CONTROL OF WOOD RAW MATERIAL INVENTORY WITH LAGRANGE MULTIPLIER METHOD IN PT. XYZ

Shabrina Tsalsabela Ivanda[1]
Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, Indonesia
belaivanda123@gmail.com

Enny Aryanny[2]
Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, Indonesia
enny.ti@upnjatim.ac.id

Abstract

PT. XYZ is a company engaged in the manufacturing industry that uses wood as the main raw material located in the city of Surabaya. PT. XYZ has a problem of less-than-optimal control of raw material inventory which has an impact on the swelling of inventory costs and over capacity of storage space. This study aims to determine the control of wood raw material inventory according to the capacity of the storage space so as to provide a minimum total inventory cost at PT. XYZ. The method used is the Lagrange Multiplier method. Based on the results of the study, the total new storage space was 287.99 m³. The total annual inventory cost of Rp 130.753.379 is smaller than the company's method of Rp 152.898.329, the Lagrange Multiplier method provides savings of 14.48%. The size of the spruce wood order is 58.69 m³ with each order being 9 days, basswood wood is 34.42 m³ with each order being 13 days, and pine wood is 50.89 m³ with each order being 18 days. This study proves that the Lagrange Multiplier method is an effective approach to overcome storage capacity constraints, optimize order quantities, and minimize inventory costs.

Keywords: Inventory, Lagrange Multiplier, Raw Material

INTRODUCTION

Effective management of raw material inventory remains a persistent challenge in manufacturing industries, especially those dependent on natural resources. In sectors such as wood-based manufacturing, inventory control becomes increasingly complex due to the perishable nature of the materials, their substantial storage requirements, and vulnerability to global market price fluctuations. Balancing the need for uninterrupted production with the imperative to avoid excessive storage costs is a common dilemma faced by companies in this sector (Lorenza et.al., 2024).

PT. XYZ, a piano manufacturing company located in Surabaya, relies heavily on high-quality wood such as pine, spruce, and basswood as its primary raw materials. To meet quality standards and ensure continuous production, the company has routinely procured wood in large volumes. However, inconsistencies between purchasing and actual production demands have led to a significant overstock in inventory.

Between March 2024 and February 2025, company records show: a) Pine wood: Purchased 711.29 m^3, used 650.49 m^3 (91.45%), surplus 60.83 m^3; b) Spruce: Purchased 1,612.99 m^3, used 1,283.26 m^3 (79.55%), surplus 329.73 m^3; c) Basswood: Purchased 651.05 m^3, used 633.31 m^3 (97.2%), surplus 17.74 m^3.

This results in a total remaining inventory of 408.3 m^3, far exceeding the warehouse's maximum capacity of 288 m^3 by 120.27 m^3. As a consequence, surplus wood is stored outside, exposing it to environmental damage and accelerating material degradation. This situation contributes to increased storage costs, potential quality loss, and financial inefficiencies across operations. Traditional inventory methods have not adequately addressed these constraints, especially when multiple raw materials must share a limited storage capacity.

This condition underscores the urgency for PT. XYZ to adopt a more robust and efficient inventory control system. This study applies the Lagrange Multiplier method to optimize the inventory levels of pine, spruce, and basswood, aiming to minimize total inventory costs without disrupting production. The Lagrange Multiplier method is well-suited for scenarios involving multiple inventory items and limited storage space, allowing companies to balance production needs with capacity constraints (Isro'ah et.al., 2022). By integrating these constraints into the optimization process, the method supports decision-making in raw material procurement and stock control (Setiawan & Ernawati, 2023).

While various inventory models have been employed in manufacturing, limited studies have specifically addressed multi-material inventory optimization under physical storage constraints, particularly within wood-based industries. This research aims to fill that gap by providing a practical and cost-effective approach tailored to the unique challenges faced by PT. XYZ.

REVIEW OF LITERATURE

Inventory plays a strategic role in buffering fluctuations in customer demand and supporting smooth production processes. While traditionally considered essential, inventory is increasingly viewed as a form of waste within lean manufacturing systems, where efficiency and minimalism are prioritized (Purnomo & Riani, 2018). Nevertheless, the complete absence of inventory can expose companies to higher risks, such as production delays and customer dissatisfaction.

Inventory refers to goods or materials stored for resale or to support operational activities, including manufacturing and assembly (Yanuarsyah & Napianto, 2021). According to Hilman & Kusuma (2021), inventory serves several functions, including the buffer function, economic lot sizing function, and anticipation function. Associated with these functions are various cost components ordering costs, holding costs, and shortage costs which companies must optimize to maintain competitiveness, (Nurpadia et al., 2022).

Economic Order Quantity (EOQ) is a classical inventory control model designed to identify the optimal order quantity that minimizes total inventory costs while meeting projected demand (Fahmi, 2018). In practice, most firms handle multiple inventory items rather than a single product, prompting the use of multi-item EOQ models that account for joint replenishment. (Mubasysyir et al., 2024). The EOQ model for multi-item scenarios can be represented as follows:

$$TIC = \sum_{i=1}^{n} D_i P_i + \frac{S}{T} + \frac{1}{2} \sum_{i=1}^{n} H_i T D_i \quad (1)$$

Where:

- D_i : demand for item *i*,
- P_i : unit price of item *i*,
- S : ordering cost,
- T : cycle time,
- H_i : holding cost per unit for item *i*.

The Lagrange Multiplier method is a fundamental optimization technique based on calculus, used to optimize functions with multiple variables under equality constraints. It is especially useful in inventory management for companies handling multiple product types within limited storage space. This method helps optimize production and inventory costs while accounting for warehouse constraints. By applying it, companies can manage stock more efficiently, avoiding issues such as overstocking, high holding costs, or stockouts that risk losing customers. The model considers the interaction between different product types and typically focuses on one or two constraints in practice (Ishaq & Ernawati, 2021).

$$\sum_{i=1}^{n} W_i Q_i \leq W \quad (2)$$

Where:

- W_i : space requirement per unit of item *i*,
- Q_i : quantity of item *i* ordered,
- W : total available warehouse space.

Forecasting in inventory control is the process of predicting future demand for goods or raw materials based on historical data. Accurate forecasting is essential for efficient inventory management, helping companies avoid overstocking or stockouts, which can impact costs and customer satisfaction. It enables better planning for procurement and production, while optimizing storage and purchasing expenses (Saputri et al., 2023). Forecasting supports producing the right quantity of goods to ensure effective use and transactional value, making precise estimation crucial to reduce uncertainty and dependency on unpredictable factors (Hudaningsih et al., 2020).

Although not the primary focus of this study, forecasting plays a supporting role by providing input values D_i used in optimization models such as EOQ with Lagrange constraints. Thus, reliable forecasting is foundational for effective inventory control.

Forecasting methods are generally divided into qualitative and quantitative approaches. Qualitative forecasting is used when historical data is insufficient and relies on expert judgment and systematic information gathering, employing techniques like the Delphi method and market research (Ahmad, 2020). On the other hand, quantitative forecasting uses historical data and statistical analysis to make objective predictions, typically through time series models like Moving Average and Exponential Smoothing or causal models that analyze the relationship between variables (Septianti & Dahtiah, 2021).

Forecast verification methods, such as the Moving Range Chart (MRC), can be used to evaluate the accuracy of forecasting methods by comparing predicted and actual values (Devi et al., 2023). However, in this study, forecasting is primarily treated as a preliminary step to feed demand data into the Lagrange-based EOQ model.

RESEARCH METHOD

This study employs a quantitative research design with the objective of evaluating warehouse capacity and optimizing inventory management through cost analysis and mathematical modeling. The research was conducted at PT. XYZ in Surabaya, East Java, starting from January 2025 and continuing until all necessary data were successfully collected to support the analysis.

The study utilized both primary and secondary data collection methods. Primary data were gathered through structured interviews with inventory managers and warehouse supervisors to understand current procurement procedures, storage policies, and cost structures. Direct observations were also carried out in the warehouse to monitor space utilization, material handling, and storage configurations. Additionally, documentation such as monthly inventory reports, procurement records, and usage logs was analyzed to obtain historical and operational data. Secondary data were obtained from relevant books, academic journals, and company documents related to inventory control, economic order quantity (EOQ), and optimization under constraint.

The study focused on several key variables that are critical in inventory cost modeling and optimization, including: 1) Raw material purchases: Monthly volume of three types of wood materials acquired by the company; 2)Wood prices: Unit prices of each wood type at the time of procurement; 3) Ending inventory: The quantity of stock remaining at the end of each month; 4) Ordering cost: Fixed administrative and operational expenses incurred each time an order is placed; 5) Holding cost: The cost to store one unit of inventory per period, including space, handling, and risk of obsolescence; 6) Warehouse capacity: The total available storage space (in cubic meters); 7) Safety stock: The buffer stock maintained to prevent stockouts during demand or supply fluctuations; 8) Lead time: The time interval between placing an order and receiving the inventory; 9) Order quantity: The number of units procured in each ordering cycle.

The analysis began with an **evaluation of warehouse capacity**, assessing whether the storage space could accommodate the three wood types without exceeding physical limits. This step identified potential overcapacity issues that could affect operational efficiency.

Subsequently, a **cost analysis** was performed using two methods: (1) the company's existing ordering approach and (2) the **Economic Order Quantity (EOQ)** model. This comparison aimed to assess cost differences and determine potential savings from using EOQ.

To further optimize inventory decisions, the **Lagrange Multiplier method** was applied. This mathematical approach allowed the researcher to find the optimal order quantities for each wood type while accounting for the warehouse's capacity constraint, with the goal of minimizing total inventory costs.

Separately, a **forecasting analysis** was conducted using raw material purchase data from **March 2024 to February 2025**. A horizontal demand pattern was identified, and several forecasting techniques were evaluated. The method with the **lowest Mean Absolute Deviation (MAD)** was selected for accuracy. This forecasting method was then validated through a **Moving Range (MR) Chart** to ensure the stability of the prediction.

Finally, demand forecasts for the period **March 2025 to February 2026** were generated and incorporated into the Lagrange optimization model. This step ensured that the projected procurement plan aligned with warehouse limitations while maintaining cost efficiency.

RESULTS AND DISCUSSION

Descriptive Statistics of Raw Materials

The data used is the company's inventory data for a period of one year from March 2024 - February 2025. The raw materials observed were spruce, basswood, and pine. Purchase data for spruce, basswood, and pine wood is explained in Table 1 below:

Table 1.
Raw Material Purchase Data

No	Month	Spurce (m^3)	Basswood (m^3)	Pine (m^3)
1	March 2024	113,23	54,25	59,60
2	April 2024	93,45	55,60	58,25
3	May 2024	91,46	53,56	62,89
4	June 2024	180,93	53,86	55,64
5	July 2024	109,58	52,80	57,85
6	August 2024	90	53,75	65,31
7	September 2024	187,9	55,02	59,27
8	October 2024	204,03	54,95	58,69
9	November 2024	177,15	53,55	59,01
10	December 2024	89,4	53,71	55,55
11	January 2025	182,55	54,83	60,79
12	February 2025	93,31	55,17	58,44
	TOTAL	1.612,99	651,05	711,29

Details of raw material price data can be seen in the table below:

Table 2.
Raw Material Price

No	Types of Raw Materials	Purchase Price per m^3
1	Spurce	Rp 5.780.000
2	Basswood	Rp 6.990.000
3	Pine	Rp 3.490.000

The booking fee data consists of administration fees, telephone and internet fees, and loading and unloading labor costs. Here are the details of the booking fees:

Table 3.
Order Cost

No	Type of Fee	Total Fee
1	Administration Fee	Rp 100.000
2	Telephone and Internet Fee	Rp 125.000
3	Loading and Unloading Fee	Rp 1.000.000
	Total Order Cost	Rp 1.225.000

Storage cost data consists of operational costs, raw material handling costs, labor costs due to additional handling, inventory insurance costs, and damage risk costs. Details of storage costs can be seen in Table 4.

Table 4.
Storage Cost

No.	Cost Type	Total Cost
1	Tax Cost	3%
2	Electricity Cost	1%
3	Labore Cost Due to Additional Handling	3%
4	Inventory Insurance Cost	6%
5	Damage Risk	2%
Total Storage Cost		15%

PT. XYZ has a raw material storage space with a capacity of 288 m^3 and can accommodate 140 pallets to store 3 types of wood raw materials, including spruce, basswood, and pine. Raw material handling media, dimensions of raw material handling media, and raw material capacity per handling media can be seen in Table 5:

Table 5.
Warehouse Storage Capacity

No.	Description	Raw Material Storage Media	Raw Material Capacity per Handling Media (Pallet) (m^3)	Raw Material Storage Dimension (Wi) (Length x Width x Height) (m^3)
1	Spurce	Pallet	2,04	4 x 1 x 1,02 = 4,08
2	Basswood	Pallet	2,04	4 x 1 x 1,02 = 4,08
3	Pine	Pallet	2,04	4 x 1 x 1,02 = 4,08
	Maximum Volume of Storage Space Capacity			**288 m^3**

Safety stock refers to buffer inventory maintained to anticipate fluctuating raw material demand and reduce the risk of stockouts due to uncertainty. At PT. XYZ, safety stock levels are set for each type of wood: 48.96 m^3 for spruce, 40.8 m^3 for basswood, and

44.88 m³ for pine. Additionally, the lead time defined as the duration from order placement to material arrival is consistently two weeks for all three types of raw materials. These figures are crucial for maintaining stable production operations amid varying demand.

There is the data on the size of the wood raw material order made by PT. Surya Raya Nusatama:

Table 6.
Order Size Data

No.	Raw Material	Order Size (m^3)
1	Spurce	142,8
2	Basswood	61,2
3	Pine	81,6

Inventory Cost Using Company Method

From the warehouse capacity data and order size data, the total storage space calculation can be calculated using the following formula:

$$\sum_{i=1}^{n} W_i \, Q_i \leq \text{W}$$

$$(4{,}08 \times \frac{142{,}8}{2{,}04}) + (4{,}08 \times \frac{61{,}2}{2{,}04}) + (4{,}08 \times \frac{81{,}6}{2{,}04}) \leq 288 \text{ m}^3$$

$$571 \text{ m}^3 \geq 288 \text{ m}^3$$

Based on the calculations that have been done, the storage space capacity of the company's method of 571 m^3 is not optimal because it exceeds the storage space capacity of PT. XYZ of 288 m^3.

After calculating the total storage space using the company method, the next step is to calculate the total cost using the company method.

TCp = Ordering Cost + Storage Cost

$$= \sum_{i=1}^{n} \left(\frac{D_i}{Q_{Li^*}} \text{ x Ordering Cost}\right) + \sum_{i=1}^{n} \left(\frac{Q_{Li^*}}{2} \text{x Raw Material Price x Storage Cost Percentage}\right)$$

$$= \begin{pmatrix} \left(\frac{1.612{,}99}{142{,}8} \times \text{Rp } 1.225.000\right) + \left(\frac{142{,}8}{2} \times \text{ Rp } 5.780.000 \times 15\%\right) + \\ \left(\frac{651{,}05}{61{,}2} \times \text{ Rp } 1.225.000\right) + \left(\frac{61{,}2}{2} \times \text{Rp } 6.990.000 \times 15\%\right) + \\ \left(\frac{711{,}29}{81{,}6} \times \text{Rp } 1.225.000\right) + \left(\frac{81{,}6}{2} \times \text{Rp } 3.490.000 \times 15\%\right) + \end{pmatrix}$$

= Rp 13.836.924 + Rp 61.903.800 + Rp 13.031.168 + Rp 32.084.100 + Rp 10.678.006 + Rp 21.358.800

TCp = Rp 152.893.329

Based on the calculation results of total inventory costs that include ordering costs and storage costs using the company method at PT. XYZ, the cost was Rp152.893.329.

Inventory Cost Using EOQ and Lagrange Method

Following the inventory control calculation using the company's existing method, the next step involves applying the Lagrange Multiplier method. The initial phase focuses on determining the unconstrained inventory level by using the Economic Order Quantity (EOQ) formula (Qi*). This calculation is based on key data such as raw material purchases, purchase prices, ordering costs, and storage costs, which are used to determine the optimal order quantity using the EOQ formula:

$$Q^* = \sqrt{\frac{2\ x\ Di\ x\ Ai}{a\ x\ Ci}}$$

- Spurce Wood

$$Q^* \quad = \sqrt{\frac{2\ x\ 1.612{,}99\ x\ \ Rp\ 1.225.000}{15\%\ x\ \ Rp\ 5.780.000}} = 67{,}51\ m^3$$

- Basswood

$$Q^* \quad = \sqrt{\frac{2\ x\ 651{,}05\ x\ \ Rp\ 1.225.000}{15\%\ x\ \ Rp\ \ Rp\ 6.990.000}} = 39\ m^3$$

- Pine Wood

$$Q^* \quad = \sqrt{\frac{2\ x\ 711{,}29\ x\ \ Rp\ 1.225.000}{15\%\ x\ \ Rp\ \ Rp\ 3.490.000}} = 57{,}7\ m^3$$

Based on storage space capacity data and calculations using the EOQ method, the total new storage space can be calculated using the EOQ method as follows:

$$\sum_{i=1}^{n} W_i\ Q_i \leq \text{W}$$

$$(4{,}08 \times \frac{67{,}51}{2{,}04}) + (4{,}08 \times \frac{39}{2{,}04}) + (4{,}08 \times \frac{57{,}7}{2{,}04}) \leq 288\ m^3$$

$$328{,}43\ m^3 \geq 288\ m^3$$

Based on the calculations that have been done, the total new storage space is obtained, which is 328.43 m^3. This result is not optimal because it exceeds the storage space capacity owned by PT. XYZ by 288 m^3, so it is necessary to calculate using the Lagrange Multiplier method.

After calculating the total new storage space using the Economic Order Quantity (EOQ) method, the next step is to calculate the inventory with constraints using the Lagrange Multiplier method. Based on the maximum warehouse capacity data (W), the total new storage space with EOQ, and inventory calculations using the EOQ method, the Lagrange Multiplier method can be used to calculate the maximum capacity of raw materials in the storage space as follows:

$$Q_{Li}^* \quad = \frac{\text{Maximum Warehouse Capacity}}{\text{Results of Warehouse Capacity Calculation Using EOQ}} \times Q_i^*$$

- Spurce Wood

$$Q_{Li}^* \quad = \frac{288}{67{,}51} \times 328{,}43 = 59{,}20\ m^3$$

- Basswood

$$Q_{Li}^* \quad = \frac{288}{39} \times 328{,}43 = 34{,}2\ m^3$$

- Pine Wood

$$Q_{Li}^* \ = \frac{288}{57{,}7} \times 328{,}43 = 50{,}59\ m^3$$

Based on the results of inventory calculations using the Lagrange Multiplier method (Q_{Li}^*) and warehouse capacity data, the total new warehouse inventory can be determined with Q_{Li}^* as follows:

$$\sum_{i=1}^{n} W_i\ Q_i^* \leq \text{W}$$

$$(4{,}08 \times \frac{59{,}2}{2{,}04}) + (4{,}08 \times \frac{34{,}2}{2{,}04}) + (4{,}08 \times \frac{50{,}59}{2{,}04}) \leq 288\ m^3$$

$$287{,}99\ m^3 \leq 288\ m^3$$

Based on the calculations that have been done, the total new storage space obtained using the Lagrange Multiplier method is 287,99 m^3 . This result shows the optimal value because the order made does not exceed the storage capacity of PT. XYZ which is 288 m^3, so there is no excess capacity of the raw material storage space.

After getting the minimum results from the calculation of the total storage space for new basswood, spurge, and pine using the Lagrange Multiplier method, then calculate the total cost using the Lagrange Multiplier method based on the ordering cost data, storage cost data, and total purchase data for each raw wood material (basswood, spurce, and pine), total inventory data using the Lagrange Multiplier method, and price data for each raw wood material.

$$TC\ Q_{Li}^* = \text{Ordering Cost} + \text{Storage Cost}$$

$$= \sum_{i=1}^{n}\left(\frac{D_i}{Q_{Li*}} \text{ x Ordering Cost}\right) + \sum_{i=1}^{n}\left(\frac{Q_{Li*}}{2} \text{ x Raw Material Price x Storage Cost Percentage}\right)$$

$$= \begin{pmatrix} \left(\frac{1.612,99}{59,2} \times \text{Rp } 1.225.000\right) + \left(\frac{59,2}{2} \times \text{ Rp } 5.780.000 \times 15\%\right) + \\ \left(\frac{651,05}{34,2} \times \text{ Rp } 1.225.000\right) + \left(\frac{34,2}{2} \times \text{Rp } 6.990.000 \times 15\%\right) + \\ \left(\frac{711,29}{50,59} \times \text{Rp } 1.225.000\right) + \left(\frac{50,59}{2} \times \text{Rp } 3.490.000 \times 15\%\right) + \end{pmatrix}$$

= Rp 33.375.236 + Rp 25.664.483 + Rp 23.317.949 +
Rp 17.930.753 + Rp 17.221.884 + Rp 13.243.075

$TC\ Q_{Li}^*$ = Rp 130.753.379

From the results of calculating the total inventory costs using the Lagrange Multiplier method, the minimum total inventory costs obtained are Rp 130.753.379.

Table 7.
Comparison of Total Inventory Cost of Company Method with Lagrange Multiplier Method

Company Method	Lagrange Multiplier Method	Total Inventory Cost Difference
Rp 152.893.329	Rp 130.753.379	Rp 22.139.905

Based on the comparison of total inventory costs, the Lagrange Multiplier method yields the most optimal results, as it produces lower total inventory costs than the company's current approach. This finding aligns with the theoretical justification presented by Ishaq & Ernawati, (2021), who states that the Lagrange Multiplier method is particularly effective for solving constrained optimization problems in inventory management. Additionally, similar applications in prior studies (Isro, 2022) have demonstrated the method's capability to minimize inventory-related costs under given constraints.

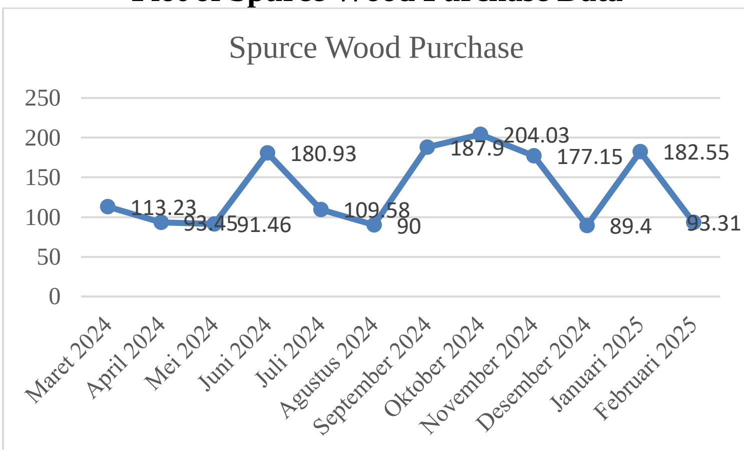
The lower costs achieved through the Lagrange approach are primarily due to its ability to balance order quantity and frequency while adhering to space limitations, thereby reducing excessive holding costs. In practical terms, this implies that the company could optimize its procurement policy by adjusting order sizes to fit existing warehouse capacity more efficiently, avoiding overstocking and minimizing waste. Additionally, this outcome invites strategic considerations: Should the company continue operating within its current storage constraints, or is there a cost-benefit justification for expanding warehouse capacity to allow for larger, less frequent orders? These trade-offs between storage cost and ordering frequency must be carefully evaluated to align inventory strategy with overall operational efficiency and cost control objectives.

Forecasting and Control Verification

The first step in planning raw material inventory control using the Lagrange Multiplier method is forecasting the purchase volume of raw materials. Historical data from March 2024 to February 2025 were analyzed by plotting time series graphs for each type of wood to identify demand patterns. The following figures illustrate the historical purchase plots:

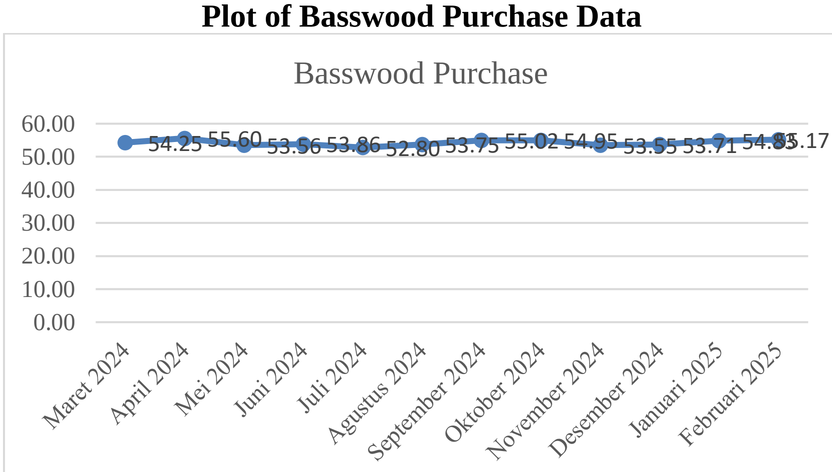
- Spurce Wood

Figure 1
Plot of Spurce Wood Purchase Data



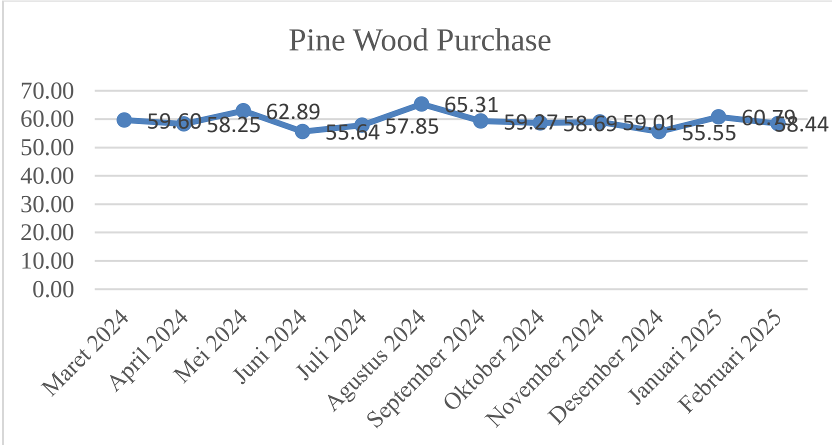
- Basswood

Figure 2
Plot of Basswood Purchase Data



- Pine Wood

Figure 3
Plot of Pine Wood Purchase Data



From the plotted data, it is evident that the demand pattern for each type of wood over the one year follows a horizontal trend, indicating relatively stable and consistent demand over time. Accordingly, forecasting methods suitable for horizontal data patterns namely Moving Average, Single Exponential Smoothing, and Double Exponential Smoothing were applied. The Mean Absolute Deviation (MAD) for each method was calculated to evaluate the forecasting accuracy, with the lowest MAD selected as the most suitable method for each wood type.

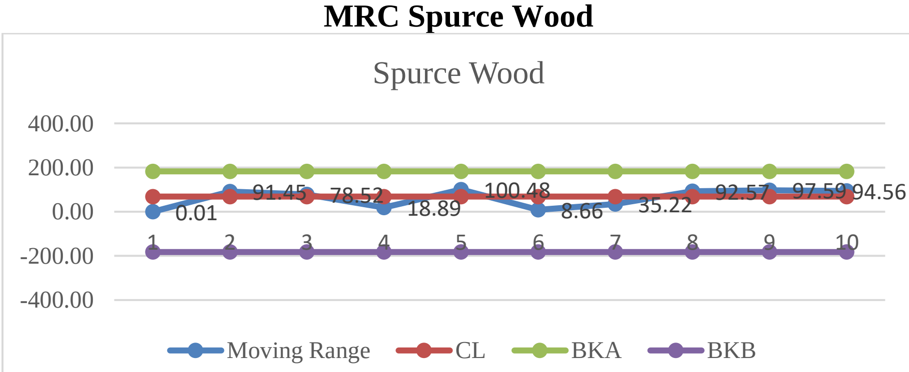
Table 8.
Comparison of MAD Values in Each Forecasting Method

Types of Raw Materials	Moving Average Methode	Single Exponential Smoothing Methode	Double Exponential Smoothing Methode
Spurce	54,74	**46,93**	47,78
Basswood	0,98	**0,76**	0,79
Pine	3,19	**2,41**	2,54

The Single Exponential Smoothing method was chosen for all wood types, as it consistently yielded the smallest MAD. After selecting the smallest Mean Absolute Deviation (MAD) value from the demand forecasting method, an MRC test is conducted to determine whether the demand data is controlled or not based on the forecasting method used. The following is a forecast verification for the entire purchase of wood raw materials:

- Spurce Wood

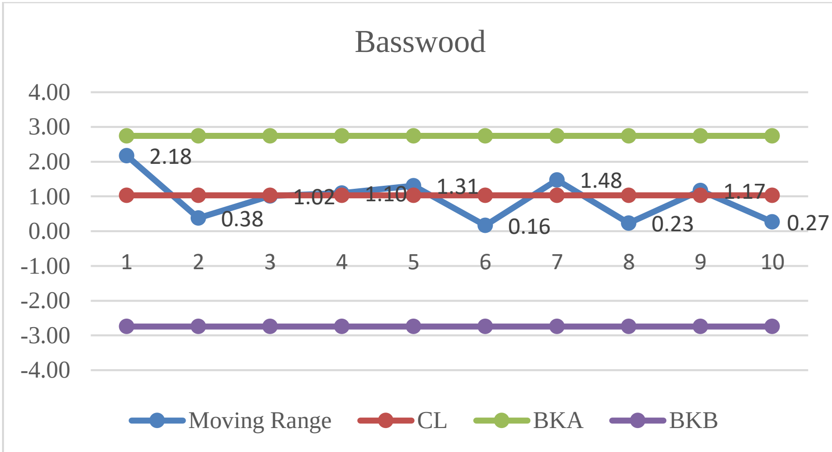
Figure 4
MRC Spurce Wood



From the image above, it can be seen that the data for purchasing spruce wood raw materials does not contain data that exceeds the upper or lower control limits. The data are within control limits, indicating stable demand.

- Basswood

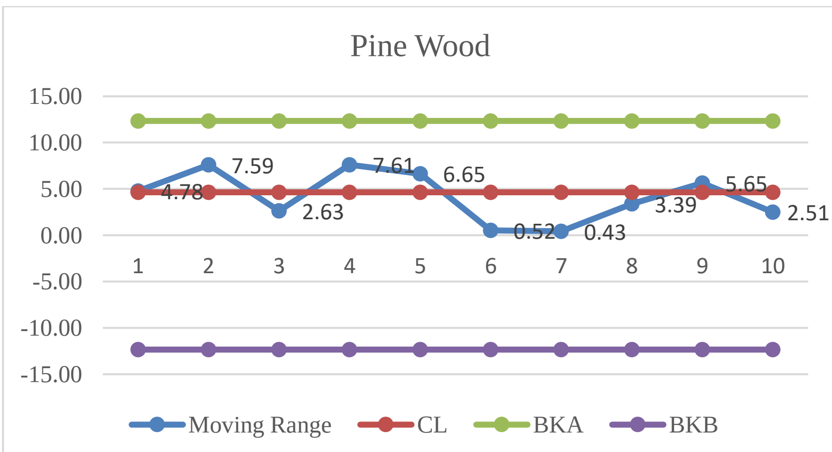
Figure 5
MRC Basswood



From the image above, it can be seen that the data obtained from purchasing basswood raw materials does not contain data that exceeds the upper or lower control limits, confirming demand consistency.

- Pine Wood

Figure 6
MRC Pine Wood



From the image above, it can be seen that the data on purchasing pine wood raw materials does not contain data that exceeds the upper or lower control limits. There are no anomalies, confirming that the forecasting model is statistically in control.

After knowing the results of the Moving Range Chart test for each raw material, the next step is to determine the results of the wood raw material purchase forecast.

Table 9.
Wood Raw Material Purchase Forecast March 2025 to February 2026

No	Month	Spurce	Basswood	Pine

		(m^3)	(m^3)	(m^3)
1	March 2025	130,54	54,3	59,27
2	April 2025	130,54	54,3	59,27
3	May 2025	130,54	54,3	59,27
4	June 2025	130,54	54,3	59,27
5	July 2025	130,54	54,3	59,27
6	August 2025	130,54	54,3	59,27
7	September 2025	130,54	54,3	59,27
8	October 2025	130,54	54,3	59,27
9	November 2025	130,54	54,3	59,27
10	December 2025	130,54	54,3	59,27
11	January 2026	130,54	54,3	59,27
12	February 2026	130,54	54,3	59,27
	TOTAL	1.612,99	1.566,48	651,6

Based on the table above, the total forecast for purchasing wood raw materials for March 2025 to February 2026 is 1,566.48 m^3 spruce wood, 651.6 m^3 basswood wood, and 711.24 m^3 pine wood.

The forecast results for the period of March 2025 to February 2026 confirm a stable monthly demand for each type of wood. This is consistent with the horizontal trend observed in historical data. The absence of any points outside the control limits in the MRC test, along with the low MAD values, indicates that the selected forecasting model is both accurate and reliable. This stability in demand supports better planning for procurement and inventory control, making the next stage inventory optimization using the Lagrange Multiplier more predictable and efficient.

4.5 Inventory Control with Lagrange Multiplier Method March 2025 – February 2026

Following the inventory control calculation using the company's existing method, the next step involves applying the Lagrange Multiplier method. The initial phase focuses on determining the unconstrained inventory level by using the Economic Order Quantity (EOQ) formula (Qi*). This calculation is based on key data such as raw material purchases, purchase prices, ordering costs, and storage costs, which are used to determine the optimal order quantity using the EOQ formula:

$$Q^* = \sqrt{\frac{2 \; x \; Di \; x \; Ai}{a \; x \; Ci}}$$

- Spurce Wood

$$Q^* = \sqrt{\frac{2 \; x \; 1.566{,}48 \; x \; Rp \; 1.225.000}{15\% \; x \; Rp \; 5.780.000}} = 66{,}53 \; m^3$$

- Basswood

$$Q^* = \sqrt{\frac{2 \; x \; 651{,}6 \; x \; Rp \; 1.225.000}{15\% \; x \; Rp \; Rp \; 6.990.000}} = 34{,}42 \; m^3$$

- Pine Wood

$$Q^* = \sqrt{\frac{2 \; x \; 711{,}24 \; x \; Rp \; 1.225.000}{15\% \; x \; Rp \; Rp \; 3.490.000}} = 50{,}89 \; m^3$$

Based on storage space capacity data and calculations using the EOQ method, the total new storage space can be calculated using the EOQ method as follows:

$$\sum_{i=1}^{n} W_i \, Q_i \leq \text{W}$$
$$(4{,}08 \times \frac{66{,}53}{2{,}04}) + (4{,}08 \times \frac{39{,}02}{2{,}04}) + (4{,}08 \times \frac{57{,}69}{2{,}04}) \leq 288 \text{ m}^3$$
$$326{,}49 \text{ m}^3 \geq 288 \text{ m}^3$$

Based on the calculations that have been done, the total new storage space is obtained, which is 329,49 m^3. This result is not optimal because it exceeds the storage space capacity owned by PT. XYZ by 288 m^3, so it is necessary to calculate using the Lagrange Multiplier method.

After calculating the total new storage space using the Economic Order Quantity (EOQ) method, the next step is to calculate the inventory with constraints using the Lagrange Multiplier method. Based on the maximum warehouse capacity data (W), the total new storage space with EOQ, and inventory calculations using the EOQ method, the Lagrange Multiplier method can be used to calculate the maximum capacity of raw materials in the storage space as follows:

$$Q_{Li}^* = \frac{\text{Maximum Warehouse Capacity}}{\text{Results of Warehouse Capacity Calculation Using EOQ}} \times Q_i^*$$

- Spurce Wood
  $Q_{Li}^* = \frac{288}{133{,}07} \times 326{,}49 = 58{,}69 \text{ m}^3$
- Basswood
  $Q_{Li}^* = \frac{288}{78{,}04} \times 326{,}49 = 34{,}2 \text{ m}^3$
- Pine Wood
  $Q_{Li}^* = \frac{288}{57{,}7} \times 326{,}49 = 50{,}89 \text{ m}^3$

The following is a calculation of the time interval for ordering raw wood materials:

- Spurce Wood
  $T = (\frac{Q}{D} \text{ x Working Day}) = \frac{58{,}69}{1.566{,}48} \text{ x } 256 \text{ days} = 9 \text{ days}$
- Basswood
  $T = (\frac{Q}{D} \text{ x Working Day}) = \frac{34{,}42}{651{,}6} \text{ x } 256 \text{ day} = 13 \text{ days}$
- Pine Wood
  $T = (\frac{Q}{D} \text{ x Working Day}) = \frac{50{,}89}{711{,}24} \text{ x } 256 \text{ day} = 18 \text{ days}$

Based on the results of the calculations that have been carried out, the time interval for each order is obtained, namely, for spruce wood for 9 days, basswood for 13 days, and pine wood for 18 days.

Based on the results of inventory calculations using the Lagrange Multiplier method (Q_{Li}^*) and warehouse capacity data, the total new warehouse inventory can be determined with Q_{Li}^* as follows:

$$\sum_{i=1}^{n} W_i \, Q_i^* \leq \text{W}$$
$$(4{,}08 \times \frac{58{,}69}{2{,}04}) + (4{,}08 \times \frac{34{,}42}{2{,}04}) + (4{,}08 \times \frac{50{,}89}{2{,}04}) \leq 288 \text{ m}^3$$
$$288 \text{ m}^3 \leq 288 \text{ m}^3$$

Based on the calculations that have been done, the total new storage space obtained using the Lagrange Multiplier method is 288 m^3 . This result shows the optimal value because the order made does not exceed the storage capacity of PT. XYZ which is 288 m^3, so there is no excess capacity of the raw material storage space.

After getting the minimum results from the calculation of the total storage space for new basswood, spurge, and pine using the Lagrange Multiplier method, then calculate the total cost using the Lagrange Multiplier method based on the ordering cost data, storage cost data, and total purchase data for each raw wood material (basswood, spurce, and pine), total inventory data using the Lagrange Multiplier method, and price data for each raw wood material.

$$TC\ Q_{Li}^* = \text{Ordering Cost} + \text{Storage Cost}$$

$$= \sum_{i=1}^{n}\left(\frac{D_i}{Q_{Li^*}} \text{ x Ordering Cost}\right) + \sum_{i=1}^{n}\left(\frac{Q_{Li^*}}{2} \text{ x Raw Material Price x Storage Cost Percentage}\right)$$

$$= \begin{pmatrix} \left(\frac{1.566,48}{58,69} \times \text{Rp } 1.225.000\right) + \left(\frac{58,69}{2} \times \text{ Rp } 5.780.000 \times 15\%\right) + \\ \left(\frac{651,6}{34,42} \times \text{ Rp } 1.225.000\right) + \left(\frac{34,42}{2} \times \text{Rp } 6.990.000 \times 15\%\right) + \\ \left(\frac{711,24}{50,89} \times \text{Rp } 1.225.000\right) + \left(\frac{50,89}{2} \times \text{ Rp } 3.490.000 \times 15\%\right) + \end{pmatrix}$$

= Rp 32.697.046 + Rp 25.441.431 + Rp 23.190.563 + Rp 18.044.478 + Rp 17.119.969 + Rp 13.320.974

$TC\ Q_{Li}^*$ = Rp 129.814.460

From the results of calculating the total inventory costs using the Lagrange Multiplier method, the minimum total inventory costs obtained are Rp 129.814.460.

CONCLUSION

Based on the analysis, the implementation of the Lagrange Multiplier method for inventory management at PT. XYZ proved to be more optimal than the company's existing method. It resulted in a total storage volume of 287.99 m³, staying within the maximum warehouse capacity of 288 m³, and an annual inventory cost of Rp 130,753,379. Compared to the company's current method, which incurs a total cost of Rp 152,898,329, the Lagrange Multiplier method yields savings of Rp 22,139,950 or 14.48%. Forecasting for the March 2025 to February 2026 period further demonstrates improved efficiency, with a projected annual inventory cost of Rp 129,814,460 and full utilization of the 288 m³ storage space. The optimized ordering strategy includes ordering 58.69 m³ of spruce every 9 days, 34.42 m³ of basswood every 13 days, and 50.89 m³ of pine every 18 days. This method not only optimizes storage and reduces inventory costs but also offers a more efficient ordering strategy, making it an effective and economical solution for managing wood raw material inventories. Based on the previous discussion, this study suggests that PT. XYZ should manage its raw material inventory by carefully considering purchase quantities and available storage space to prevent overstocking and increased inventory costs. The company is encouraged to adopt the Lagrange Multiplier method to minimize overall inventory expenses and achieve optimal order quantities within warehouse capacity. Additionally, future researchers are advised to explore potential improvements in warehouse capacity, such as implementing vertical storage or racking systems, to enhance space utilization.

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