory Malang apples at X Hypermarket with the optimization results using the consecutive method and Silver Meal method and determine the quantity and frequency of Malang apple orders at X Hypermarket.

## 2. METHODS

### 2.1. *Total inventory cost of current conditions*

Calculation of the total inventory cost of current conditions using the equation:

TIC = ordering cost + holding cost
$TIC = n.o + h.\ \Sigma Q$ ... (1)

Information:
TIC = Total Inventory Cost (US$)
n = frequency of reordering (times)
o = ordering cost, the reorder cost per lot (US$)
h = holding cost per item per unit time (US$)
Q = the quantity of inventory (kg)

### 2.2. *Consecutive method*

The main idea of the consecutive method is to check the possibility of reducing the total cost, with the addition of a reordering occurs when a reduction in inventory storage costs is greater than the cost of the ordering. Consecutive method approach involves solving equations in a way that can be easily done by computing software such as Matlab and Mathematica. Consecutive method not only achieves the lowest total cost but also ensure timely replenishment of the end of the planned time horizon (Wang, 2002) [19].

Analysis of the data using a method developed by Wang (2002) aims to determine the optimal replenishment policy in order to obtain the total cost to a minimum by non-linear demand trends. The replenishment policy to be analyzed consists of the timing and amount of replenishment / reorder will do. In this method, it is assumed that the lead time is 0 and there is no shortage, so it does not calculate the shortage cost.

Stages in this analysis are:

a. Creating demand / sales equation

b. Finding the value of t * (reordering time)

t* found using Newton Raphson method

Setting of the t * with : $c_2A(t^*) > c_1$

c. Calculating the quantity of inventory using the equation:

$$Qi\ (t) = \int_t^{t_i} f(u)\ du. \quad t_{i-1} \le t \le t_i \qquad ...(2)$$

d. Calculating total inventory cost using the equation:

$$W = nc_1 + c_2 \sum_{i=0}^{n-1} \int_{t_i}^{t_{i+1}} Q_{i+1}(u) du \qquad ...(3)$$

e. The first replenishment optimal based on the conditions:

$$\left.\frac{dA}{dt}\right|_{t = t^*} = \int_{t^*}^{t_i} f\ (u)\, du - (t^* - t_{i-1}) f\ (t^*) = 0 \qquad ...(4)$$

Information:

f (t) : demand rate at time t
H : time horizon (day)
c1 : ordering cost, the replenishment costs per lot (US $)
c2 : holding cost per item per unit time (US $)
n : number of replenishment in [0, H] (times)
t * : reordering time (day)
A : reduction of quantity inventory (Qi (t)) at time ($t - t_{i-1}$) when reordering at time t

### 2.3. *Silver Meal method*

Silver Meal Method developed by Edward Silver and Harlan Meal is one of the methods for planning and controlling the supply of materials based on period costs which the purchase of materials is only done at the beginning of the period while holding cost is only charged on materials that store more than one period . Silver Meal starts at the very beginning of the first period, in which the purchase of materials made when the supply of materials accounted for zero. The principle of Silver Meal model is based on the several demand upcoming periods has been predicted earlier. This method focuses on the lot size to be able to minimize the total costs per period, where the lot size is obtained by summing the need for several periods in a row as the lot size tentative (temporary) (Wohos et al., 2014) [20].

Silver Meal is one of the heuristic methods which is a method with the approach that is easy to use, and the repetition of the work will get better results when compared with the other heuristics. This method is trying to find the minimum average cost in each period for a number of periods that have been planned. Silver Meal method used for problems in which the variation of demand over a period of time to the next time period is quite high (Meilani and Ryan, 2013) [8]. The purpose of Silver Meal method is to determine the time additions in the period to minimize the total relevant cost per period (Madinah et al., 2015) [7].

Equation Silver Meal method used is as follows:

$$K(m) = \frac{1}{m}\ (o + h\,D_2 + 2hD_3 + \cdots + (m-1)h\,D_m) \qquad ...(5)$$

Calculated value of K (m), where m = 1,2,3, ..., m, and the count is stopped when the value of K (m + 1)> K (m)

Information :

Dm : value demand in the period ke- m (D1, D2, D3, ..., Dm) (kg)
K(m) : An average inventory costs per unit time (US $)
m : Period
o : ordering cost (US $)
h : holding cost per unit / period (US $)

## 3. RESULT AND DISCUSSION

### 3.1 *Inventory Management Malang Apple at X Hypermarket*

At X Hypermarket, a quality assessment for fruits and vegetables only be done through external quality observation alone. Malang apples sorted physically, where an otherwise good fruit is a fruit with the outer appearance of approaching a clean (minimal black lines). In addition, the fruit also has a color combination of red skin on the top and green at the

bottom that indicates the fruit approaches maturity. Malang apples were sold at X Hypermarket, ordered independently / directly to the local suppliers.

Within six months from May to October 2013, X Hypermarket order Malang apples to seven local suppliers as much as 34 times. Total ordering in May 2013 amounted to 267 kg, in June 2013 amounted to 110 kg, in July 2013 amounted to 62 kg, in August 2013 amounted to 234 kg, September 2013 amounted to 134 kg, and in October 2013 amounted to 97 kg.

Determination of a number of materials ordered must correspond to the amount of the demand, if too much will result in overstock and if out of stock can not meet consumer demand. According to Sampeallo (2012) [14], when the supply of material owned company less than required then the smooth process of trade will be disturbed, customer needs are not being met so that the company would lose customers and the opportunity to earn income due to the depletion of material. If the excessive supply of material resulting in inefficient use of funds so can increase the holding cost and maintenance cost and increase the risk that the materials are damaged or missing.

Cost is the most important factor that must be considered before choosing a supplier company. Costs directly affect the profit margin which is the main goal of the company (Mwikali and Stanley, 2012) [10].

X Hypermarket applying the techniques of inventory in bulk, where this technique has the disadvantage that overstock. Overstock that occurs can cause damage to the Malang apple and will enforce X Hypermarket to make more sales to wholesalers. Sale to wholesalers is due Malang apple that can not be sold to consumers directly, so the cheaper price will be sold to wholesalers or sometimes even less than the purchase price from the supplier. Overstock that occurred at X Hypermarket also resulted holding cost increases. According to Nurhasanah et al. (2014) [11] when the company experienced overstock raw materials in the warehouse, will greatly affect the increased holding cost in a warehouse.

Sales in May to October 2013 is very fluctuate, ie 172.02 kg; 146 kg, 127.06 kg; 151.88 kg; 124.04; and 122.66 kg. This fluctuates sales result to fluctuate stock /non-linear of X Hypermarket inventory. According to Patil and Chapgaon (2016) [12], there are many factors that influence the demand variability. These fluctuations can be attributed to external factors such as changes in trends (rapid changes in consumer preferences) or events affecting the geographic area (such as a major earthquake or natural disaster). Sometimes, fluctuations may also be due to increased marketing efforts have been successful in attracting consumers to the product.

Ordering cost at X Hypermarket is the cost incurred to meet the administrative order for the supplier selected. The ordering cost consists of the cost of product delivery transportation and transaction costs of purchasing the product. Ordering cost for each supplier is different according to a policy that determined by the supplier. According to Shah (2009) [18], an ordering cost includes all fixed costs (the cost component that does not vary with the size of the order) related to an order. The main component of the ordering cost covers the administrative costs associated with the ordering, transportation costs, and revenue costs (costs incurred for administrative work to be done at the time of receiving the order). The value of the average ordering cost used US$ 9.48.

Procurement of raw materials in X Hypermarket using inbound delivery system which is the delivery made by the supplier. Inbound delivery is a process in the reception in the delivery of materials to the receipt of materials (warehouse). This process begins when the goods are ready to be shipped by the vendor and have been determined through what path and transportation used, until when the materials arrive at the warehouse and warehouse receivers make material receipt. Therefore, ordering cost is set to once a reservation is quite high. Priyono (2008) [13], risks that may arise in the delivery of supply (inbound supply) of raw materials in the company are delays in deliveries from suppliers, not exactly the amount of raw materials delivered, an error specification of raw materials delivered and the quality of raw materials lacking / not good.

Holding cost at X Hypermarket is the estimated cost to meet the storage needs of the product. Holding cost calculation is based on the risks that may occur, the need for prevention, and warehousing of products. Values holding cost at the X Hypermarket is 24% of the lowest price the product at a certain period consisting of a 15% opportunity cost, 3% damage cost, and 6% warehousing costs. The average holding cost is used US$ 0.553 / year.

### 3.2 *Inventory Cost Analysis of Malang Apple using Consecutive Method*

The first stage in this analysis is to make equality of the sales data. The sales data is divided into two, the first from May to July 2013 and the second from

August to October 2013. Sales equation f (t) from May to July 2013 is f (t) = 0.0002 $t^2$ - 0.04 t + 6.2228 and sales equation f (t) from August to October 2013 is f (t) = 0.0005 $t^2$ - 0.0563 t + 5.6454. Sales equation model will be different when sales data is also different, so the determination of the sales equation is an important step that will affect the timing and quantity of reordering. The results for the calculation of inventory optimization is divided into two because it is based equations sales.

Table 1. Inventory Optimization using Consecutive Method for Malang Apple from May to July 2013

| n | t* (days to-) | Q (kg) |
|---|---|---|
| 1 | 0.000 | 124.569 |
| 2 | 21.383 | 116.731 |
| 3 | 44.111 | 109.154 |
| 4 | 67.734 | 104.676 |
| | 92.000 | |
| **Total *order* (kg)** | | **455.130** |
| **W (total *cost*) (US$)** | | **92.08** |

Table 2. Inventory Optimization using Consecutive Method for Malang Apple from August to October 2013

| n | t* (days to-) | Q (kg) |
|---|---|---|
| 1 | 0.000 | 114.822 |
| 2 | 22.533 | 104.343 |
| 3 | 46.686 | 95.066 |
| 4 | 69.957 | 96.665 |
| | 92.000 | |
| **Total *order* (kg)** | | **410.897** |
| **W (total *cost*) (US$)** | | **87.31** |

Based on Table 1 and Table 2, for three months, the largest reservation within 24 days and the smallest is 22 days. Malang apples were sold at X Hypermarket has been given a coating that can last approximately 1.5 months, so the distance reordering of 24 days can still be done. In addition, the storage area which uses cooling can also maintain the shelf life of fresh fruits such as apples Malang. The order quantity contained in the first order in the amount of 124.569 kg with ordering total for the three months amounted to 455.130 kg. The results of the ordering total approaching the number of sales during May to July 2013 in the amount of 445.074 kg, so the calculation results almost in line with the existing sales data.

The shelf life of apples is between 1 month to 3 months. Recommended storage temperature is the state's most effective to inhibit the ripening process and prevent the growth of microbial spoilage and to avoid distortions of cold storage. Generally, apples have optimum storage temperature of $30^0$ F - $32^0$ F or about $0^0$ C. The freezing point is the highest for apples $29.3^0$F or $-2^0$C so that apples can be stored at temperatures around minus $1^0$C - $0^0$C or more (Santoso, 2012) [16].

Purposes of determining the optimal inventory level are to minimize the amount of four types of inventory costs consist of the holding cost, setup cost, ordering cost, and shortage cost (Samson and Prakash, 2008) [15]. The ordering cost is influenced by the frequency of spare part ordering and once ordering cost (Kersten et al., 2010) [6]. The important aspect of ordering rules center is the number / lot size of ordering, minimum ordering, and the frequency of ordering (Davis, 2013) [3].

### 3.3 *Inventory Cost Analysis of Malang Apple using Silver Meal Method*

Silver Meal method has the criteria that the lot size selected must be able to minimize the total cost per period. The use of this method aims to minimize the average cost of each period. Inventory optimization of Malang apple using Silver Meal method shown in Table 3.

Inventory management has a goal to have the right material in the right quantity at the right time and place. The specific objectives of inventory control are to make sure the operation runs continuously, maximize sales, protect assets, and minimize inventory costs. Inventory cost control is to maintain inventory at optimum levels is the level that minimizes shortage / stock-outs and eliminating excess inventory, save money and contribute to operating profit. To determine the optimal level, managers must pay attention to the amount of purchases of materials, because it affects a number of inventory levels (Moore et al., 2008) [9].

Table 3. Inventory Optimization of Malang Apple using Silver Meal Method

| **Period** | **Sales Quantity (kg)** | ***Order*** | ***Order* Quantity (kg)** |
|---|---|---|---|
| 1 | 45.760 | 1 | 84.010 |
| 2 | 38.250 | | |
| 3 | 32.400 | 2 | 116.268 |
| 4 | 42.380 | | |
| 5 | 41.488 | | |
| 6 | 32.499 | 3 | 94.717 |
| 7 | 35.779 | | |
| 8 | 26.439 | | |
| 9 | 27.433 | 4 | 87.889 |
| 10 | 32138 | | |
| 11 | 28.318 | | |
| 12 | 21.638 | 5 | 97.096 |
| 13 | 38.888 | | |
| 14 | 36.570 | | |
| 15 | 35.892 | 6 | 97.966 |
| 16 | 34.372 | | |
| 17 | 27.702 | | |
| 18 | 33.155 | 7 | 85.823 |
| 19 | 23.379 | | |
| 20 | 29.289 | | |
| 21 | 31.409 | 8 | 88.007 |
| 22 | 28.639 | | |
| 23 | 27.959 | | |
| 24 | 28.309 | 9 | 83.507 |
| 25 | 29.129 | | |
| 26 | 26.069 | | |
| 27 | 8.354 | 10 | 8.354 |
| **Total Holding Cost (US$)** | | | **8.34** |
| **Total Ordering Cost (US$)** | | | **94.77** |
| **Total Inventory Cost (US$)** | | | **103.11** |

### 3.4 *Comparison of Inventory Cost Optimization of Malang Apple*

Selection of optimization results based on the minimum total inventory cost. Inventory cost comparison of Malang apple can be seen in Table 4. The total cost that compares is total inventory cost of consecutive method without using the equation W with a total inventory cost of Silver Meal method. The best result of optimization is using consecutive method. Determining the correct ordering of the vendor or the size of the lot to be submitted to the productive facilities of the company involves a search for the minimum total cost resulting from the combined effects of four individual cost are holding cost, setup cost, ordering cost, and shortage cost. The time of ordering is an important factor that can affect the cost of inventory (Jacobs et al., 2011) [5]. In inventory management, an important aspect is to reduce the amount of stock in order to maintain minimal inventory costs. At the same time, it is also important for companies to have sufficient stock on hand to keep production and sales running smoothly with the lowest possible cost (Arlbjorn et al., 2010) [2].

## 4. CONCLUSION

After processing and analysis of data, it could be concluded as follows:
(1) The optimization result using consecutive method is 8 times reordering within 6 months and the reorder quantity of 866.027 kg. The optimization result using Silver Meal method is 10 times reordering within 6 months, and the reorder quantity of 843.64 kg.
(2) The optimization method which chosen is consecutive method with the 8 times reorder number in 6 months with the number of order quantity of 886.027 kg consisting of the first order (day 0) 24.569kg; second order (day 22) 116.731 kg; third order (day 45) 109.154 kg; fourth order (day 68) 104.676 kg; fifth order (day 92) 114.822 kg; sixth order (day 115) 104.343 kg; seventh order (day 139) 95.066 kg; and eighth order (day 162) 96.665 kg, with total inventory cost of US$ 179.4.

Table 4. Inventory Cost Comparison of Malang Apple

| | **Current Conditions** | **Consecutive Method** | | **Silver Meal Method** |
|---|---|---|---|---|
| Quantity order (kg) | 904 | 866.027 | | 843.64 |
| Frequency order (time) | 34 | 8 | | 10 |
| Total Inventory Cost (US$) | 347.46 | Using the equation W<br>179.39 | Without equation W, using the equation:<br>$TIC = n.o + h.\sum Q$<br>92.27 | 103.11 |
| Saving (%) | | 48.37 | 73.45 | 70.32 |

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