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Comparison of Three Time Series Forecasting Methods on Linear Regression, Exponential Smoothing and Weighted Moving Average

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Abstract

The purpose of this study is to compare the 3 forecasting methods Linear Regression, Exponential Smoothing and Weighted Moving Average based on the smallest error value or close to zero. From the results of this study, the Linear Regression method was obtained as the correct method with a predicted value of 502 students, the smallest error value was MAD 27.83, MSE 1152.1 MAPE 8.1%. The Tracking Signal value moves between 1 and -1, the movement is within the control limits of the tracking signal standard deviation distribution 4 and -4, meaning that the method is correct. The Moving Range value moves between 68 and -46, this value is within the MR control limits of 117.83 and -117.83, this result shows that this means that this method has been tested for truth and can be accepted as well. Thus, indicating that the Linear Regression method as a forecasting method is appropriate and acceptable as a basis for future decision making. The level of accuracy of the error and the value in control shows that there is a time series data relationship between the x variable, namely time, and the variable y, namely actual data. In addition, it produces trending data movement patterns, meaning that data movements experience a significant increase over a long period of time or for 7 periods.

Keywords: Forecasting, Quantitative, MAD, MSE, MAPE

1. Introduction

There are two approaches to quantitative forecasting, namely the (time series) model and the regression model. Time series is a method that deals with historical data to predict the future, which is related to time, weeks, months or years. Application with Exponential Smoothing and Weight Moving Average methods. Causal methods are methods that consider variables or factors that affect the forecasted amount or cause-and-effect relationships as assumptions, such as linear regression forecasting models [1].

Three error accuracy models of forecasting methods. MAD (Mean Absolute Deviation) is an accuracy model of the average absolute deviation, by evaluating the method obtained using the accumulation formula of the absolute error rate of errors or averaging the forecast errors [2].MAD can be applied to measure error values in the same units as actual data. MAD is applied to the comparison formula to find the tracking signal value[3].

MSE (Mean Squared Error) is an accuracy model to measure the overall level of forecasting error by squaring each error result[4]. MSE represents the average squared difference between the predicted and observed values. MSE (Mean Square Error) can be applied when producing moderate error values or smaller error results, but can also produce very large errors. The weakness of the MSE model is that it tends to dominate large deviation values because there is squaring [5].

MAPE (MeanAbsolute Percentage Error) is a positive mean absolute percent error accuracy model, obtained from the amount of historical data. The purpose is to anticipate the results of negative error values, so that it can easily determine the average error value correctly[6]. MAPE is applied to evaluate the forecasting accuracy of a variable. MAPE helps to represent how large the error value of the forecasting method is.

Tracking Signal merupakan parameter untuk memvalidasi m Forecasting method by estimating the actual value. The tracking signal value is called good if the RSFE is lower, the positive error is balanced with the negative error, the number is close to zero, within the control limits of 4 and -4. In the tracking signal control map, the control limits move between 4 and -4 derived from 3.75 statistical control limits, the relationship between MAD and standard deviation of the distribution (1.25MAD=1SD) [7].

Moving Range is a verification of the predictive stability of the cause and effect affecting demand. Moving range is applied for comparison between actual values and predicted values in the same period. The purpose of verifying predicted values with control limits [8]. If the value is within the control limits then the method is good, but if it is outside the control limits then the method needs to be reviewed.

The purpose of this research is to compare 3 methods of Linear Regression, Exponential Smoothing and Weight Moving Average. The result of the research is to obtain the right forecasting method with the smallest error accuracy value of the three forecasting methods.

2. Literature Review

2.1. Forecasting Methods

2.1.1. Linear Regression Method

Linear Regression is a method of equating two variables, namely the dependent variable and the independent variable. The independent variable explains the dependent variable. In regression analysis, the variable relationship is linear, changes in variable X will be followed by variable Y in a fixed manner. In a non-linear relationship, changes in variable X are not followed by variable Y proportionally[9]. Linear regression equation:

$$Y = a + b\,X$$

Description:

Y = Dependent variable

X = Independent variable

a = Constant number (intercept)

b = Coefficient of linear regression direction (slope)

2.1.2. Exponential Smoothing

Exponential Smoothing is a moving average forecasting method, new observations will be prioritized for forecasting over older observations because they are more relevant. If (a) is small then the smoothing is large, while (a) is large then the smoothing is small [10]. Exponential Smoothing Formula:

$$F_{t+1} = \alpha A_t + (1 - \alpha)\, F_t$$

Description:

F_t = Prediction

A_t = Actual

F_(t+1) = Forecasting time (t+1)

a = constant $0 \leq a \leq 1$

2.1.3. Weighted Moving Average

A forecasting model to add weight to recent data that is more relevant than past data. In this model, the latest data has a greater weight than the old data.Weighted Moving Average Formula [11] :

$$\text{WMA}_M = \frac{np_M + (n-1)np_{M-1} + 2p_{(M-n+2)} + p_{(M-n+1)}}{n + (n-1) + \cdots + 1 + 2}$$

Description:

n = Period or *time interlude*

= Nilai riil periode ke m

= Prediction result

The weighting validation stages of the Weighted Moving Average method can be seen in Table 1.

Table. 1. WMA Weight Validation.

Period	Weighting Coefficient (N)
1 Past period	N
2 Past period	N-1
3 Past period	N-2
…	…
…	…
N-1 Past period	N-(N-2) = 2
N Past period	N-(N-1) = 1

2.2. Accuracy Model

Forecasting error accuracy models, such as Mean Square Error (MSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). Forecasting accuracy will be correct, if the results of the error value are getting smaller or closer to zero [12]. MAD (Mean Absolute Deviation) is a measure of model error, resulting from the average difference between the predicted and observed values (actual values).

$$\text{MAD} = \sum_{t-1}^{n} \frac{|A_t - F_t|}{n}$$

MSE (Mean Squared Error) is the average of the squared difference between the predicted and observed values (actual values). The mean squared error amplifies the influence of numbers with large errors, but minimizes the number of errors.

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

MAPE (Mean Absolute Percentage Error) is the average absolute difference between the predicted value and the percentage of the actual value.

$$\text{MAPE} = \sum_{t-1}^{n} \frac{(|A_t - F_t| \div A_t \times 100)}{n}$$

Based on Lewis (1982), the MAPE value is interpreted into several indicators, which can be seen in Table 2.

Table. 2. MAPE Indicator

MAPE Indicator	
<10%	Very Accurate
10%-20%	Good
20%-50%	Average
>50%	Not Accurate

The smaller the MAPE value, the smaller the forecasting error, the greater the MAPE value, the greater the forecasting error. The RSFE formula is ∑ (actual demand in period x - forecasting demand in period x), or the cumulative (sum) of the difference between actual demand and forecasting demand. Tracking signal aims to determine the accuracy of the forecasting method based on the control limits. The value is obtained from the RSFE value divided by the MAD value [13].

$$Tracking\ signal\ = \frac{RSFE}{MAD}$$

The tracking signal limits -4 and +4 are derived from 3.75 with the statistical control limit theory in the relationship of MAD and standard deviation in a normally distributed population as 1.25 MAD = 1 SD (Standard Deviation of the distribution) [14]. If the tracking signal is outside the control limits, then the prediction model needs to be reviewed, as the prediction accuracy is not acceptable.

Moving range is a statistical control map used in quality control, checking the correctness of forecasting methods based on control limits [15].

$$MR\ = |(F_{t-1} - A_{t-1}) - (F_t - A_t)|$$

Average Moving Range

$$\overline{MR} = \frac{\sum MR}{n-1}$$

Control Moving Range

$$\text{UCL}\ =\ 2{,}66\ x\ \overline{MR}\ \ and\ \text{DCL} = -2{,}66\ x\ \overline{MR}$$

If there are points or data that are within the control moving range, then the forecasting method is correct and acceptable. If, outside the control moving range, it needs to be reviewed.

3. Result and Discussion

3.1. Research Flowchart

The research flowchart helps explain the stages of research from the initial phase to the final phase, the flowchart can be seen, as in Figure 1.

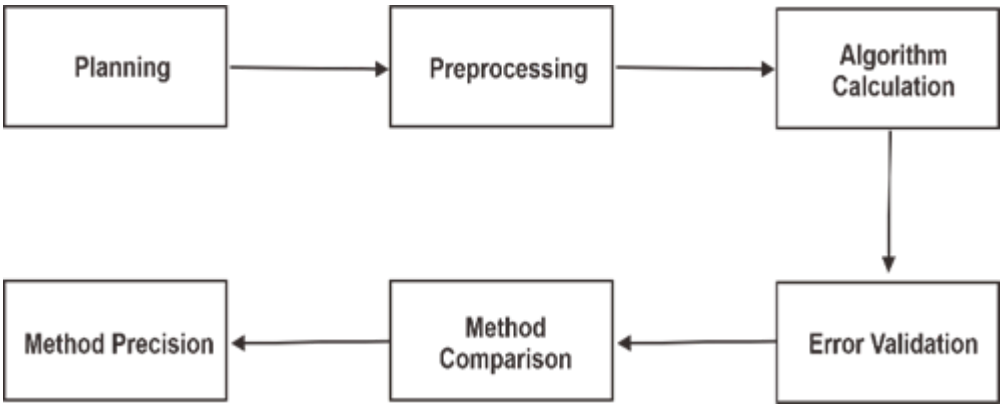

Figure. 1. Research flowchart

An explanation of the concept of the research stages is as follows:

Planning: The planning stage and the collection of primary and secondary data through interviews and observations. Primary data obtained through interviews and secondary data in the form of tabulated data on the number of students for 7 years, the results can be seen in Table 3.

Table. 3. Student data tabulation

School Year	Major				
	TBSM	DKV	AKL	OTKP	Total
2016/2017	73	54	146	62	335
2017/2018	78	65	105	60	308
2018/2019	62	67	100	58	287
2019/2020	99	107	102	96	404
2020/2021	119	107	126	87	439
2021/2022	111	112	108	108	439
2022/2023	120	115	120	150	505

Preprocessing: The data that has been obtained will be reprocessed to obtain the research variables. Assumed variables (x) school year and (y) number of students, can be seen in Table 4.

Table. 4. Data variabel

School Year (x)	Students (y)
2016/2017	335
2017/2018	308
2018/2019	287
2019/2020	404
2020/2021	439

2021/2022	439
2022/2023	505

Algorithm Calculation: This stage is carried out data processing using the Linear Regression, Exponential Smoothing and Weighted Moving Average methods. Stages of data processing, as follows:

Error Validation Linear Regression: Assumed value (t) period, (Yt) actual, ((Y)̂t) forecast, the results of processing the error value in the linear regression forecasting method can be seen in Table 5.

Table. 5. Linear regression error results

t	Yt	Ŷt	t -t	|t -t|	(t -t)²	|Yt-t|/t
1	335	289,143	45,857	45,857	2102,864	0,137
2	308	322,143	-14,143	14,143	200,024	0,046
3	287	355,143	-68,143	68,143	4643,468	0,237
4	404	388,143	15,857	15,857	251,444	0,039
5	439	421,143	17,857	17,857	318,872	0,041
6	439	454,143	-15,143	15,143	229,310	0,034
7	505	487,143	17,857	17,857	318,872	0,035
	2717			**194,857**	**8064,857**	**0,570**
n			**(bias)**	**MAD**	**MSE**	**MAPE**
Ft-8		**520,143**		**27,8367**	**1152,122**	**8,1%**

The data above shows the error results in the linear regression method with MAD 27.836; MSE 1152.12; MAPE, 8.1%. This method produces a forecasting value of 520,143 in the 8th period.

Linear Regression Tracking Signal Control: Assuming the value of (At) actual, (Ft) forecast, the tracking signal value processing results can be seen in Table 6.

Table. 6. Tracking signal linear regression

A_t	F_t	*Error*	RSFE	*Cum Abs Error*	*Cum Abs*	MAD	TS
335	289,1	45,9	45,9	45,9	45,9	45,9	1,0
308	322,1	-14,1	31,7	14,1	60,0	30,0	1,1
287	355,1	-68,1	-36,4	68,1	128,1	42,7	-0,9
404	388,1	15,9	-20,6	15,9	144,0	36,0	-0,6
439	421,1	17,9	-2,7	17,9	161,9	32,4	0
439	454,1	-15,1	-17,9	15,1	177,0	29,5	-0,6
505	487,1	17,9	0,0	17,9	194,9	27,8	0,0

The data shows the tracking signal results move between 1.1 and -0.9. The value is within the standard deviation tracking control limits of 4 and -4. Indicates the method is good, but needs to be reviewed with other forecasting methods.

The tracking signal linear regression control map aims to determine the movement of data within or outside the control limits. The results can be seen in Figure 2.

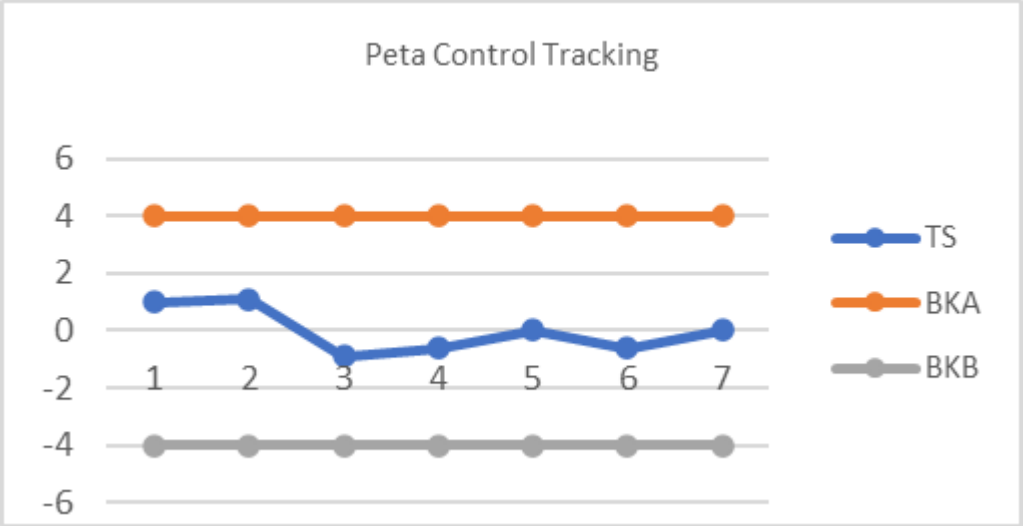

Figure. 2. Map control tracking signal

The movement graph of the linear regression method can be seen in Figure 3.

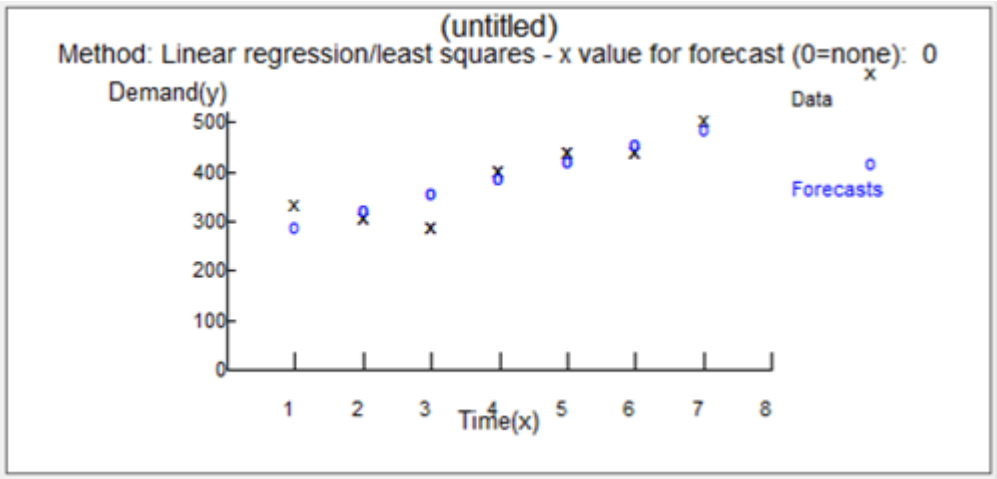

Figure. 3. Linear regression graph

The results show that there is a trend in data movement or data movement tends to increase for 7 years.

3.2. Exponential Smoothing alpha 0,2

Error Validation Linear Regression: Assumed value (t) period, (Yt) actual, ((Y)ŧ) forecast, alpha 0,2. The results of processing the error value in the alpha 0.2 exponential smoothing forecasting method can be seen in Table 7.

Table. 7. Tracking signal linear regression

t	A_t	F_t	$A_t - F_t$	$\lvert A_t - F_t \rvert$	$(A_t - F_t)^2$	$\lvert A_t - F_t \rvert / A_t$
1	335	-	-	-	-	-
2	308	335	- 27	27	729	0,08

3	287	330	- 43	43	1849	0,13
4	404	321	83	83	6889	0,26
5	439	338	101	101	10201	0,29
6	439		81	81	6561	0,23
7	505		131	131	17161	0,35
	2717		**326**	TABLE 8**466**	**43390**	**1,34**
n	**Total**		**(bias)**	**MAD**	**MSE**	**MAPE**
F -8				**77,6**	**7231,6**	**22%**

The data shows the error results in the exponential smoothing method alpha 0.2 with MAD 77.6; MSE 7231.6; MAPE 22%. Produces a forecast value of 400 in the 8th period.

Exponential Smooting Tracking Control: Assuming the value of (A_t) actual, (F_t) forecast, the tracking signal value processing results can be seen in Table 8.

Table. 8. Result of tracking signal ES alpha 0,2

A_t	F_t	*error*	*RSFE*	*abs error*	*cum abs*	MAD	TS
335	-	-	-	-	-	-	-
308	335	- 27	- 27	27	27	27	-1
287	330	- 43	- 70	43	70	35	-2
404	321	83	13	83	153	51	0,26
439	338	101	114	101	254	63,5	1,80
439		81	195	81	335	67	2,91
505		131	326	131	466	77,6	4,2

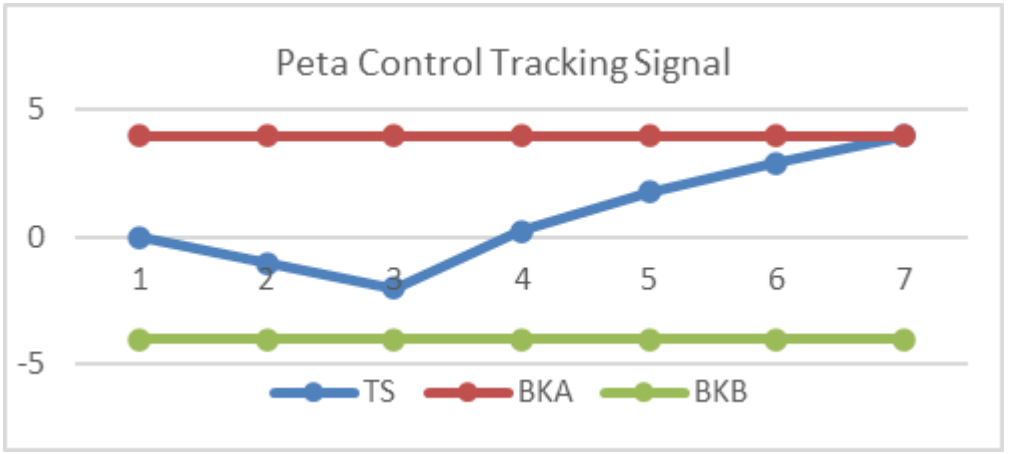

Figure. 4. Tracking signal control map

The data shows the tracking signal results are at movements of 4 and -2. The value is within the standard deviation tracking control limits of 4 and -4. Indicates the method is good, but needs to be reviewed with other forecasting methods.

In Figure 4, the results of the tracking control map of exponential smoothing alpha 0.2, show that the tracking value is within the tracking signal control limits of 4 and -2.

The movement graph of the exponential smoothing method alpha 0.2, can be seen in Figure 5.

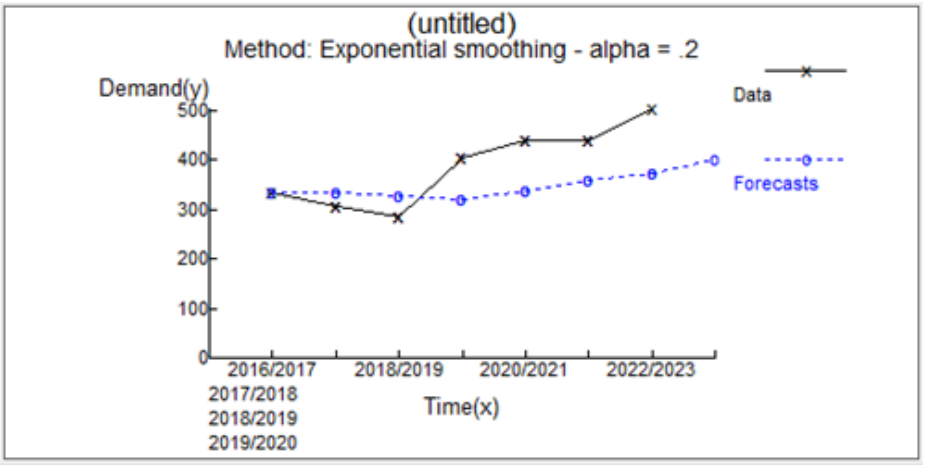

Figure. 5. Graph of ES 0.2

It shows that the movement of data is smooth, there is significant and good smoothing over 7 years. The smaller the alpha value, the higher the smoothing of data changes and movements.

3.3. Exponential Smoothing alpha 0,9

Table. 9. Result error ES alpha 0.2

t	At	Ft	At - Ft	| At -Ft|	(At -Ft)2	| At - Ft |/At
1	335	-	-	-	-	-
2	308	335	- 27	27	729	0,09
3	287	311	- 23,7	23,7	561,1	0,08
4	404	289	114,6	114,6	13140,04	0,28
5	439	393	46,4	46,4	2158,8	0,10
6	439	434	4,6	4,6	21,5	0,01
7	505	439	66,4	66,4	4417,5	0,13
	2717		**181,5**	**282,9**	**21028,6**	**0,71**
n	**Total**		**(bias)**	**MAD**	**MSE**	**MAPE**
F-8		**498**		**47,15**	**3504,7**	**11,8%**

The data above shows the error results in the exponential smoothing method alpha 0.9 with MAD 47.15; MSE 3504.7; MAPE 11.81%. Produces a forecast value of 498 in the 8th period.

Table. 10. Hasil tracking signal ES alpha 0,9

t	A_t	F_t	*error*	*RSFE*	*cum abs error*	*cum abs*	MAD	TS
1	335	-	-	-	-	-	-	-
2	308	335	- 27	- 27	27	27	27	-1
3	287	311	- 24	- 51	24	50	25	-2
4	404	289	115	64	115	165	55	1,2
5	439	393	46	110	46	211	53	2,0
6	439	434	5	115	5	216	43	2,6
7	505	439	66	181	66	282	47	3,8

The data shows the tracking signal results are at movements of 3,8 and -2. The value is within the standard deviation tracking control limits of 4 and -4. Indicates the method is good, but needs to be reviewed with other forecasting methods.

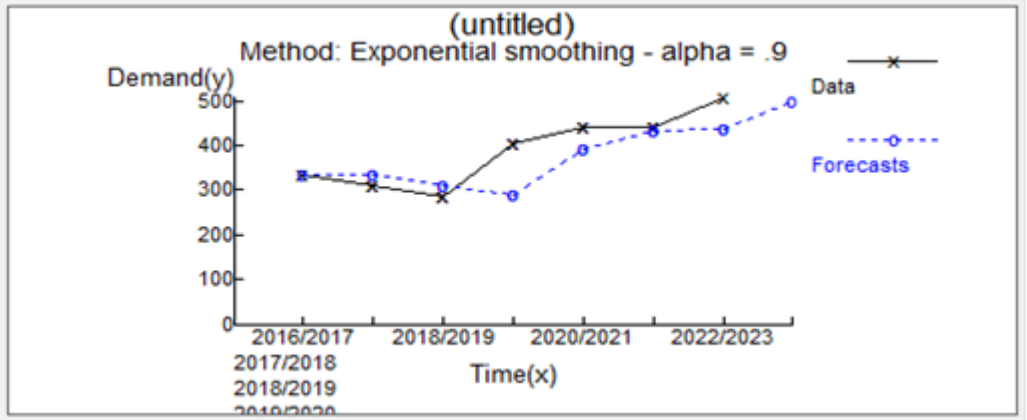

Figure. 6. Graph of ES 0.9

It shows that the data movement is not smooth, there is a rough and imperfect smoothing for 7 years. The higher the alpha value, the smaller the smoothing in data changes.

3.4. Weighted Moving Average

Error Validation WMA: Assumed value (t) period, (A_t) actual, ($\hat{F}_t$) forecast. the results of processing the error value in the alpha 0.2 exponential smoothing forecasting method, can be seen in Table 11.

Table. 11. Error results

(t)	(At)	(Ft)	At -Ft	| At - Ft |	(At - Ft)2	|At - Ft | /At
1	335	-	-	-	-	-
2	308	-	-	-	-	-
3	287	317	-30	30	900	0,10
4	404	294	110	110	12100	0,27
5	439	365	74	74	5476	0,16
6	439	427	12	12	144	0,027

7	505	439	66	66	4356	0,13
				292	22976	0,687
	F-8	**483**		**MAD**	**MSE**	**MAPE**
				58,4	**4595,2**	**13,7%**

Shows the weighted moving average method with weight = 2 or 2 years. Obtained MAD 58; MSE 4595.2; MAPE 13.7%. The forecast value is 483 in the 8th period.

Table. 12. Tracking signal WMA 2

t	At	Ft	*Error*	*RSFE*	*abs error*	*cum abs*	MAD	TS
1	335	-	-	-	-	-	-	-
2	308	-	-	-	-	-	-	-
3	287	317	-30	- 30	30	30	30	-1
4	404	294	110	80	110	140	70	1,57
5	439	365	74	154	74	214	71,3	2,16
6	439	427	12	166	12	226	56,5	2,94
7	505	439	66	232	66	292	58	4

Table 11 shows that the tracking value data movement is between 4 and -1.

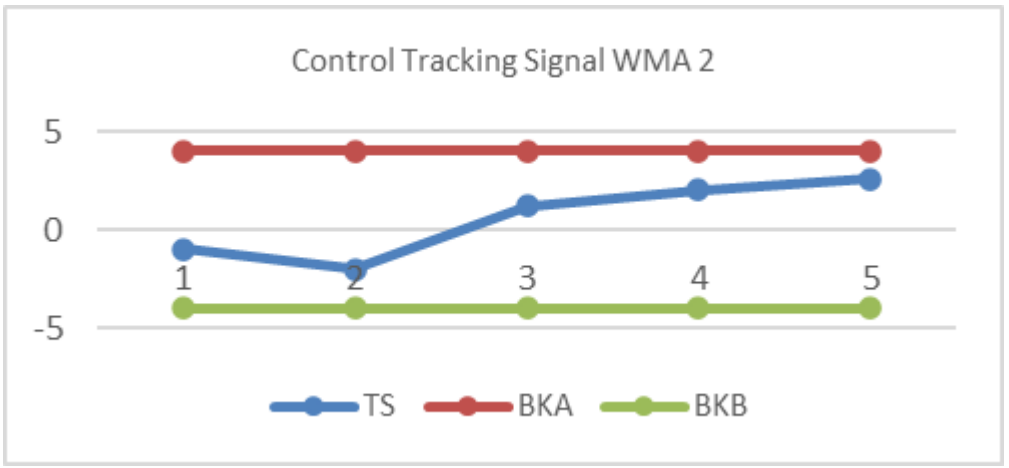

Figure. 6. WMA tracking signal map 2

In Figure 6, the results of the tracking signal control map WMA weight = 2, show the movement of tracking values within the tracking signal control limits of 4 and -1.

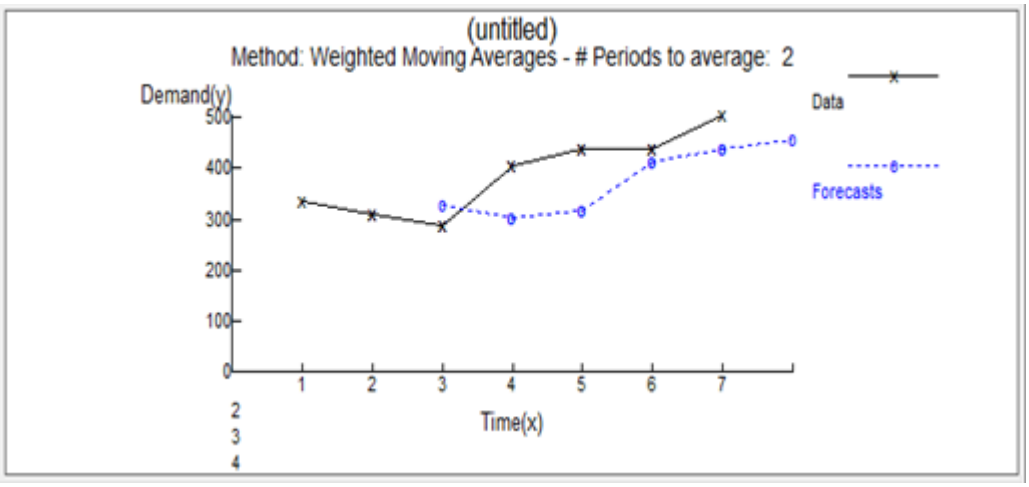

Figure. 7. WMA graph 2

Showing a weighted moving average graph with a weight of 2, there is a movement of data that has increased for 7 years. The data is trending because the movement tends to experience a steady increase.

Method Comparison: The stage of comparing the error and control tracking values of the three forecasting methods. The goal is to get the lowest error value. The comparison results can be seen in Table 13.

Table. 13. Comparison results

No	Methods Forecasting	Manual			
		MAD	MSE	MAPE	TS
1.	*Linear Regression*	27,83	1152,1	8,1%	1 dan -1
2.	*Exponential Smoothing* (a=0,2)	77,6	7231,6	22%	4,2 dan -2
	Exponential *Smoothing* (a=0,9)	47,15	3504,7	11,8%	3,8 dan -2
3.	*Weighted Moving Average* (bobot =2)	58,4	4595,2	13,7%	4 dan -1

The comparison results show that the Linear Regression method has the smallest error value and is close to zero with an MAD value of 27.83; MSE 1152.1 MAPE 8.1%, and tracking signal limits of 1 and -1. This means that the method is an appropriate forecasting method, compared to the exponential smoothing method alpha 0.2 and 0.9 and weighted moving average weight 2.

Method Precision: After obtaining the accuracy of the smallest error value and tracking signal. Then, the Moving Range formula is carried out, to determine whether the correctness of the method is acceptable or not, with control limits. Assumed UCL (Up Control Limit) and DCL (Down Control Limit) control limits.

From Table 14 of the moving range results, the movement value (MR) = -44.3 and the control limits UCL (Up Control Limit) = 117.83 and DCL (Down Control Limit) = -117.8 are obtained. After that, verify the moving chart control.

4. Conclusion

Based on the comparison results of 3 forecasting methods, it can be concluded that the Linear Regression method has the smallest error value MAD 27.83, MSE 1152.1 and MAPE 8.1%. The movement of the tracking signal value is between 1 and -1 (within the control deviation of 4 and -4) and the moving range is between 68 and -46 (within the

control limits of MR 117.38 and - 117.38)[16]. Shows that the linear regression method is an appropriate and acceptable forecasting method, compared to the exponential smoothing and moving average methods. The same results were obtained in research [17], with research on the number of production of Joint Brake Rod parts for 6 months. Every 1 month can produce between 1000-4000. Comparison of linear regression and exponential smoothing methods alpha 0.1 and 0.5, the results show that the smallest and correct error value in the linear regression method with MAD 341.2, MSE 185, and MAPE 11%. The movement of the tracking signal between 1 and -1 is within the control limits. Shows the influence of the time series data relationship between time and actual variables. However, the research has not used the moving range as the truth of the method is acceptable or not.

It is recommended for further research, to compare with the time series moving average and exponential smoothing holt-winter forecasting methods[18]. In addition, more than 7 years of historical data can be added. The goal is to find out the pattern of data movement and measure the accuracy of the method, as well as get a better prediction value with a smaller error rate.

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