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# Forecasting of Average Air Temperature in the City of Pekanbaru Using the Holt-Winters Method

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**Abstract** - *Global climate change causes significant fluctuations in air temperature, including in the city of Pekanbaru therefore, a predictive system is needed that can help the government and the community in dealing with climate impacts, one of which is through air temperature forecasting. This study aims to forecast the average air temperature in Pekanbaru City using the Holt-Winters Exponential Smoothing method, which is known to be effective in capturing seasonal patterns and trends. The data used is monthly average air temperature data from 2017 to 2024 obtained from BMKG. The analysis was carried out using an addictive approach and model evaluation was carried out based on the Mean Absolute Percentage Error (MAPE) value. The results show that the best model is obtained on a parameter with an MAPE value of 2.684. This model is then used to forecast the air temperature in 2025, which is predicted to decrease gradually. The results of this forecast are expected to be a reference in planning and decision-making related to climate change mitigation in the Pekanbaru area.*

**Keywords:** *forecasting, air temperature, Holt-Winters, time series, Pekanbaru.*

## 1. Introduction

Climate change has become one of the most real global challenges of the 21st century, having a significant impact on various sectors of human life. One of the main features of climate change is the increase in global average temperatures and weather instability that occurs over time. In many regions, including Indonesia, the impact of this phenomenon can be seen in the form of increased air temperatures, seasonal irregularities, and shifts in weather patterns that are difficult to predict [1]. Air temperature is one of the most important meteorological parameters in daily life. Extreme temperature changes can have negative impacts, both in the health, agriculture, transportation, and urban spatial planning sectors [2].

The city of Pekanbaru, as one of the major cities in Indonesia, has experienced quite significant temperature fluctuations in recent years. Based on historical data, the average temperature in the city shows an increasing trend and seasonal irregularity, with a striking difference between the dry season and the rainy season. These fluctuations indicate a typical seasonal pattern, but no longer run as consistently as they did in previous decades [1]. This condition poses challenges for the government and the community to anticipate the impact of temperature changes.

One of the approaches used to estimate the value of air temperature in the future is the statistical method of forecasting. In statistics, forecasting of temperature data generally uses the time series analysis method, which uses historical patterns to make future projections. With this approach, trends, seasonality, and random fluctuations in the data can be identified [3]. One of the most effective time series forecasting methods is the Holt-Winters Exponential Smoothing method, which takes into account three important components in forecasting.

The Holt-Winters method is suitable for air temperature data because it typically has a consistent annual or monthly seasonal pattern. There are two types of approaches in this method, namely additive and multiplicative. The additive approach is used when the seasonal amplitude is constant, while the multiplier approach is used when the seasonal amplitude varies proportionally to the trend. The advantage of this method lies in its flexibility in adjusting models based on the latest data, so that forecasting results remain relevant and adaptive [3].

Therefore, the application of the Holt-Winters method in air temperature forecasting in the city of Pekanbaru is a potential approach to answer the need for predictive climate information. With increasingly volatile temperature trends, the development of forecasting models that can capture trend and seasonal elements in historical data is becoming important as a reliable data-driven solution [4].

## 2. Research Methods

### 2.1. *Time Series Analysis*

Time series analysis (Time series analysis) is a branch of statistical science that focuses on analyzing data collected sequentially over a certain period of time. A time series can be defined as a series of observations of a variable taken over time and recorded sequentially according to the time order in which they occur at fixed intervals [5]. Time series data can be daily, weekly, monthly, quarterly, or yearly, depending on the frequency of observations made [6].

The main purpose of time series analysis is to understand the patterns and structures of historical data, as well as to utilize that information to make forecasts (Forecasting) values in the future. Thus, time series analysis has become a very important tool in decision-making in various fields, such as economics, finance, business, and environmental science [6].

In conducting time series analysis, there are several assumptions that need to be met so that the forecasting results obtained are reliable. These assumptions include [6]:

a. Availability of Historical Data: Time series analysis requires historical data that is long and relevant enough to be able to identify existing data patterns and structures.
b. Quantitative Data: The information used in time series analysis must be convertible into a quantitative form in the form of numerical data.
c. Sustained Patterns: It is assumed that the patterns identified in historical data will continue in the future.

Time series data generally consists of several components that interact with each other and affect the observed values. These components include [6]:

1) Trend: A long-term trend in the data, which can be either an uptrend or a downtrend.
2) Seasonality: A pattern that repeats periodically over a period of time, such as daily, weekly, monthly, or yearly.
3) Cyclical: Fluctuations that occur over a longer period of time than seasonal, usually related to the economic cycle.
4) Random: A random variation that cannot be explained by other components.

One of the important concepts in time series analysis is stationarity. A time series is said to be stationary if its statistical characteristics (such as means and variance) do not change over time [7]. Stationary time series data will facilitate the modeling and forecasting process. There are two types of stationery that need to be considered [6]:

1) Stationary in Average: The average of the data does not change over time.
2) Stationary in Variance: The variance of the data does not change over time.

If the time series data is not stationary, then it is necessary to perform a transformation or differencing to achieve stationarity before modeling is carried out [5]

### *2.2. Forecasting*

Forecasting (Forecasting is a technique to estimate a value in the future by paying attention to past and current data. Forecasting is an important tool in effective and efficient planning, especially in time series analysis (Time series), which aims to extrapolate historical data patterns to the future [1].

Forecasting methods can generally be classified into two main categories:

1) Time-Series models: such as Moving Average, ARIMA, Exponential Smoothing, and Holt-Winters, which rely on the relationship between variables and time.
2) Causal Model: such as regression, which looks at the relationship between predicted variables and other independent variables [8]

### *2.3 Exponential Smoothing Method*

The *Exponential Smoothing* method is one of the time series forecasting methods that is quite popular because of its ease of calculation and adaptability to data that changes gradually. This method works by assigning an exponentially decreasing weight to the values of previous observations.

*Exponential smoothing* is a procedure for reducing the calculation using the latest observation data. Each data used in this method is given a weight symbolized by alpha ($\boldsymbol{\alpha}$), gamma ($\boldsymbol{\gamma}$), and Betha ($\boldsymbol{\beta}$) which is determined freely by trial and error. The alpha value ($\boldsymbol{\alpha}$), ranges from 0 to 1. It is the value that produces the smallest error rate that will be selected for use in the forecasting [9].

#### *2.3.1. Single Exponential Smoothing (SES)*

Single exponential smoothing, known as Simple Exponential Smoothing which is used on short-term forecasting, usually only 1 month ahead. This model assumes that the data fluctuates around a fixed mean value, with no consistent growth trends or patterns [10]. The formula for *Single exponential smoothing* are as follows:

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

Where:

$Y_t$ : data in period t
$F_t$ : forecasting at t time
$F_{t-1}$ : forecasting at the time $F_{t-1}$
$\alpha$ : the value of the smoothing parameter with a magnitude of 0 < < 1$\alpha$

*2.3.2 Double Exponential Smoothing (DES) Holt*

Double exponential smoothing is a type of forecasting that is carried out when there is a consistent trend or change in the data that has been obtained. What is meant by trend here is the forecasted estimate of the average growth at the end of each period. The following is the formula of the *Double exponential smooting* [11].

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (2)$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1} \quad (3)$$

$$F_{t-1} = L_t + T_t \quad (4)$$

With:
$L_t$ : the estimated level of the data set of period t
$Y_t$ : the actual value of the previous period
$T_t$ : Estimated previous trend in the period t
$\alpha$ : Leveling Constant
$\beta$ : Constant Smoothing
$F_{t-m}$ : M forecast results

*2.3.3 Triple Exponential Smoothing (TES) Holt-Winters*

This method is used when the data shows seasonal trends and behaviors. To overcome seasonality, an equation parameter called the "*Holt-Winters*" according to the name of the inventor. Method *Holt-Winters* It is often referred to as the exponential leveling approach. This method is divided into two parts, namely the seasonal multiplicative method (*Multiative Seasonal Method*) used for seasonal data variations that experience increase/decrease (fluctuations), and seasonal additive methods used for constant seasonal variations [8].

1. *Holt-Winters Exponential Smoothing* with Multiplicative Model

The equations used in the multiplicative model are:
Exponential smoothing of original (overall) data

$$L_t = \alpha \frac{Y_t}{S_{t-s}} + (1-\alpha)(L_{t-1} + b_{t-1}) \quad (5)$$

Trend factor smoothing

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \quad (6)$$

Seasonality smoothing

$$S_t = \gamma \frac{Y_t}{L_t} + (1-\gamma)S_{t-s} \quad (7)$$

Forecast for the future period

$$F_{t+m} = (L_t + b_t m)S_{t-s+m} \quad (8)$$

According to Makridakis et al, the equation for determining the initial value of the multiplicative model is as follows:

a. The initial value of exponential smoothing is used the following equation:

$$S_L = \frac{1}{L}(X_1 + X_2 + \cdots + X_L) \quad (9)$$

b. The initial value of trend factor smoothing is used as follows:

$$b_L = \frac{1}{L}\left(\frac{X_{L+1} - X_1}{L} + \frac{X_{L+2} - X_2}{L} + \cdots + \frac{X_{L+L} - X_L}{L}\right) \quad (10)$$

c. The initial value of seasonal factor smoothing is used the following equation:

$$l_k = \frac{X_k}{S_L} \quad (11)$$

With:
$S_L$ : the initial value of exponential smoothing
$b_L$ : the initial value of trend factor smoothing
$l_k$ : Seasonal Factor Smoothing Initial Value ()$k = 1,2, \dots, l$
L : Seasonal Length ()$L = 3, L = 6\ atau\ L = 12$

2. *Holt-Winters Exponential Smoothing* with Additive Model

The equations used in additive models are:
Exponential smoothing of original (overall) data

$$L_t = \alpha(Y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1}) \quad (12)$$

Trend factor smoothing

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

Seasonality smoothing

$$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-s} \quad (14)$$

Forecast m for the future period

$$F_{t+m} = L_t + b_t m + S_{t-s+m} \quad (15)$$

According to Makridakis et al, the equation for determining the initial value of the additive model is as follows:

1. The initial value of exponential smoothing is used the following equation:

$$S_L = \frac{1}{L}(X_1 + X_2 + \cdots + X_L) \quad (16)$$

2. The initial value of trend factor smoothing is used as follows:

$$b_L = \frac{1}{L}\left(\frac{X_{L+1}-X_1}{L} + \frac{X_{L+2}-X_2}{L} + \cdots + \frac{X_{L+L}-X_L}{L}\right) \quad (17)$$

3. The initial value of seasonal factor smoothing is used the following equation:

$$l_k = (X_k - S_L) \quad (18)$$

### *2.4 Measuring Forecasting Errors*

The use of the forecasting method depends on the data patterns to be analyzed. If the method used is considered correct for forecasting, then the selection of the best forecasting method is based on the level of accuracy of forecasting [9]. According to Heizer and Render, there are three measures commonly used to summarize forecasting errors, namely, *Mean Absolute Deviation* (MAD), *Mean Squared Error* (MSE), and *Mean Absolute Percentage Error* (MAPE). This study uses MAPE to measure forecasting errors that have smaller values than other methods**.**

According to Heizer and Render, *the Mean Absolute Percentage Error* (MAPE) is calculated using the absolute error in each period divided by the actual observations for that period. MAPE is an error measurement that calculates the size of the percentage deviation between actual data and forecast data. The formula for MAPE is as follows:

$$\text{MAPE} = \left(\frac{100\%}{n}\right)\sum_{t=1}^{n}\frac{|Y_t - F_t|}{Y_t} \quad (19)$$

With:

$Y_t$ : Actual data for the period t

$F_t$ : Forecast value for the period t

$n$ : Amount of data

## 3. Research Methods

### *3.1 Types of Research*

The type of research used in this study is descriptive quantitative research. This study aims to describe and predict the average air temperature in the city of Pekanbaru using the time series forecasting method. The data used is in the form of secondary data, namely average monthly air temperature data from 2017 to 2024 obtained from the BMKG Riau Climatology Station. This study utilizes the Holt-Winters Exponential Smoothing method to build a forecasting model that considers trend and seasonal elements in the data.

### *3.2 Data Analysis Techniques*

The data analysis technique used is time series analysis with the Triple Exponential Smoothing (Holt-Winters) approach. The analysis procedure is carried out in several stages, namely:

1) Descriptive analysis of air temperature data to see historical patterns and trends.
2) Determination of the initial value of exponential, trending, and seasonal smoothing components.
3) Identify models by a combination of various smoothing parameters: alpha (α), beta (β), and gamma (γ).
4) The best model selection is based on the smallest Mean Absolute Percentage Error (MAPE) value of various combinations of parameters.
5) Forecast the average value of air temperature in 2025 using the best models obtained.

### *3.3 Software*

In this study, data processing and analysis were carried out using Microsoft Excel and Minitab. Microsoft Excel is used for initial processes such as air temperature data processing, exponential smoothing value calculations, and temperature graphing. Minitab is used to assist in more complex time series analysis, including model validation, automatic calculation of MAPE values, and more structured data visualization and forecasting results. The combination of these two software provides ease and precision in applying the Holt-Winters Exponential Smoothing method optimally.

## 4. Results and Discussion

### *4.1 Descriptive Analysis*

The data used is data taken from the BMKG Riau Climatology Station. The data to be processed is the average air temperature data in the city of Pekanbaru in 2017-2024.

**Table 1 Actual Data**

| Year | Moon | Average Air Temperature | Year | Moon | Average Air Temperature |
|---|---|---|---|---|---|
| 2017 | January | 26,8 | 2021 | January | 25,9 |
| | February | 28,6 | | February | 27 |
| | March | 26,9 | | March | 26,6 |
| | April | 27,4 | | April | 27 |
| | May | 27,7 | | May | 27,4 |
| | June | 27,7 | | June | 27,3 |
| | July | 27,5 | | July | 27,4 |
| | August | 28,3 | | August | 26,8 |
| | September | 27,6 | | September | 26,6 |
| | October | 27,7 | | October | 27,3 |
| | November | 26,8 | | November | 27 |
| | December | 27,1 | | December | 26,6 |
| 2018 | January | 26,7 | 2022 | January | 26,5 |
| | February | 27 | | February | 26,3 |
| | March | 27,1 | | March | 27,5 |
| | April | 27,8 | | April | 27,2 |
| | May | 27,7 | | May | 27,7 |
| | June | 27,8 | | June | 26,8 |
| | July | 27,6 | | July | 27 |
| | August | 27,9 | | August | 26,8 |
| | September | 27,4 | | September | 26,7 |
| | October | 26,8 | | October | 26,3 |
| | November | 27,1 | | November | 26,6 |
| | December | 27,2 | | December | 26 |
| 2019 | January | 26,9 | 2023 | January | 25,9 |
| | February | 27,3 | | February | 26,4 |
| | March | 27,8 | | March | 26,4 |
| | April | 28 | | April | 26,2 |
| | May | 28,2 | | May | 28 |
| | June | 27,6 | | June | 27,7 |
| | July | 27,8 | | July | 27,5 |
| | August | 28 | | August | 27,1 |
| | September | 27,5 | | September | 27,6 |

| | | | | | |
|---|---|---|---|---|---|
| | October | 27 | | October | 27,3 |
| | November | 26,9 | | November | 27 |
| | December | 26,6 | | December | 31,1 |
| 2020 | January | 22,2 | 2024 | January | 26,4 |
| | February | 22,5 | | February | 27,2 |
| | March | 22,8 | | March | 27,8 |
| | April | 23 | | April | 27,9 |
| | May | 23 | | May | 27,5 |
| | June | 22,3 | | June | 27,2 |
| | July | 22,2 | | July | 27,9 |
| | August | 22,4 | | August | 27,8 |
| | September | 22,2 | | September | 27,8 |
| | October | 22 | | October | 28,0 |
| | November | 22,6 | | November | 26,3 |
| | December | 22,2 | | December | 26,4 |

The following is a graph of the average air temperature in the city of Pekanbaru:

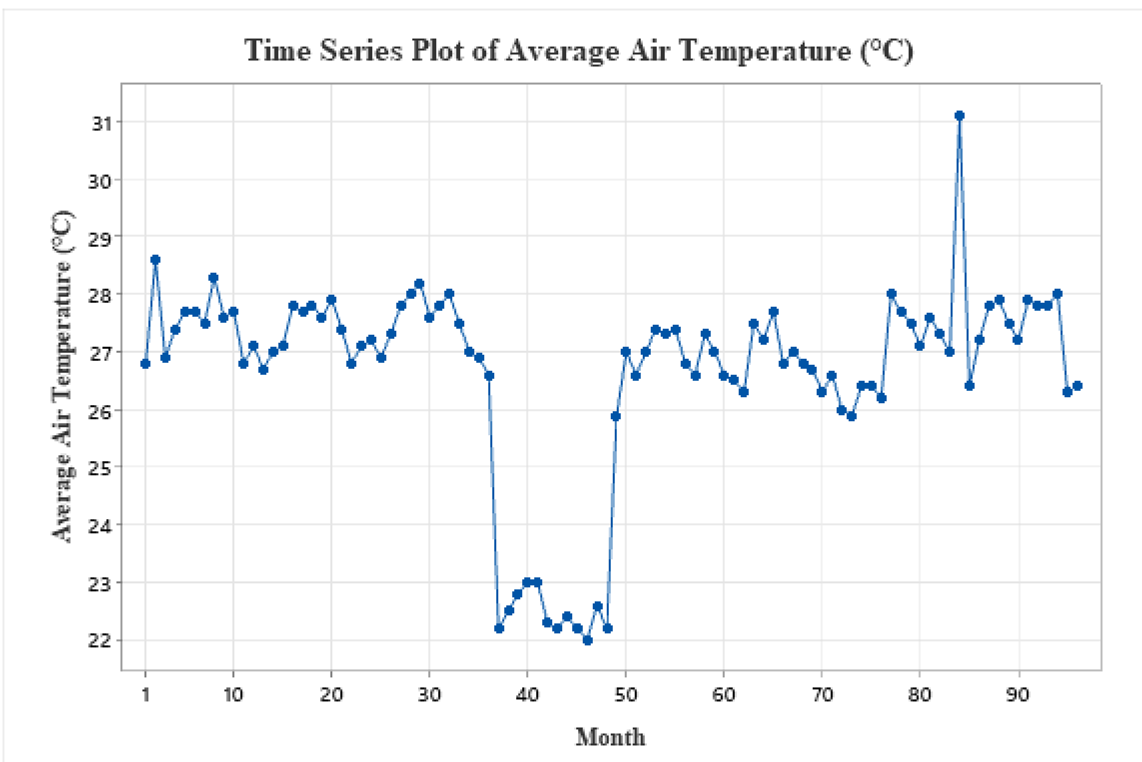


**Figure 1 Graph of Average Air Temperature Data in the City of Pekanbaru in 2017 – 2024**

Based on Figure 1, it can be seen that the average air temperature in the city of Pekanbaru fluctuated in a pattern that was mostly stable, but experienced a sharp decline from January to December 2020, then increased again in 2021 and experienced an extreme spike in December 2023. After that, the temperature returns to its original relatively stable pattern. This indicates a temporary disturbance in temperature patterns that can be caused by extreme weather factors, natural phenomena, or possible data errors.

### *4.2 Determination of Initial Value*

Furthermore, calculations were carried out to determine the initial value of exponential smoothing ($S_L$), trend factor smoothing ($b_L$), and seasonal factor smoothing ($l_k$) for Average Air Temperature data in Pekanbaru City. Determining the exponential smoothing value can be done directly, namely by selecting the average value of one initial period to be the initial smoothing value. Based on the data used, the seasonal period is L = 12 because the data used is monthly data. So that the results of the calculation of the initial value are obtained as follows:

1. Exponential smoothness initial value ($S_L$)
   In calculating the initial value of exponential smoothing, Equation (9) is used, namely:

$$S_L = \frac{1}{L}(X_1 + X_2 + \cdots + X_L)$$
$$S_{12} = \frac{1}{12}(X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12})$$
$$S_{12} = \frac{1}{12}(26{,}8 + 28{,}6 + 26{,}9 + 27{,}4 + 27{,}7 + 27{,}7 + 27{,}5 + 28{,}3 + 27{,}6 + 27{,}7 + 26{,}8 + 27{,}1)$$
$$S_{12} = \frac{1}{12}(330{,}1)$$
$$S_{12} = 27{,}5083$$

   Thus, the initial value of exponential smoothness ($S_L$) is 27.5083

2. Initial value of trend factor smoothing ($b_L$)
   In the calculation of the initial value of the smoothing of the trend factor, Equation (.10) is used, namely:

$$b_L = \frac{1}{L}\left(\frac{X_{L+1} - X_1}{L} + \frac{X_{L+2} - X_2}{L} + \cdots + \frac{X_{L+L} - X_L}{L}\right)$$
$$b_{12} = \frac{1}{12}\left(\frac{X_{13} - X_1}{12} + \frac{X_{14} - X_2}{12} + \frac{X_{15} - X_3}{12} + \frac{X_{16} - X_4}{12} + \frac{X_{17} - X_5}{12} + \frac{X_{18} - X_6}{12} + \frac{X_{19} - X_7}{12} + \frac{X_{20} - X_8}{12} + \frac{X_{21} - X_9}{12} + \frac{X_{22} - X_{10}}{12} + \frac{X_{23} - X_{11}}{12} + \frac{X_{24} - X_{12}}{12}\right)$$
$$b_{12} = \frac{1}{12}\left(\frac{26{,}7 - 26{,}8}{12} + \frac{27 - 28{,}6}{12} + \frac{27{,}1 - 26{,}9}{12} + \frac{27{,}8 - 27{,}4}{12} + \frac{27{,}7 - 27{,}7}{12} + \frac{27{,}8 - 27{,}7}{12} + \frac{27{,}6 - 27{,}5}{12} + \frac{27{,}9 - 28{,}3}{12} + \frac{27{,}4 - 27{,}6}{12} + \frac{26{,}8 - 27{,}7}{12} + \frac{27{,}1 - 26{,}8}{12} + \frac{27{,}2 - 27{,}1}{12}\right)$$
$$b_{12} = \frac{1}{12}\left(\frac{-0{,}1}{12} + \frac{-1{,}6}{12} + \frac{0{,}2}{12} + \frac{0{,}4}{12} + \frac{0}{12} + \frac{0{,}1}{12} + \frac{0{,}1}{12} + \frac{-0{,}4}{12} + \frac{-0{,}2}{12} + \frac{-0{,}9}{12} + \frac{0{,}3}{12} + \frac{0{,}1}{12}\right)$$
$$b_{12} = \frac{1}{12}(-0{,}0083 - 0{,}1333 + 0{,}0167 + 0{,}0333 + 0 + 0{,}0083 + 0{,}0083 - 0{,}0333 - 0{,}0167 - 0{,}075 + 0{,}025 + 0{,}0083)$$
$$b_{12} = \frac{1}{12}(-0{,}1667)$$
$$b_{12} = -0{,}0138$$

   Thus, the initial value of trend factor smoothing ( is -0.0138$b_L$)

3. Seasonal factor smoothing starting value ($l_k$)
   In calculating the initial value of seasonal factor smoothing, Equation (11) is used, namely:

$$l_k = \frac{X_k}{S_L}$$

$$l_1 = \frac{X_1}{S_{12}} = \frac{26{,}8}{27{,}5083} = 0{,}974 \qquad l_7 = \frac{X_7}{S_{12}} = \frac{27{,}5}{27{,}5083} = 0{,}999$$
$$l_2 = \frac{X_2}{S_{12}} = \frac{28{,}6}{27{,}5083} = 1{,}039 \qquad l_8 = \frac{X_8}{S_{12}} = \frac{28{,}3}{27{,}5083} = 1{,}028$$
$$l_3 = \frac{X_3}{S_{12}} = \frac{26{,}9}{27{,}5083} = 0{,}977 \qquad l_9 = \frac{X_9}{S_{12}} = \frac{27{,}6}{27{,}5083} = 1{,}003$$
$$l_4 = \frac{X_4}{S_{12}} = \frac{27{,}4}{27{,}5083} = 0{,}996 \qquad l_{10} = \frac{X_{10}}{S_{12}} = \frac{27{,}7}{27{,}5083} = 1{,}006$$
$$l_5 = \frac{X_5}{S_{12}} = \frac{27{,}7}{27{,}5083} = 1{,}006 \qquad l_{11} = \frac{X_{11}}{S_{12}} = \frac{26{,}8}{27{,}5083} = 0{,}974$$
$$l_6 = \frac{X_6}{S_{12}} = \frac{27{,}7}{27{,}5083} = 1{,}006 \qquad l_{12} = \frac{X_{12}}{S_{12}} = \frac{27{,}1}{27{,}5083} = 0{,}985$$

### *4.3 Model Identification*

After obtaining the initial value of exponential smoothing, trend factor smoothing and seasonal factor smoothing, the next step is to identify the model using *the Holt-Winters exponential smoothing* method. The parameters used in this method consist of 3 parameters, namely alpha ($\boldsymbol{\alpha}$), betha ($\boldsymbol{\beta}$) and gamma ($\boldsymbol{\gamma}$). These parameters have a value range of 0 << 1, 0 << 1, and 0 << 1. In this study, the researcher used several parameter values that were determined by trial and error, namely, for alpha ($\boldsymbol{\alpha}$) the value of 0.1 was used; 0,3; 0.5 for betha ($\boldsymbol{\beta}$) is used a value of 0.2; 0,4; 0.6 and for gamma($\boldsymbol{\gamma}$) a value of 0.3 is used; 0,6; 0.9, this is done to reduce the time in the forecasting process, because the more constant the number of constants, the forecasting process will take a long time. This calculation uses Equations (2.5), (2.6), and (2.7), which are performed repeatedly by combining all the predetermined values of alpha ($\boldsymbol{\alpha}$), betha ($\boldsymbol{\beta}$), and gamma ($\boldsymbol{\gamma}$).

### *4.4 Best Model Selection*

After identifying the model by combining all the values of the parameters alpha ($\boldsymbol{\alpha}$), betha ($\boldsymbol{\beta}$), and gamma ($\boldsymbol{\gamma}$) that have been determined for the average data of air temperature in the city of Pekanbaru, then the best model is selected. The selection of the best model is carried out by looking at the value of the size of the forecasting error, namely, the smallest MAPE using Equation (3.19) can be seen in Table 2.

**Table 2 MAPE Forecast Error Size Values**

| No. | $\boldsymbol{\alpha}$ | $\boldsymbol{\beta}$ | $\boldsymbol{\gamma}$ | MAPE (%) |
|---|---|---|---|---|
| 1. | 0,1 | 0,2 | 0,3 | 5,518 |
| 2. | 0,1 | 0,2 | 0,6 | 5,911 |
| 3. | 0,1 | 0,2 | 0,9 | 6,173 |
| 4. | 0,1 | 0,4 | 0,3 | 6,806 |
| 5. | 0,1 | 0,4 | 0,6 | 6,979 |
| 6. | 0,1 | 0,4 | 0,9 | 7,822 |
| 7. | 0,1 | 0,6 | 0,3 | 6,724 |
| 8. | 0,1 | 0,6 | 0,6 | 7,402 |
| 9. | 0,1 | 0,6 | 0,9 | 10,906 |
| 10. | 0,3 | 0,2 | 0,3 | 3,384 |
| 11. | 0,3 | 0,2 | 0,6 | 3,647 |
| 12. | 0,3 | 0,2 | 0,9 | 4,225 |
| 13. | 0,3 | 0,4 | 0,3 | 3,457 |
| 14. | 0,3 | 0,4 | 0,6 | 3,881 |
| 15. | 0,3 | 0,4 | 0,9 | 4,979 |
| 16. | 0,3 | 0,6 | 0,3 | 3,388 |
| 17. | 0,3 | 0,6 | 0,6 | 3,700 |
| 18. | 0,3 | 0,6 | 0,9 | 5,225 |
| 19. | 0,5 | 0,2 | 0,3 | 2,684 |
| 20. | 0,5 | 0,2 | 0,6 | 2,814 |
| 21. | 0,5 | 0,2 | 0,9 | 2,967 |
| 22. | 0,5 | 0,4 | 0,3 | 2,798 |
| 23. | 0,5 | 0,4 | 0,6 | 2,914 |
| 24. | 0,5 | 0,4 | 0,9 | 3,063 |
| 25. | 0,5 | 0,6 | 0,3 | 2,810 |
| 26. | 0,5 | 0,6 | 0,6 | 2,943 |
| 27. | 0,5 | 0,6 | 0,9 | 3,253 |

Based on Table 2, it can be seen that the smallest MAPE value is found at $\alpha$ = 0.5, $\beta$ = 0.2 and $\gamma$ = 0.3, which is 2.684. Therefore, the best model lies in the MAPE value which has the parameters $\alpha$ = 0.5,$\beta$ = 0.2 and $\gamma$ = 0.3 which is 2.684.

### *4.5 Forecasting*

Then forecasting is carried out on the average air temperature for the coming year, namely 2025. The following is a graph of the results of the average air temperature forecast in the city of Pekanbaru in 2025.

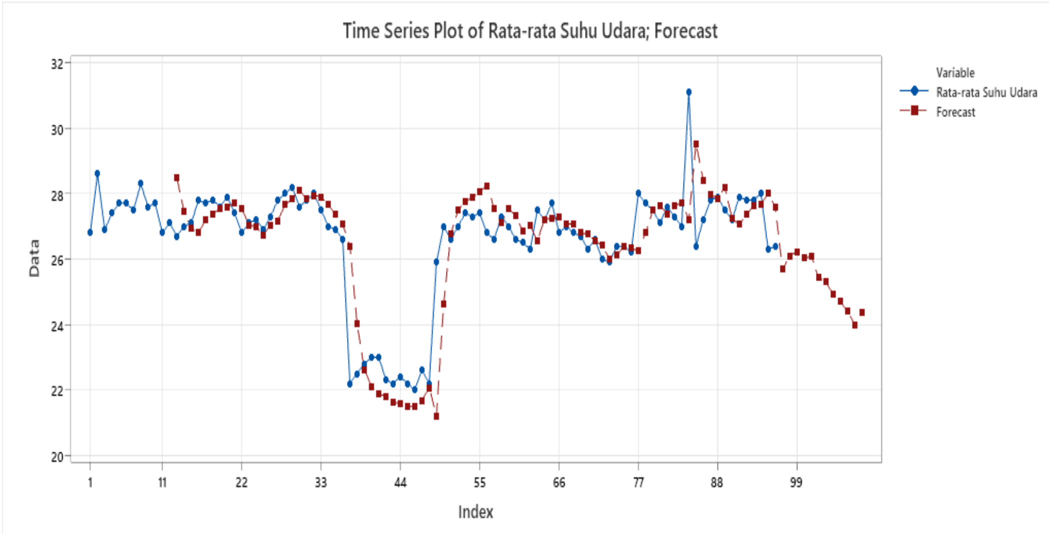


**Figure 2: Graph of Average Air Temperature Forecast Results in Pekanbaru City in 2025**

The graph in Figure 2 above is a graph of the results of forecasting the Average Air Temperature in the city of Pekanbaru in the coming year, namely 2025, using the *Holt-Winters Exponential Smoothing* method when the parameters $\alpha$ = 0.5, $\beta$ = 0.2 and $\gamma$ = 0.3. The *Holt-Winters Exponential Smoothing* model is based on $\alpha$ =0.5, $\beta$ =0.2 and $\gamma$ =0.3 is as follows:

1. Exponential smoothing of actual (whole) data

$$L_t = \alpha(Y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1})$$
$$= 0{,}5(Y_t - S_{t-s}) + (1-0{,}5)(L_{t-1} + b_{t-1})$$
$$= 0{,}5(Y_t - S_{t-s}) + (0{,}5)(L_{t-1} + b_{t-1})$$

2. Trend factor smoothing

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$
$$= 0{,}2(L_t - L_{t-1}) + (1-0{,}2)b_{t-1}$$
$$= 0{,}2(L_t - L_{t-1}) + (0{,}8)b_{t-1}$$

3. Seasonality smoothing

$$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-s}$$
$$= 0{,}3(Y_t - L_t) + (1-0{,}3)S_{t-s}$$
$$= 0{,}3(Y_t - L_t) + (1-0{,}7)S_{t-s}$$

4. Forecast m for the future period

$$F_{t+m} = (L_t + b_t m)S_{t-s+m}$$
$$= (0{,}5(Y_t - S_{t-s}) + (1-0{,}5)(L_{t-1} + b_{t-1}) + \ 0{,}2(L_t - L_{t-1}) + (1-0{,}2)b_{t-1}(m))L_{t-L+m}$$
$$= (0{,}5(Y_t - S_{t-s}) + (0{,}5)(L_{t-1} + b_{t-1}) + \ 0{,}2(L_t - L_{t-1}) + (0{,}8)b_{t-1}(m))L_{t-L+m}$$

The best models obtained to predict the Average Air Temperature in the City of Pekanbaru in the coming year 2025 are:

$$F_{96+m} = (25{,}61223 + (-0{,}20223)m)S_{96-12+m}$$

Based on the graph in Figure 2 above, it is descriptively explained that the Average Air Temperature in the city of Pekanbaru in the coming year, namely 2025, will decrease. The results of the Average Air Temperature forecast in 2025 for January to December are as follows:

**Table 3 Forecast Results of Average Air Temperature in Pekanbaru City in 2025**

| Moon | Average Air Temperature (ºC) |
|---|---|
| January | 25,67957 |
| February | 26,10052 |
| March | 26,22207 |
| April | 26,04312 |
| May | 26,07665 |
| June | 25,44070 |
| July | 25,30217 |
| August | 24,92868 |
| September | 24,69206 |
| October | 24,41851 |
| November | 23,99875 |
| December | 24,38747 |

Based on Table 3, the results show that the average forecast value of air temperature in the city of Pekanbaru for the coming year, namely 2025, is relatively or likely to decrease, where the average air temperature drops the most in November, which is 23.99875ºC. The results of this average air temperature forecast in the future can at least be used as a reference for short and medium-term planning by interested parties on climate and air temperature information in the region.

## 5. Conclusion

From the description of the results and discussion above, it can be concluded that the best model obtained to predict the average air temperature in the city of Pekanbaru in 2025 lies in the minimum MAPE value of 2.684 with the parameters $\boldsymbol{\alpha}$= 0.5, $\boldsymbol{\beta}$ = 0.2 and $\boldsymbol{\gamma}$ = 0.3 is $\boldsymbol{F_{96+m} = (25,61223 + (-0,20223)m)S_{96-12+m}}$. The average air temperature forecast in Pekanbaru City for the coming year, namely 2025, is that in January the average air temperature is 25.67957 ºC, in February 26.10052 ºC, in March 26.22207 ºC, in April 26.04312 ºC, in May 26.07665 ºC, in June 25.44070 ºC, in July 25.30217 ºC, in August 24.92868 ºC, in September 24.69206 ºC, in October 24.41851 ºC, in November 23.99875 ºC, and in December 24.38747 ºC.

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