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Madiun City Labor Force Participation Rate (LFPR) Forecast Model with Double Exponential Smoothing Holt

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Abstract

The Labour Force Participation Rate (LFPR) is a percentage of the number of workers in the population of working age (+15 years). Madiun City which is one of the largest cities in East Java Province. However, LFPR of Madiun city only ranks 34 out of 39 regencies/cities in East Java. This situation has become a serious concern for the Madiun City Government, especially the Department of Manpower, to address this issue so that the productive-age population can work optimally. The percentage is issued annually by Statistics Indonesia (BPS) provinces, districts, or cities. The LFPR has time series data, so to predict the percentage of LFPR in the following year, we can use the Double Exponential Smoothing method with the Holt parameter. In this study, Holt parameters suitable for predicting Madiun City LFPR percentage are $\alpha = 0.5$ and $\gamma = 0.4$. The forecast result of Madiun City LFPR percentage with Double Exponential Smoothing Holt (DESH) in 2024 is 68.76% and in 2025 is 69.21%. The MSE value is 29.284, the RMSE is 5.411, and the MAPE value is 5.273%.

Keywords: Double Exponential Smoothing Holt, Forecasting, LFPR, Madiun
MSC2020: 62M10

1. Introduction

The Labour Force Participation Rate (LRPR) is a percentage of the number of workers in the population of working age (+15 years) [1]. Unemployment is a situation in which a person has entered the working age but has not yet had a job, either in search of a job or in preparation for a new enterprise. The government issued the LFPR to measure the percentage of the labor force against the number of people of working age (+15 years) [2].

By 2023, the LFPR of the Republic of Indonesia was 69.48%. That means there are still 30.52% of the working-age population not included in the participation of the labor force [3], [4]. Madiun City is one of the largest cities in East Java, with a population of 201.460 people. The LFPR percentage became a government indicator for addressing the

unemployment problem.

This research was done to predict the percentage of Madiun City LFPR. LFPR data is data about the period of time with the annual period. Data is issued by BPS provinces, districts, or cities every year. Exponential smoothing is a method of predicting data over time by giving exponential weight to the latest data. There are three types of exponential methods: single, double, and triple. Single Exponential Smoothing (SES) is a time series forecasting method that gives more weight to the most recent data. This method uses a single smoothing parameter. SES is suitable for data that does not show a trend or seasonality. Double Exponential Smoothing (DES) expands SES by considering the trend in the data. This method uses two components: level and trend. DES is suitable for data that shows a clear trend pattern but does not have seasonal components. Meanwhile, Triple Exponential Smoothing (TES) adds a seasonal component, making it possible to forecast data with seasonal patterns in addition to trends. TES uses three components: level, trend, and seasonality.

The research found that the Double Exponential Smoothing (DES) method is the best method for predicting, with a Mean Absolute Percentage Error (MAPE) value of less than 10% [5], [6], [7]. Meanwhile, in the study [8] stated that DES performs well in predicting inflation rates in South Sulawesi Province. Similarly, [9] reported that the DES model with Holt's parameters performed excellently in predicting rice prices, achieving a MAPE value of 7.91%. In addition, [10] and [11] concluded in their research that the DES with Holt's parameters better than DES Brown in forecasting poverty data. Furthermore, [12] and [13] highlighted that DES is effective for forecasting Covid-19 cases and export volumes in East Borneo, with MAPE values in their research also below 10%. This indicates that the DES method is reliable for forecasting in various scenarios.

Therefore, this research aims to create a predictive model of the Madiun City LFPR using the Double Exponential Smoothing Method with the Holt parameter or Double Exponential Smoothing Holt. The results of this research are expected to be used as a reference by the government or related parties in solving the problems related to the Madiun City LFPR.

2. Methods

2.1 Types and Data Sources

The data used in this research is secondary data taken from the website of BPS Madiun City. The data used is the Labour Force Participation Rate (LFPR) of the City of Madiun, Province of East Java, from 2001 to 2023 [3], [4].

2.2 Data Analysis

LFPR data is a type of time period data that is collected based on an annual period. A method that can be used to predict Madiun City LFPR data is by using Double Exponential Smoothing Holt (DESH) [12]. The measures used in analyzing the data on this study are as follows:

1. Data collection;
2. Data descriptions;
3. Determines the level completion parameter Alpha ($\boldsymbol{\alpha}$) and the trend completion parameters gamma ($\boldsymbol{\gamma}$). Fixing of $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ values is done trial and error. $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ values are between 0 and 1 [9].
4. It establishes the initial level value ($\boldsymbol{S_1}$) and the initial completion value ($\boldsymbol{T_1}$). In this study, the initialization process yields the first level and completion values.
$$\boldsymbol{S_1 = X_1} \text{ and } \boldsymbol{T_1 = X_2 - X_1}. \quad (1)$$
5. Forms the forecast model of Madiun City LFPR with the selected α and γ values.
$$\boldsymbol{S_t = \alpha\, X_t + (1-\alpha)(S_{t-1} + T_{t-1})} \quad (2)$$
$$\boldsymbol{T_t = \gamma\,(S_t - S_{t-1}) + (1-\gamma)T_{t-1}} \quad (3)$$
$$\boldsymbol{F_{t+m} = S_t + T_t \cdot m} \text{ , } (\boldsymbol{m} \text{ future period}) \quad (4)$$
6. Calculating the value of the forecast of Madiun City LFPR for the years 2024-2025.
7. After analysis and prediction using the DESH method. the next is the selection of the best method. The choice of the best method is seen from the measure of the error of prediction. The error measurement in this study was done using Mean Square Error (MSE), Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE).
   - Mean Square Error (MSE). MSE is the average difference between the actual data and the predicted data. MSE is a method for evaluating errors, or errors that are squared and then added to the number of observations [8].

$$\boldsymbol{MSE = \frac{1}{n}\sum_{t=1}^{n}(X_t - F_t)^2} \quad (5)$$

   - Root Mean Square Error (RMSE). RMSE is the result of the MSE curvature. RMSE describes the measure of the spread of error values in making predictions. A predictive model is said to be good if it has a small RMSE value [14].

$$\boldsymbol{RMSE = \sqrt{MSE}}$$
$$\boldsymbol{= \sqrt{\frac{1}{n}\sum_{t=1}^{n}(X_t - F_t)^2}} \quad (6)$$

   - Mean Absolut Percentage Error (MAPE). MAPE is also often used to measure the accuracy of a predictive model [15]. MAPE are the average of the total percentage of error (difference) between the actual data and the forecast data. A good model is a model that has a small value of MAPE [16].

$$\boldsymbol{MAPE} = \left(\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{t=1}}^{\boldsymbol{n}}\frac{|\boldsymbol{X_t}-\boldsymbol{F_t}|}{\boldsymbol{X_t}}\right) \times \mathbf{100\%} \quad (7)$$

There are four categories based on MAPE values that can be interpreted as shown in the following Table 2. [17]:

Table 2. MAPE Accurary Value Criteria

MAPE Value	Criteria
$MAPE < 10\%$	Excellent
$10\% \leq MAPE < 20\%$	Good
$20\% \leq MAPE < 50\%$	Worth it
$MAPE \geq 50\%$	Bad

3. Results and Discussion

3.1 Data Description Analysis

The data description analysis is used to look at the conditions and characteristics of the data used in the research. The data used is 23, i.e. data over the years from 2021 to 2023. For further description of the research data you can see in the following table.

Table 3. Data Description

Variable	Mean	Variance	Minimum Data	Maximum Data
Labour Force Participation Rate (LFPR) of Madiun City ($\boldsymbol{X}$)	64.29	16.81	55.56	69.29

In Table 3, it can be seen that the lowest percentage of Madiun City LFPR occurred in 2002 at 55.56% and the highest in 2023 at 69.29%. LFPR of Madiun city experienced a significant increase from 2002 to 2003 and a sharp decline in 2004. Another steep decline occurred in 2007. The mean percentages of Madiun City LFPR in the last 23 years were 64.29%, with a variance of 16.81. Here is a graph of the Madiun City LFPR for the last 23 years.

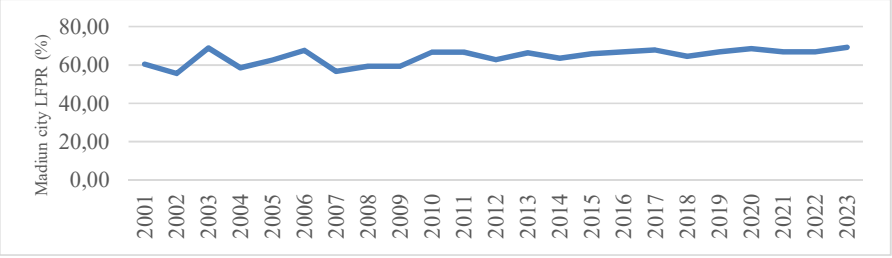

Figure 1. Graph of the Madiun City LFPR

Figure 1 shows that data patterns have experienced sharp fluctuations from 2001 to 2010 and from 2011 to 2023 the fluctuation tends to decrease. Seeing the occurrence of such

data patterns can lead to a prediction of the value of Madiun City LFPR in the next year using the DESH method.

3.2 Forecasting Model with DESH

In the analysis of predictive models using the DESH method, alpha and gamma values are selected using trial and error methods until a small error value is obtained. As for the alpha and gamma values selected are (α, γ) ={(0.6, 0,4),(0.6, 0.3), (0.5, 0,4), (0.5, 0.3), (0.4, 0.4), (0.4, 0.3)}, Based on equations (2), (3) and (4), then the DESH equation model for Madiun City LFPR is as follows:

$$\boldsymbol{S_t = 0.6X_t + 0.4(S_{t-1} + T_{t-1})} \quad (8)$$

$$\boldsymbol{T_t = 0.4(S_t - S_{t-1}) + 0.6T_{t-1}} \quad (9)$$

$$F_{t+m} = S_t + T_t \cdot m \quad (10)$$

Next, the calculation of the predictions will be done using DESH.

- For $t = 1$, based on equation (1), obtained:
  $\boldsymbol{S_1 = 60.42}$
  $T_1 = 55.56 - 60.43$
  $= -4.86$
  By using the equation (10), Then the 2nd prediction data is:
  $F_2 = 60.42 - 4.86$
  $= 55.56$
- For $t = 2$, based on equation (8) and (9), obtained:
  $\boldsymbol{S_2 = 0.6 \cdot 55.56 + 0.4(60.42 - 4.86)}$
  $\boldsymbol{= 55.56}$
  $T_2 = 0.4\ (55.56 - 60.42) + 0.6(-4.86)$
  $= -4.86$
  $F_3 = 55.56 - 4.86$
  $= 50.70$

It's the same for $t = 3, 4, \ldots, 23$.

- For $t = 23$,
  $S_{23} = 0.6 \cdot 69.29 + 0.4(67.193 + 0.021)$
  $\boldsymbol{= 68.46}$
  $T_{23} = 0.4\ (68.46 - 67.19) + 0.6(0.021)$
  $= 0.519$

For the 24th and 25th data predictions are as follows, with $m = 1,2$:

$F_{24} = 68.46 + 0.519 \cdot 1$
$= 68.98$
$F_{25} = 68.46 + 0.519 \cdot 2$
$= 69.50$

The calculations above also apply to other alpha and gamma values. The results of DESH Forcast calculation can be seen in the following Table 4.

Table 4. DESH Forecast Calculation Results

No.	Year	Actual Data (%)	Forecast Data (%)					
			$\alpha = 0.6$ $\gamma = 0.4$	$\alpha = 0.6$ $\gamma = 0.3$	$\alpha = 0.5$ $\gamma = 0.4$	$\alpha = 0.5$ $\gamma = 0.3$	$\alpha = 0.4$ $\gamma = 0.4$	$\alpha = 0.4$ $\gamma = 0.3$
1	2001	60.42	60.42	60.42	60.42	60.42	60.42	60.42
2	2002	55.56	55.56	55.56	55.56	55.56	55.56	55.56
3	2003	68.91	50.70	50.70	50.70	50.70	50.70	50.70
4	2004	58.50	61.14	60.04	58.59	57.68	56.04	55.31
5	2005	62.63	58.43	57.26	57.31	56.08	55.47	54.29
6	2006	67.64	60.84	59.59	59.80	58.33	57.93	56.34
7	2007	56.65	66.44	64.98	65.12	63.36	62.96	60.92
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
23	2023	69.29	67.21	67.30	67.35	67.44	67.42	67.61
24	2024	-	68.98	68.95	68.76	68.76	68.53	68.61
25	2025	-	69.50	69.40	69.21	69.16	68.90	68.94

From calculations using the DESH model with $(\alpha, \gamma) = \{(0.6, 0.4),(0.6, 0.3), (0.5, 0.4), (0.5, 0.3), (0.4, 0.4), (0.4, 0.3)\}$. Madiun City LFPR is predicted to increase from 2024 to 2025. In 2024, it ranges between 68.53% and 68.98% and in 2025 it ranges 68.90% to 69.50%. Here are the actual data graphs and forecast data using DESH.

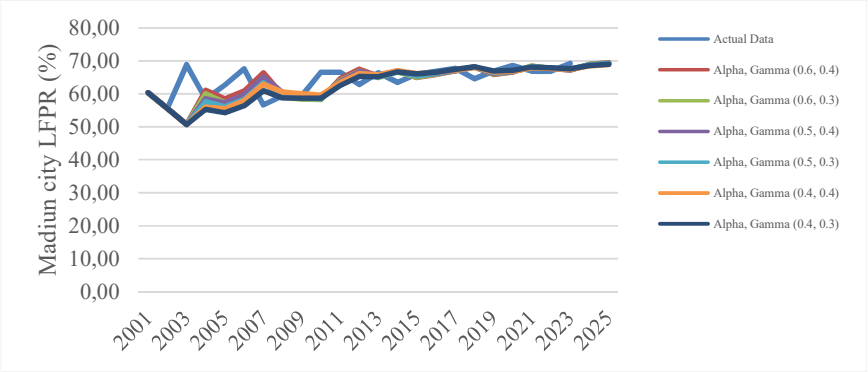

Figure 2. Actual Data and Forecast Data Graph with DESH

Figure 2 shows that the forecast data is close to actual data. or that the difference between actual data and predicted data is not too far away. This means that the DESH model with $(\alpha, \gamma) = \{(0.6, 0.4), (0.6, 0.3), (0.5, 0.4), (0.5, 0.3), (0.4, 0.4), (0.4, 0.3)\}$ are suitable for predicting the Madiun City LFPR. Next, the MSE, RMSE, and MAPE values will be calculated to measure the prediction error using the DESH method. The result of the calculation using the equations (5), (6) and (7) can be seen in the following Table 5.

Table 5. Error Value

DESH		MSE	RMSE	MAPE (%)
Alpha	Gamma			
0.6	0.4	30.234	5.499	5.593
0.6	0.3	29.953	5.473	5.531
0.5	0.4	29.284*	5.411*	5.273*
0.5	0.3	29.975	5.475	5.313
0.4	0.4	29.984	5.476	5.396
0.4	0.3	32.281	5.682	5.504

*minimum

In Table 5. it was found that the MSE score was 3.435 to 3.622 and the RMSE was 1.853 to 1.903. It is seen that the error in predicting the Madiun City LFPR with the DESH method is quite good. Meanwhile. the MAPE value are between 5.273% to 5.593%. Based on thse MAPE value criterion, if MAPE < 10% indicate that the forecast results are excellent. The MAPE value of the Madiun City LFPR in the prediction of the DESH method was under 10%. which shows that the predictions of Madiun City LFPR using the DESH method is already excellent. The best DESH method for forecasting the LFPR in Madiun city is the DESH model with an alpha of 0.5 and gamma of 0.4, yielding an MSE of 29.284, an RMSE of 5.411, and a MAPE of 5.273%.

4. Conclusion

Based on the results of the analysis and discussion shown. it can be concluded that the predictive model using DESH with alpha 0.5 and gamma 0.4 is best model at predicting Madiun City LFPR. As for the DESH model obtained. it is:

$$\boldsymbol{S_t = 0.5X_t + 0.5(S_{t-1} + T_{t-1})}$$

$$\boldsymbol{T_t = 0.4(S_t - S_{t-1}) + 0.6T_{t-1}}$$

$$F_{t+m} = S_t + T_t \cdot m$$

The result forecast Madiun City LFPR using DESH model is 2024 of 68.76% and in 2025 of 69.21%. MSE value is 29.284, RMSE value is 5.411 and MAPE value is 5.273%.

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