

## Determination of Inventory Policy to Address Raw Material Shortages Using Lagrange Multiplier and Capacity Restriction at Coffee Shop X

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| Article Information                                                                                                                 | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| <b>Article History</b><br><br><b>Received</b> : June 23, 2026<br><b>Revised</b> : July 11, 2026<br><b>Published</b> : July 20, 2026 | <p>Managing inventory well in a business is extremely important. It is not uncommon that if this is neglected, it will result in lost sales. A coffee shop in Yogyakarta experienced a similar situation. Some coffee menu items have to be unavailable for order due to a shortage of Arabica and Robusta coffee beans. In addition, this café also faces budget constraints for purchasing coffee beans and limited storage. Therefore, the Lagrange Multiplier method, supplemented with capacity constraints, is used to solve this problem. Based on the calculation results, the optimum order quantity for each type of coffee bean is 3 kg, which does not exceed the maximum storage capacity of 10 kg and is still within the budget of Rp700,000.00. Additionally, reorder point (ROP) was obtained as 0.46 kg (Arabica) and 0.13 kg (Robusta), and safety stock (SS) was 0.32 kg (Arabica) and 0.07 kg (Robusta). After conducting the inventory simulation, it was found that there were no stockouts of coffee beans, and the inventory costs incurred were Rp3,942,710.55 for Arabica coffee beans and Rp1,097,546.31 for Robusta coffee beans. An implication of these is the possibility to fulfill the customer orders while considering the budget and storage limitations.</p> |
| <b>Keywords:</b><br><br><i>Budget Constraint;<br/>Inventory;<br/>Limited Storage;<br/>Stockout.</i>                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

## INTRODUCTION

The company can achieve cost efficiency if it can manage its inventory well. To manage inventory effectively, the company needs to formulate inventory management policies. These inventory management policies vary, starting from determining the ordering schedule with suppliers, setting stock levels for each item, conducting stocktaking, determining safety stock to ensure smooth production, implementing a storage system to maintain product quality, and handling damaged or defective goods.

This inventory management policy can incur inventory costs (Reid & Sanders, 2013). Inventory costs represent the total expenditures associated with maintaining and managing stock, serving as a critical determinant of a firm's operational profitability (Leluc et al., 2023). The inventory cost contributes 20-30% of the company's total logistics cost (Azzi et al., 2014). Effective inventory management requires a precise balance between ordering costs, holding costs, and shortage costs to minimize total expenditures while maintaining service levels (Mohamed, 2024; Munyaka & Yadavalli, 2022). Ordering costs encompass the fixed and variable expenses triggered by procurement activities, such as administrative processing and transportation (Mor et al., 2021).

Conversely, holding costs account for the capital tied up in stored goods, including warehousing expenses and the risk of inventory obsolescence (Sharma et al., 2024). Shortage costs, or penalty costs, emerge when existing supply fails to meet customer demand, potentially resulting in lost sales or the need for costly backordering processes (Castellano & Glock, 2021). Optimizing these three components is essential for firms to mitigate the financial impact of storage activities, which may include insurance, tax fees, and maintenance costs (Soleh et al., 2021), while simultaneously reducing the penalties associated with customer dissatisfaction or lost sales (Manche, 2024).

Discussing the scarcity of products, the unfulfilled orders in retail and service sectors often manifest as lost sales rather backorders (Sindu & Beena, 2024). This paradigm necessitates that firms face penalty costs that often exceed the standard cost of keeping items in stock (Huh et al., 2009). These penalties are not just direct expenses; they also cover harder-to-track issues such as the loss of customer goodwill over time, which complicates financial planning (Liang, 2024). Ignoring the long-term impact of stockouts means companies often underestimate the real costs, leading to poor inventory decisions (Anderson et al., 2006).

Based on existing research, inventory issues with determining the optimal order quantity and when to reorder, considering the total inventory cost, are commonly addressed (Vania & Yoline, 2021; Oktavia & Djunawan, 2024; Tannady & Pratama, 2019). The issue of stockouts is also found in several case study research. A business must implement backorders due to fluctuating demand, considering inventory costs and resolving it with a continuous review model, probabilistic EOQ, using Monte Carlo simulation (Alawiyah, 2026; Nirmal et al., 2022). However, instead of backorders, there are also lost sales events that make this issue more effectively resolved using an analytic approach, namely with the probabilistic EOQ model and including safety stock calculations (Sari et al., 2016). Still with lost sales events, in addition to considering total inventory costs, storage space capacity is also taken into account, which is then resolved with the EOQ model (Irawan et al., 2025; Isrofi & Utami, 2026; Nainggolan & Sunarni, 2019; Utama, 2016). In general, the above studies mostly address stockout issues that only consider total inventory costs and storage space limitations. Additionally, some studies also calculate SS to prevent stockouts. However, stockout issues that consider not only total inventory costs and storage space limitations but also the capital constraints for purchasing products from suppliers have not been addressed. In fact, it is these constraints that are encountered in the problem of this research.

The problem found at Coffee Shop X is that certain coffee menu items are unavailable when the coffee shop opens. Specific coffee menu items are closed and cannot be ordered by customers during operating hours. The unavailability of these menu items occurs due to the depletion of raw materials, causing some coffee menu items to be closed and unavailable for ordering. As a result, the customers decided not to order and left the coffee shop. This caused coffee shop X to lose sales. Ordering coffee beans from suppliers is still done randomly based on estimates. Coffee shop X also cannot stock a large quantity of coffee beans in its storage warehouse due to space limitations and the capital cost of purchasing coffee beans.

The issue of stockouts or raw material shortages has been frequently encountered in previous studies. This research focuses on solving the stockout problem occurring at Coffee Shop X. Instead of solely focusing on inventory costs or storage capacity, this study also considers the budget available for purchasing coffee beans. By calculating the optimal order quantity, determining when to order, and calculating safety stock, it is expected to resolve the stockout issue at this coffee shop while taking into account inventory costs, coffee bean storage space, and the capital cost of purchasing coffee beans. That is what sets this research apart from other studies.

## RESEARCH METHODS

Based on the results of the problem identification process, it is known that the issue faced by Coffee Shop X is experiencing lost sales. Lost sales occur due to a shortage of raw materials, causing the coffee drink menu that uses those raw materials to be out of stock and unavailable for order. In addition, Coffee Shop X has budget constraints for the

procurement of coffee beans. Therefore, the method that will be used is the Lagrange Multiplier method.

The Lagrange multiplier is a method of inventory control that is useful for determining order quantities with the aim of minimizing total inventory costs (Agus Setiawan & Hayati, 2012). In its application, this method considers investment limitations or budget constraints. Equation 1 below is the calculation of total inventory costs exceeding the budget or not.

$$\sum_{i=1}^n C_i Q_i \leq B \quad (1)$$

$C_i$  = Purchase price per unit of raw material  $i$

$Q_i$  = Optimal order quantity of raw material  $i$

$B$  = The size of the company's budget

The first stage in this method is to calculate the order quantity by ignoring constraints, so to calculate the order quantity, Equation 2 below can be used.

$$Q_i^* = \sqrt{\frac{2A_i D_i}{\alpha C_i}} \quad (2)$$

After  $Q_i^*$  is obtained, if the result meets the cost constraint, then the order quantity is  $Q_i^*$ . However, if it does not meet the constraint, the order quantity is recalculated using Equation 3 below.

$$Q_{li}^* = \sqrt{\frac{2A_i D_i}{C_i(\alpha + 2\lambda^*)}} \quad (3)$$

The value of  $\lambda^*$  can be calculated using the formula in Equation 4.

$$\lambda^* = \frac{1}{2} \left( \frac{1}{B} \sum \sqrt{2A_i D_i C_i} \right)^2 - \frac{\alpha}{2} \quad (4)$$

Equation 4 substituted into Equation 3 will yield Equation 5.

$$Q_{li}^* = \frac{B}{\sum_{i=1}^n C_i Q_i^*} Q_i^* = \frac{B}{E} Q_i^* \quad (5)$$

As mentioned, this coffee shop X not only has budget constraints for purchasing coffee beans but also storage space limitations. Therefore, a new mathematical constraint has been added as shown in Equation 6.

$$\sum_{i=1}^n F_i Q_{li}^* \leq S - Sa \quad (6)$$

$Q_i^*$  = Optimal order quantity without raw material constraints  $i$

$Q_{li}^*$  = Optimal order quantity with Lagrange raw material  $i$

$A_i$  = Cost of ordering raw material  $i$  per order

$D_i$  = Average demand for raw material  $i$  per period

$\alpha$  = Percentage of holding costs

$C_i$  = Purchase price per unit of raw material  $i$

$\lambda^*$  = Lagrange multiplier

$E$  = Total budget without obstacles

$F_i$  = The volume of storage space needed to store raw material  $i$

$S$  = Warehouse capacity

$Sa$  = Final inventory capacity

In addition to determining the optimal order quantity, calculations for reorder points and safety stock are also performed as shown in Equations 6 and 7.

$$ROP = SS + (L \times Q_{li}^*) \quad (6)$$

$$SS = Sd \times \sqrt{L} \times Z \quad (7)$$

$Sd$  = Standard deviation

$ROP$  = Reorder point

$SS$  = Safety stock

$L$  = Lead time

$Z$  = Safety factor

In general, the first step taken is to recap the inventory cost data, the purchase of coffee bean raw materials from suppliers, and the coffee demand. The purpose of data recapitulation is to simplify the calculation process. After recapping the data, the next step is to determine the method to be used, namely the Lagrange Multiplier method with the addition of storage space limitation constraints. The explanation regarding the method has been provided above. The next step is to perform calculations using this method, as well as to calculate the reorder point and safety stock. Next, the creation of the simulation model. The simulation model created is based on the results of the Lagrange Multiplier method, followed by the simulation and validation of the simulation model. Here is Figure xx illustrating the stages carried out in this research.

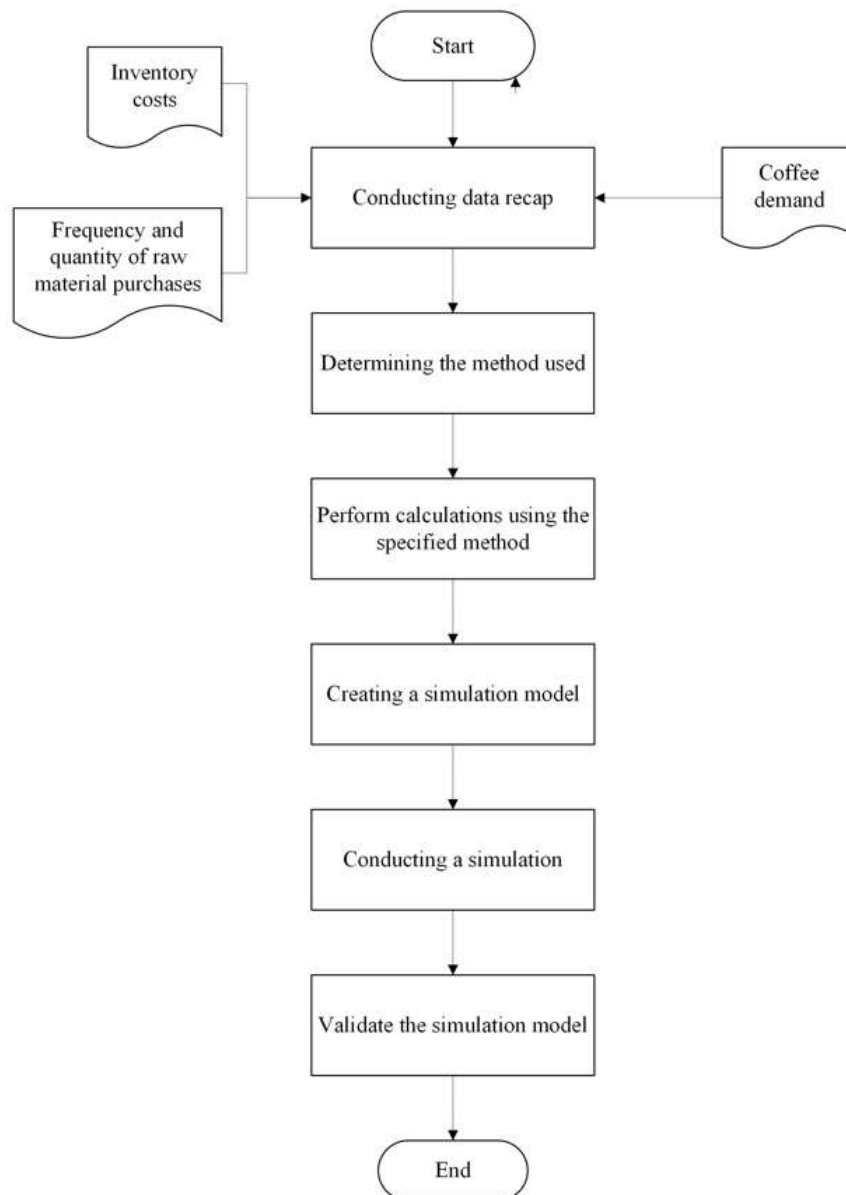


**Figure 1.** Research Flowchart

## RESULTS AND DISCUSSION

The first step taken is to calculate the optimal order quantity, safety stock (SS), and reorder point (ROP) for each type of coffee bean, Arabica and Robusta. This is done to assist Coffee Shop

X in ordering coffee beans from the supplier. The next step is to conduct a simulation using the existing calculations to ensure that the calculations do not result in lost sales.

### Inventory Calculation

Coffee shop X, located in Terban, Gondokusuman, Yogyakarta, offers a variety of coffee menus, some light snacks, and heavy meals. The coffee drinks sold here are not only hot coffee but also ice coffee. The types of coffee beans used in this café are arabica and robusta beans. The coffee beans are purchased in 1 kg packages and are already roasted. The coffee bean demands will be analysed first to identify demand patterns.

The demand data used is the demand data for Arabica coffee beans from July to December as shown in Figure 2, and the demand data for Robusta coffee beans from July to December as shown in Figure 3. In Figures 2 and 3, the demand data for both types of coffee beans is the result of observations conducted over six months in grams, which is the unit used in daily operations by Coffee Shop X.

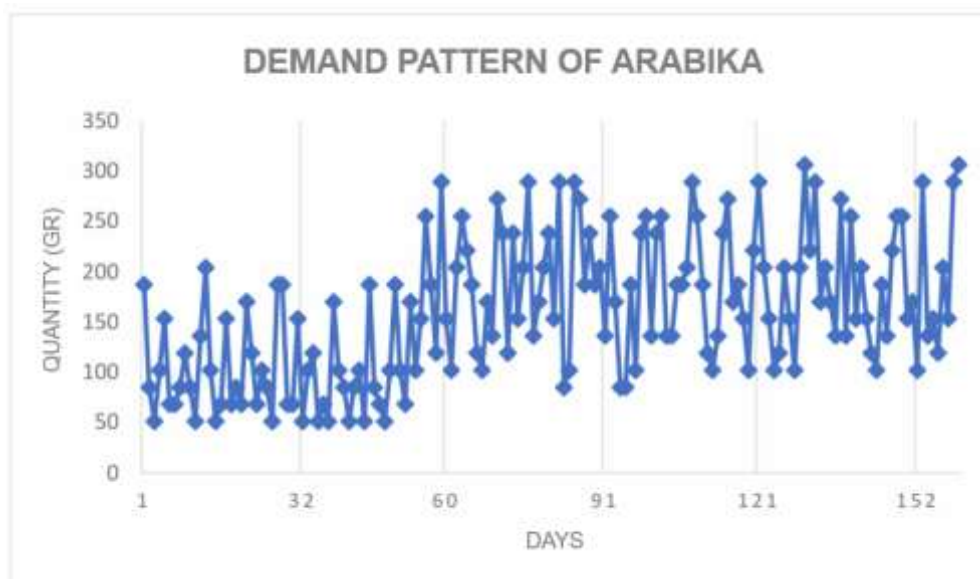


**Figure 2.** Demand Pattern of Arabika Coffee Beans

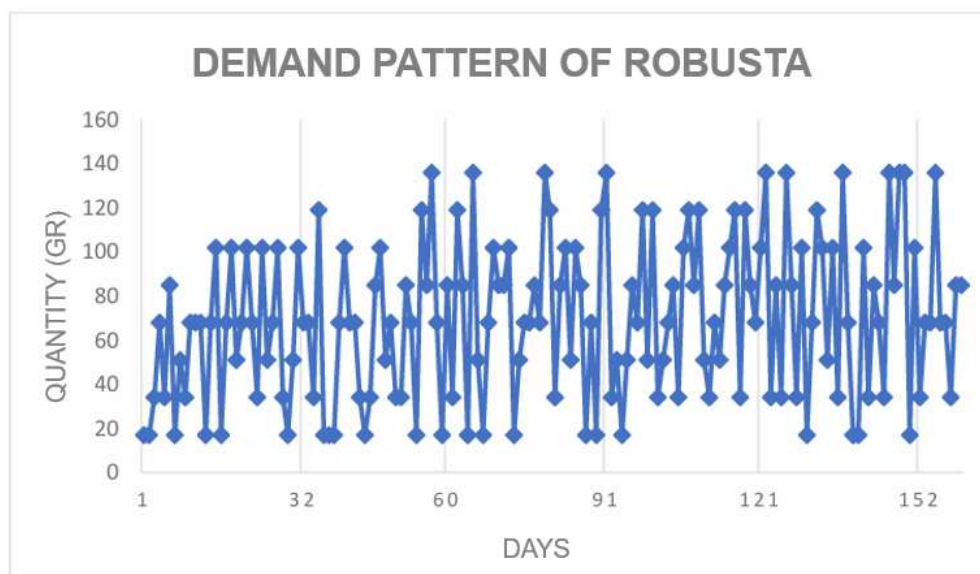


**Figure 3.** Demand Pattern of Robusta Coffee Beans

After collecting demand data for six months in grams and days, the next step is to aggregate it monthly and convert the unit to kg. This kg unit is used by coffee shop X when placing orders to the supplier. Table 1 and Table 2 show the aggregation results of the demand for Arabica and Robusta coffee beans in kg. Based on the two tables below, the average demand for Arabica coffee beans is 4.22 kg, while for Robusta coffee beans it is 1.84 kg.

**Tabel 1.** Monthly Aggregated Recap of Arabica Coffee Bean Demand

| Month             | Demand (kg) |
|-------------------|-------------|
| July              | 2.77        |
| Agust             | 2.69        |
| September         | 4.91        |
| October           | 5.00        |
| November          | 4.95        |
| December          | 5.03        |
| Average per Month | 4.22        |

**Tabel 2.** Monthly Aggregated Recap of Robusta Coffee Bean Demand

| Month             | Demand (kg) |
|-------------------|-------------|
| July              | 1.48        |
| Agust             | 1.48        |
| September         | 2.02        |
| October           | 1.90        |
| November          | 2.07        |
| December          | 2.01        |
| Average per Month | 1.84        |

At coffee shop X, the lead time required from placing an order with the supplier until the coffee raw materials arrive takes one day. Regarding the coffee raw materials, coffee shop X only has one supplier. Every time an order is placed, Coffee Shop X incurs an ordering cost consisting of telephone and transportation costs amounting to Rp15,250.00 per order. In addition to the ordering cost, there are also holding costs. These holding costs consist of storage depreciation and damage costs, which vary for each type of coffee bean. The holding cost for Arabica coffee beans is Rp9,250.00 per kg per month, and the holding cost for Robusta coffee beans is Rp8,000.00 per kg per month. Since all the data has been collected, the Lagrange Multiplier calculation can be performed.

The calculation begins by determining the order quantity while ignoring the existing constraints ( $Q_i$ ). After the results are obtained, it is then checked whether they are satisfactory. If not, then it can be continued using the Lagrange Multiplier method. Here is an example of the calculation of Arabica coffee beans that still ignores the cost constraint.

$$Q_{Arabika}^* = \sqrt{\frac{2 \times 15250 \times 4.22}{0.02 \times 155000}} = 7.09 \approx 7kg$$

So, the order quantity without considering constraints for Arabica coffee beans is 7.09 kg, which is then rounded to 7 kg, while for Robusta coffee beans, it is 6.52 kg, which is then rounded to 7 kg. This rounding is done because raw material orders can only be made in 1 kg increments. Next, substitute  $Q_i^*$  into the total cost budget calculation for purchasing both types of coffee beans.

$$(Rp155.000,00 \times 7) + (Rp80.000,00 \times 7) = Rp1.645.000,00 > B = Rp700.000,00$$

Based on the calculation results, it was found that the outcome is not satisfactory because it exceeds the budget of coffee shop X, where the budget provided is Rp700,000.00 for each order, while the total cost incurred is Rp1,645,000.00. Therefore, the order quantity needs to be recalculated using

the formula  $Q_{li}^*$ . Before calculating it, the Lagrange multiplier factor ( $\lambda^*$ ) needs to be calculated first.

$$\lambda^* = \frac{1}{2} \left( \frac{1}{700,000} \left( \sqrt{2 \times 15,250 \times 4,22 \times 155,000} + \sqrt{2 \times 15,250 \times 1,84 \times 80,000} \right) \right)^2 - \frac{0,02}{2}$$

$$\lambda^* = 0,5(0.30)^2 - 0.01$$

$$\lambda^* = 0.036$$

Next, substitute the obtained  $\lambda^*$  into the following Arabica coffee bean calculation equation:

$$Q_{l(arabika)}^* = \sqrt{\frac{2 \times 15,250 \times 4,22}{155,000(0.02 + 2(0.036))}}$$

$$Q_{l(arabika)}^* = \sqrt{\frac{128,847.25}{13,739.07}} = 3.06 \approx 3 \text{ kg}$$

So, the order quantities were obtained by considering the constraint for Arabica coffee beans at 3.06 kg, which was then rounded to 3 kg, and for Robusta coffee beans at 2.82 kg, which was then rounded to 3 kg. The rounding was done because raw material orders can only be made in 1 kg increments. The next step is to substitute  $Q_{li}^*$  into the cost equation to check whether the obtained result is within the budget or not.

$$(Rp155.000,00 \times 3) + (Rp80.000,00 \times 3) = Rp465.000,00 + Rp240.000,00 = Rp705.000,00$$

Based on the calculations above, the cost incurred for each order is Rp705,000.00. The cost incurred exceeded the budget provided by Rp5,000.00 (0.71%), which was Rp700,000.00. The deviation of 0.71% is tolerable as it represents the true cost-minimizing order quantity under operational constraints, consistent with Lindback's finding that moderate deviations from economic lot sizes incur insignificant economic consequences (Lindback, 1967). With active constraints, the optimum naturally occurs at or slightly beyond the constraint boundary to achieve the true cost minimum (Alnahhal et al., 2024). It was then also discussed with the café owner, and this excess is still tolerable.

Next, it is necessary to calculate whether the order quantity meets the storage capacity constraint or not. Each of the raw materials, namely Arabica and Robusta, has a storage capacity of 10 kg. The optimal order quantity for Arabica and Robusta coffee beans is 3 kg each, which means the total storage space required for the coffee beans is 6 kg. Therefore, the calculated  $Q_{li}^*$  obtained has met all the constraints.

The next calculation is to determine the safety stock (SS) and reorder point (ROP) for Arabica and Robusta coffee beans. The calculations below are an example of the SS and ROP calculations for Arabica coffee beans.

$$Sd_{Arabika} = 1.06 \text{ kg}$$

$$L = 1 \text{ day} = 0.03 \text{ month}$$

$$SL = 95\% \text{ with z-value is 1.65, so:}$$

$$SS_{Arabika} = 1.06 \times \sqrt{0.03} \times 1.65 = 0.32 \text{ kg}$$

$$ROP_{Arabika} = 0.32 + (0.03 \times 4.22) = 0.46 \text{ kg}$$

Based on the calculations that have been made, the safety stock (SS) for Arabica coffee beans is 0.32 kg and for Robusta coffee beans is 0.07 kg. This safety stock is useful to prevent stockouts, especially when demand is high (Castellano & Glock, 2021). Coffee Shop X will also reorder Arabica coffee beans when the stock in the warehouse is down to 0.46 kg, while they will reorder Robusta coffee beans when the stock in the warehouse is down to 0.13 kg.

Here is the summary table (Table 3) for the calculation of  $Q_i$ ,  $Q_{li}^*$ ,  $\lambda^*$ , SS, and ROP for Arabica and Robusta coffee beans:

**Tabel 3.** Inventory Policy of Arabika and Robusta Coffee Beans

|         | $Q_i$ (kg) | $Q_{li}^*$ (kg) | $\lambda^*$ | SS (kg) | ROP (kg) |
|---------|------------|-----------------|-------------|---------|----------|
| Arabika | 7.09       | 3.06            | 0.036       | 0.32    | 0.46     |
| Robusta | 6.52       | 2.82            | 0.036       | 0.07    | 0.13     |

### Inventory Simulation

The simulation model was created with the help of Microsoft Excel. The simulation model for Arabika and Robusta is the same. The simulation model for both consists of columns for days, random numbers, demand, stock, order decision (yes or no), order quantity, lead time, incoming quantity, raw material purchase cost, ordering cost, holding cost, and lost sales cost. Figure 4 is an example of the simulation table for Arabika coffee bean inventory that is used. It should be noted that the same table format is also used for Robusta coffee beans.

| Arabika |                |                  |             |            |        |                     |           |                        |               |                      |                            |               |              |                 |
|---------|----------------|------------------|-------------|------------|--------|---------------------|-----------|------------------------|---------------|----------------------|----------------------------|---------------|--------------|-----------------|
| Days    | Random numbers | Demand (portion) | Demand (kg) | Stock (kg) | Order? | Order Quantity (kg) | Lead Time | Incoming Quantity (kg) | Shortage (kg) | Lost Sales (portion) | Raw Material Purchase Cost | Ordering Cost | Holding Cost | Lost Sales Cost |
|         |                |                  |             |            |        |                     |           |                        |               |                      |                            |               |              |                 |

**Figure 4.** The Inventory Simulation Table

Random numbers in the simulation represent consumer demand, which is random in nature. The generation of random numbers is done using the function  $f(x) = \text{rand}()$ . After the random number is generated, the demand can be calculated. The initial demand column will have the unit of portions. However, this unit will later be converted to kg according to the ordering unit to the supplier. It should be noted that one portion consists of 17 grams, so the demand (kg) is obtained using the formula demand (portions) multiplied by 0.017 kg. The stock column illustrates the total raw material inventory available on that day. The stock calculation is obtained by subtracting the demand for that day from the previous day's stock. If new raw materials arrive on that day, they are added to the inventory.

Order Column? determined based on the available stock. If the available stock on that day is less than the reorder point, an order needs to be placed. If the available stock on that day is more than the reorder point, no order needs to be placed. The order quantity column has a unit of kg, with the amount corresponding to the calculation results using the Lagrange Multiplier method. The lead time for each order is one day. The lead time for ordering Arabika and Robusta coffee beans is the same. In the lead time column, if an order is placed, the lead time will automatically count down according to the duration of the lead time. The arrival column depicts the arrival of raw materials spaced one day apart (lead time) and will be filled after placing an order for raw materials with the supplier. Inventory shortages indicate the quantity of raw materials that cannot be met. The column for stock shortages occurs when demand exceeds the available supply or stock. The lost sales column represents the number of coffee drinks that should have been sold but could not be sold due to a lack of inventory. Lost sales in the simulation are measured in portions, so lost sales are obtained by dividing the inventory shortage by 0.017 and then rounding up.

Next is the column for the raw material purchase cost, which is the expense incurred for each purchase of raw materials. The purchase cost for Arabika coffee beans is Rp155,000.00 per kg and Robusta coffee beans is Rp80,000.00 per kg. The order cost column represents the expense incurred each time raw materials are ordered. The order cost for both Arabika and Robusta coffee beans is the same, which is Rp15,250.00 per order. The holding cost column represents the expense incurred due to the storage of raw materials. The holding cost for Arabika coffee beans is Rp9,250.00 per kg per month or Rp355.77 per kg per day, while the holding cost for Robusta coffee beans is Rp8,000.00 per kg per month or Rp307.69 per kg per day. The holding cost is calculated by multiplying the available stock by the holding cost per kg per day. The lost sales cost column represents the cost incurred due to the loss of coffee drink sales. The lost sales cost per serving for both Arabika and Robusta coffee beans is the same, which is Rp 29,000.00.

The next step is to validate the simulation model using Microsoft Excel. Validation is performed using the t-Test: Two-sample Assuming Unequal Variance. Validation is conducted to ensure that the simulation model accurately represents the real system. The simulation model is considered valid if there is no significant difference between the simulation results and the results of the real system (Indrawati & Madarja, 2022). Based on the validation test results using the t-Test with a significance level ( $\alpha$ ) of 0.05, there is no significant difference between the demand for Arabica coffee beans in the real system and the results generated by the simulation model, thus the simulation model is validated. Similarly, the validation test results for Robusta coffee beans showed that using the same significance level ( $\alpha$ ), there was no significant difference between the demand for Robusta coffee beans in the real system and the results generated by the simulation model, thus validating the simulation model.

Based on the inventory simulation results, the average total inventory cost for Arabica coffee beans using the Lagrange Multiplier method is Rp3,942,710.00, and the average lost sales generated is 0 portions. Next, the inventory simulation results for Robusta coffee beans. The average total inventory cost generated using the Lagrange Multiplier method is Rp1,097,546.31, and the average lost sales generated is 0 portions.

## CONCLUSION

The lost sales problem experienced by Coffee Shop X, which is also hindered by limited capital in purchasing coffee beans from suppliers and storage capacity, affects the performance of this business. The Lagrange Multiplier method can address the lost sales issue by helping to determine the quantity of Arabica and Robusta coffee beans that should be ordered from suppliers, taking into account the available budget and the maximum storage capacity for coffee beans. Based on the calculations, the optimum order quantity for Arabica and Robusta is 3 kg each, where the total purchase cost required is Rp705,000.00, while the available budget is Rp700,000.00 which the excess can still be tolerated. From the maximum inventory capacity, the total storage space needed is 6 kg, while the maximum capacity is 10 kg for each type of coffee bean. Safety stock calculations and order timing determinations were also carried out. The SS for Arabica and Robusta is 0.32 kg and 0.07 kg, respectively, while the ROP is 0.46 kg for Arabica and 0.13 kg for Robusta. Based on the calculations using the Lagrange Multiplier method, inventory simulation was conducted. According to the simulation results, the Lagrange Multiplier method was able to avoid lost sales with an inventory cost of Rp3,942,710.55 for Arabica and Rp1,097,546.31 for Robusta.

This study has found that generally, the purchase budget and limited storage space are constraints that can be resolved simultaneously in terms of inventory. The resolution of these two constraints has not been widely discussed in previous research. By considering both constraints in inventory policy formulation, a business can prevent stockouts, meaning customer orders can be fulfilled, ensuring that arriving customers are not disappointed, while also not forgetting the available purchasing capital and limited storage space.

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