E-ISSN 2503 - 1430
ISSN 2541 - 3090

Journal of Industrial Engineering Management
(JIEM Volume 9. No 3 2024)

COMPARATIVE ANALYSIS OF MOVING AVERAGE AND DOUBLE EXPONENTIAL SMOOTHING METHODS FOR FORECASTING ASTM A252 GR 2 PIPE DEMAND AT PT XYZ

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Article History :
Submitted Dec 14, 2024
Revised Dec 16, 2024
Accepted December5, 2024
Available online December 24, 2024

ABSTRACT

Raw material inventory planning is a crucial aspect in the manufacturing industry to ensure smooth production and cost efficiency. However, PT XYZ has not implemented a forecasting method in its raw material planning system, so that procurement decisions are still reactive to actual demand. This study aims to analyze and compare forecasting methods using Double Exponential Smoothing (DES) and Moving Average (MA) to determine the most accurate method in projecting raw material needs for Non-API spec pipe products, type ASTM A252 GR 2 at KT 24 PT XYZ. The data used is historical demand data, which is then analyzed using POM-QM for Windows software. The results of the analysis show that the Moving Average method with a two-month period (MA-2) has the smallest Mean Squared Error (MSE), which is 182067, and a Mean Absolute Percentage Error (MAPE) value of 1.24%, which indicates a higher level of accuracy than other methods. Thus, the MA-2 method is recommended to be implemented in PT XYZ's raw material planning system to improve production efficiency and reduce the risk of excess or shortage of stock. For further research, it is recommended to develop a forecasting model by considering external factors such as market trends and seasonality, and integrating machine learning or hybrid forecasting methods to improve prediction accuracy. In addition, the implementation of an Enterprise Resource Planning (ERP)-based system with a forecasting module can also be a solution for long-term planning efficiency.

Keywords: Forecasting, Double Exponential Smoothing, Moving Average, POM-QM, Inventory Planning

Published By:
Fakultas Teknologi Industri
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DOI : http://dx.doi.org/10.33536/jiem.v9i3.1897

1. INTRODUCTION

Technological developments and increasingly tight industrial competition require companies to increase production efficiency and optimize inventory planning and control processes. In the manufacturing industry, product sales greatly affect business sustainability, so companies need to manage sales and production carefully in order to meet market demand effectively. One crucial aspect in company operations is raw material inventory management (Reyhan, Purwoko and Yudhistira, 2024). Poorly managed inventory can cause various problems, such as excess stock that increases storage costs or shortages that hamper production and reduce customer satisfaction. Therefore, a forecasting method is needed that can help companies determine the optimal amount of raw materials to meet future demand.

To drive business development and progress, companies must make accurate decisions. Therefore, companies need to be able to project product inventory and sales in order to meet customer needs effectively (Marlim and Hajjah, 2021). Forecasting is the process of predicting future needs, including elements such as quantity, quality, time, and location required to meet demand for goods or services (Lusiana and Yuliarty, 2020). For effective production planning, it is important to have a deep understanding so that the products produced can meet customer demand and expected time.

Currently, PT XYZ, a company engaged in the steel pipe manufacturing sector, is facing problems in raw material inventory planning because it has not implemented a forecasting method in its production process. Without proper forecasting, the company is at risk of experiencing uncontrolled production fluctuations, causing inefficiency and potential operational losses. To overcome this, this study aims to provide an analysis of the proposed forecasting method using a comparison of the two methods, namely Double Exponential Smoothing (DES) and Moving Average (MA) with the support of POM-QM for Windows software. This method is expected to help the company in making more accurate projections of raw material needs, thereby supporting production efficiency and supply stability (Yusta *et al.*, 2023).

The production division of PT XYZ is a division that is responsible for managing production process activities starting from raw materials to finished products. The main purpose of production is to utilize company resources to produce goods that meet customer needs and demands. Production planning requires a good understanding to ensure that the products produced meet customer demand and are available according to the expected schedule (Anastasya Bernike Br Ginting *et al.*, 2024). To achieve this goal, the use of the Double Exponential Smoothing and Moving Average methods in the forecasting process is very important. This method will help ensure that future predictions can be used as a useful reference for raw material preparation. However, in practice, expectations often do not match reality. Plans that have been made tend to experience major changes, which can pose significant risks in product procurement and of course will result in additional costs (Syaddyah, Ratnawati and Wahyuni, 2020). If raw materials are insufficient, the company may suffer losses, while excess raw materials will increase storage costs. Thus, production planning is very important to keep the company's operations effective and efficient (Rahman Lutfi and Sasongko, 2022).

In several previous studies, forecasting methods such as Exponential Smoothing and Moving Average have been applied for various purposes, including stock price forecasting and product sales projections. For example, research conducted by (Dinanti and Suryati, 2023) shows that the Exponential Smoothing (DES) method can produce a high level of accuracy in predicting stock prices with a MAPE value below 2%, while research (Azkiya *et al.*, 2023) found that the DES method with certain parameters was able to provide very accurate sales projections with a MAPE of 0.18%. In addition, research by (Azahra *et al.*, 2022) shows that the Weighted Moving Average (WMA) method is effective in predicting the amount of sugarcane production,

with an MSE value of 1,833.07 and an MAE of 36.07.

However, until now, PT XYZ has not implemented a forecasting method in its raw material inventory planning. The absence of a structured forecasting system causes the company to experience uncertainty in determining the amount of raw materials to be provided, so that it can be at risk of experiencing shortages or excess stock. Therefore, this study will fill this gap by analyzing the application of forecasting methods to the raw material needs of non-API spec pipes type ASTM A252 GR 2 at KT 24 using the Double Exponential Smoothing and Moving Average methods.

Thus, based on the basic bag, it can be said that the novelty of this study lies in the comparative analysis of forecasting methods based on Double Exponential Smoothing and Moving Average to optimize pipe raw material inventory planning at PT XYZ, which has never been applied in the company before. In addition, this study uses POM-QM for Windows software to assist the analysis, which can provide forecasting results with a higher level of accuracy compared to the manual approach. The justification for this study is based on the need for the industry to have a forecasting system that can reduce uncertainty in production planning, so that companies can make data-based decisions in managing their inventory. By implementing the right forecasting method, PT XYZ can increase production efficiency, reduce storage costs, and ensure the availability of raw materials according to market needs.

2. METHODS

This study uses a quantitative descriptive approach to analyze and compare forecasting methods in pipe product demand planning at PT XYZ. The methods used are Double Exponential Smoothing (DES) and Moving Average (MA) with the help of POM-QM for Windows software to determine the most accurate forecasting method. The study population includes all demand data for Non-API spec pipe products type ASTM A252 GR 2 at KT 24 PT XYZ, while the sample is in the form of monthly demand data in a certain period. Data collection techniques are carried out by collecting secondary data in the form of historical demand data, as well as interviews with the company, especially the production division, to understand the existing raw material planning system.

This research was conducted within a period of one month, starting from December 11, 2023 to January 23, 2024 during the implementation of practical work at PT XYZ, a company engaged in the steel pipe manufacturing sector located in Bekasi City. The data obtained were analyzed using forecasting methods, then compared based on the MAD (Mean Absolute Deviation), MSE (Mean Squared Error), and MAPE (Mean Absolute Percentage Error) values to measure the level of accuracy. The results of this study are expected to provide recommendations for more optimal forecasting methods for PT XYZ in planning raw material needs more efficiently and reducing uncertainty in the production process.

Double Exponential Smoothing (DES) is a forecasting method that uses recent historical data and involves repeated calculations (Apriosa, Orisa and Rudhistiar, 2024). Exponential Smoothing is a forecasting technique that improves prediction accuracy by smoothing out observed data from previous periods. This method reduces fluctuations by giving exponentially decreasing weights to data from older periods in a time series (Abdy, Thaha and Lukman, 2023). The Double Exponential Smoothing method is applied when the data shows a trend pattern. In this method, smoothing is done by updating two principal components to handle trend changes in the data (Asmaradana, Widodo and Artikel, 2023). The Double Exponential Smoothing method forecast is calculated using the following equation:

1. Determine the first Smoothing (S't)
   $$S't = \alpha.Xt + (1 - \alpha)S't - 1 \quad (1)$$
2. Determine the second Smoothing (S)
   $$S''t = \alpha.Xt + (1 - \alpha)S''t - 1 \quad (2)$$
3. Determining the magnitude of the constant (α)
   $$\alpha = S't + (S't - S''t) \quad (3)$$
   $$\alpha = 2S't + ''t \quad (4)$$
4. Determining the size of the slope/trend coefficient (b)
   $$b = \alpha(1 - \alpha)(S't - S''t) \quad (5)$$
5. Determining the size of the forecast (Ft + m)
   $$Ft + m = at + bt.m \quad (6)$$

Information:

Ft + m = Forecast value at period t.
a = Smoothing constant.
b = Trend coefficient.
S"t = Double Smoothing at period t
α = Smoothing coefficient (0 < α < 1)
Xt = Demand at period t
S"t−1 = Forecast at time t-1 (previous time)

Moving Average is a forecasting technique that uses historical data to estimate future outcomes (Sylvia, 2023). This method is done by calculating the average of a number of observation values to produce a projection for the next period. This method reduces data fluctuations by smoothing out variations, thus providing a more stable and measurable estimate (Rodiah, 2022). Forecasting using Moving Average can be seen as follows:

$$MA\,(n) = \sum \frac{Ai}{n} \qquad (7)$$

3. FINDINGS AND DISCUSSION

3.1. Data Collection

The data in the product inventory planning of pipes taken is in the form of demand data taken directly in the field through interviews. Through these interviews, the data is processed in such a way that when data processing can be carried out and can provide solutions to the problems that are being solved. Interviews were conducted in the PT XYZ work environment with employees related to their fields. The following is table 1 and figure 1 which show the demand data for non-API spec pipe raw materials type ASTM A252 GR 2 in KT 24 in 2023.

Table 1. 2023 Demand Data

Year	Month	Demand
2023	January	744
	February	1537
	March	676
	April	966
	May	223
	June	0
	July	28
	August	520
	September	370
	October	0
	November	0
	December	608
TOTAL		5672

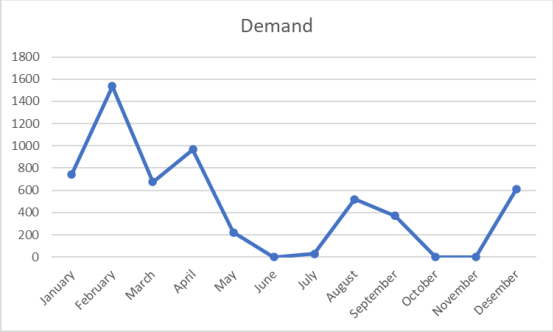

Figure 1. 2023 Demand Data Graph

Based on Table 1 and Figure 1, the demand data for Non-API pipe raw materials type ASTM A252 GR 2 in KT 24 in 2023 shows quite significant fluctuations every month. The highest demand occurred in February with 1,537 units, followed by April with 966 units. Conversely, the lowest demand occurred in July, which was 28 units, and June which had no demand at all (0 units).

The trend reflects the existence of an unstable demand pattern, which is likely influenced by factors such as project schedules, production cycles, and raw material availability. This irregularity poses a challenge in inventory planning, as sharp spikes and drops in demand can lead to overstock or stockouts, which impact production efficiency and storage costs (Sari, 2022).

3.2. Data Processing

The first thing in data processing is to calculate Double Exponential Smoothing. This method was chosen because of its ability to handle data with trends, so that it can provide more accurate forecasting results than simple forecasting methods. By considering the optimal smoothing parameter values, DES will produce a more stable estimate of future demand and can be used as a basis for planning raw material inventory at PT XYZ. Below is a table 2 summary of the results of manual data processing using the Double Exponential Smoothing (DES) method applied with various alpha values from 0.1 to 0.9.

Table 2. DES Method Forecasting Results

Number	Method	MSE Value	MAD Value	MAPE Value
1	Double Exponential Smoothing α = 0,1	188459,47	362,59	3,60
2	Double Exponential	184329,21	359,35	2,71

Number	Method	MSE Value	MAD Value	MAPE Value
	Smoothing α = 0,2			
3	Double Exponential Smoothing α = 0,3	200615,59	365,39	1,72
4	Double Exponential Smoothing α = 0,4	222536,62	372,84	1,30
5	Double Exponential Smoothing α = 0,5	251376,72	393,76	2,07
6	Double Exponential Smoothing α = 0,6	289850,80	433,16	2,65
7	Double Exponential Smoothing α = 0,7	341188,15	491,02	3,01
8	Double Exponential Smoothing α = 0,8	411434,19	558,84	3,18
9	Double Exponential Smoothing α = 0,9	512192,32	623,95	3,17
Smallest MSE Value		184329,21	359,35	1,30

Based on table 2 above, which is the calculation of Double Exponential Smoothing with an α value between 0.1 and 0.9, it was found that the smallest MSE value was 184,329.21 at α = 0.2. The results of the Double Exponential Smoothing test with α = 0.2, as listed in Table 2, show a MAD value of 359.35, an MSE of 184,329.21, and a MAPE of 2.71274. These values describe the average deviation of the forecast produced using the Double Exponential Smoothing method. So the alpha value of 0.2 from the DES method was selected to compare the forecast results with the Moving Average method.

Next is to calculate the Moving Average. This method is chosen because of its simplicity in calculating the average demand in a certain period, so it can reduce data fluctuations and provide a clearer picture of demand trends (Khadarusman, Kusrini and Kusnawi, 2024). Based on the calculation, the forecasting results with Moving Average show that the MA-2 period provides the best accuracy with a Mean Squared Error (MSE) value of 182067 and a Mean Absolute Percentage Error (MAPE) of 1.24%. The complete results of the Moving Average calculation can be seen in Table 3 below.

Table 3. Moving Average 2 period Method Forecasting Results

Measure	Value
Error Measures	
Bias (Mean Error)	-130,1
MAD (Mean Absolute Deviation)	372,1
MSE (Mean Squared Error)	182067,3
Standard Error	477,058
MAPE (Mean Absolute Percent Error)	87,289%
Forecast	
Next Period	304

Based on the calculation of table 3 above, the MAD MA (2) value is 372.1. MAD MA (2X3) is 380.1. While the MSE MA (2) value is 182067. MSE MA (2X3) is 270682 and the MAPE MA (2) value is 1.246981. MAPE (2X3) is 7.475175. These values describe the average maximum deviation resulting from forecasting using the Moving Average method.

Next is the recapitulation of forecasting results that present a summary of the use of the Double Exponential Smoothing (DES) and Moving Average (MA) methods in predicting the raw material requirements for Non-API type ASTM A252 GR 2 pipes at KT 24. The evaluation was carried out by comparing the accuracy levels of the two methods based on the Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) values. The method with the smallest MSE value is considered the best approach in producing more accurate predictions (Almaliki *et al.*, 2024). The recapitulation results of the forecasting of the two methods are presented in Table 4 below, which is used as a basis for selecting the optimal forecasting method.

Table 4. Forecast Results Summary

Period (0)	Demand (x)	Forecasting Methods		
		MA (2)	MA (2X3)	DES (0,2)
January	744			
February	1537			
March	676	1141		1061,2
April	966	1107		938,8
May	223	821		966,0
June	0	595	1023	686,2
July	28	112	841	399,4
August	520	14	509	211,1
September	370	274	240	280,0
October	0	445	133	273,7
November	0	185	244	125,6
December	608	0	301	25,7

			204,0	Smallest Value
MSE	182067	270682	184329,21	182067
MAD	372,100	380,071	359,35	359,349
MAPE	1,24698	7,47518	2,71274	1,24698

Based on the analysis of the two forecasting methods used, it was found that the Moving Average (MA) method has the smallest MSE value, which is 182,067. The smallest MAD value is obtained from the Double Exponential Smoothing (DES) method with $\alpha = 0.2$, which is 359.349. On the other hand, the method that produces the smallest MAPE is Moving Average (MA), with a value of 1.24698.

Before determining the forecast results for several future periods using the selected method, and before performing calculations with POM-QM for Windows, it is important to first test the validity of the method. Validation testing is carried out using Tracking Signal, which aims to map the error pattern of the selected method and evaluate its movement. If the error value remains within the tolerance limit, then the forecasting method can be said to be valid and suitable for use for further predictions (Sebastian Rudi, Agus Pranoto and Xaverius Ariwibisono, 2023). However, if there is an error value that exceeds the tolerance limit, further analysis is needed to identify whether the spike in demand, whether positive or negative, has the potential to reoccur in the future. Figure 5 below presents a Tracking Signal graph from the Moving Average method.

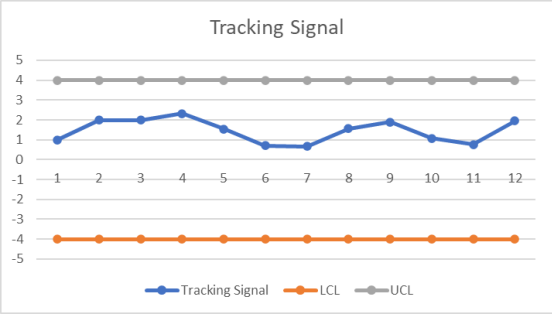

Figure 2. Signal Tracking Graph

Based on the Tracking Signal graph on the Moving Average method above, it can be observed that all error values are within the specified tolerance limits, namely between the Upper Control Limit (UCL) and the Lower Control Limit (LCL). This shows that the forecasting method used does not experience significant bias and remains within acceptable control limits (Indah Vindari *et al.*, 2023). Thus, the Moving Average method can be declared valid and feasible to be used to forecast demand in the future period. The accuracy of this forecast provides a stronger basis for decision making related to production and inventory planning.

Furthermore, to ensure the validity and accuracy of the forecasting results, in addition to manual calculations and signal tracking, data processing is also carried out using the POM-QM for Windows software. The use of this software allows for more systematic calculations and minimizes the potential for errors in the forecasting process. The following are the results of the Moving Average method calculations that have been processed using POM-QM for Windows as validation of the manual calculation results. Below is Figure 2 which is a forecast calculation using the 2-month Period Moving Average method on the POM QM software.

	Demand(y)	Forecast	Error	|Error|	Error^2	|Pct Error|
January	744					
February	1537					
March	676	1140,5	-464,5	464,5	215760,3	68,713%
April	966	1106,5	-140,5	140,5	19740,25	14,545%
May	223	821	-598	598	357604	268,161%
June	0	594,5	-594,5	594,5	353430,3	0%
July	28	111,5	-83,5	83,5	6972,25	298,214%
August	520	14	506	506	256036	97,308%
September	370	274	96	96	9216	25,946%
October	0	445	-445	445	198025	0%
November	0	185	-185	185	34225	0%
December	608	0	608	608	369664	100%
TOTALS	5672		-1301	3721	1820673	872,887%
AVERAGE	472,667		-130,1	372,1	182067,3	87,289%
Next perio...		304	(Bias)	(MAD)	(MSE)	(MAPE)
				Std err	477,058	

Figure 3. 2 Month Moving Average Forecasting Using POM QM Software

The calculation results of the Moving Average method (2) obtained through POM-QM for Windows show similarities with the results of manual calculations, indicating that the forecasting process has been carried out correctly and consistently. From the calculation results table, it can be seen that the Mean Squared Error (MSE) value is 182067.3 and the Mean Absolute Percentage Error (MAPE) is 87.289%, in accordance with the results obtained manually.

In addition, the forecast value for the next period is 304, which shows a demand trend based on previous data patterns. With this conformity, it can be concluded that the Moving Average (2) method can be used as a valid forecasting

approach for companies in estimating raw material needs more accurately. Below is Figure 3 which shows the results of the accuracy of the 2-month moving average forecast using the POM QM software.

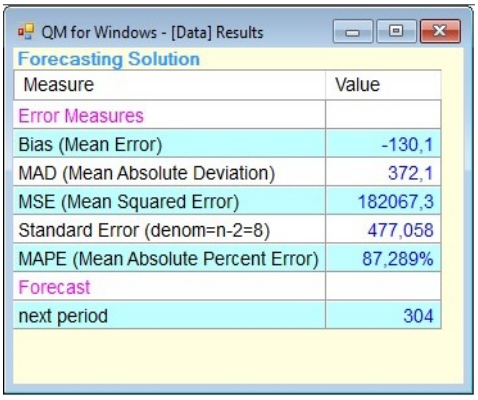

Figure 4. Forecasting Accuracy Results of Moving Average Period 2 Months Using POM QM Software

Next, Figure 4 below shows the results of forecasting calculations using the Moving Average method with a period of two months for the next 12 periods. This calculation is carried out to predict future raw material needs based on previous demand patterns, so that companies can plan inventory more optimally.

	Demand(y)	Forecast
January	0	
February	0	
March	1141	0
April	1107	570,5
May	821	1124
June	595	964
July	112	708
August	14	353,5
September	274	63
October	445	144
November	185	359,5
December	0	315
TOTALS	4694	
AVERAGE	391,167	
Next period forecast		92,5

Figure 5. Forecasting Accuracy Results of 2-Month Moving Average Period in the Next 12 Periods Using POM QM Software

In the forecasting process, there is a possibility of differences between the actual data and the forecast results produced. This deviation can be caused by various factors, including errors in calculations and limitations of the model in capturing certain patterns or trends in historical data. Therefore, to assess the level of accuracy of the method used, the calculation of the Mean Squared Error (MSE), Mean Absolute Deviation (MAD), and Mean Absolute Percentage Error (MAPE) values is carried out. The following table 6 shows a comparison of the calculation results of the three parameters as an indicator of the level of error in forecasting.

Table 6. Comparison of MSE, MAD, MAPE Results

METHOD	MA (2)	MA (2X3)	DES (0,2)
MSE	182067	270682	184329,21
MAD	372,100	380,071	359,35
MAPE	1,24698	7,475184	2,7127

Table 5 above presents a comparison of forecasting accuracy between the methods used based on MSE, MAD, and MAPE values. The calculation results show that the method with the smallest MSE value is MA (2), with a value of 182,067, while the method with the largest MSE value is MA (2X3), which reaches 270,682. In terms of MAD, the DES method with $\alpha = 0.2$ has the smallest value of 359.35, while the MA (2X3) method records the highest MAD value, which is 380.071. Meanwhile, in MAPE, the MA (2) method shows the smallest relative error rate with a value of 1.24698, while the MA (2X3) method has the largest MAPE, which is 7.4751. Based on these results, the MA (2) method can be said to be a more accurate method in forecasting compared to other methods because it has a smaller error value.

4.CONCLUSION AND SUGGESTION

Based on the results of the study, it can be concluded that PT XYZ does not yet have a structured forecasting system in raw material planning, so it has the potential to experience stock imbalances that have an impact on production efficiency. Therefore, this study conducted a forecasting analysis using the Double Exponential Smoothing (DES) and Moving Average (MA) methods with the help of POM-QM for Windows software to determine the best method in predicting the raw material needs of Non-API type ASTM A252 GR 2 pipes at KT 24.

The results of the analysis show that the Moving Average method with a two-month period (MA-2) provides the best level of accuracy compared to other methods, with a Mean Squared Error (MSE) value of 182067 and a Mean Absolute Percentage Error (MAPE) of 1.24%. With higher accuracy, the MA-2 method is recommended for use by PT XYZ in planning

its raw material inventory. The implementation of this method is expected to reduce uncertainty in raw material procurement, optimize production efficiency, and reduce storage costs due to excess stock.

Theoretically, the research that has been conducted contributes to enriching the study on the application of forecasting methods in raw material inventory planning, especially in the manufacturing industry. The results of this study also strengthen the theory that choosing the right forecasting method can improve the accuracy of demand predictions and optimize the supply chain process. In terms of practice, the implications of this study are to provide recommendations for PT XYZ to start implementing a data-based forecasting system to improve the efficiency of raw material management and reduce operational risks due to stock imbalances.

For future research, it is recommended to develop more complex forecasting models by considering external factors such as market trends, economic cycles, and seasonal variables. In addition, the integration of machine learning or hybrid forecasting methods can be an alternative to improve prediction accuracy. The implementation of an Enterprise Resource Planning (ERP)-based system with a forecasting module can also be a strategic step to support more accurate decision making in production and inventory planning.

ACKNOLEDGEMENT

The author would like to express his gratitude to PT XYZ for the opportunity and willingness to accept me to conduct research until the data is complete with the hope that this research can be a support in preparing for production to estimate the number of products to be produced, which aims for effective and efficient planning.

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