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FORECASTING OF INTERNATIONAL FLIGHTS PASSENGER AT SOEKARNO-HATTA AIRPORT USING THE TRIPLE EXPONENTIAL SMOOTHING METHOD

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Abstract: This study aims to predict the number of passengers at Sorkarno-Hatta Airport using the method with the first step testing the stationary pattern and seasonal pattern from the data. The triple exponential smoothing method is better at predicting seasonal data on the number of passengers at Soekarno Hatta airport. The best triple exponential smoothing model that can be used to predict the number of passengers at Soekarno Hata Airport is $F_t= 0.40x_t+0.31S_t+0.91S_{t-1}+1.89\ b_{t-1} +0.60\ I_{t-L}$ with optimal parameters α = 0.10, β = 0.01, and γ = 0.30.

1. INTRODUCTION

Soekarno-Hatta Airport (Soetta) is one of the busiest airports in Indonesia. The Official Airline Guide (OAG) Aviation stated that Soekarno-Hatta Airport occupies the ninth position as the busiest airport in the world. However, due to the outbreak of the Covid-19 pandemic, the number of flights has decreased, and many flights have even been closed, thereby reducing the number of passengers. Along with the reduction in the Covid-19 outbreak, flight activities began to return to normal. Reporting from Angkasapura2.co.id, Soekarno-Hatta Airport serves an average of 579 flights every day during December 2022. This requires Soekarno-Hatta Airport to always prepare a large number of seats. However, the number of passengers has a fluctuating pattern, at one point the number of passengers will increase (a lot) and at another time it will return to normal. To be able to see the number of passengers in the future, forecasting can be done.

The exponential smoothing method is one approach that's frequently utilized in forecasting. Single exponential smoothing, double exponential smoothing, and triple exponential smoothing are the three variations of the exponential smoothing method. Double exponential smoothing is used for data with trends but cannot be utilized for data with seasonality, while single exponential smoothing is used for stationary data (Aimran & Afthanorhan, 2014).

For data with seasonality and patterns, the triple exponential smoothing technique known as the Holt's Winter approach is typically utilized (Siregar & Puspitasari, 2023). The number of airplane passengers will usually increase along with the school holiday season or religious holidays. So it can be said that the data on the number of airplane passengers has a seasonal pattern. Previously Siregar and Puspita in 2023 researched PT. Bakrie Pasaman Plantation using the Holt's winter exponential smoothing method concluded that forecasting using the Holt-Winter Multiplicative Exponential Smoothing Model provides forecasting results with the smallest error value.

Based on the description above, this study will examine Forecasting the Number of Passengers at Soekarno-Hatta Airport Using the Triple Exponential Smoothing Method. In addition, it will be observed whether forecasting using triple exponential smoothing is more suitable for data containing trends and seasonality than double exponential smoothing.

2. LITERATURE

2.1. Smoothing Technique

The smoothing method is a forecasting technique that determines the value for a year by averaging values from several years. This technique smoothes the transfer of data from one period to the next. The smoothing method and the exponential smoothing method are the two categories into which these techniques can be divided (Ginantra & Anandita, 2021).

2.2. Method of Triple Exponential Smoothing

The smoothing method is a forecasting technique that determines the value for a year by averaging values from several years. This technique smoothes the transfer of data from one period to the next. The smoothing method and the exponential smoothing approach can be used to divide these methods into two groups.

The exponential smoothing approach can be used to calculate forecasting using the equation below:

$$S_t = S_{t-1} + \alpha[S_t - S_{t-1}] \tag{1}$$

which S_t is new presumption or prediction of time value t, S_{t-1} is predicted value in period t-1 (last time period), S_t is actual data on the current period, and α is exponential smoothing weighting constant ($0 < \alpha < 1$).

Equation 1 $S_t - S_{t-1}$ is the forecast error and can be written in the form:

$$S_t = \alpha S_t + (1-\alpha)[S_{t-1}] \tag{2}$$

Forecasting on this method can be written as follows:

$$F_t = \alpha S_t + (1-\alpha)F_{t-1} \tag{3}$$

$$F_t = \alpha S_t + (1-\alpha)[\alpha S_{t-1} + (1-\alpha)F_{t-2}] \tag{4}$$

$$F_t = \alpha S_t + \alpha(1-\alpha)S_{t-1} + (1-\alpha)^2 F_{t-2} \tag{5}$$

$$F_t = \alpha S_t + \alpha(1-\alpha)S_{t-1} + (1-\alpha)^2[\alpha S_{t-2} + (1-\alpha)F_{t-3}] \tag{6}$$

If the process in equation 2 repeats, substitution F_{t-1} with components S_{t-2} , F_{t-2} and S_{t-3} repeated like that then the result is as follows:

$$F_t = \alpha S_t + \alpha(1-\alpha)S_{t-1} + (1-\alpha)^2 S_{t-2} + (1-\alpha)^3 S_{t-3} + (1-\alpha)^4 S_{t-4} + \cdots + (1-\alpha)^{t-1} S_1 + (1-\alpha)^t F_1 \tag{7}$$

In simple terms, equation 3 can be written in forecasting notation:

$$F_t = \alpha S_t + (1-\alpha)F_{t-1} \quad (8)$$

with F_t is prediction for time t; S_t is actual data on the current period, and F_{t-1} is estimate or estimated value for the period t-1. Single exponential smoothing is used for stationary data and double exponential smoothing is used for data containing trends, but both cannot be used for data containing seasonality. (Singh et al., 2019).

The triple exponential smoothing method or commonly known as Holt's Winter Method is a forecasting method proposed by Holt by using a quadratic equation. This method is more suitable for making forecasts from fluctuating data or experiencing tidal waves. This method can overcome data problems by using trend and seasonal data component patterns which cannot be overcome by moving average methods and other exponential smoothing methods. If the historical identification of the actual demand data shows seasonal fluctuations, it is necessary to adjust for seasonal effects by calculating the seasonal index. As an example to explain the effect of seasonality using seasonal index numbers (Himawan & Silitonga, 2020; Jonnius, 2017; Kramar & Alchakov, 2023; Triana, 2015).

The triple exponential smoothing method is used in forecasting time series data that follows a seasonal pattern. Based on 3 smoothing equations, namely: for exponential, trend, and seasonal elements.

The general equation for the exponential smoothing method is written as follows:

$$\begin{aligned} S_t &= \alpha(x_t - S_{t-1}) + S_{t-1} \\ &= (\alpha x_t - \alpha S_{t-1}) + S_{t-1} \\ &= \alpha x_t - \alpha S_{t-1} + S_{t-1} \\ S_t &= \alpha x_t + (1-\alpha)S_{t-1} \quad (9) \end{aligned}$$

with S_t is Exponential smoothing in year t, x_t is t-th data, and α is exponential smoothing weighting constant ($0 < \alpha < 1$).

Equation 9 applies the usage of a single smoothing constant in the single exponential smoothing approach, namely α with a weighting value $0 < \alpha < 1$. Holt created this method in 1957 by adding a trend factor to the equation because the single exponential smoothing method cannot be used for trending data. The model, which is also known as a double exponential smoothing model, is essentially a single smoothing model with an additional weight that captures trends (Ginantra & Anandita, 2021; Himawan & Silitonga, 2020; Shastri et al., 2018; Singh et al., 2019). Therefore, Holt added a trend element to equation 9. A new equation could be written:

$$\begin{aligned} S_t &= \alpha(x_t - S_{t-1} - b_{t-1}) + S_{t-1} + b_{t-1} \\ S_t &= \alpha(x_t - S_{t-1} - b_{t-1}) + S_{t-1} + b_{t-1} \\ &= (\alpha x_t - \alpha S_{t-1} - \alpha b_{t-1}) + S_{t-1} + b_{t-1} \\ &= \alpha x_t - \alpha S_{t-1} + S_{t-1} - \alpha b_{t-1} + b_{t-1} \\ &= \alpha x_t + (1-\alpha)S_{t-1} + (1-\alpha)b_{t-1} \\ S_t &= \alpha x_t + (\alpha - 1)(S_{t-1} + b_{t-1}) \quad (10) \end{aligned}$$

with l_t is smoothing of seasonal factors, L is seasonal length, and b_t is trend smoothing

Equation 10 is then known as the double exponential smoothing method. This method is also commonly known as Holt's Linear. To calculate trend smoothing, the following equation is used:

$$b_1 = \beta(S_1 - S_{1-1}) + (1-\beta)b_{1-1}$$
$$b_2 = \beta(S_2 - S_{2-1}) + (1-\beta)b_{2-1}$$
$$.$$
$$.$$
$$.$$
$$b_t = \beta(S_t - S_{t-1}) + (1-\beta)b_{t-1} \quad (11)$$

with β is smoothing weighting constant for trend $(0 < \beta < 1)$ and $S_t - S_{t-1}$ is the difference between the exponential smoothing.

Because it uses two smoothing constants, i.e., α and β, The double exponential smoothing method is the name given to this technique. The double exponential smoothing method is the name given to this technique. The double exponential smoothing method, however, is only applicable to data with a trend and cannot be utilized for data with seasonality. (Booranawong et al., 2021; Singh et al., 2019). Holt in 1960 developed this method by incorporating seasonal elements into the data. A new equation can be written:

$$S_t = \alpha(x_t - S_{t-1} - b_{t-1}) + S_{t-1} + b_{t-1} - \alpha l_{t-12}$$
$$= S_{1-1} + b_{1-1} + \alpha(x_1 - S_{1-1} - b_{1-1} - l_{1-12})$$
$$= S_{1-1} + b_{1-1} + \alpha x_1 - \alpha S_{1-1} - \alpha b_{1-1} - \alpha l_{1-12}$$
$$= \alpha x_t - \alpha l_{1-12} + (1-\alpha)S_{t-1} + (1-\alpha)b_{t-1}$$
$$S_t = \alpha(x_t - l_{t-L}) + (1-\alpha)(S_{t-1} + b_{t-1}) \quad (12)$$

with l_t is smoothing of seasonal factors.

Triple Exponential Smoothing Method is a smoothing method used for data that contains trends and seasonality. This method is also commonly known as Holt's Winter. Because this method uses trend and seasonality elements, it is also necessary to calculate trend and seasonal alignment. The equation for calculating trend smoothing is written as follows:

$$b_t = \beta(S_t - S_{t-1}) + (1-\beta)b_{t-1} \quad (13)$$

with β is constant weighting smoothing for trend $(0 < \beta < 1)$.

Then the equation to calculate the seasonal smoothing is written as follows:

$$l_1 = \gamma(x_1 - S_1) + (1-\gamma)l_{1-12}$$
$$l_2 = \gamma(x_2 - S_2) + (1-\gamma)l_{2-12}$$
$$.$$
$$.$$
$$l_t = \gamma(x_t - S_t) + (1-\gamma)l_{t-L} \quad (14)$$

which γ is smoothing weight constant for seasonality $(0 < \gamma < 1)$.

To determine the smoothing constant α if the data used has an unstable historical pattern then the value of the smoothing constant α has a value close to 1, but if the data used has a historical pattern that does not fluctuate or is relatively stable then the value of the smoothing constant α is close to 0 Forecasting using the triple exponential smoothing method is to calculate exponential smoothing, trend smoothing, and seasonal smoothing. After the three factors have found their smoothing values, the last step is to forecast the data for the upcoming p period using the formula:

$$\begin{aligned} \hat{Y}_{t+1} &= S_t + 1.b_t + l_{t-L+1} \\ \hat{Y}_{t+2} &= S_t + 2.b_t + l_{t-L+2} \\ \hat{Y}_{t+3} &= S_t + 3.b_t + l_{t-L+3} \\ &\vdots \\ \hat{Y}_{t+p} &= S_t + pb_t + l_{t-L+p} \end{aligned} \quad (15)$$

With $\hat{Y}_t$ = the value to be forecast and p = the time period to be forecast

This method uses three smoothing constants namely α, β, and γ with a weighting value ranging from 0 to 1(Kramar & Alchakov, 2023; Santoso & Kusumajaya, 2019; Suryani et al., 2023).

3. METHODOLOGY

3.1. Data and Sources

This study used secondary data obtained from the website of the Central Statistics Agency, namely data on the number of passengers at Soekarno-Hatta Airport for the period January 2012 to December 2022.

3.2. Method

The analytical method used in this study is:

i. Stationarity Test
   1) Identify with the graph of the autocorrelation function (ACF).
   2) Using the unit root test with the Augmented Dickey-Fuller statistical test method (Paparoditis & Politis, 2018).

ii. Seasonal Pattern Test
   1) Presenting a time series graph
   2) Seasonal data test uses a seasonal index that can be calculated using the simple average method (Masrudin et al., 2018).

iii. Initial Value

The initial value is the value used to calculate the coefficients' starting values $(a_0, b_0, \ldots, i_0)$. If the time series data does not meet the coefficients, then to determine these values can be done by calculating the initial value with several methods. The process used to determine the starting value is as follows:

Initial Values for Exponential Smoothing

$$S_0 = \frac{1}{L} \sum_{i=1}^{L} x_L \quad (17)$$

with S_{1-1} or S_0 is Initial values for exponential smoothing

Initial Values for Trend Smoothing

$$b = \frac{1}{L}\left(\frac{x_{L+1}-x_1}{L} + \frac{x_{L+2}-x_2}{L} + \cdots + \frac{x_{L+L}-x_L}{L}\right) \quad (18)$$

with b_{1-1} atau b_0 is the initial value for the trend factor.

Initial Value for Seasonal Smoothing

$$I_k = x_k - S \quad (19)$$

which I_k is Initial value for the k-th seasonal factor and k is seasonal period and k is 1, 2, …, L.

iv. Triple Exponential Smoothing

The triple exponential smoothing method is a forecasting method proposed by Holt using a quadratic equation. This method is more suitable for making forecasts from fluctuating data or experiencing tidal waves. This method can overcome data problems by using trend and seasonal data component patterns which cannot be overcome by moving average methods and other exponential smoothing methods. If the historical identification of the actual demand data shows seasonal fluctuations, it is necessary to adjust for seasonal effects by calculating the seasonal index. As an example to explain the effect of seasonality using seasonal index numbers (Triana, 2015). The following is the mathematical equation of the triple exponential smoothing method:

Parameters α, $\boldsymbol{\beta}$, and γ Optimum

The Best Triple Exponential Smoothing Model

Level Smoothing

$$S_t = \alpha \cdot (x_t - I_{t-L}) + (1-\alpha) \cdot (S_{t-1} + b_{t-1}) \quad (20)$$

Trend Smoothing

$$b_t = \beta \cdot (S_t - S_{t-1}) + (1-\beta) \cdot b_{t-1} \quad (21)$$

Seasonal Smoothing

$$I_t = \gamma \cdot (X_t - S_t) + (1-\gamma) \cdot I_{t-L} \quad (22)$$

Triple Exponential Smoothing

$$F_t = S_t + b_t + I_{t-1} \quad (23)$$

Error Model Criteria

$$MAD = \frac{1}{n}\sum_{i=1}^{n} |(x_t - \hat{x}_t)| \quad (24)$$

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n} \left|\frac{(x_t - \hat{x}_t)}{x_t}\right|\right) \times 100 \quad (25)$$

by N is the amount of data observed, $\hat{Y}_t$ is forecast of t-th, and Y_t is t-th data. A data model will have very good performance if the MAPE value is below 10% (Kramar and Al, 2023).

v. Forecasting

$$F_{t+p} = S_t + pb_t + I_{t+p-1} \quad (26)$$

with F_{t+p} is Forecasting value

3.3. Data Analysis

The stages of analysis in this study are:

i. Testing Data Assumptions. This stage tests for data stationarity, trend patterns, and seasonal patterns in the data.

ii. Triple Exponential Smoothing Analysis. At this stage several analyzes are carried out, namely:
   a. Calculates initial exponential smoothing, trend smoothing, and seasonal smoothing.
   b. Determine the parameters α, β, and γ

iii. Define the Best Threefold Exponential Smoothing Model. At this stage, the best triple exponential smoothing model is sought with the MAPE (Mean Absolute Percentage Error) and MAD (Mean Absolute Deviation) error criteria.

iv. Data Forecasting with the Best Triple Exponential Smoothing Model, this stage calculates the forecasting value with the best model that has been selected.

4. RESULTS AND DISCUSSION

Following is the time series plot of data on the number of passengers at Soekarno-Hatta Airport from January 2017 to December 2022. From Figure 1 it is known that even though in 2020 airport passengers have decreased due to the covid 19 outbreak, it can be seen that the number of passengers has increased every July and December. This shows that the data has a seasonal pattern. Furthermore, the data stratation test is carried out, if the data contains seasonal elements then the data will contain unit roots so that the data is not stationary.

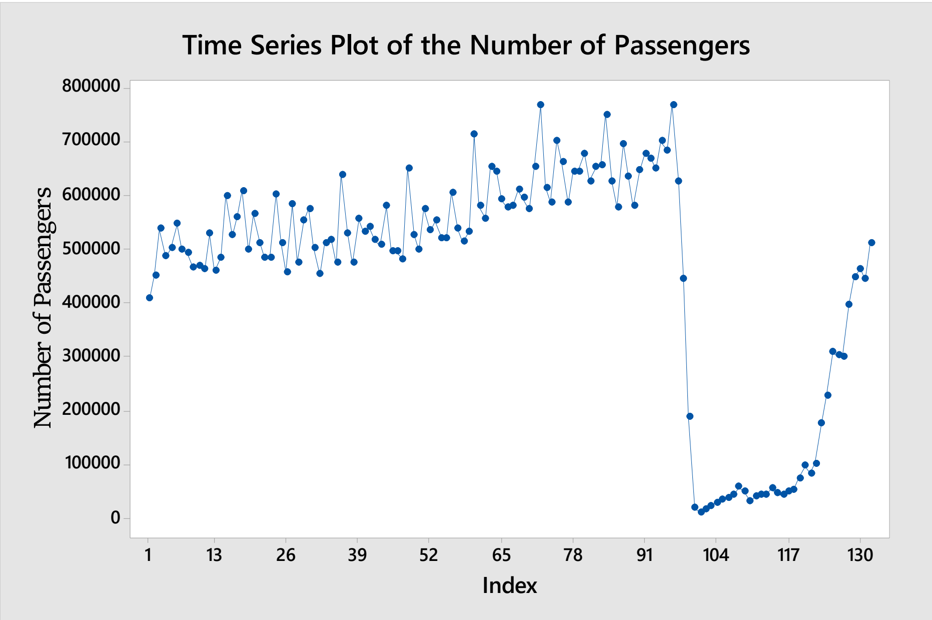

Figure 1. Time Series Plot

4.1. Test Data Assumptions

4.1.1. Stationary Test

Test the stationarity of the data by looking at the data plots and ACF graphs of the original data. In Figure 2 it can be seen that several lines on the ACF graph have values that exceed the boundaries of the significant area so that it can be said that ACF is significant (data not stationary) and decreases exponentially towards the zero point so that it can be said that the data is not stationary.

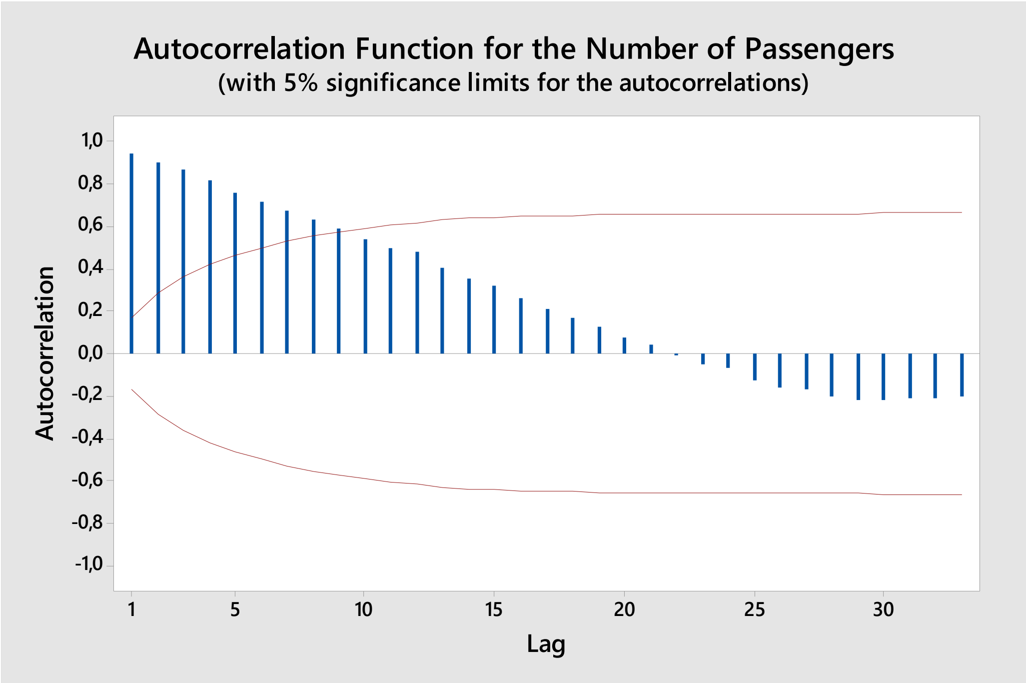

Figure 2. Graph of Autocorrelation Function (ACF)

The following is a test of data assumptions:

Table 1. Data Assumption Test Values Have Unit Roots

Critical test value	t-test	Prob.*
Dickey - Fuller Augmentation Statistical Test	-2.112	0.5299

Testing the assumptions as follows:

$H_0 : \delta = 0$ (such as is stationary or contains a unit root)

$H_1 : \delta \neq 0$ (does not contains a unit root or is stationary)

Based on Table 1 it can be seen that the Dickey Fukker Augmentation (ADF) test gets a p-value > 0.05, namely 0.5299 > 0.05 so it accepts H0 and it can be concluded that the data has a unit root and is not stationary.

In Figure 1 it can be seen that the data is influenced by trend patterns because the graph shows increasing fluctuations, namely movement from the bottom left to the top right on the graph even though at the beginning of 2020 flight activity at Soekarno-Hatta Airport, specifically for international departures, experienced a decline due to flight closures due to the

Covid-19 outbreak pandemic but in the following months experienced a tendency (trend) to increase again.

4.1.2. Seasonal Test

Because the data repeats in some months, Figure 1 shows that it has seasonal characteristics. To see seasonal fluctuations, run calculations using the seasonal index formula. The outcomes are as follows:

Table 2. Seasonal Index Values

Month	Mean (%)	Seasonal Index
Jan	8.29%	1.00
Feb	7.71%	0.93
Mar	8.77%	1.05
Apr	7.91%	0.95
May	7.98%	0.96
June	8.28%	0.99
July	7.94%	0.95
Aug	8.47%	1.02
Sept	8.13%	0.98
Oct	8.20%	0.98
Nov	8.25%	0.99
Dec	10.06%	1.21
Total		**12**

Based on the calculation results above, it can be seen that the seasonal variation in each month ranges from 1 and the total seasonal index is 12. It can be concluded that the data contains seasonality.

4.2. Triple Exponential Smoothing

4.2.1. Initial Value

Calculate the initial value of each smoothing to determine the initial value of each smoothing.

Exponential Smoothing Initial Value

$$S = \frac{1}{L}\sum_{k=1}^{L} x_k = 486422.3$$

Based on the calculation above, it can be concluded that the initial value for exponential smoothing is S = 486422.3.

Trend Smoothing Initial Value

$$b = \frac{1}{L}\left(\sum_{k=1}^{L}\frac{y_{L+k}-y_k}{L}\right) = \frac{1}{12}(3560{,}83) = 3711.87$$

Based on the calculations above, it can be concluded that the initial value for trend smoothing is b = 3711.87.

Initial Seasonal Smoothing Value

Based on data calculations, the initial value for seasonal smoothing in the first period to the 12th period in a row is I_1=-79819, I_2=-36159, I_3=50617, I_4= -1711, I_5=13773, I_6= 59336, I_7=11189, I_8=5986, I_9=-22015, I_{10}= -17222, I_{11}= -25405, and I_{12}= 41434.

4.2.2. Determinate α, $\boldsymbol{\beta}$, and γ Optimum Parameters

A common problem encountered in determining forecasting using the exponential smoothing method is determining the size of the smoothing parameter. Simulation is needed to determine which parameters α, $\boldsymbol{\beta}$, and γ produce the smallest error in a forecast. The values of the three parameters lie between 0 to 1. After simulating the calculation of the smoothing forecast with a combination of different constant values, the optimum parameters α, $\boldsymbol{\beta}$, and γ are obtained, namely:

Table 3. Optimum Parameter Value

Parameter	Value
α	0.10
$\boldsymbol{\beta}$	0.01
γ	0.30

4.2.3. Find The Best Triple Exponential Smoothing Model

The triple exponential smoothing model that is good for predicting the number of passengers departing through Juanda airport is as follows:

$S_t=0.10(x_t-l_{t-L})+(0.9)(S_{t-1}+b_{t-1})$

$b_t=0.01\ (S_t-S_{t-1})+(0.99)b_{t-1}$

$l_t=0.30\ (x_t-S_t)+(0.70)l_{t-L}$

$F_t=0.10(x_t-l_{t-L})+(0.9)(S_{t-1}+b_{t-1})+0.01\ (S_t-S_{t-1})+(0.99)b_{t-1}+0.30\ (x_t-S_t)+(0.70)l_{t-L}$

$F_t=0.40x_t+0.31S_t+0.91S_{t-1}+1.89\ b_{t-1}+0.60\ l_{t-L}$

4.3. Forecasting

After obtaining an adaptive model, then a calculation of the prediction of the number of passengers at Soekarno-Hatta airport for international departures is carried out for one year, namely January 2023 to December 2023.

Table 4. Forecasting Results with Triple Exponential Smoothing

Month-	Number of Passengers (people)
Jan 23	292821
Feb 23	259018
Mar 23	285523
Apr 23	263133
May 23	275480
June 23	288249
July 23	287208
Aug 23	324027
Sept 23	326125
Oct 23	335007
Nov 23	334427
Dec 23	401361

The following is a time series graph for forecasting the number of passengers at Soekarno-Hatta Airport.

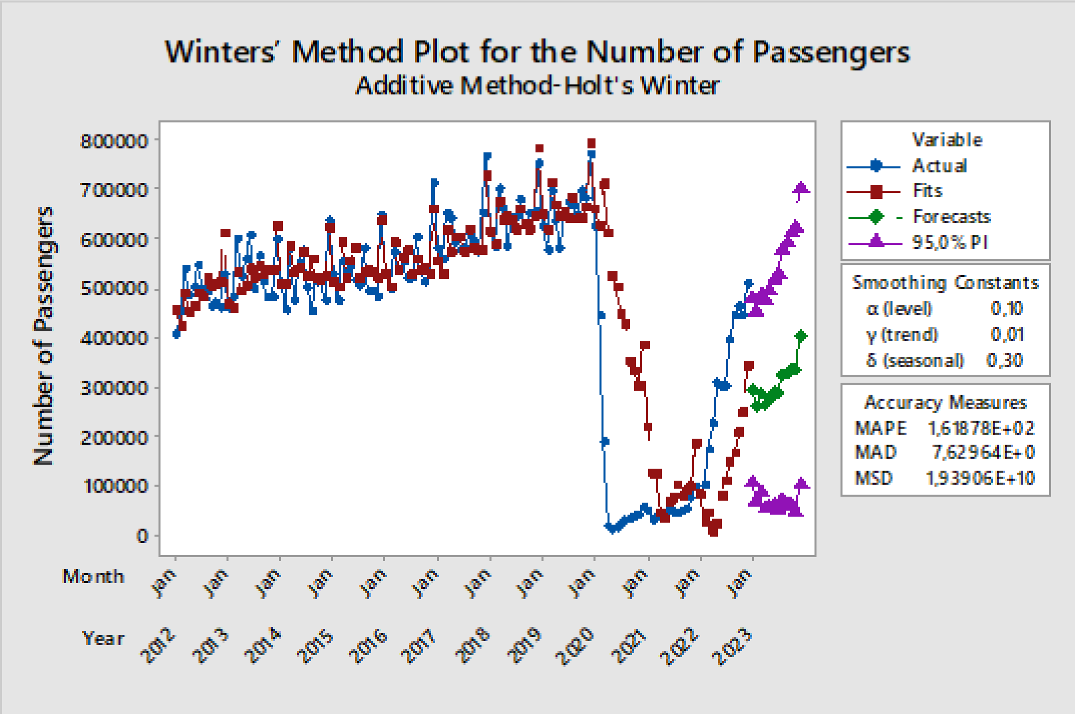

Figure 3. Time Series Graph Forecasting Using Triple Exponential Smoothing

In Figure 3, the black line is a plot of data on the number of passengers at Soekarno-Hatta Airport for the period January 2012 to December 2022. The red line is a data smoothing line and the green line is a plot of the forecast value of the number of passengers at Soekarno-Hatta Airport. Hatta from January 2023 to December 2023.

Next, observe whether the data forecast contains a seasonal pattern. When compared with forecasting using the double exponential smoothing model, the following values are obtained:

Table 5. Comparison of MAD and MAPE Values

No	Method	MAD	MAPE
1	Triple Exponential Smoothing	7.629	161.87
2	Double Exponential Smoothing	9.373	165.57

Based on Figure 3 and Figure 4, it is explained that the movement of data using triple exponential smoothing is closer to the original data pattern than the data modeled using double exponential smoothing. Likewise, from the time series graph shown in Table 5, it can be seen that the lowest MAD and MAPE values are found in the Additive-Triple Exponential Smoothing model compared to the Double Exponential Smoothing model.

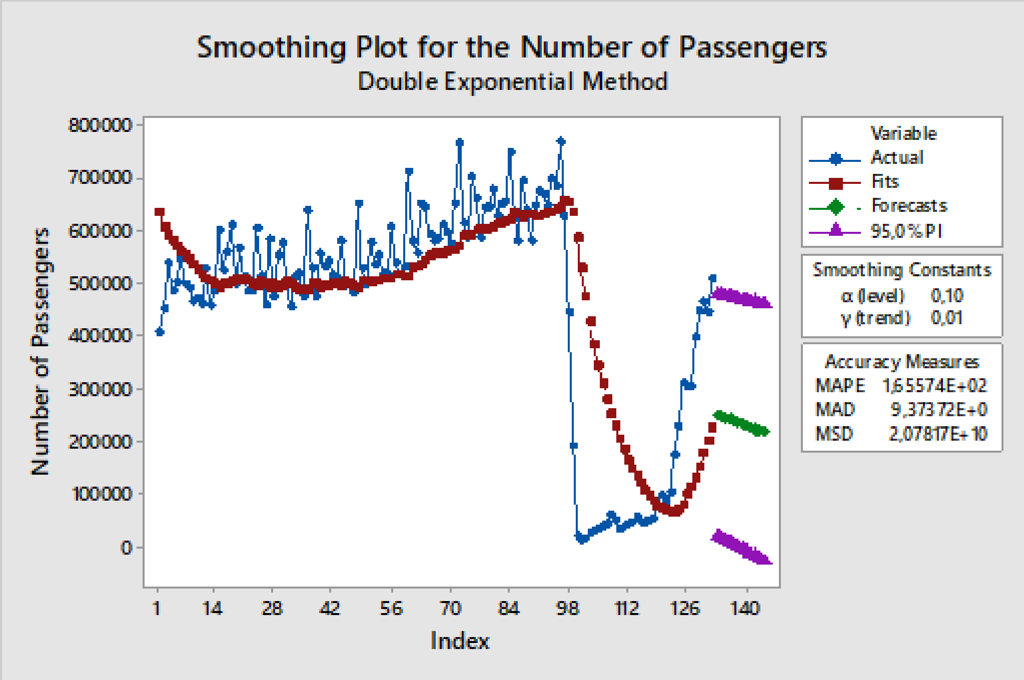

Figure 4. Time Series Graph Using Triple Exponential Smoothing

5. CONCLUSION

Conclusions that can be drawn from the results of the study is:

1. Data on the number of passengers at Soekarno Hatta Airport for international departures from January 2012 to December 2022 contains trend and seasonal factors so that they can be predicted using an adaptive triple exponential smoothing model.
2. The best triple exponential smoothing model that can be used in predicting the number of passengers at Soekarno Hata Airport is adalah $F_t = 0.40x_t + 0.31S_t + 0.91S_{t-1} + 1.89\, b_{t-1} + 0.60\, l_{t-L}$ with optimum parameters $\alpha = 0.10$, $\beta = 0.01$, and $\gamma = 0.30$.
3. The triple exponential smoothing method is better than the double exponential smoothing method in predicting seasonal passenger data at Soekarno Hatta Airport.

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