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Controlling the Inventory of Boiler Ash Raw Materials in Organic Fertilizer Using the Minmax Method (Case Study: UMTR Belilas Organic Fertilizer)

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A B S T R A C T

This study evaluates the inventory management of boiler ash raw materials in an independent organic fertilizer company, UMTR Belilas, using the Min-Max method supported by forecasting. The main problem in this study is that consumer demand is often not met on time due to suboptimal inventory management. The purpose of this research is to maintain the availability of raw materials in order to meet consumer demand optimally while reducing the risk of out-of-stock and overstocking. The results show that the application of the Min-Max method results in a minimum stock limit of 88.5 kg and a maximum stock of 171 kg, with an optimal purchase quantity of 82.5 kg per order. The safety stock level is calculated at 6.1 kg, while the Reorder Point (ROP) is set at 88.5 kg. With an order frequency of 120 times per year, this method has succeeded in optimizing storage costs through faster stock turnover. The combination of the Min-Max method and forecasting has proven to be effective in responding to fluctuations in demand, ensuring the availability of raw materials on time, and supporting the operational sustainability of organic fertilizer production.

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1. INTRODUCTION

Manufacturing plays an important role in national economic growth through its contribution to gross domestic product (GDP) and increased added value. However, challenges in managing raw material inventories are often a significant obstacle, especially from the manufacturing sector that relies on raw materials from external parties (Harahap et al., 2023). Organic fertilizer is one of the many manufactured products that go through the processing process. The implementation is to regenerate and increase the effectiveness of microorganisms in the soil as plant food and can add value to a product (Putri et al., 2022). UMTR Belilas Organic Fertilizer is an independent business that produces waste-based organic fertilizers such as boiler ash. Boiler ash raw materials are the most widely used materials in producing organic fertilizer at UMTR Belilas, in addition to being a waste that has the potential to pollute the environment so

that utilization in fertilizer production must be done quickly. Limited supply and dependence on availability from external suppliers are also problems with boiler ash supply. Supply deviations and fluctuations in consumer demand result in operational and storage cost overruns and the risk of losing customers. To overcome these problems, the implementation of effective inventory control methods is a must for the Company to be able to respond better to operational needs. One relevant approach is the minmax method, which is designed to dynamically determine the minimum and maximum limits of the supply based on actual needs and future predictions. With the application of the minmax method, the Company can maintain a balance between sufficient inventory to meet consumer demand and reduce the risk of accumulation of raw materials which can increase storage costs and reduce quality

The minmax method also provides flexibility in inventory management by allowing factories to adjust stock limits according to changes in demand patterns that are often volatile. Supported by accurate demand forecasts, this method is able to help companies manage resources more efficiently, minimize operational costs, and optimize the strategic decision-making process related to raw material management (Saripudin & Wahyudin, 2024). This study aims to evaluate the in-depth application of the minmax method in the management of boiler ash raw material inventory. The main focus of the study is to identify the extent to which the method can improve the operational efficiency of companies, reduce potential losses due to supply instability, and ensure that consumer needs can be met consistently and in a timely manner.

2. LITERATURE REVIEW

Control is the act of preventing or managing a change in parameters, situations or conditions that include management stages to maximize the achievement of goals (Mevia & Purnomo, 2023). Inventory is goods in the form of raw materials, semi-finished and finished goods that are prepared to meet the purpose of an agency or business line (Pradana & Jakaria, 2020). Some of the inventory functions are as follows: 1) Decoupling Function, 2) Economiclot Sizing Function, and 3) Anticipation Function (Sofwan et al., 2020). Types of inventory are also managed in a company based on their functions and objectives, which are as follows: 1) Raw materials, 2) Purchase of spare parts/components, 3) Auxiliary materials, 4) Work supplies in the process, 5) Finished goods inventory (Manik et al., 2021). Inventory costs consist of several types as follows: 1) purchase costs, 2) pawnshop costs, 3) storage costs, 4) inventory shortage costs (Ratningsih, 2021).
Inventory control is a management process that has the purpose of regulating and supervising the flow of inventory in a line of the Company. Inventory control ensures that the inventory of goods, both raw materials, goods in process and finished goods (Manik et al., 2021). The functions and objectives of inventory control include the following: 1) providing a choice of goods to meet consumer demand, 2) separating some materials from the production process, 3) protecting the Company from inflation and price increases, 4) marketing can serve consumers as quickly as possible, 5) production operates efficiently, 6) in the event that they want to minimize forms of investment that can negatively impact the market (Hernawati et al, 2020). This study takes advantage of a gap from previous research on specific case studies, namely boiler ash in organic fertilizers that have not been studied in previous research. This will certainly open up a new perspective on controlling factory waste inventory that can be managed and reused. The next gap is in terms of cost optimization and planning that combines the Minmax and Forecasting methods for more mature planning from the accuracy results of the two DA methods; AM facing fluctuations in demand and stock uncertainty.

Forecasting

Forecasting is the data and information used by the Company to develop future strategies. Through forecasting, companies can create strategies in the form of production parameters and supply of raw materials, so that the company's profit expectations increase (Mollah & Saputra, 2022). There are several types of forecasting methods as follows:

1. Moving Averages

Moving average is a forecasting method that is carried out by taking a group of values to find the average value as a prediction of the upcoming period (Sartika, 2020)

$$Y'_{t+1} = \frac{T_{t-n+1} + \ldots \cdot 1 + T_{t+1} + T_t}{n} \quad (1)$$

Information:
Y'_{t+1} = approximate value T+1
Tt = Rill Value of period t
N = time series used

2. Weighted Moving Average
The Weighted Moving Average is a simple form of the rise of the moving average. This gives more weight to newer data than older ones (Silvya et al., 2020).

$$WMA = \frac{(\sum(Dt \text{ x weight}))}{(\sum \text{weight})} \quad (2)$$

Information:
Dt = actual data for period t
Weight = weight given/month

3. Exponential Smoothing
The exponential smoothing method is a moving average method that gives more weight to the last data than the initial data. The exponential smoothing method uses alpha values to determine the most optimal forecasting results (Wirabhuana et al., 2007).

$$Ft = \alpha\ A\ (t) + (I - \alpha)F(t - 1) \quad (3)$$

4. Linear Regress
Linear regression is a test of the relationship between two groups of data, namely non-free variables (Y) and independent variables (X)

$$\hat{Y} = a + bX \quad (4)$$

Information:
$\hat{Y}$ = the value of the Y variable from the estimated result
Y = non-free variable (predicted)
a = *intercept,* $\hat{Y}$ value on X = 0
b = *slope,* the average change Y to the action of one unit X
X = free variable

A measure of forecast accuracy that shows the degree of deviation between expected demand and actual demand. The measurement of forecasting results is as follows:

1. Mean Absolute Deviation
The mean absolute deviation is the mean absolute error over a period of time, regardless of whether the estimate is greater or smaller than the actual result.

$$MAD = |\ At - Ft/n| \quad (5)$$

Information:
At = actual demand in the tth period
Ft = estimated demand in the tth period
N = number of forecast periods involved

2. Mean Square Error
Mean square error is an alternative method in forecasting methods. This approach is important because this technique produces moderate errors favored by forecasting that results in very large errors.

$$MSE = \frac{\Sigma(\text{forecasting error})^2}{N} \quad (6)$$

3. Mean Absolute Percentage Error
Mape is a relative measure of error. MAPE is generally more informative than MAD because it shows the percentage of error in the estimated results compared to the actual demand for a given time period, providing information on whether the percentage of errors is too high or too low.

$$MAP = \frac{\Sigma(\text{Absolute deviation})/(\text{Actual Value}) \text{ X } 100\%}{N} \quad (7)$$

MinMax
Minmax is a necessary method to prevent the occurrence of raw material shortages and excess raw materials. This method is used to control the supply of raw materials and its application is carried out so that warehouses can know the minimum and maximum stock (Kurniaanto et al., 2022). The instruments in the minmax method that are calculated in its application are as follows: (Saripudin & Wahyudin, 2024)
1. Security Stock
Determination of stocks for inventory to anticipate uncertainties in demand and supply of raw materials.

$$SS = (\text{Maximum request} - \bar{X}) \times LT \quad (8)$$

2. Minimum Stock
Minimum stock value is the minimum limit

value that must be available to the agency in meeting production quantities.

$$\text{Stok minimum} = (T \times LT) + SS \quad (9)$$

Information
T = average use of goods/period
LT = wait time
SS = Safety stock

3. Maximum Stock
The maximum value is the maximum limit value of the inventory available in the company to meet the production needs of a product.

$$\text{Maximum stock} = 2\,(H \times LT) + SS \quad (10)$$

Information
T = average use of goods/period
LT = wait time

4. Minmax Purchase Quantity
To calculate the economical purchase quantity, the Min Max can be calculated using the following formula:

$$Q = \max - \min \quad (11)$$

5. Reorder Points
A reorder point is a reorder point when inventory is left

$$\text{Reorder Point} = (T \times LT) + SS \quad (12)$$

Information
T = average usage
LT = wait time
SS = safety stock

6. Order Frequency
Order frequency is the average number of orders in a given period of time.

$$F = \frac{D}{Q} \quad (13)$$

Information
D = Request
Q = Reorder Rate

7. Total Inventory Cost
It consists of an ordering fee, which is the cost of purchasing goods or ordering from a supplier, and a storage fee, which is a cost associated with storage.

$$TIC = \frac{D}{Q}S + \frac{Q}{2}H \quad (14)$$

Information
TIC = Total Inventory Cost
S = Single Order Fee
D = number of raw material requirements
H = storage cost/unit
Q = Minmax Purchase Amount

3. RESEARCH METHODS

The research method is a part that contains a series of activities that are arranged systematically and gradually during the research. These stages are outlined in the research implementation flow diagram to facilitate understanding of the research stages as follows (Figure 1).

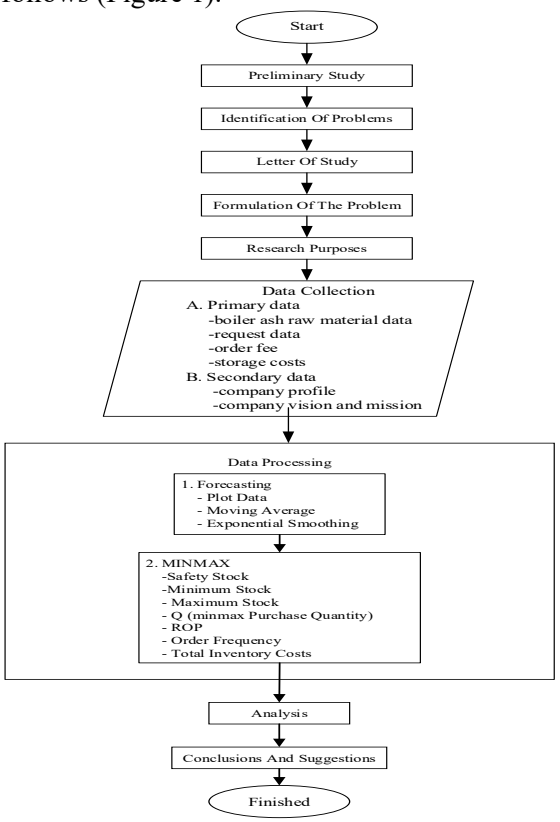

Figure 1. Flowchart research

4. RESULTS AND DISCUSSION

Based on the results of data targeting using the minimax method and the support of the prediction method, we can review the results in the following subsection.

Table 1. Boiler Ash supplies

Month	Inventory (kg)	Demand based on requirement (kg)
July	755	825
August	750	675
September	750	600
October	750	750
November	750	960
December	750	1050
January	750	1020
February	750	900
March	750	870
April	750	645
May	750	675
June	750	765
Entire	**9005**	**9735**
Medium		**811,25**

(Source: Data collection and processing, 2024)

Based on the table above, it shows that demand is greater than supply, so many consumer needs are not met. The price data of boiler ash raw materials supplied by the owner is as follows:

750 kg x IDR.4.000 = IDR.3.000.000

The price above also includes transportation costs from the supplier to the owner. The costs incurred in the context of procurement of boiler ash for the UMTR Belilas fertilizer factory are in the form of memorandum/document and telephone costs with the following details.

Table 2. Booking Fee Data

Cost Type	Fees (IDR)
Notes / Documents	5.000
Telephone	10.000
Entire	**15.000**

(Source: Data collection and processing, 2024)

The storage cost of boiler ash raw materials consists of collection costs, insurance costs and raw material maintenance costs. Here is a breakdown of boiler ash storage costs:

$$\text{Storage costs} = \frac{\text{IDR.150.000}}{750}$$

$$= \text{IDR.200/kg}$$

Based on the available data, the total cost of inventory at the orgaanical fertilizer plant is as follows:

$$\text{TIC mill} = \left(\frac{D}{Q} \times S\right) + \left(\frac{Q}{2} \times H\right)$$

$$= \left(\frac{9735}{250} \times \text{IDR } 15000\right) + \left(\frac{250}{2} \times \text{IDR } 200\right)$$

$$= \text{IDR } 584.000 + \text{IDR } 25.000$$

$$= \text{IDR } 609.000$$

From TIC, the cost of purchasing raw materials in one year is included to find out the amount of costs incurred in one year to produce organic fertilizers.

Total raw material cost = 9735 kg x IDR 4,000

= IDR 38,940,000

Based on the calculation above, the total cost incurred for the procurement of boiler ash raw materials is IDR 39,550,000.

Data Plot

A data plot is a visual representation to illustrate patterns, trends, and trends from the data it sources from. The following is a data pattern on demand for boiler ash raw materials (Figure 2).

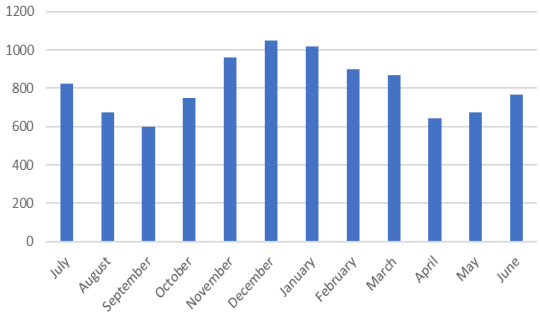

Figure 2. Demand based on needs data
(Source: Data Collection and Processing, 2024)

The data plot above shows that the raw material demand data pattern is horizontal, so what is suitable is simple forecasting methods such as moving averages and exponential smoothing.

Moving Averages

The moving average method uses 2-period, 3-period and 4-period forecasts. Of the three periods, the smallest mape value was chosen which indicates that the period is optimal from the other two periods.

Table 3. Recapitulation of the value of the Supreme Court's error

Time	MAD	MSE	MAPE
2	141	25638,75	17,823%
3	155	33108,33	18,54%
4	174,375	41705,86	20,916%

(Source: Data collection and processing, 2024)

Exponential Smoothing

The exponential smoothing method uses alpha values of 0.1, alpha 0.2 and alpha 0.3. From the estimates for the three alpha values, the smallest mape value is chosen which indicates that the estimate with the optimal alpha value of the other two.

Table 4. Recapitulation of ES error values

Alpha	MAD	MSE	MAPE
0.1	125,345	22619,32	16,139%
0.2	120,986	23415,66	15,603%
0.3	121,202	23279,48	15,621%

(Source: Data collection and processing, 2024)

Selection of the Best Method

Of the two methods, which are between moving averaage and exponential smoothing, choose the one that produces the smallest mape value.

Table 5. Selection of the best method

Time/ Alpha	MAD	MSE	MAPE
2	141	25638,75	17,823%
3	155	33108,33	18,54%
4	174,375	41705,86	20,916%
0.1	125,345	22619,32	16,139%
0.2	120,986	23415,66	15,603%
0.3	121,202	23279,48	15,621%

(Source: Data collection and processing, 2024)

Based on the Table 5, it can be seen that the method that produces the smallest mape value is the exponential smoothing method with an alpha value of 0.2, which is 15.603%.

Forecasting with the Selected Method

Based on previous calculations, it is known that the chosen method is exponential smoothing with an alpha of 0.2. Here is a breakdown of the estimated data from exponential smoothing (alpha 0.2).

Table 6. Approximate results of the chosen method

Moon	Demand based on requirement (kg)	Estimated yield (kg)
July	825	825
August	675	825
September	600	795
October	750	756
November	960	755
December	1050	796
January	1020	847
February	900	881
March	870	885
April	645	882
May	675	835
June	765	803
Next period		**795**
Entire		**9884**
Medium		**824**

(Source: Data collection and processing, 2024)

MINMAX

The minmax method is a method that allows a company line to take a simple approach to controlling the inventory used in maintaining the balance of raw material inventory. The instruments calculated in the minmax method are as follows:

1. Safety stock

Determination of inventory stock to anticipate fluctuations in demand and supply of raw materials.

Safety Stock = (Maximum demand $-\bar{X}$)×LT
= (885 – 824) x 0,1
= 6.1 kg

2. Minimum Stock

Minimum limit values that must be available to meet high demand volumes

Minimum stok = (824 x LT) + SS
= (824 x 0,1) + 6,1
= 88.5 kg

3. Maximum stock

The maximum limit value that must be maintained to exceed the specified limit

Maximum stock = 2 (H x LT) + SS
= 2 (824 x 0.1) + 6.1
= 171 kg

4. Minmax purchase quantity (Q)

The most economical amount for the purchase of raw materials

Q = max – min
= 171 – 88.5
= 82.5 kg

5. Reorganization (ROP)

Rearrange points when inventory is left

Reorder Point = (T × LT) + 6.1
= (824 x 0.1) + 6.1
= 82.4 + 6.1
= 88.5 kg

6. Order frequency

Frequency is the number of ordering activities carried out for the procurement of raw materials

$$F = \frac{D}{Q}$$

$$= \frac{9884}{82,5}$$

= 120 times in a year

The frequency of 120 times a year is designed to keep the inventory optimal according to the minmax method and keep the risk of damage during storage. This strategy prioritizes the efficiency and quality of the storage cost balance, so that it can respond to fluctuations in consumer demand.

7. Total Inventory Cost

The total inventory cost obtained based on the calculation of the minmax method is as follows:

$$TIC = \left(\frac{D}{Q} \times S\right) + \left(\frac{Q}{2} \times H\right)$$
$$= \left(\frac{9884}{82,5} \times 15.000\right) + \left(\frac{82,5}{2} \times 200\right)$$
$$= \text{IDR } 1.805.340$$

The cost of purchasing raw materials is included to find out the overall cost needed in the procurement of boiler ash raw materials for the manufacture of organic fertilizer.

Total raw material cost = 9884 kg x IDR 4,000
= IDR 39,536,000

Based on the calculations that have been made, it can be seen that the total cost needed in the estimation of boiler ash raw materials after using the minmax method is Rp 41,341,340. The results of data processing using the minmax method and with the help of forecasting or forecasting methods can estimate the demand that is likely to occur in the next period and the stock of boiler ash raw materials will not experience stockout or overstocking. The results of this study show that by using forecasting and minimax methods, future demand can be accurately predicted and inventory management can be carried out as planned. This ensures that consumer needs can be met without overstocking or understocking. This study makes a significant contribution compared to previous studies, which generally only focus on inventory recording or requirement calculation without considering forecasting aspects to avoid fluctuations in demand. By applying the Min-Max method, this study succeeded in optimizing the management of boiler ash raw material inventory which often has fluctuating demand. In addition, this study also integrates cost reduction efforts, an aspect that has rarely been discussed in previous studies.

5. CONCLUSION

Based on the results of the research, controlling the inventory of boiler ash raw materials with the minmax method supported by forecasting is able to maintain the optimal availability of raw materials to meet consumer demand. Forecasting methods that provide accurate demand predictions allow for adjustments to the planned order quantity. The determination of the minimum and maximum limits of the minmax method also prevents the availability of raw materials from running out of stock or overstocking. Although the cost is greater than the calculation before using the minmax method, the minmax method can answer the fluctuations in consumer demand and can reduce storage costs due to the rapid turnover of raw materials. This research contributes to an efficient inventory control strategy and supports the operational sustainability of organic fertilizer production at the UMTR Belilas Fertilizer Factory. With the research that has been carried out, several suggestions can be considered by companies to be able to balance inventory costs with the availability of boiler ash raw materials through proper evaluation and forecasting, so that costs can be reduced without sacrificing raw material stock. Additionally, it is important to consider external factors, such as fluctuations in consumer demand and other operational costs, in setting future inventory control policies. For future researchers, it is recommended to apply or combine other methods with existing methods, to get various solutions that are more suitable to the conditions of the case study being studied.

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