Inventory Planning Analysis for Carboxymethyl Celullosa (CMC) at PT. XYZ

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Abstract

PT XYZ is a manufacturing company that produces clay roof tiles with one of the raw materials is Carboxymethyl Cellulose (CMC) for the glazing process. Currently, CMC inventory management faces a problem where during January-December 2023 there was an average overstock of 2,467 kg/month or Rp225,241,200/month. In order to minimize overstock and reduce inventory costs, it is necessary to analyze CMC inventory planning. Inventory analysis begins with forecasting to determine CMC requirements for the January-December 2024 period. The inventory planning methods used were Economic Order Quantity (EOQ) and Economic Order Interval (EOI). The selected forecasting method was Double Moving Average because it has the smallest forecasting error with a MAPE of 10.86% and valid MR Chart verification. The results of the analysis of total inventory costs during the period January-December 2024 using the EOQ method amounted to Rp2,139,459,931 while the EOI method amounted to Rp2,139,739,357. Based on the cost difference between the two methods, it is proven that the EOQ method is cheaper than the EOI method, and the results of the cost comparison analysis using the method used by the company is proven that if the company uses the EOQ inventory method the company will be able to save Rp7,042,779 or 0.33% per year. Thus the EOQ method is the right method in minimizing the total cost of CMC inventory and can minimize the risk of overstock.

Keywords: Carboxymethyl Cellulose (CMC), Economic Order Interval (EOI), Economic Order Quantity (EOQ), Forecasting, Inventory Planning.

1. Introduction

Inventory management is one of the most crucial aspects in the manufacturing industry, as it directly affects production efficiency and cost control. If the supply of raw materials runs smoothly, the production process will also proceed smoothly. However, if the raw materials for production are insufficient, it will disrupt production activities and result in a decline in production output (Karamoy et al., 2022). There are evidene of relationship between inventory management practices and the company performances based on several previous researches (Kuoumanakos, 2008; Mahajan et al., 2022)

At PT XYZ, which is engaged in the production of clay roof tiles, Carboxymethyl Cellulose (CMC) inventory management is a major challenge. CMC is an important raw material used in the roof tile production for the clay tile glazing process, so its availability and management greatly affect the course of operations. However, PT XYZ still faces several obstacles in implementing an effective inventory planning system.

This research aims to overcome these obstacles by analyzing the current CMC inventory system at PT. XYZ, applying the right forecasting method, and determining the optimal inventory planning strategy using the Economic Order Quantity (EOQ) and Economic Order Interval (EOI) methods. This approach is expected to improve inventory efficiency, reduce costs, and increase the availability of raw materials for the production process. In addition, this research also aims to provide practical recommendations that can be applied by other manufacturing companies facing similar challenges in their inventory management. These classic models are deterministic model that specify for a procedure for selecting the appropriate size of replenishment quantity under constant demand conditions. Though it could benefit from some improvement like the addition of some costs (e.g entropy cost), EOQ still widely used in the business practice (Jaber & Rosen, 2008)

Accurate forecasting of CMC requirements in PT XYZ is a key factor for the successful implementation of the inventory planning. Therefore, this research was also evaluate various forecasting methods to determine the one that best fits the company's historical data patterns. One of the main raw materials in glazing is Carboxymethyl Cellulose (CMC), which is an important adhesive material in glazing manufacturing. CMC helps increase the strength of the roof tiles, and without CMC, the roof tiles would be more prone to cracking, breaking, or deformation. Currently, CMC can only be obtained through imports from countries such as Italy, Japan, and Colombia.

The CMC import process takes a long time, so good and precise control of raw material inventory is needed to avoid raw material shortages that can hinder the production process. CMC purchases at PT XYZ are

made monthly through distributors without proper inventory planning, causing a buildup of inventory in the warehouse. During 2023, there was an average inventory of CMC of 2,467 kg or Rp225,241,200 per month. This buildup of inventory can cause losses due to the capital embedded in CMC inventory as well as high storage costs. Therefore, it is necessary to analyze CMC inventory planning to provide solutions to the inventory planning system in the company.

Based on the way CMC orders were made by the company, it was known that the inventory model used was an independent system with orders once a month. However, without considering the estimated CMC requirements, this system was not optimal. This study aims was to analyze CMC inventory planning to improve production efficiency by determining CMC requirements to minimize inventory. By comparing the economic order interval (EOI) and economic order quantity (EOQ) methods, can be known the method that results in the lowest inventory cost. It is hoped that the results of this study can make a significant contribution to the management of raw material inventory at PT. XYZ and become a reference for other companies in the same industry. The historical data for CMC are showed in Table 1 and the pattern of historical usage for CMC along January - December 2023 is showed in Figure 1:

Table 1. CMC Data for January – December 2023 (kg)

Month/Year	Beginning Stock	Purchasing	Usage	Ending Stock
Jan'23	2200	1000	1250	1950
Feb'23	1950	1200	1150	2000
March'23	2000	1000	1450	1550
April'23	1550	1000	1000	1550
May'23	1550	1100	1100	1550
June'23	1550	1500	1000	2050
July'23	2050	1500	1150	2400
August'23	2400	1300	1050	2650
Sept'23	2650	2000	1350	3300
Oct'23	3300	1250	1400	3150
Nov'23	3150	2000	1375	3775
Dec'23	3775	1400	1500	3675

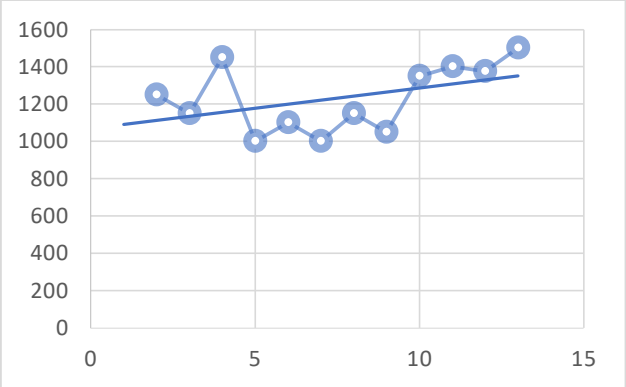

Figure 1. Historical Data Pattern of CMC Usage for Jan – Dec 2023

Figure 1 shows that the historical demand has slightly increasing trend, so in this research, the forecasting methods used are Double Moving Average, Double Exponential Smoothing, and Linear Regression.

2. Material and Methods

2.1. Material

The object of this research was CMC inventory planning, one of the main raw materials in the manufacture of glaze for the clay tile glazing process at PT. XYZ. PT XYZ is a company engaged in the clay tile manufacturing industry, where the glazing process plays an important role in ensuring product quality and durability. This was analyzed CMC inventory planning to improve production efficiency, reduce storage costs, and minimize the risk of raw material shortages that can hinder the smooth production process.

The research procedure was carried out in several stages. First, CMC demand data from January-December 2023 was collected and recorded in a table. Second, the data that has been collected was analyzed to identify historical data patterns which presented in graphical form. Third, based on historical data patterns, developed an

accurate forecasting model. Fourth, inventory planning was carried out using the EOQ method by calculating the optimal order quantity, reorder point, order frequency per year, annual ordering cost, annual storage cost, and total inventory cost. Fifth, inventory planning was carried out by the EOI method by determining the optimal order time interval, maximum inventory, number of orders per year, annual ordering costs, annual storage costs, and total inventory costs. Sixth, the results of inventory planning calculations by EOQ dan EOI method were compared to determine the method that provide the minimum inventory cost.

2.2. Methods

In this research, the main focus is the optimization of Carboxymethyl Cellulose (CMC) inventory planning at PT XYZ, which is an important raw material in roof tile production. CMC is used in the glazing process to improve the physical quality of roof tiles, such as strength and aesthetic appearance. CMC is a water-soluble cellulose-derived compound that has a wide range of applications in other industries, including pharmaceuticals, textiles, and food (Rahman et al., 2021). As an essential raw material, CMC inventory management must be done effectively to avoid overstock problems that cause high storage costs.

To address this issue, this study utilizes a forecasting approach to predict future CMC requirements. Forecasting is the process of predicting the demand or need for a raw material in the future (Tiranda et al., 2022). In the context of this research, the forecasting method was used to determine the need for CMC at PT XYZ. The method used to perform forecasting was time series analysis. Here are 4 components that affect the analysis of time series data patterns, including (Baroto, 2023):

a. Cycle Pattern

A cyclical pattern occurs when long-term demand fluctuations form a sine wave or periodic pattern. Cyclical patterns are generally more difficult to identify than seasonal patterns. Suitable forecasting methods for cyclical patterns are moving average, weight moving average, and exponential smoothing.

b. Seasonal Patterns

Seasonal patterns occur when demand data fluctuates regularly within a certain time interval, usually a year. Demand is influenced by the season, such as higher umbrella sales in the rainy season. Suitable forecasting methods for this pattern are winter, moving average, or weight moving average methods.

c. Eratic/Random Pattern

Erratic or random patterns occur when demand fluctuations cannot be explained by cyclical, seasonal, or trend patterns. Random data is often vague and difficult to predict with standard methods.

d. Trend Patterns

Trend patterns arise when demand shows an upward or downward trend over the long term. When data is plotted over a long period of time, these patterns can form trend lines. Suitable forecasting methods for trend patterns are linear regression, double moving average, or double exponential smoothing.

In this study, according to Fig 1, the authors chose a forecasting method with trend pattern. The three forecasting methods to be applied include Double Moving Average (DMA), Double Exponential Smoothing (DES), and Linear Regression. These three methods were chosen with the consideration that the observed historical data patterns show fluctuations and an increasing trend. By using these three methods, it is expected to produce accurate projections for the upcoming period. After the forecasting process was complete, determined the best method by comparing the forecast error of each method. The forecasting method chosen was the method with the smallest forecasting error. The best forecasting method was used to predict CMC needs during January-December 2024.

1. Double Moving Average (DMA) is a forecasting method that utilizes two moving averages to project future values based on historical data patterns. This method is effective in producing smoother forecasts and is responsive to both short-term and long-term trends. The following is a calculation formula that can be used (Z. A. Sari & Andarwati, 2024):

   First moving average formula:

   $$S_t' = \frac{\Sigma A_t}{\mathrm{n}} \quad (1)$$

   Second moving average formula:

   $$S_t'' = \frac{\Sigma S_t'}{\mathrm{n}} \quad (2)$$

   DMA trend component formula:

   $$\mathrm{a_t} = 2.S_t' - S_t'' \quad (3)$$

   DMA seasonal component formula:

   $$\mathrm{b_t} = \frac{2}{(\mathrm{n}-1)(S_t'-S_t'')} \quad (4)$$

   Double Moving Average forecasting formula:

   $$\mathrm{f_{t+m}} = \mathrm{a_t} + \mathrm{b_t}\,.\,\mathrm{m} \quad (5)$$

   Description:

   S' = The result of the first moving average calculation

S" = The result of the second moving average calculation
n = Number of demand data
A_t = Actual demand at period t
a_t = Trend at period t
b_t = Seasonal at period t
F_t = Forecasting at period t
m = Number of periods ahead of time t for forecasting

2. Double Exponential Smoothing (DES) is a development of the exponential smoothing method that utilizes two parameters to capture levels and trends in the data, making it suitable for data with fluctuating patterns. The formula used is as follows (Z. A. Sari & Andarwati, 2024):
First smoothing formula:
$$S_t' = \propto A_t + (1 - \propto)\, S'_{t-1} \quad (6)$$
Second smoothing formula:
$$S_t'' = \propto S'_t + (1 - \propto)\, S'_{t-1} \quad (7)$$
DES trend component formula:
$$a_t = 2\,.\,S'_t - S''_t \quad (8)$$
DES seasonal component formula:
$$b_t = \left(\frac{\propto}{(1-\propto)}\right)(S'_t - S''_t) \quad (9)$$
Double exponential smoothing forecasting formula:
$$F_{t+m} = a_t + b_t\,.\,m \quad (10)$$
Description:
S_t' = First smoothing calculation result
S_t'' = Result of second smoothing calculation
n = Number of demand data
A_t = Actual demand at period t
a_t = Trend at period t
b_t = Seasonal at period t
F_t = Forecasting at period t
m = Number of periods ahead of time t for forecasting

3. Linear Regression, as one of the accurate statistical methods, is used to identify and visualize trends in data affected by strong relationships between independent and dependent variables. This method produces more detailed predictions compared to other forecasting methods. The following is the formula that will be used (Baroto, 2023):
Formula constant value a:
$$a = \frac{\Sigma Yi \times \Sigma Xi^2}{n \times \Sigma Xi^2} - \frac{\Sigma Xi \times \Sigma XiYi}{(\Sigma Xi)^2} \quad (11)$$
Formula for degree of slope of regression line:
$$b = \frac{n\Sigma XiYi - [\Sigma XiYi]}{n\Sigma Xi^2 - (\Sigma Xi)^2} \quad (12)$$
Linear regression forecasting formula:
$$y' = a + b.x \quad (13)$$
Description:
n = Number of demand data
A_t = Actual demand
a = Fixed value/intercept
b = The degree of slope of the regression line equation/regression coefficient
y' = Forecasting
x = Independent variable that affects y
y_i = The i dependent variable/actual demand of the i period
x_i = The i independent variable/the number of forecasting periods involved

After the forecasting was completed, the accuracy of the forecast results was measured, namely the magnitude of the difference between the forecast results and the actual demand. MAPE (Mean Absolute Percentage Error) is one of the evaluation metrics used to evaluate forecasting errors in percentage form. MAPE measures the average of the absolute percentage error relative to the actual value. The formula for calculating MAPE is as follows (Rizqi et al., 2021):
$$\text{MAPE} = \left(\frac{100}{n}\right)\Sigma \left|\frac{A_t - F_t}{A_t}\right| \quad (14)$$
Description:
A_t = Actual demand at period t

F_t = Forecasting at period t
n = Number of observations

The next stage was to verify the forecasting results using the MR Chart. Moving Range Chart is a tool used in statistical control of processes to monitor variations in production processes or measurements over time. MR Chart is generally used when only one observation is measured at each time period (Elsa Nuroktavany et al., 2020). MR chart is used to compare the predicted and actual demand values of demand for the same period. The center line of the MR chart is at point 0. The moving range (MR) formula is defined as (Wulansari et al., 2023):

$$MR_t = | (F_t - A_t) - (F_{t-1} - A_{t-1}) | \quad (15)$$

The average moving range formula:

$$\overline{MR} = \frac{\Sigma MR}{n-1} \quad (16)$$

Description:
MR_t = Moving range at period t
F_t = Forecasting at period t
A_t = Actual demand at period t
$\overline{MR}$ = Average of all moving ranges
n = Number of data

The following are the control limits of the MR Chart:
Upper control limit (UCL) = +2,66 $\overline{MR}$
Lower control limit (LCL) = -2,66 $\overline{MR}$

Testing in an uncontrolled condition is a point outside the control limits. In this test, the MR map is divided into six regions of equal width.
Region A = ± 2/3 (2,66 $\overline{MR}$) = ± 1,77 $\overline{MR}$
Region B = ± 1/3 (2,66 $\overline{MR}$) = ± 0,89 $\overline{MR}$
Region C consists of the portion above and below the center line.

There are several tests that can be done to identify and analyze an uncontrolled condition, namely:
2 or 3 consecutive points are in one of the regions A
4 or 5 consecutive points are in one of the B regions
There are 8 consecutive points on either side of the center line

After the demand needs were projected, the next step was to carry out inventory management. Inventory planning is a method or methodology that helps companies decide on size, quantity, variety and quality. Companies that do not plan their inventory levels properly can face obstacles in production and distribution (N. Sari, 2022). In this study, there are 2 inventory management methods used, namely:

1. Economic Order Quantity (EOQ)

EOQ is an amount of inventory ordered at each order at the most efficient cost, in other words, the total inventory cost consisting of ordering costs and storage costs is minimal or lowest (Syukron & Kholil, 2018). The following are the formulas for the EOQ method according to Ford-Harris (Baroto, 2023):

Economic order quantity formula:

$$Q = \sqrt{\frac{2 .D.S}{H}} \quad (17)$$

Ordering cost formula:

$$TO = \left(\frac{D}{Q} \text{ x } S\right) \quad (18)$$

Inventory cost formula:

$$TH = \left(\frac{Q}{2} \text{ x } H\right) \quad (19)$$

Purchase cost formula:

$$TP = (D \text{ x } P) \quad (20)$$

Inventory cycle:

$$t = \frac{Q}{D} \quad (21)$$

Reorder point formula:

$$ROP = (L - t) \times d \quad (22)$$

Ordering frequency formula:

$$N = \frac{D}{Q} \quad (23)$$

Total inventory cost formula:

$$TIC = (D \text{ x } P) + \left(\frac{D}{Q} \text{ x } S\right) + \left(\frac{Q}{2} \text{ x } H\right) \quad (24)$$

Description:
Q = Economic order quantity (EOQ)

D = Annual demand
S = Ordering fee for each order
P = Purchase cost for each order
H = Inventory cost per unit per year
ROP = Reorder point
d = Average demand or demand rate
L = Lead time
t = Inventory Cycle
N = Order frequency
TIC = Total inventory cost

2. Economic Order Interval (EOI)

EOI is an inventory management method also known as a periodic inventory system. This method focuses on determining the optimal ordering time interval for managing inventory, in contrast to a continuous inventory system that is more oriented towards existing inventory stock levels (Ariesty & Andari, 2021). The following are the formulas of the EOI method (Baroto, 2023):

Optimal ordering interval:

$$T* = \sqrt{\frac{2 . S}{D . H . P}} \quad (25)$$

Maximum inventory formula:

$$E = \frac{D\,(T* + L)}{N} \quad (26)$$

Ordering frequency formula:

$$m = \frac{1}{T^*} \quad (27)$$

Total inventory cost formula:

$$TIC = (D \times P) + \left(\frac{S}{T^*}\right) + \left(\frac{D \times H \times T^*}{2}\right) \quad (28)$$
$$= (\text{Purchase Cost}) + (\text{Ordering Cost}) + (\text{Holding Cost})$$

Description:
D = Annual demand (units/year)
S = Annual ordering cost
H = Inventory cost per unit per year
P = Purchase cost
T* = Optimal ordering interval (in years)
L = Lead time
N = Number of working days in a year

3. Results and discussion

The first step in CMC inventory control efforts for the coming period was to estimate CMC demand through a forecasting process using historical CMC demand/usage data from January to December 2023 contained in Table 1. From the results of the data pattern at Figure 1, it can be concluded that the company shows an increasing trend data pattern for CMC demand. Therefore, the forecasting method to be applied were Double Moving Average, Double Exponential Smoothing, and Linear Regression because they match the pattern of historical data that fluctuates upwards. Based on the results of forecasting calculations using 3 methods, the recapitulation of forecasting calculation results are shown in the Table 2.

Table 2. Recapitulation of Forecasting Calculation

No.	Method	MAPE	MR *CHART*
1	DMA	10.86%	Valid
2	DES	13.91%	Valid
3	LR	11.16%	Valid

The conclusion obtained from the calculation of forecasting methods using these 3 methods can be seen from the forecast error and the results of the MR Chart, the selected method is the DMA method which has the smallest forecast error and a valid MR Chart. The next step was to determine the results of forecasting for the Jan-Dec 2024 using the selected method, namely the DMA method. Table 3 perform forecasting result using the DMA method.

Table 3. Forecasting results for Jan-Dec 2024 using the DMA method (kg)

Month	t	Results of Forecasting
Jan	13	1563.89
Feb	14	1633.33
Mar	15	1702.78
Apr	16	1772.22
May	17	1841.67
Jun	18	1911.11
Jul	19	1980.56
Aug	20	2050.00
Sept	21	2119.44
Oct	22	2188.89
Nov	23	2258.33
Dec	24	2327.78
Demand/year		23,350

After calculating the forecasting demand for months 13 to 24 using the DMA method, the next step was to carry out a CMC inventory planning analysis by comparing 2 methods, namely the Economic Order Quantity (EOQ) and the Economic Order Interval (EOI). Based on Table 3, the product demand for Jan-Dec 2024 is 23,350 kg, the inventory cost is Rp18,262.80/kg/year, and the cost of purchasing CMC is Rp91,314/kg. For ordering cost obtained from several cost aspects, shown di Table 4.

Table 4. Ordering Cost

No	Cost Component	Ordering Cost
1	Internet Fee	Rp23.000,00
2	Tax Cost	Rp15.112,47
3	Electricity Fee	Rp42.155,00
Total		Rp80.267,47

From these data, calculations were then carried out using the Economic Order Quantity (EOQ) method and the Economic Order Interval (EOI) method. Then the results of the recapitulation of the two inventory methods are shown in Table 5.

Table 5. Recapitulation of EOQ and EOI Methods

Raw Material	Economic Order Quantity (EOQ)			Economic Order Interval (EOI)		
	Q	ROP	Total Inventory Cost	T*	E	Total Inventory Cost
CMC	531,33 kg	520 kg	Rp2,139,459,931	11 days	1,686 kg	Rp2,139,739,357

Based on Table 5, it was found that the smallest CMC inventory cost is Rp2,139,459,931 using the EOQ method with a difference cost of Rp279,425.53. Therefore, the selected inventory method is the EOQ method because it is proven to be cheaper. Furthermore, to prove whether the EOQ method is the right method for the company to use, an analysis of the inventory planning method used by the company this time is carried out.

3.1. Economic order quantity (EOQ) method inventory chart

The following is the result of an inventory chart using the EOQ method which shows the inventory decreases over time and then replenished when it reaches the reorder point (ROP). In Figure 2 it is found that the economic order quantity (Q) for CMC is 531.33 kg every time the company place an order, when the inventory drops to 520 kg, the company must reorder to avoid running out of stock with the lead time required 15 days to receive the order after the order is placed and the inventory cycle is every 7 days.

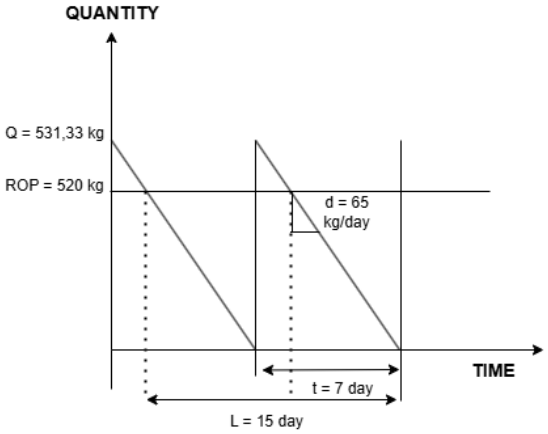

Figure 2. EOQ Inventory Method

3.2. Economic order interval (EOI) method inventory chart

The following is the result of an inventory chart using the EOI method which illustrates an inventory management pattern where orders are placed at fixed time intervals with respect to the current inventory level, not based on a specific order quantity as in the EOQ method. Based on the EOI inventory cycle in Figure 3, it is found that the maximum amount of CMC inventory is 1,686 kg, which means that the maximum amount of inventory stored by the company each month should not exceed 1,686 kg so that there is no accumulation of inventory in the inventory warehouse. The time interval between each order is fixed at 11 days, which means orders are placed every 11 days with the required lead time of 15 days to receive the order after the order is placed.

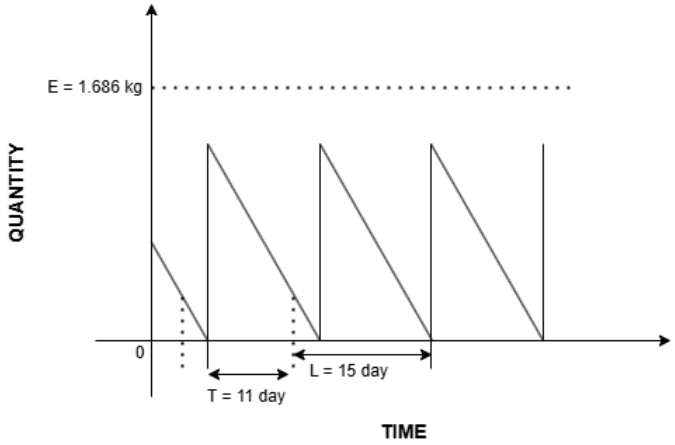

Figure 3. EOI Inventory Method

3.3. Analysis of the difference between EOQ method and the method used by the company (existing)

The company orders CMC every month or 12 orders in a year, so the number of CMCs ordered each time an order placed is:

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

$$12 = \frac{23{,}350}{Q}$$

$$Q = 1{,}946 \text{ kg}$$

Based on the calculation using the formula above, the amount of CMC ordered is 1,946 kg per order. Next, calculate the Total Inventory Cost (TIC) for one year as follows:

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

$$TIC = 2{,}132{,}181{,}900 + 993{,}532 + 13{,}327{,}278$$

$$TIC = Rp2{,}146{,}502{,}710$$

The total inventory cost if the company uses the current method is Rp2,146,502,710. Based on the results of the calculation of inventory costs above, if the company uses the EOQ method the company will be able to save Rp7,042,779 per year or 0.33%.

3.4. Research results

The Double Moving Average (DMA) method shows the smallest forecasting error with a MAPE of 10.86%. Verification with MR Chart indicated that the forecasting results were within the control limit so the DMA method was reliable for inventory planning. The EOQ method was found to be more cost efficient for CMC inventory compared to the EOI method. The forecasting data was based on historical data from January to December 2023. Improved forecasting accuracy directly impacts the efficiency of inventory planning. This suggests that with more accurate planning, companies can reduce unnecessary storage costs and ensure adequate availability of raw materials for the production process. Future demand patterns for CMC may vary, which will affect the accuracy of the forecasting model used. There is potential for further cost reduction if additional optimization methods are integrated in inventory planning. In addition, changes in market and economic conditions may affect the effectiveness of currently used methods. Thus, this study confirms that the application of the EOQ method can improve the efficiency of inventory management and reduce the costs associated with storing raw materials.

4. Conclusion

Based on the results of forecasting calculation using the Double Moving Average method, it can be concluded that this method is reliable enough to forecast future demand with a low forecast error, indicated by the Mean Absolute Percentage Error of 10.86%. From the forecasting, it is known that the demand for Carboxymethyl Cellulose for the coming year (2024) is 23,350 kg. In the context of inventory planning, this forecasting becomes the basis for determining the right inventory management method to minimize total costs.

The two methods analyzed in this report are Economic Order Quantity (EOQ) and Economic Order Interval (EOI). The EOQ method is used to determine the optimal order quantity so that the total inventory cost consisting of ordering costs and storage costs can be minimized. Based on the calculation results, the economic order quantity is 531,33kg per order, with a reorder point when the inventory reaches 520 kg. In the inventory analysis with the EOI method, it is found that ordering CMC can be done at 11 days intervals with a maximum inventory level of 1,686 kg.

Based on the results of the inventory cost calculation, it shows that the EOQ method results in a lower total annual inventory cost than the EOI method. The total cost of inventory using the EOQ method is Rp2,139,459,931 while the EOI method is Rp2,139,739,357 with a cost difference of Rp279,426. Thus, the EOQ method is a more appropriate inventory planning method to be used at PT. XYZ to minimize inventory costs and minimize the risk of overstock.

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