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Sulfuric Acid Demand Forecasting Analysis Using Double Moving Average and Double Exponential Smoothing Methods at PT Petrokimia Gresik

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ABSTRACT

PT Petrokimia Gresik is the most complete fertilizer producer in Indonesia, offering a wide range of fertilizers and non-fertilizers for agro-industrial solutions. One of its key non-fertilizer products is Sulfuric Acid. In planning future production, forecasting sales demand is the first crucial step. However, the company faces a challenge with inconsistencies between sales forecasts and actual sales of Sulfuric Acid. Discrepancies between forecasted and actual sales can lead to significant differences, impacting production planning and inventory management. To address this issue, this study aims to identify the most effective demand forecasting method. The study considers two alternative forecasting methods: Double Moving Average and Double Exponential Smoothing. Using a quantitative approach, with data collected through field observations, the study finds that the Double Exponential Smoothing method, with a smoothing constant (α) of 0.2, results in the lowest error rate. The Mean Absolute Deviation (MAD), which measures the average absolute difference between actual and forecasted sales, is 1.0185. Additionally, the Mean Squared Error (MSE), which gives more weight to larger errors through squaring, is calculated as 1.25681. Based on these results, the study recommends the Double Exponential Smoothing method as the most effective forecasting tool for the company.

INTRODUCTION

The company has a vision, mission, and goals for future growth by setting targets and being responsive to change. Managerial leadership is a key factor in the success of the company, because their decisions affect employees and the future of the company (Chaerunnisa & Momon, 2021). In facing high levels of competition, companies must plan production carefully to build a good company reputation by providing quality products or services that can meet market needs on time and in the right quantities, with the hope of increasing profitability. Managerial decisions and product innovation determine the success of the company, with good decision making and a good understanding of market conditions and forecasting product demand for the future period being important keys (Ernawati, 2019). Forecasting is defined as the process of estimating future values of a variable using information from previous and current values. It is an important tool for businesses and organizations because it helps in making accurate decisions related to production, inventory, marketing, and other activities (Pradana et al., 2020). Forecasting is the process of predicting or estimating future events or outcomes based on existing data or information. In various fields, such as economics, business, and meteorology, forecasting is used to make better decisions. Forecasting methods can be qualitative, such as surveys and interviews, or quantitative, such as statistical analysis and mathematical models. Forecasting is an approach used to plan the

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future in detail, based on historical information from the previous period to the present (Dinanti & Suryati, 2023). This process aims to reduce the possibility of errors in anticipating future situations. Forecasting allows for taking more appropriate steps in dealing with possible challenges, so that it can provide a competitive advantage for organizations or businesses (Anna Nita Kusumawati et al., 2021)

There are two types of comprehensive forecasting, namely qualitative forecasting and quantitative forecasting (Setyawan et al., n.d.).The main purpose of forecasting is to reduce uncertainty and help plan appropriate steps (Listiowarni et al., 2020). PT Petrokimia Gresik is a company that produces fertilizers and non-fertilizer products. PT Petrokimia Gresik strives to fulfill consumer desires, from which PT Petrokimia produces supporting parts or components for fertilizer production materials.

PT. Petrokimia Gresik, as a fertilizer company in Indonesia, not only produces fertilizers, both subsidized and non-subsidized fertilizers (Yanyuni & Widjajati, 2022). However, PT Petrokimia Gresik also produces raw materials, one of which is Sulfuric Acid products with a minimum H2SO4 content of 98% and in liquid form, which are used for mixing the fertilizer industry (ZA, SP 36, SP 18) and chemicals (Phosphoric Acid, Alum, PAC, Rayon Fiber, Alcohol, Detergent) and others. PT Petrokimia Gresik's non-fertilizer products play an important role in diversifying its revenue streams and reducing its dependence on fertilizer sales. These products contribute to the overall growth and stability of the company by serving various industries and applications (Widyadhini, 2021).

In producing non-fertilizer products, the type of Sulfuric Acid must be precise. If the demand for Sulfuric Acid products is low, the raw material for Sulfuric Acid, namely sulfur, will accumulate in storage and affect the quality of the sulfur. Likewise, if the demand for Sulfuric Acid products is high, then the raw materials for Sulfuric Acid will experience a shortage, forcing the purchase of raw materials which of course requires a faster time. To avoid these problems and unstable sales fluctuations, the steps that can be taken are to forecast product sales to ensure product availability in accordance with future demand.

In this research, the Double Moving Average and Double Exponential Smoothing methods were used as calculation tools for the actual sales data for Sulfuric Acid at PT Petrokimia Gresik. The Double Moving Average method is more appropriate for analyzing random fluctuations in demand volume, where companies choose this method when they predict a spike in demand in the following month (Sarumaha, 2021). Double Exponential Smoothing method is applied when the data shows a trend. Exponential Smoothing with trend works like simple smoothing, but with the difference that two components—level and trend—must be updated each period. Level is a smoothed estimate of the data value at the end of each period, while trend is a smoothed estimate of the average growth at the end of each period (Sariaman Manullang & Abil Mansyur, 2023). MAD is an average value of the absolute error in a period, regardless of whether the forecast has a higher or lower result than the actual value (Aprilianti et al., 2020). MSE provides an important alternative in forecasting analysis because it is able to capture moderate errors, which are desired in forecasting rather than large errors (Arisandi et al., 2023).

The purpose of this study is to determine the most optimal forecasting method for planning the prognosis of Sulfuric Acid products by PT Petrokimia Gresik with the smallest error rate. Calculating the forecast of Sulfuric Acid product demand and measuring the accuracy of the results in forecasting with MAD and MSE. Based on this, the author uses the Double Moving Average and Double Exponential Smoothing methods.

RESEARCH METHODS

At this stage, the data on the planned realization of Sulphate Acid sales for the period July'23-July'24 is collected from the Master Results or daily reports and obtained from the staff of the Production Planning and Energy Management Department.

Double Moving Average

The Double Moving Average (DMA) method is one of the forecasting techniques in statistics that is often used to smooth historical data and identify long-term trends (Aziza, 2022). When using the moving average method for forecasting, the current data value is used in the computation process, and the old data values are deleted. The data quantity whose average value shifts from the first known data value to the t data produces the average value (Khamaludin, 2019).

a. Determining the Single Moving Average value

$$St' = \frac{Xt+Xt-1+Xt-2+\cdots+Xt-k-1}{k} \quad (1)$$

b. Determining the Double Moving Average value

$$St" = \frac{St+St-1+St-2+\cdots+St-k-1}{k} \quad (2)$$

c. Determining constant values

$$at = 2S't - S"t \quad (3)$$

d. Determining the trend coefficient value

$$bt = \frac{2}{k-1}\,(S't - S"t) \quad (4)$$

e. Determine the value of the forecast

$$ft + m = at + btm \quad (5)$$

Double Exponential Smoothing

Double Exponential Smoothing (DES) is a forecasting technique used to predict data values in future periods based on historical data. This method is a development of Single Exponential Smoothing, with the addition of components to account for trends in the data (Adryan et al., 2022)

a. Determine the first smoothing

$$S't = \propto .Xt + (1-\propto).S't - 1 \quad (6)$$

b. Determine the second smoothing

$$S"t = \propto .S't + (1-\propto).S"t - 1 \quad (7)$$

c. Determining the magnitude of the constant

$$a = S't + (S't - S"t) \quad (8)$$

d. Determining the size of the slope/trend coefficient (b)

$$b = \frac{a}{1-a}\,(S't - S"t) \quad (9)$$

e. Determining the size of the forecast

$$Ft + m = at + bt\,.m \quad (10)$$

Forecasting Result Measurement

The measure of forecasting accuracy, which evaluates the extent to which forecasting results match actual demand, is an assessment of how far the actual demand and forecast results differ. There are various methods for evaluating the error of a forecasting technique (Rizal et al., 2021). Almost all of these methods use the average of a function that measures the difference between the actual value and the predicted value, which is called the residual(Masdupi & Linda, 2019).

$$e_t = X_t - S_t \quad (11)$$

Mean Absolute Demand

The MAD calculation is used to calculate the absolute average error (Maharani & Fauzan, 2019). Assuming that each forecast has an absolute value for each error, the mean absolute deviation measures the accuracy of the forecast.

$$MAD = \frac{\sum_{t=1}^{n}|A_t - F_t|}{n} = \frac{\sum absolute\ dari\ forecast\ error}{n} \quad (12)$$

Mean Squared Error

Mean Squared Error (MSE) is a metric that shows the average of the squared errors of the forecast value with the actual value (Kurniawan & Herwanto, 2021). MSE is often used to evaluate the level of accuracy of an estimate by measuring the magnitude of the error in the forecast (Samuel et al., 2020).

$$MSE = \frac{\sum_{t=1}^{n}(A_t - F_t)^2}{n} \quad (13)$$

Table 1. Description of symbol

Symbol	Description
xt	Actual data value at period t
St	Forecast value in period t
St'	Single Moving Average
S"t	Double Moving Average
S't	Single Exponential Smoothing value
S"t	Double Exponential Smoothing value
At	actual demand in period t
at	Constant
m	Duration of the prediction interval
at,bt	Smoothing Constant
ft+m	Forecast
k	Time Order
Ft	forecast in period t
et	forecast error in period t
n	number of forecast periods
$\propto$	Smoothing parameter with range $0 < \propto < 1$

RESULTS AND DISCUSSION

At the data collection stage, it was obtained from the PPPE (Production Planning & Energy Management Dept.) section. The data taken was the Master Production Results of PT Petrokimia Gresik during the period July 2023 - July 2024. The data obtained on the realization of sales of non-fertilizer products of the Sulfuric Acid type are as follows:

Table 2. Historical Data on Sales Realization of Sulfuric Acid

Month	Realization
Juli'23	13.264
Agustus'23	18.988
September'23	22.690
Oktober'23	34.569
November'23	24.860
Desember'23	30.212
Januari'24	11.756
Februari'24	11.301
Maret'24	33.962
April'24	22.259
Mei'24	17.698
Juni'24	15.658
Juli'24	17.940

(Source: PT Petrokimia Gresik)

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a. Double Moving Average Ordo 3 month

The 3-period Double Moving Average forecasting model is obtained by first finding each formula starting from July 2023 as explained below:

a. Determining the Single Moving Average value

$$St' = \frac{Xt + Xt - 1 + Xt - 2 + \cdots + Xt - k - 1}{k}$$

$$St' = \frac{13.264 + 18.988 + 22.690}{3}$$

$$St' = 18.314$$

b. Determining the Double Moving Average value

$$St" = \frac{St + St - 1 + St - 2 + \cdots + St - k - 1}{k}$$

$$St" = \frac{18.314 + 25.416 + 27.373}{3}$$

$$S"t = 23.701$$

c. Determining constant values

$$at = 2S't - S"t$$

$$at = 2(18.314 - 23.701)$$

$$at = 78.4469$$

d. Determining the trend coefficient value

$$bt = \frac{2}{k - 1}\ (S't - S"t)$$

$$bt = \frac{2}{3 - 1}\ (18.314 - 23.701)$$

$$bt = 3.67211$$

e. Determine the value of the forecast

$$ft + m = at + btm$$

$$ft + m = 78.4469 + 3.67211$$

$$ft + m = 82.119$$

The calculation for finding the forecast demand error level is as follows:

$$e_t = X_t - S_t$$

$$e_t = 30.212 - 82.119$$

$$e_t = -51.907$$

The results of the calculations to find the level of forecast accuracy using the MAD method are as follows:

$$MAD = \frac{\sum_{t=1}^{n} |A_t - F_t|}{n} = \frac{\sum absolute\ dari\ forecast\ error}{n}$$

MAD = (51.907+129.792+185.319+204.626+239.386+289.21+347.471+385.146) / 8 = 48.143

The results of the calculations to find the level of forecast accuracy using the MSE method are as follows:

$$MSE = \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n}$$

MSE=(2694.337+6066.073+3083.248+372.760+1208.258+2482.431+3394.344+1419.406)/8 = 2590.107

The calculation continues until the last data, namely data in July 2024. So the results of the Sulfuric Acid sales forecast for the next 6 periods using the 3-month Double Moving Average.

b. Double Moving Average Ordo 4 month

a. Determining the Single Moving Average value

$$St' = \frac{Xt + Xt - 1 + Xt - 2 + \cdots + Xt - k - 1}{k}$$

$$St' = \frac{13.264 + 18.988 + 22.690 + 34.569}{4}$$

$$St' = 22.378$$

b. Determining the Double Moving Average value

$$St" = \frac{St + St - 1 + St - 2 + \cdots + St - k - 1}{k}$$

$$St" = \frac{22.378 + 25.277 + 28.083 + 25.349}{4}$$

$$S"t = 25.272$$

c. Determining constant values

$$at = 2S't - S"t$$

$$at = 2(22.378 - 25.272)$$

$$at = 75.9701$$

d. Determining the trend coefficient value

$$bt = \frac{2}{k - 1}\ (S't - S"t)$$

$$bt = \frac{2}{4 - 1}\ (22.378 - 25.272)$$

$$bt = 0.07763$$

e. Determine the value of the forecast

$$ft + m = at + btm$$

$$ft + m = 75.9701 + 0.07763$$

$$ft + m = 76.048$$

The calculation for finding the forecast demand error level is as follows:

$$e_t = X_t - S_t$$

$$e_t = 11.756 - 76.048$$

$$e_t = -64.747$$

The results of the calculations to find the level of forecast accuracy using the MAD method are as follows:

$$MAD = \frac{\sum_{t=1}^{n} |A_t - F_t|}{n} = \frac{\sum absolute\ dari\ forecast\ error}{n}$$

MAD = (64.74675+24.6348+43.16425+41.7605+48.257+49.24275)/6 = 45.301

The results of the calculations to find the level of forecast accuracy using the MSE method are as follows:

$$MSE = \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n}$$

MSE=(4192.142+606.871+1863.152+1743.939+2328.738+2424.848)/6=2193.282

The calculation continues until the last data, namely data in July 2024. So the results of the Sulfuric Acid sales forecast for the next 6 periods using the 4-month Double Moving Average.

c. Double Exponential Smoothing

For the calculation of the next period forecast, it can be done through the previous sales realization data of Sulfuric Acid. An example of the calculation of the demand forecast for Sulfuric Acid uses the Double Exponential Smoothing method (α = 0.2). It should be noted that α = 0.2 is used, namely the selection of the optimal α using the Solver feature in Excel. The equation used is:

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a. Determine the first smoothing

$$S't = \propto . Xt + (1-\propto). S't - 1$$
$$S't = 0{,}2\ (18.988) + (1 - 0{,}2)\ 13.264$$
$$S't = 14.665$$

b. Determine the second smoothing

$$S"t = \propto . S't + (1-\propto). S"t - 1$$
$$S"t = 0{,}2\ (14.665) + (1-\propto).13.264$$
$$S"t = 13.607$$

c. Determining the magnitude of the constant

$$a = S't + (S't - S"t)$$
$$a = 2(14.665) - 13.607$$
$$a = 15{,}723$$

d. Determining the size of the slope/trend coefficient (b)

$$b = \frac{a}{1-a}\ (S't - S"t)$$
$$b = \frac{0{,}2}{1-0{,}2}\ (14.665 - 13.607)$$
$$b = 0{,}3429$$

e. Determining the size of the forecast

$$Ft + m = at + bt\,.\,m$$
$$Ft + m = 15.723 + 0{,}3429\ (1)$$
$$Ft + m = 16.066$$

The calculation for finding the forecast demand error level is as follows:

$$e_t = X_t - S_t$$
$$e_t = 22.690 - 16.066$$
$$e_t = 6.62$$

The results of the calculations to find the level of forecast accuracy using the MAD method are as follows:

$$MAD = \frac{\sum_{t=1}^{n} |A_t - F_t|}{n} = \frac{\sum absolute\ dari\ forecast\ error}{n}$$

MAD=(1.4123+1.7591+0.8977+1.0813+0.3852+0.4928+1.9171+0.8747+0.7183+0.7182 +0.9472)/11 = 1.0185

The results of the calculations to find the level of forecast accuracy using the MSE method are as follows:

$$MSE = \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n}$$

MSE=(1.9946+3.0946+0.8059+1.1693+0.1484+0.2428+3.6754+0.7651+0.5159+0.5158 +0.8971/11= 1.2568

From the forecasting results that have been carried out, the next step is to calculate the standard error using the MAD (Mean Absolute Demand) and MSE (Mean Squared Error) techniques and forecast from the methods.

Table 3. MAD and MSE analysis results and forecast results

Methods	n	Forecast	MAD	MSE
Double Moving Average	3 month	48.302 45.309 42.315 39.322 36.328	17.6640	2590.107
Double Moving Average	4 month	55.166 53.078 50.990 48.902 46.814	45.3010	2193.282
Double Exponential Smoothing	**α = 0,2**	44.726 18.229 17.946 17.664 17.382 17.099 16.817	1.0185	1.25681

The calculation continues until the last data, namely data in July 2024. So the results of the Sulfuric Acid sales forecast for the next 6 periods using the 4 Double Exponential Smoothing method (α = 0.2).

From the research results from (Tobing, 2022), the double moving average method is more recommended for forecasting demand. This is in line with research from (Hudiyanti et al., 2019) that compares the double moving average and double exponential smoothing methods. From this research, the double exponential smoothing method is better for forecasting than the double moving average method.

CONCLUSION

Determination of movement value and weight value can affect the accuracy of each method. By using the movement value of period n = 3 and period n = 4 in the double moving average method, the value obtained with n = 4 has good accuracy (smallest error rate), namely MAD 45.3010 and MSE 2193.282.

After comparing two forecasting methods, namely double moving average and double exponential smoothing, it was found that the double exponential smoothing method with a weight value of 0.2 provided more accurate forecasting results for sulfuric acid demand at PT Petrokimia Gresik. This is indicated by the lower error value, namely MAD (Mean Absolute Deviation) of 1.0185 and MSE (Mean Squared Error) of 1.25681 compared to the double moving average method. In other words, the double exponential smoothing method with a weight of 0.2 is able to predict sulfuric acid demand with a smaller error rate, so it can be used as a better reference in production planning and inventory management in the company.

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