Analysis of Inventory Control of Perishable Goods with Capital Constraints and Warehouse Capacity Using the Lagrange EOQ Method (Case Study: UD. XYZ)

Ahmad Taufiqur Rahman, Dzakiyah Widyaningrum[*]

Faculty of Engineering, Universitas Muhammadiyah and Universitas Gresik Jl. Sumatera No. 101 GKB, Randuagung, Gresik 61121, East Java, Indonesia

ahmadtaufiqur07@gmail.com, dzakiyah@umg.ac.id[*]

Abstract. *Inventory control is a company policy in managing goods in order to optimize the number of orders and minimize inventory costs. The object of this research is PT XYZ in Gresik city which produces tempeh and tofu. Several raw materials are needed in the production process, one of which is soybeans. As the main raw material for making tempeh and tofu, soybeans are perishable goods. Previously, the company used a method based on past usage data in controlling its inventory, resulting in bloated inventory costs and a buildup of raw materials in the warehouse. Therefore, researchers need a method that is economical and takes into account the limitations of the company. The Lagrange EOQ method is a model that measures the order quantity by looking at one or more restrictions. The results of the Lagrange EOQ method get an order quantity of 20 sacks of soybeans with an order frequency of 27 times a year, a total inventory cost of Rp. 665,575, an ROP of 12 sacks and a safety stock of 10 sacks.*

1.   Introduction

Every company must maintain sufficient raw material inventory to meet production needs so that the company can run smoothly [1]. Companies must manage an efficient production system by creating excellent planning and control, starting from raw material inventory management to the final product of value [2]. Control and handling of raw materials are important factors that affect the smooth running of the production process in order to achieve the desired goals [3]. Ideal stock can lessen organization costs, like the expense of requesting and putting away unrefined components. Consequently, the executives approaches connected with stock will be key in aiding the organization.

According to [4] Stock control is a framework that covers all parts of business stock administration, including buying, delivering, getting, following, warehousing, putting away, supplanting, and repurchasing. Stock control strategies assist with diminishing dangers in business production network the board. Stock decrease is a significant part of functional administration [5]. On the other hand, if the company tries to reduce inventory, the company will face difficulties. The problem of running out of inventory disrupts the smooth or continuous production process of the company. Business people must be able to plan inventory control carefully, raw materials are not too large and not too small. One of the control activities is especially the stage of supplying raw materials.

UD.XYZ is a Home Industry participated in the food area, to be specific creating tempeh and tofu.

This business can possibly be grown further, on the grounds that this item is a regular Indonesian food that is generally utilized as a side dish consistently by individuals from different circles. In making tempeh and tofu, several raw materials are needed including soybeans, yeast, plastic, vinegar and so on, but the main concern is the supply of soybeans because soybeans are the main staple for making tempeh and tofu, besides that soybeans are perishable *goods* which means that the material is easily damaged and cannot be stored for a long period of time, Therefore, companies need to calculate soybean inventory control so that spoilage does not occur which will affect inventory costs and can be detrimental to the company. It is known that UD. XYZ is a small-scale company that has several limitations in controlling availability, counting capital restrictions that can spend Rp. 10,000,000 for each soybean buy and the stockroom region claimed is 53 M², where the soybean stockpiling region is just 13 M² with a distribution center level of ± 2.5 M. Whenever loaded up with soybeans, it can store a limit of 13 M² with a level of ± 2.5 M. When loaded up with soybeans, it can store a limit of 20 sacks.

Previously, the company carried out inventory management based on experience, so that the procurement of raw materials was often late which could later hamper the production process and there was often a buildup of raw materials in the warehouse which resulted in bloated inventory costs. The following is soybean inventory data for 2022.

Tabel 1 Soybean inventory with warehouse capacity at UD. XYZ
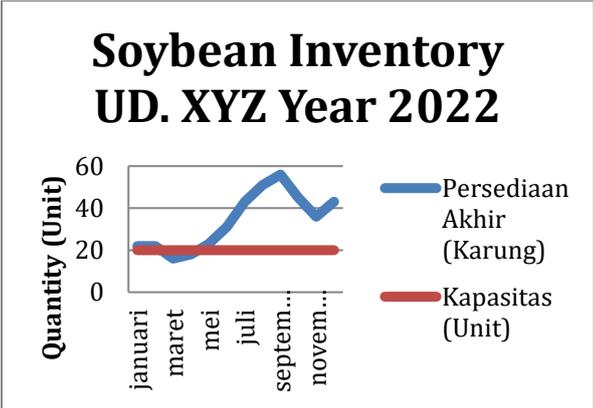
(Sumber : UD. XYZ)

Based on Table 1, the soybean inventory exceeds the capacity of the warehouse, which is only enough to hold 20 sacks of soybeans, and often the company owner's house is used as temporary storage. Therefore, an economical inventory control model is needed and can adjust to the company's capabilities.

To determine the optimal order size for each item and reduce ordering and shipping costs, namely by performing EOQ calculations [6]. However, sometimes the results of the EOQ calculation do not match the limitations of the company. According to [7] The EOQ Lagrange method is a method used to optimize production costs based on existing inventory constraints. Based on the problems obtained, this research aims to find out and analyze the results of calculating the most economical soybean inventory control based on the company's capabilities.

2. Methods
2.1 Observation

This research was conducted at UD. XYZ which is one of the MSMEs in Gresik city. The observation results obtained will later be reviewed with literature that is in accordance with the problems that exist in the company.

2.2 Data collection

The information assortment strategy was completed by meeting and gathering organization information in 2022. The data used in this study are data on the purchase and use of UD raw materials. XYZ for one year. According to [8] the cost of raw material inventory includes holding costs and procurement costs. In addition, the data needed to complete the research are order lead *time* data, *service light,* warehouse capacity and maximum investment costs incurred by the company.

2.3 Raw Material Purchasing Analysis

Company Method

The calculation for purchasing raw materials using the company's method [9]is as follows:
$$Company\ Method = Soybean\ needs/frequency \tag{1}$$

Economic *Order Quantity* (EOQ) *Method*

According to [10] the EOQ method is the quantity of inventory purchases made efficiently so that the total cost of inventory is as low as possible. Based on [11] the EOQ calculation can be formulated as follows:
$$EOQ = \sqrt{\frac{2.S.D}{H}} \tag{2}$$

Where:

EOQ   economical purchase quantity
S   procurement cost
D   forecasted demand at a given time
H   cost

    After knowing the optimal amount of raw material orders, the frequency of new orders can be calculated [12]. According to [11] it can be formulated as follows:
$$I = \frac{D}{EOQ} \tag{3}$$

Details:

I   frequency of purchase within a certain time
D   forecasted demand at a given time
EOQ   economical purchase quantity

Lagrange EOQ Method

According to [13] *EOQ Lagrange* is a method used to optimize inventory costs by considering various constraints faced in the warehouse. The calculation of the lagrange *method* uses maximum and minimum limits. There are several calculations that need to be done using the *Lagrange method* [14] including the following:
$$Q * Li = \sqrt{\frac{2.A_i D_i}{C_i.(a+2)}} \tag{4}$$

    While the constraint value (λ) can be obtained with the following calculation:
$$\lambda = \frac{1}{2}\left(\frac{1}{B}\sum \sqrt{2.A_i.D_i.C_i}\right)^2 \tag{5}$$

    Then to calculate the total investment from the *Lagrange* calculation is as follows:
$$\sum_{i=1}^{n} C_i.Q^*Li \le B \tag{6}$$

Information:

Ci   : product price (Rp/Unit)
Ai   : ordering cost (Rp)

Di   : total demand (Unit/Year)
Q*Li   : Lagrange optimal order quantity (Unit)
l   : Lagrange multiplier factor
a   : storage cost (percentage)
B   : maximum investment value spent by the company (Rp)

2.4 Total Inventory Cost Analysis
The total inventory cost is the sum of the purchase cost, inventory cost and ordering cost [15] which can be formulated as follows:

$$TC = \frac{A_i D_i}{Q^*} + \frac{Q^*(aCi)}{2} \tag{7}$$

Meanwhile, according to [16] the calculation of the company's total inventory cost is as follows:

$$Company\ TIC = (Frequency\ of\ messages\ x\ cost\ of\ one\ message) + (average\ raw\ material\ usage\ x\ holding\ cost\ per\ unit) \tag{8}$$

2.5 Reorder Point
Reorder Point is a certain condition or delay that requires the company to reorder raw materials, so that the arrival of raw materials coincides with the exhaustion of previously purchased raw material inventory . ROP can be formulated as follows:

$$ROP = (d.Lt) + SS \tag{9}$$

Where is :
ROP   : reorder point
D   : average use of raw materials per day
SS   : safety stock (Safety Stock)
Lt   : waiting time (Lead Time)

According to [17] the purpose of safety stock is to minimize stock-out situations and reduce the cost of additional inventory and the total cost due to stock-outs. Storage costs here will increase with the reorder coming from the reorder point due to safety stock. The Safety *Stock* formula can be formulated as follows:

$$SS = SDxZ \tag{10}$$

Information:
SS   : safety stock
SD   : standard deviation
Z   : service level (adjusted for company capabilities)

Meanwhile, the standard deviation formula is as follows:

$$SD = \sqrt{\sum \frac{(x-\bar{x})^2}{n}} \tag{11}$$

Information:
SD   : standard deviation
x   : number of raw materials used each period
$\bar{x}$: average quantity of raw materials used
n   : amount of data

3.   Results and Discussion
3.1 Soybean Usage
UD. XYZ in controlling soybean inventory only relies on sales forecasting in the previous period, so there is often a shortage of materials (*Stockout*) or excess materials (*Overstock)*. To find out the optimal amount of raw material orders, you must first know the amount of raw material requirements needed each month. The amount of soybean usage per month during 2022 is as follows:

Table 2 Soybean use in 2022

Month	Quantity
January	45
February	50
March	54
April	57
May	45
June	47
July	40
August	37
September	40
October	44
November	39
December	35
Total	**533**
Average	**44.4**

(Source: UD. XYZ)

3.2 Soybean Reservation

UD. XYZ purchases soybeans 3 times a month with different order quantities. The following is soybean order data at UD. XYZ during the year 2022.

Table 3Soybean orders for 2022

month	Frequency (Times)	Order quantity (Sacks)
January	3	55
February	3	50
March	3	48
april	3	59
with	3	50
June	3	55
July	3	52
August	3	45
September	3	45
October	3	33
November	3	30
December	3	42
Total	**36**	**564**
Tariffs	**3**	**47**

(Source: UD. XYZ)

3.3 Inventory Cost
Procurement cost (S)

Procurement costs are all costs incurred during the procurement process. Based on data obtained from the company, procurement costs include:

Table 4 breakdown of the company's procurement costs in 2022

Needs	Cost (Rp) / Frequency
Shipping cost	15,000
Credit	500
Total	**15,500**

(Source: UD. XYZ)

Storage cost

Storage costs are costs associated with inventory and inventory maintenance. Based on the observations obtained, the company's storage costs include the following:

Table 5 Company ownership cost breakdown for 2022

Needs	Cost (Rp) / Year
Electricity	1,117,200
Maintenance and Safety	12,000,000
Tax	341,220
Total	**13,458,420**
Total / Unit	**25,250**
Percentage	**5%**

(Source: UD. XYZ)

Based on table 5, storage costs are obtained from electricity bills, maintenance and security and taxes with a total storage cost per year of Rp. 13,208,724 and a total storage cost per unit of Rp. 25,250 with a percentage of 5% of the product price per unit.

3.4 Company Limitations
In running the company, the owner of UD. XYZ has limitations in purchasing and storage capacity of raw materials, including the following:

Table 6 Company limitations

Warehouse		Investment Cost (IDR)
area (M²)	Capacity (Unit)	
13	20	10,000,000

Based on table 6, the maximum investment cost that the company can spend is Rp. 10,000,000 and the warehouse capacity can only store 20 units with an area of 13 M². Furthermore, in determining the reorder point, supporting data is needed to complete the calculation, including: *Lead Time* (waiting time) for 1 day, *service level of* 25% and average use of raw materials per day is 2 units.

3.5 Raw Material Purchasing Analysis

Company method

The requirement for soybeans during 2022 is 533 sacks with a recurrence of requesting in one year of multiple times, so the acquisition of unrefined components as per the organization's technique is as per the following:

$$Company\ Method = Soybean\ needs\ for\ one\ year/Frequency \tag{12}$$

$$Company\ Method = \frac{533}{36} = 15\ Sacks \tag{13}$$

The results of the calculation for purchasing raw materials using the company's method show that the number of orders is 15 sacks with a frequency of ordering 36 times.

Economic *Order Quantity* (EOQ) *Method*

Soybean purchases using the EOQ method can be formulated as follows:

$$EOQ = \sqrt{\frac{2.S.D}{H}} \tag{14}$$

$$Q^* = \sqrt{\frac{2.15500.533}{25250}} = 25.58 \approx 26\ Sacks \tag{15}$$

The calculation of the order frequency using the EOQ method is as follows:

$$I = \frac{D}{Q} \tag{16}$$

$$I = \frac{533}{25,58} = 20.83 \approx 21\ Times \tag{17}$$

The results of the calculation of purchasing raw materials using the EOQ method show that the quantity per order is 26 units with a frequency of ordering 21 times a year. The result is that the order quantity exceeds the warehouse capacity and exceeds the company's maximum investment cost, which is Rp. 13,130,000, so the next step will be the calculation of the *EOQ lagrange* method.

Lagrange EOQ Method

Based on the observation results, supporting data is obtained to complete the *Lagrange* EOQ calculation *as* follows:

Total demand (Di)   = 533 Units
Pre-set storage fees (a)   = 5%
Product Price (Ci   = Rp. 505,000
Message fee (Ai)   = Rp. 15,500
Maximum investment value (B) = Rp. 10,000,000

Before calculating the quantity per order using *Lagrange's* EOQ method can be done, first calculate the value of λ. The calculation of λ value is as follows:

$$\lambda = \frac{1}{2}\left(\frac{1}{B}\sum\sqrt{2.Aj.Dj.Cj}\right)^2 - \frac{a}{2} \tag{18}$$

$$\lambda = \frac{1}{2}\left(\frac{1}{10000000}\sum\sqrt{2.15500.533.50500}\right)^2 - \frac{0,05}{2} \tag{19}$$

$$\lambda = 0,017 \tag{20}$$

Based on the above calculation, the value of λ is 0.017, so after that the optimal number with restrictions will be calculated, the calculation is as follows:

$$Q^*That = \sqrt{\frac{2.Aj.Dj}{Cj.(a+2\lambda)}} \tag{21}$$

$$Q^*That = \sqrt{\frac{2.15500.533}{505000.(0,05+2.0,017))}} \qquad (22)$$

$$Q^*Li = 19.8 \approx 20 \; Units \qquad (23)$$

To figure out the recurrence of orders set in one year, the complete interest for one year is partitioned by the aftereffects of the EOQ Lagrange computation, the estimation is as per the following:

$$I = \frac{Dj}{Q^*That} \qquad (24)$$

$$I = \frac{533}{19,8} = 26.91 \approx 27 \; Times \qquad (25)$$

In view of the Lagrange EOQ computation, it is observed that the ideal request amount is 20 units with a request recurrence for one year of multiple times. Where the complete expense doesn't surpass the organization's most extreme venture cost of Rp. 9,999,000 and the quantity of orders doesn't surpass the stockroom limit.

3.6 Total Inventory Cost Analysis

Inventory control cannot be separated from the costs incurred, so the company must know how much it costs to control soybean inventory. Total inventory costs can be calculated using the formula:

$$Company \; TC = (Frequency \; of \; messages \; x \; Cost \; of \; one \; message) +$$
$$(average \; soybean \; usage \; x \; storage \; cost \; per \; unit) \qquad (26)$$

$$Company \; TC = (3 \; x \; 15500) + (44,4 \; x \; 24,782) = Rp. \, 1,147,227 \qquad (27)$$

Meanwhile, the total inventory cost for the EOQ method is as follows:

$$TC \; EOQ = \frac{A_jD_j}{Q^*} + \frac{Q^*(aC_j)}{2} \qquad (28)$$

$$TC \; EOQ = \frac{15500.533}{26} + \frac{26.(5\%.505000)}{2} = Rp. \, 646,000 \qquad (29)$$

And for the total cost of inventory using the *Lagrange* EOQ method as follows:

$$TC \; Q^*That = \frac{A_jD_J}{Q^*That} + \frac{Q^*Li(aC_j)}{2} \qquad (30)$$

$$TC \; Q^*That = \frac{15500.533}{20} + \frac{20(5\%.505000)}{2} = Rp. \, 665,575 \qquad (31)$$

The total inventory cost from the calculation of the EOQ method results in more economical inventory costs compared to the company method and the *Lagrange* EOQ method. However, in terms of the number of orders, the EOQ method exceeds the capacity of the warehouse which can only accommodate 20 units.

3.7 Comparison of calculation results of Inventory control methods

Carry out calculations for controlling soybean supplies at UD. XYZ needs to consider several aspects starting from the number of orders, warehouse capacity, and inventory costs. From the results of inventory control calculations using several methods, several differences were obtained, including the following:

Table 7 Perbandingan hasil perhitungan metode pengendalian persediaan

Need	EOQ Method	Lagrange EOQ method	Company method
Number of messages (Units)	26	20	15
Frequency (Times)	21	27	36
TC (Rp)	665.575	646.000	1.147.227

Based on table 7, the EOQ method obtains a total inventory cost of at least Rp. 665,775, but the number of orders exceeded the warehouse capacity limit, which means the EOQ method is not suitable for controlling soybean supplies at UD. XYZ, while controlling soybean inventory using the EOQ Lagrange calculation, the number of orders is 20 units, which means it does not exceed the warehouse capacity, but the total inventory cost is greater than with the EOQ method, namely a difference of Rp. 19,575.

Therefore, the EOQ method only emphasizes inventory costs, not the values that are the company's limitations, so it is the most suitable method to use to control soybean inventory at UD. XYZ is the EOQ Lagrange method even though it has greater inventory costs than the EOQ method. After determining the order quantity, reorder points will be calculated to avoid soybean shortages and delays in the production process.

3.8 Reorder Point
Safety stock
The safety *stock calculation* aims to minimize the shortage of raw materials when product demand has increased significantly, the Safety *Stock* calculation is as follows:

Table 8. Calculation of Deviation of soybean usage in 2022

Month	x	$\bar{x}$	x-$\bar{x}$	(x-$\bar{x}$)^2
January	45	44.4	0.6	0.34
February	50	44.4	5.6	31.17
March	54	44.4	9.6	91.84
April	57	44.4	12.6	158.34
May	45	44.4	0.6	0.34
June	47	44.4	2.6	6.67
July	40	44.4	-4.4	19.51
August	37	44.4	-7.4	55.01
September	40	44.4	-4.4	19.51
October	44	44.4	-0.4	0.17
November	39	44.4	-5.4	29.34
December	35	44.4	-9.4	88.67
Total	**533**	**533.0**	**0.0**	**500.92**
Tariffs	**44.4**			

(Source: Data processed)

$$St. Deviasi = \sqrt{\sum \frac{(x-\bar{x})^2}{n}} \qquad (32)$$

$$St. Deviasi = \sqrt{\sum \frac{500{,}92}{12}} = 41{,}74 \qquad (33)$$

Based on the results of the standard deviation calculation and it is known that the service level for soybean raw materials is 25%, the safety *stock* calculation is as follows:

$$SS = SDxZ \qquad (34)$$
$$SS = 41.74 \, x \, 0.25 = 10.44 \approx 10 \, Sacks \qquad (35)$$

The Safety *Stock* calculation gets a total of 10.44 which is rounded up to 10 sacks.

Reorder Point (ROP)

It is known that the Lead *Time* or waiting time for product orders to be received is 1 day, and the number of working days in a year is 312 days, so the average use of raw materials per day is 2 units and the results of the safety *stock* calculation obtained are 10 units so that the ROP can be calculated as follows:

$$ROP = (d \ x \ LT) + SS \qquad (36)$$
$$ROP = (2 \ x \ 1) + 10 = 12 \ Sacks \qquad (37)$$

From the results of the above calculations, the reorder point will be made when the stock in the warehouse remains 12 sacks.

4.   Conclusion

In solving problems at UD. XYZ researchers analyzed several inventory control methods including the EOQ method and the EOQ Lagrange method. The EOQ method is a model for determining lot/order size to minimize inventory costs. However, the problem is not just the size of the order, but the company also has limited capital and warehouse capacity. The EOQ Lagrange method is a calculation to determine the number of lot sizes by considering one or two constraints. Based on the results of this research, it was found that controlling the inventory of soybeans which is a perishable item using the Economic Order Quantity (EOQ) method resulted in a total inventory cost that was less than the method used by the company and the EOQ Lagrange method, namely with a total inventory cost of IDR. 646,000 with an order quantity of 26 units, but the order quantity exceeds UD's warehouse capacity. XYZ can only accommodate 20 units, so the most optimal method for the company's conditions is to use the EOQ Lagrange method even though the total cost is greater than the EOQ method, namely IDR. 665,575 but the number of orders does not exceed the warehouse capacity, namely 20 units with an order frequency of 27 times and reorders will be made when the stock in the warehouse reaches 12 sacks.

Further research can also be carried out on inventory control on raw materials for tempeh and other tofu, so that the calculation results can help companies control inventory more economically. And the results of the research can be used as a reference for future researchers to solve the same problem.

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