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Tree Triple Exponential Smoothing Analysis in Forecasting of Fertilizer Sales

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ABSTRACT

The majority of Indonesia's population relies on the agricultural sector, making fertilizer an essential raw material to increase productivity. PT. Pupuk Iskandar Muda (PIM), faces challenges in maintaining the balance of urea fertilizer production and demand. In 2021, PIM's urea fertilizer production was unable to meet demand, while in 2019, 2020, and 2022 there was overproduction. This inventory non-optimization can lead to productivity bottlenecks and increased storage costs. One solution to this problem is forecasting. This research uses the Triple Exponential Smoothing (TES) forecasting method in forecasting urea fertilizer sales for the next period. The data used is fertilizer sales data from PT PIM for the 2019-2023 period. Evaluation of the accuracy value is done using the MAD, MSE, and MAPE matrices. The results of this study indicate that the TES method with a smoothing weight value of Alpha = 0.4, Beta = 0.2, and Gamma = 0.4 produces a MAD value of 22,017.75, MSE of 990,752,983.08, and MAPE of 22.3% which can be categorized as quite feasible to use in forecasting the demand for urea fertilizer at PT PIM seen from the MAPE value.

1. INTRODUCTION

Most Indonesians depend on and work in the agricultural sector for their livelihood, and agriculture plays an important role in the economy of Indonesia, which is known as an agrarian country. In this case, fertilizer is one of the important raw materials for the agricultural industry to produce quality production [1]. Suboptimal fertilizer inventory can cause losses. Because, if the fertilizer supply is lacking and the amount of fertilizer demand is not met, it will hamper the productivity of agricultural products which has an impact on food availability, but if the fertilizer supply is excessive or overstock, there will be a buildup of fertilizer which results in an increase in fertilizer storage and handling costs [2]. PT Pupuk Iskandar Muda (PIM) is a subsidiary of PT Pupuk Indonesia (Persero) engaged in domestic agricultural business, trade and services that increase agricultural productivity. PIM prepares fertilizers in its marketing area which includes Aceh, North Sumatra, West Sumatra, Riau and Riau Islands. One of the fertilizers produced by PIM is urea fertilizer, overall based on PIM annual report data in 2019 PIM produced 337,547 tons of urea fertilizer with sales of 291,495.25 tons, in 2020 PIM produced 402,108 tons of urea fertilizer with sales of 383,696.53 tons, in 2021 produced 391,099 tons of urea fertilizer with sales of 467,777.55 tons, in 2022 produced fertilizer production of 526,580 tons with consumption of 477,991.15 tons. Based on the data above, it can be seen that the amount of urea fertilizer production in 2021 has not been able to meet the demand for fertilizer in the PIM marketing area. Whereas in 2019, 2020, and 2022 there was an overproduction of fertilizer. This can be an internal problem for the company. If there is no ideal solution to deal with fertilizer production shortages and overproduction that can be a loss in the future [3].
The solution that can be done is to plan to meet consumer demand, especially those that are uncertain. One way to predict the amount of uncertain consumer demand in the future is to do forecasting in making decisions on planning the amount of product availability [4]. Forecasting is an effort to evaluate past situations to help predict the future using certain methods or techniques [5]. Forecasting can be done with various methods, including Triple Exponential Smoothing. Triple Exponential Smoothing is a method based on three smoothing equations, stationary, trend, and seasonal. To get good forecasting results, these three smoothing parameters are used [6] [7]. Based on the description of the problem, the author will conduct research to analyze the Triple Exponential Smoothing forecasting method to determine whether this forecasting method is good for making predictions of urea fertilizer sales at PIM in the future.

2. LITERATURE REVIEW

2.1 Urea Fertilizer

Urea fertilizer is an inorganic fertilizer made by a factory and contains nitrogen, potassium, and phosphate. Nitrogen is the most important element for plant growth, especially leaf growth. Most of the nitrogen that plants need to photosynthesize consists of nitrate and ammonium. To obtain the SNI (Indonesian National Standard) value, the nitrogen content of urea fertilizers distributed in the community has been measured. Artificial urea fertilizer is a single fertilizer containing the main nitrogen nutrient in the form of granules (prill) or granules (granule) with the chemical formula CO (NH2)2. The quality standard of artificial urea fertilizer must comply with SNI Number 02-2801-2010 [8].

2.2 Preprocessing

Preprocessing is done to clean, normalize, and prepare data so that it can be better processed by analysis algorithms or machine learning models. The dataset is first cleaned, corrected, and transformed without changing its originality [9].

2.3 Data Mining

Data mining can be defined as the complex decomposition of a set of data into information that has implicit potential (not real or obvious) that was previously unknown. It can also be defined as extracting and analyzing large portions of data using automated or semi-automated tools to find patterns that have meaning or intent [10]. The basic concept of data mining is to find hidden information in databases. It is also a part of Knowledge Discovery in Databases (KDD) to find patterns and useful information in data [11]. Data mining is divided into several groups based on the tasks it can perform

1. Description: Researchers and analysts usually try to find ways to describe patterns and trends hidden in the data they collect.
2. Estimation: Except that the estimation target variable is more numerical than categorical, estimation is similar to classification. The model is built with a complete list that provides the target variable value as a predicted value; then, at the next review, the estimated value of the target variable is based on the predicted variable value.
3. Forecasting: Prediction and classification are similar, except that prediction predicts the value of a future outcome.
4. Clustering: It is a method to group lists of data, observations, or cases in classes so that they have similarities. These sets of lists are called clusters because these lists have similarities with each other and have no similarities with other lists in the cluster.
5. Classification: In variable classification, the objective is categorical. For example, inventory can be categorized into three classes: high, medium, and low.
6. Association: Identifying relationships between different events that occur at the same time. Shopping cart analysis is a term more commonly used in the business world

2.4 Forecasting

Preprocessing is done to clean, normalize, and prepare data so that it can be better processed by analysis algorithms or machine learning models. The dataset is first cleaned, corrected, and transformed without changing its originality [9]. Forecasting is a common statistical task performed by businesses. It helps in making decisions about production schedules, transportation, and personnel and provides direction for long-term strategic planning [12]. Forecasting requires processing historical data to produce a forecast, which can be used as a reference for decision making needed for the future [13]. A business can use forecasting to plan more effectively for the future [5]. Forecasting has three types based on timeframe, namely:

1. Long time horizon: Forecasting with data within 2 years or more.
2. Medium time horizon: Forecasting with data within 3 months to 2 years.
3. Short time horizon: Forecasting with data within 0 to 3 months [14].

In forecasting, there are quantitative and qualitative methods. Qualitative methods use the opinions of experts to make decisions. Quantitative methods use historical company data to make decisions [15].

2.5 Metode Triple Exponential Smoothing (TES)

TES is a forecasting method based on three smoothing equations, namely the level smoothing equation, trend component, and seasonal component, each of which has different parameters [16]. TES requires the values of the smoothing weights alpha (α), beta (β), and gamma (γ) to be determined in a freehand manner, where there is no specific method to find the best values of alpha (α), beta (β), and gamma (γ), assuming that the values of α, β, γ are chosen on the interval, $0 \leq \alpha, \beta, \gamma < 1$ [16]. One type of TES method is additive, which has a formula for the smoothing equation and the level, trend, and seasonal components can be initialized as follows:

Smoothing equation

$$L_t = a(X_t - S_{t-s}) + (1-a)(L_{t-1} + T_{t-1}) \quad (1)$$

$$T_t = \beta(L_t - L_{t-1}) + (1-B)T_{t-1} \quad (2)$$

$$S_t = y(X_t - L_t) + (1-y)S_{t-s} \quad (3)$$

$$F_{t+m} = L_t + T_t m + S_{t-s+m} \quad (4)$$

Component Initialization

$$L_S = \frac{1}{s}(X_1 + X_2 + \cdots + X_L) \quad (5)$$

$$Ts = \frac{1}{s}\left(\frac{X_{s+1}-X_1}{s} + \frac{X_{s+2}-X_2}{s} + \cdots + \frac{X_{s+s}-X_s}{s}\right) \quad (6)$$

$$S_i = X_i - L_s \quad (7)$$

Where :

α	: level smoothing parameter, $0 \leq \alpha < 1$;
β	: trend smoothing parameter, $0 \leq \beta < 1$;
γ	: seasonal smoothing parameter, $0 \leq \gamma < 1$;
X_t	: actual data at time t;
L_t	: level smoothing at time t;
T_t	: trend smoothing at time t;
S_t	: seasonal smoothing at time t;
s	: seasonal length;
L_S	: level smoothing at time s;
Ts	: trend smoothing at time s;
S_i	: seasonal smoothing at time i , i= 1,2...,s;
F_{t-m}	: forecasting at time $(t+m)$.

2.6 Forecasting Model Accuracy Testing

Error testing is carried out to determine the accuracy value of the forecasting calculation. If the results show a small value, then the calculation results of the method are considered almost correct [16]. This is done by calculating the actual data value minus the forecasting result data, namely Mean Square Error (MSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD) [7]. Forecasting accuracy will be higher if the MAD, MSE, MAPE values are smaller (Agnes Manuhutu et al., 2021).

1. Mean Absolute Deviation (MAD): Mean Absolute Deviation is a way to sum the forecast errors without considering the algebraic sign divided by the number of observed data. In MAD, positive or negative direction errors will be treated equally, and only large errors in absolute terms are measured [17]. The sum of MAD can be calculated with the following formula:

$$MAD = \sum \frac{|Xt-Ft|}{n} \quad (8)$$

Where :

∑	= Describes the total of all absolute differences.
Xt	= Actual demand in period-t.
Ft	= Demand forecast at period-t.
n	= Number of forecasting periods involved.

2. Mean Squared Error (MSE): MSE the average of the squared differences between the forecasted and actual values is a technique that produces better error rates [7]. Mathematically, MSE is expressed by the following formula:

$$MSE = \sum \frac{(Xt-Ft)^2}{n} \quad (9)$$

Where :

∑	= Represents the total of all squared differences.
Xt	= Actual demand in period-t.
Ft	= Demand forecast at period-t.
n	= Number of forecasting periods involved.

3. Mean Absolute Percentage Error (MAPE): The average absolute percentage error, also known as MAPE, is used to show how much the forecast is wrong compared to the actual values of the list [4]. To calculate MAPE, the absolute error for each period is divided by the actual observed values for that period, then the absolute percentage errors are averaged. The final result is then multiplied by 100 and expressed as a percentage [4].

$$MAPE = \sum \frac{|Xt-Ft|}{Xt}\ 100\% \quad (10)$$

Where :

∑	= Describes the total of all *percentages error*.
Xt	= Actual demand in period-t.

Ft = Demand forecast at period-t.

MAPE has a percentage that can be used as a benchmark to determine the ability of the forecasting model, as can be seen in table 1 [15] .

Table 1. Previous Research

Percentage	Information
< 10%	Forecasting ability is very good
10% - 20%	Good forecasting ability
20% - 50%	Forecasting ability is quite good / decent
> 50%	Poor forecasting ability

3. METODOLOGY

The initial stage carried out is the collection of urea Fertilizer sales data from PT. Pupuk Iskandar Muda by conducting observations to obtain real-time urea fertilizer sales data. Furthermore, the data is preprocessed by deleting unnecessary rows and arranging the data in a vertical format to facilitate the forecasting process. then an analysis of the Triple Exponential Smoothing method will be carried out. This involves the calculation of forecasting using Triple Exponential Smoothing based on the pre-processed fertilizer sales. After forecasting is done, the results are evaluated using evaluation matrices namely Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). to assess how well the Triple Exponential Smoothing method can forecast fertilizer sales.

3.1 Data Description

The data used in this study were obtained by conducting interviews and observations at PT. Pupuk Iskandar Muda to obtain urea fertilizer sales data, where the data obtained are as follows:

Table 2. Urea Fertilizer Sales Data of PT PUPUK ISKANDAR MUDA

Month	2019	2020	2021	2022	2023
January	16,733.35	12,828.18	17,186.50	34,282.92	21,729.70
February	33,943.45	41,015.41	36,581.19	61,287.63	58,943.30
Maret	33,798.15	42,613.96	31,923.15	56,368.20	46,580.70
April	28,980.40	40,413.30	46,832.80	53,852.15	24,723.40
Mei	31,131.95	26,829.40	26,786.85	38,377.37	40,253.95
June	23,118.55	29,166.40	40,307.60	56,104.88	23,016.65
July	32,298.55	28,623.59	38,623.04	30,001.55	28,147.45
August	22,741.60	25,889.76	35,591.84	23,437.96	29,907.19
September	20,485.10	26,351.24	38,064.60	27,837.54	18,109.11
October	24,850.40	24,490.29	42,149.80	36,141.45	30,616.00
November	18,415.35	57,727.50	58,043.10	32,186.05	32,066.65
December	4,998.40	27,747.50	55,687.08	28,113.45	23,504.75
Grand Total	291,495.25	383,696.53	467,777.55	477,991.15	377,598.85

3.2 Preprocessing Data

Urea fertilizer sales data will be processed with the following steps. First, rows containing grand totals will be deleted. Next, the data will be converted to a vertical format to facilitate the forecasting process. In addition, the sales amount will be combined by quarter (every three months), so that in one year it will be divided into four quarters (Q) as follows table 3:

Table 3. Urea Fertilizer Sales Data o Preprocessing Results 2019-2023

Year	Quarter	Sales / Ton
2019	1	84.474,95
2019	2	83.230,90
2019	3	75.525,25
2019	4	48.264,15
2020	1	96.457,55
2020	2	96.409,10
2020	3	80.864,59
2020	4	109.965,29

2021	1	85.690,84
2021	2	113.927,25
2021	3	112.279,48
2021	4	155.879,98
2022	1	151.938,75
2022	2	148.334,40
2022	3	81.277,05
2022	4	96.440,95
2023	1	127.253,70
2023	2	87.994,00
2023	3	76.163,75
2023	4	86.187,40

The sales data above will be used as a graph to be analyzed. It can be seen that the 4th quarter of 2021 had the highest sales throughout the quarter at 155,879.98 tons while the 4th quarter of 2019 had the lowest sales at 48,264.15 tons. There are significant fluctuations each quarter with some identifiable seasonal trends. Each year quarter 1 and quarter 4 show relatively high sales, this is often related to the main growing season which occurs in November, December, January, February and March.

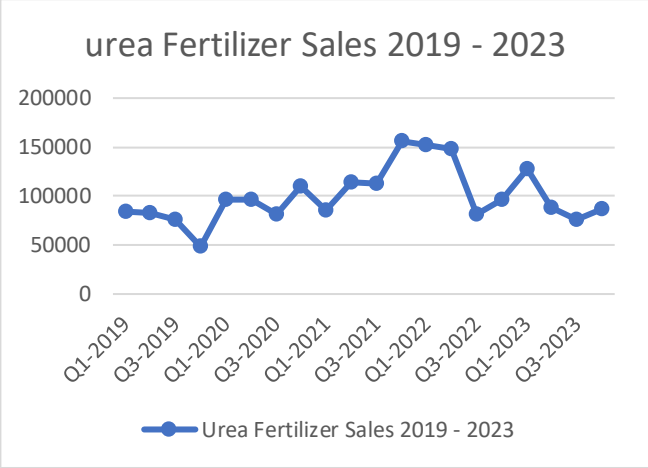

Figure 1. Urea fertilizer sales chart 2019 -2023

Quarter 3 often shows a decrease in sales compared to other quarters because it is related to the dry season or dry planting season that occurs in August, September, and October. Quarter 2 has sales that tend to stabilize and decrease slightly from quarter 1. In quarter 2, the gadu planting season usually occurs in April, May, June, and July.

3.3 Method Analysis

Using urea fertilizer sales data at PT Pupuk Iskandar Muda that has been preprocessed to calculate sales forecasting using the Triple Exponential Smoothing method.mThe initial forecasting calculation will be tested using the smoothing values $\alpha = 0.7$, $\beta = 0.2$, $\gamma = 0.1$.

3.4 Method Evaluation

Calculating the accuracy of the forecasting results of the Triple Exponential Smoothing method with several evaluation matrices, including Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) by experimenting with the smoothing values for level (α), trend (β), and seasonality (γ) is done, in order to create a more accurate model seen from the smallest MAD, MSE, MAPE values.

4. DISCUSSION AND RESULT

4.1 Triple Exponential Smoothing Calculation

First, level, trend, and seasonal initialization calculations will be performed to determine the initial values of the three smoothings as follows:

1. Level Smoothing Initialization Calculation: the level value will be taken from one season cycle of actual data. The calculation follows:

$$L_4 = \frac{1}{4}(84.474{,}95 + 83.230{,}90 + 75.525{,}25 + 48.264{,}15) = 72.873{,}81$$

2. Trend Smoothing Initialization Calculation: the trend value calculation is taken from the average difference from the previous period's data with the length of one season cycle. The calculation is as follows:

$$T4 = \frac{1}{4}\left(\frac{X_5 - X_1}{4} + \frac{X_6 - X_2}{4} + \frac{X_7 - X_3}{4} + \frac{X_8 - X_4}{4}\right)$$
$$T4 = \frac{1}{4}\left(\frac{96.457{,}55 - 84.474{,}95}{4} + \frac{96.409{,}10 - 83.230{,}90}{4} + \frac{80.864{,}59 - 75.525{,}25}{4} + \frac{109.965{,}29 - 48.264{,}15}{4}\right)$$
$$T4 = 5.762{,}58$$

3. Seasonal Smoothing Initialization Calculation: the calculation of the initial seasonal value uses actual data compared to the average of the initial level. The calculation follows:

$$S_1 = X_1 - L_4 = 84.474{,}95 - 72.873{,}81 = 11.601{,}14$$
$$S_2 = X_2 - L_4 = 83.230{,}90 - 72.873{,}81 = 10.357{,}09$$
$$S_3 = X_3 - L_4 = 75.525{,}25 - 72.873{,}81 = 2.651{,}44$$
$$S_4 = X_4 - L_4 = 48.264{,}15 - 72.873{,}81 = -24.609{,}66$$

After obtaining the initial values for level, trend, and seasonality, the calculation of level, trend, seasonal smoothing equations, and forecasting calculations will be carried out as follows:
Level, trend, seasonal, and t=5 forecasting smoothing equations:

$$L_5 = a(X_5 - S_{5-4}) + (1 - a)(L_{5-1} + T_{5-1})$$
$$L_5 = 0.7(96.457{,}55 - 11.601{,}14) + (1 - 0.7)(72.873{,}81 + 5.762{,}58)$$
$$L_5 = 82.990{,}41$$

$$T_5 = \beta(L_5 - L_{5-1}) + (1 - B)T_{5-1}$$
$$T_5 = 0.2(82.990{,}41 - 72.873{,}81) + (1 - 0.2)5.762{,}58$$
$$T_5 = 6.633{,}38$$

$$S_5 = y(X_5 - L_5) + (1 - y)S_{5-4}$$
$$S_5 = 0.1(96.457{,}55 - 82.990{,}41) + (1 - 0.1)11.601{,}14$$
$$S_5 = 11.787{,}74$$

$$F_{4+1} = L_4 + T_4 * 1 + S_{4-4+1}$$
$$F_5 = 72.873{,}81 + 5.762{,}58 * 1 + 11.601{,}14$$
$$F_5 = 90.237{,}53$$

continued until level, trend, seasonal, and forecasting smoothing equations t = 20. After that, urea fertilizer sales forecasting for 2024 is carried out as follows:

Quarter 1 2024

$$F_{20+1} = L_{20} + T_{20} * 1 + S_{20-4+1}$$
$$F_{21} = 96.416{,}34 + -14.27{,}55 * 1 + 9.355{,}53$$
$$F_{21} = 104.344{,}32$$

Quarter 2 2024

$$F_{20+2} = L_{20} + T_{20} * 2 + S_{20-4+2}$$
$$F_{21} = 96.416{,}34 + -14.27{,}55 * 1 + 8.713{,}06$$
$$F_{21} = 102.274{,}29$$

Quarter 3 2024

$$F_{20+1} = L_{20} + T_{20} * 1 + S_{20-4+1}$$
$$F_{21} = 96.416{,}34 + -14.27{,}55 * 1 + -63.52$$
$$F_{21} = 92.070{,}16$$

Quarter 4 2024

$$F_{20+1} = L_{20} + T_{20} * 1 + S_{20-4+1}$$
$$F_{21} = 96.416{,}34 + -14.27{,}55 * 1 + -19.545{,}82$$
$$F_{21} = 71.160{,}30$$

The results of forecasting calculations using the TES method for the 2024 period can be seen in table 4. Calculation of TES of fertilizer sales in 2024.

Table 4. Calculation of TES of fertilizer sales in 2024.

Year	Q	ales	Level	Tren	Seasonal	TES Forecasting
2019	1	84.474,95	-	-	11.601,14	-
2019	2	83.230,90	-	-	10.357,09	-
2019	3	75.525,25	-	-	2.651,44	-
2019	4	48.264,15	72.873,81	5.762,58	-24.609,66	-
2020	1	96.457,55	82.990,41	6.633,38	11.787,74	90.237,53
2020	2	96.409,10	87.123,55	6.133,33	10.249,93	99.980,88
2020	3	80.864,59	82.726,27	4.027,21	2.200,13	95.908,32
2020	4	109.965,29	120.228,51	10.722,22	-23.175,02	62.143,82
2021	1	85.690,84	91.017,39	2.735,55	10.076,31	142.738,47
2021	2	113.927,25	100.700,00	4.124,96	10.547,67	104.002,87
2021	3	112.279,48	108.503,04	4.860,58	2.357,76	107.025,09
2021	4	155.879,98	159.347,58	14.057,37	-21.204,28	90.188,60
2022	1	151.938,75	151.325,19	9.641,42	9.130,03	183.481,26
2022	2	148.334,40	144.740,70	6.396,24	9.852,27	171.514,28
2022	3	81.277,05	100.584,59	-3.714,23	191,23	153.494,69
2022	4	96.440,95	111.412,76	-805,75	-20.581,03	75.666,07
2023	1	127.253,70	115.868,67	246,58	9.355,53	119.737,05
2023	2	87.994,00	89.533,79	-5.069,71	8.713,06	125.967,52
2023	3	76.163,75	78.519,99	-6.258,53	-63,52	84.655,30
2023	4	86.187,40	96.416,34	-1.427,55	-19.545,82	51.680,43
2024	1	-	-	-	-	104.344,32
2024	2	-	-	-	-	102.274,29
2024	3	-	-	-	-	92.070,16
2024	4	-	-	-	-	71.160.30

Table 4 shows the results of forecasting with the TES method from 2020 first quarter to 2024 which will be used for method evaluation.

4.2 Method Evaluation

Evaluation of this method will be carried out using several MAD, MSE, and MAPE evaluation matrices to calculate the accuracy of the forecasting results of the Weighted Moving Average and Triple Exponential Smoothing methods.

1. MAD:

$$MAD = \sum \frac{\begin{array}{c}(96.457{,}55 - 90.237{,}53) + \\ (96.409{,}10 - 99.980{,}88) + \\ (80.864{,}59 - 95.908{,}32) + \cdots + \\ (86.187{,}40 - 51.680{,}43)\end{array}}{16}$$

$$MAD = \sum \frac{(6.220{,}02 + 3.571{,}78 + 15.043{,}73 + \cdots + 34.506{,}97)}{16}$$

$$MAD = 27.923{,}65$$

2. MSE:

$$MSE = \sum \frac{(96.457{,}55 - 90.237{,}53)^2 + (96.409{,}10 - 99.980{,}88)^2 + (80.864{,}59 - 95.908{,}32)^2 + \cdots + (86.187{,}40 - 51.680{,}43)^2}{16}$$

$$MSE = \sum \frac{38.688.648{,}80 + 12.757.589{,}51 + 226.313.724{,}70 + \cdots + 1.190.731.184{,}34}{16}$$

$$MSE = 1.262.568.155{,}20$$

3. MAPE:

$$MAPE = \sum \frac{\left(\left(\frac{96.457{,}55 - 90.237{,}53}{96.457{,}55}\right)100\%\right) + \left(\left(\frac{96.409{,}10 - 99.980{,}88}{96.409{,}10}\right)100\%\right) + \left(\left(\frac{80.864{,}59 - 95.908{,}32}{80.864{,}59}\right)100\%\right) + \cdots + \left(\left(\frac{86.187{,}40 - 51.680{,}432}{86.187{,}40}\right)100\%\right)}{16}$$

$$MAPE = \frac{(6{,}4 + 3{,}7 + 18{,}6 + \cdots + 40{,}0)}{16}$$

$$MAPE = 27{,}6\,\%$$

The evaluation results of the TES method with smoothing values α = 0.7, β = 0.2, and γ = 0.1 resulted in MAD = 27,923.65, MSE = 1,262,568,155.20, and MAPE = 27.6%. To find a more accurate model based on the smallest MAD, MSE, and MAPE values, we tested the value of the smoothing weights used. The following are the results of testing the value of the smoothing weight used on urea fertilizer sales data from 2019 - 2023 PT. Pupuk Iskandar Muda which is presented in Table 5.

Table 4. Smoothing value test results

Smoothing Value α,β,γ	MAD	MSE	MAPE
0.1, 0.1, 0.1	29.285,87	1.443.851.939,69	30,9 %
0.2, 0.1, 0.1	26.599,34	1.232.069.956,59	27,8 %
0.3, 0.1, 0.1	23.935,37	1.114.572.543,76	24,8 %
0.4, 0.1, 0.1	23.459,25	1.072.000.552,09	24,1 %
0.5, 0.1, 0.1	23.559,77	1.079.836.547,59	24,0 %
0.6, 0.1, 0.1	24.758,13	1.122.266.211,90	24,9 %
0.4, 0.2, 0.1	23.631,21	1.076.231.875,08	24,2 %
0.4, 0.3, 0.1	23.613,77	1.095.498.302,77	24,0 %
0.4, 0.4, 0.1	23.970,04	1.128.571.573,97	24,2 %

0.4, 0.3, 0.2	23.025,51	1.045.520.611,84	23,4 %
0.4, 0.3, 0.3	22.538,90	1.019.150.962,40	22,8 %
0.4, 0.3, 0.4	22.253,59	1.011.449.103,97	22,3 %
0.4, 0.3, 0.5	22.795,46	1.018.430.605,14	22,8 %
0.4, 0.2, 0.4	22.017,75	990.752.983,08	22,3 %
0.4, 0.2, 0.5	22.498,85	992.962.351,70	22,7 %

From the table above, it can be seen that for urea fertilizer sales with a smoothing value of 0.4, 0.2, 0.4 produces the lowest MAD, MSE, and MAPE values for urea fertilizer sales, namely 22,017.75, 990,752,983.08, and 22.3%. Based on the results of testing urea fertilizer sales data from 2019 - 2023 PT Pupuk Iskandar Muda, it can be seen that testing the smoothing values α = 0.4, β = 0.2, and γ = 0.4 is a more accurate model with forecasting results in 4 quarters in 2024, namely Q1 = 96,782.40 tons, Q2 = 84,860.22 tons, Q3 = 64,792.04 tons, and Q4 = 72452.95 tons. The following is a graphic image of the results of testing the weight value in the TES method based on the MAPE value.

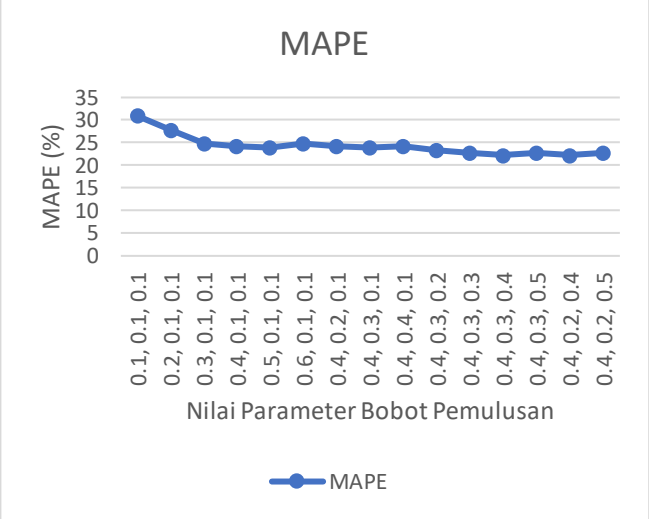

Figure 2. TES forecasting chart of α= 0.4, β= 0.2, and γ= 0.4

The forecasting results of the Triple Exponential Smoothing method with smoothing weight values α = 0.4, β = 0.2, and γ = 0.4 can be seen in Figure. 3.

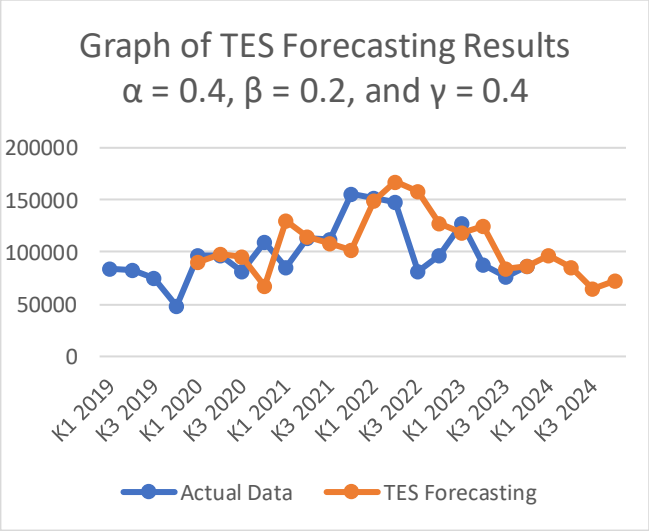

Figure 3. Graph of TES Forecasting Results α = 0.4, β = 0.2, and γ = 0.4

Triple Exponential Smoothing forecasting tends to capture the general trend of sales, but there are some periods where the difference between actual data and forecasting results is quite significant. For example, in Q4 2020 and Q4 2021, Triple Exponential Smoothing forecasting shows a considerable difference compared to the actual data. Triple Exponential Smoothing captures seasonal patterns and trends quite well, but there are still errors at some data points that show sudden changes.

5. CONCLUSION

Research conducted to forecast sales of urea fertilizer at PT Pupuk Iskandar Muda, using the Triple Exponential Smoothing method. Where in the triple Exponential Smoothing method the smoothing value that produces a more accurate model for forecasting urea fertilizer sales with a value of $\alpha = 0.4$, $\beta = 0.2$, and $\gamma = 0.4$ from the tested smoothing weight value, by producing a MAD value of 22,017.75, MSE of 990,752,983.08, and MAPE of 22.3%. Based on the MAPE value, the TES method is also declared feasible enough to be used to forecast urea fertilizer sales.

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