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FORECASTING THE NUMBER OF PASSENGERS KRL JOGJA-SOLO USING THE METHOD GRAY (1,1), MOVING AVERAGE AND EXPONENTIAL SMOOTHING

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ABSTRACT
The development of the Jogja Solo railway transportation, one of which is the electrification of the railway line. This electrification will increase the capacity of the number of passengers because it can cut travel time so that there will be more and more trips. The government's plan to extend the electrification of the KRL line to Kulonprogo and Madiun is an opportunity for growth in the number of Jogja Solo KRL passengers. This study aims to find the best forecasting model for the number of KRL Jogja Solo passengers among short-term forecasting models. The forecasting method used is the Gray Method (1.1), Moving Average and Exponential Smoothing. Furthermore, based on the forecasting results of each method, the error rate will be sought based on the MAPE, MAD and MSD values. The error prediction value among the three selected methods, namely Gray (1,1), second-order moving average and single exponential smoothing, the results obtained from the single exponential smoothing method have the slightest error value compared to the others. So, this method is the best method chosen to predict the number of Jogja Solo KRL passengers. The single exponential smoothing method is the best forecasting method because it has the mirror value, namely MAPE of 51, MAD of 50,308 and MSD of 3,891,632,651. The prediction results for the 14th-period passengers obtained a result of 202,067 people. The prediction results for the 14th-period passengers obtained a result of 202,067 people.

Keywords: forecasting, krl yogyakarta solo, gray (1,1), moving average, exponential smoothing.

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INTRODUCTION

The population movement is motivated by an imbalance in individual needs that cannot be obtained in the area where they live (Kuciswara et al., 2021). Fulfilment of needs is inseparable from the existence of work sources to improve the quality of life so that areas with better job opportunities will become targets for population mobility (Fonna, 2019). The uneven distribution of resources results in disparities in a region's economic growth rate (Effendy & Djohan, 2022). In urban areas, mobility or commuting has become commonplace (Tang, 2016). Changes in population, residence, employment, economic growth and better transportation services have resulted in people becoming commuters (Wang & Hu, 2017). Commuters are people who routinely commute to a place of work that is outside their area of residence and return home the same day. Based on BPS data for August 2021, commuters in Indonesia totalled 7.34 million, an increase of 4.49% from 2020.

The Yogyakarta and Solo regions are agglomeration areas that the government continues to develop to improve the regional economy. On November 10 2021, the Governments of Yogyakarta and Solo agreed to cooperate in regional development in the fields of tourism, economy,

transportation, and culture. The development of transportation in the Jogja Solo area has been carried out through the electrification of the railway line according to the National Railway Master Plan (RIPNAS) (Darmaning Tyas et al., 2015). This electrification will increase the capacity of the number of passengers because it can cut travel time so that there will be more and more trips. The electrification of the Jogja-Solo train line also affected the termination of the operation of the Prambanan Ekspres (Prameks) commuter train, which had previously served 27 years of Jogja-Solo commuter travellers. The Prameks train was replaced by an Electric Rail Train (KRL), which officially operated on March 1, 2021. During its journey, the Jogja-Solo KRL serves 20 trips a day with a speed of 90 km/hour and a travel time of 68 minutes. During its one year of operation since March 1 2021, Jogja Solo KRL users have reached more than 2.2 million despite the Covid-19 pandemic. The government's plan to extend the electrification of the KRL line to Kulonprogo and Madiun is an opportunity to grow the number of Jogja Solo KRL passengers.

Based on the background above, the authors are interested in predicting the number of KRL Jogja Solo passengers using the grey (1,1), Moving average and exponential smoothing methods. This study aims to find the best forecasting model for the number of KRL Jogja Solo passengers among short-term forecasting models.

METHODS

The data used in this study is secondary data obtained from PT. KAI (Persero) is the number of Jogja Solo KRL passengers from February 2021 to February 2023. Data on Jogja Solo KRL passengers can be seen in the following table.

Table 1. Data on the Number of KRL Passengers
Joogja - Solo for the Period February 2021 to. February 2022

Period	Original Data
Feb-21	94536
Mar	195018
Apr	183935
May	185092
Jun	190412
Jul	46340
Aug	49510
Sept	106384
Oct	186060
Nov	220388
dec	298190
Jan	291684
Feb	220712

The processing method used in this study is a number series forecasting method that uses historical data as the basis for forecasting (Pujiati et al., 2017). Forecasting methods used in this study include:

1. Gray Method (1,1)

Ju-Long develops a forecasting model that focuses on conditions of uncertainty and insufficient information in analyzing and understanding systems through research on the conditional analysis, prediction and decision-making (Pratiwi & Achmad, 2019). This model is known as the Gray theory or GM (d,p), where d indicates the number of differentiations and p indicates the many research variables (Ahdika, 2018). This model is very suitable for forecasting with limited data. This study uses the Gray Model (1,1), which in general has three stages, namely AGO (Accumulated Generating Operation), IAGO and the Gray Model (Marwati, nd).

2. Moving Averages

The moving average is averaging a group of observational values whose average is sought to predict the next period (Siagian & Sugiarto, nd). The longer the timeframe, the more visible the smoothing effect on forecasting results using the moving average method (Hudaningsih et al., 2020). The moving average equation can be written as follows:

$$ft + 1 = \frac{Xt + Xt - 1 + Xt - 2 + \cdots + Xt - (n - 1)}{N}$$

Were

Ft = Forecasting value for the 1st, 2nd, 3rd period... etc

Xt = Actual value of the 1st, 2nd, 3rd period... etc

N = number of moving average periods

3. Exponential Smoothing

The exponential smoothing method is a data smoothing method by repeating calculations continuously using the latest data (Ginantra & Anandita, 2019). The data is weighted with a trial number until a small forecasting error value is obtained. This study uses weights based on optimal ARIMA. The exponential smoothing equation can be written as follows :

$$Ft = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$$

Were

Ft = forecasting value for the − t period

F_{t-1} = Forecast value of the past period

A = Smoothing constant/weight

A_{t-1} = Actual value of the t period

RESULTS AND DISCUSSION

1. Total Passenger Data

Since its inauguration, the number of KRL Jogja-Solo passengers for (February 2021 to February 2022) has fluctuated. The rise and fall of passengers are due to the ongoing Covid 19 pandemic. They have an impact on community social restrictions (Orinaldi, 2021). The sharp decline occurred in July-August 2021 due to the implementation of Java-Bali Community Activity Restrictions (PPKM). After August 2021, the number of KRL passengers will gradually increase each month due to concessions for travellers. Data on the number of KRL Jogja-Solo passengers for one year (February 2021-February 2022) can be seen in the following figure.

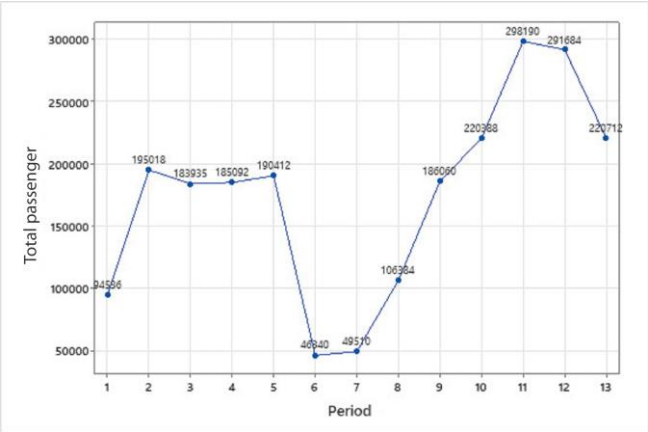

Figure 1. Number of Jogja Solo KRL Passengers from February 2021 to February 2022

The Jogja-Solo KRL passenger data for February 2021 to February 2022 will then be used to determine the best forecasting model.

2. Gray Method (1,1)

In conducting an analysis using the gray method (1,1), several steps must be followed to obtain the Rey (1,1) forecasting model, namely:

a. Determines the original (actual) data series, which is symbolized by $X^{(0)}(k)$

The original data line is data on the number of passengers from February 2021 to February 2022, as presented in the following table.

Table 2. Original $X^{(0)}(k)$ data series

Period	***1***	***2***	***3***	***4***	***5***	***6***
$X^{(0)}(k)$	94,536	195,018	183,935	185,092	190,412	46,340
Period	***7***	***8***	***9***	***10***	***11***	***12***
$X^{(0)}(k)$	49,510	106,384	186,060	220,388	298,190	291,684
Period	***13***					
$X^{(0)}(k)$	220,712					

b. Defines a data line $X^{(1)}(k)$ with 1-AGO

The data line $X^{(1)}(k)$ is obtained by adding up the value $X^{(0)}(k)$ with the previous period or denoted by $\sum_{i=1}^{k} X^{(0)}(i)$. The 1-AGO calculation is data smoothing, and its value increases. The results of 1-AGO calculations can be presented in the following table.

Table 3. Rows of data $X^{(1)}(k)$

Period	***1***	***2***	***3***	***4***	***5***	***6***
$X^{(1)}(k)$	94,536	289,554	473,489	658,581	848,993	895,333
Period	***7***	***8***	***9***	***10***	***11***	***12***
$X^{(1)}(k)$	944,843	1,051,227	1,237,287	1,457,675	1,755,865	2,047,549
Period	***13***					
$X^{(1)}(k)$	2,268,261					

c. Calculating MGO (Mean Generating Operations)$Z^{(1)}(k)$

The data line $Z^{(1)}(k)$ is obtained by calculating the average value of two $X^{(1)}$adjacent data. Calculation results can be presented in the following table.

Table 4. Data Rows$\mathbf{Z^{(1)}(k)}$

Period	***1***	***2***	***3***	***4***	***5***	***6***
$Z^{(1)}(k)$	-	192,045	381,522	566,035	753,787	872163
Period	***7***	***8***	***9***	***10***	***11***	***12***
$Z^{(1)}(k)$	920,088	998035	1,144,257	1,347,481	1,606,770	1,901,707
Period	***13***					
$Z^{(1)}(k)$	2,157,905					

d. Determine the parameters α and b

Parameters α and b are obtained from the equation $\left[\frac{a}{b}\right] = (B^T B)^{-1} B^T Y_N$ were where

$$B = \begin{bmatrix} -192.045 & 1 \\ -381.552 & 1 \\ \dots & \dots \\ -2.157.905 & 1 \end{bmatrix} \quad Y_N = \begin{bmatrix} 195.018 \\ 183.935 \\ \dots \\ 220.712 \end{bmatrix}$$

$$B^T = \begin{bmatrix} -192.045 & -381.552 & \dots & -2.157.905 \\ 1 & 1 & \dots & 1 \end{bmatrix}$$

$$B^T B^{-1} = \left(\begin{bmatrix} -192.045 & -381.552 & \dots & -2.157.905 \\ 1 & 1 & \dots & 1 \end{bmatrix} \begin{bmatrix} -192.045 & 1 \\ -381.552 & 1 \\ \dots & \dots \\ -2.157.905 & 1 \end{bmatrix} \right)^{-1}$$

$$B^T B^{-1} = \begin{bmatrix} 0 & 0 \\ 0 & 0{,}38 \end{bmatrix}$$

$$B^T Y = \begin{bmatrix} -192.045 & -381.552 & \dots & -2.157.905 \\ 1 & 1 & \dots & 1 \end{bmatrix} Y_N = \begin{bmatrix} 195.018 \\ 183.935 \\ \dots \\ 220.712 \end{bmatrix}$$

$$B^T Y = \begin{bmatrix} -2.568.035.454.412{,}5 & -2.568.035.454.412{,}5 \\ 2.173.725 & 2.173.725 \end{bmatrix}$$

$$\left[\frac{a}{b}\right] = \begin{bmatrix} -0{,}06 \\ 114.982{,}41 \end{bmatrix}$$

e. Calculates AGO predictions$\hat{x}^{(1)}(k+1)$

Values $\hat{x}^{(1)}(k+1)$ are obtained by entering the values of parameters a and b in the formula $\left(X^{(0)}(1) - \frac{b}{a}\right) e^{-ak} + \frac{b}{a}$. The following results are obtained.

Table 5. AGO Data Line$\hat{x}^{(1)}(k+1)$

Period	***1***	***2***	***3***	***4***	***5***	***6***
$\hat{x}^{(1)}(k+1)$	94,536	219,176	351,765	492,811	642,851	802,460
Period	***7***	***8***	***9***	***10***	***11***	***12***
$\hat{x}^{(1)}(k+1)$	972,249	1,152,866	1,345,002	1,549,391	1,766,815	1,998,106
Period	***13***					
$\hat{x}^{(1)}(k+1)$	2,244,147					

f. Calculating Gray's Prediction Result (1,1)

The prediction results of Gray (1,1) are obtained by the equation $\hat{x}^{(0)}(k)$and the results are:

Table 6. Gray's Prediction Results (1,1)

Period	***1***	***2***	***3***	***4***	***5***	***6***
$\hat{x}^{(0)}(k)$	124,640	132,589	141,045	150,040	159,609	169,788
Period	***7***	***8***	***9***	***10***	***11***	***12***
$\hat{x}^{(0)}(k)$	180,617	192,136	204,389	217,424	231,291	246,041
Period	***13***					
$\hat{x}^{(0)}(k)$	261,733					

The difference in the prediction results above, compared to the actual data, can be seen in the following figure.

Table 7. Comparison of Original Data with the Gray Method (1,1)

Period	Original Data	Gray (1,1)
1	94536	124640
2	195018	132589
3	183935	141045
4	185092	150040
5	190412	159609
6	46340	169788
7	49510	180617
8	106384	192136
9	186060	204389
10	220388	217424
11	298190	231291
12	291684	246041
13	220712	261733

Based on the prediction results using the gray method (1,1), a change in numbers tends to increase in each period, resulting in a smoother curve than the original data. The results of the model's accuracy analysis against the original data can be shown in the following table.

Table 8. Accuracy Value of the Gray Model (1.1)

Accuracy Value	Gray (1,1)
MAPE	62
MAD	55,111
MSD	4,399,133,058

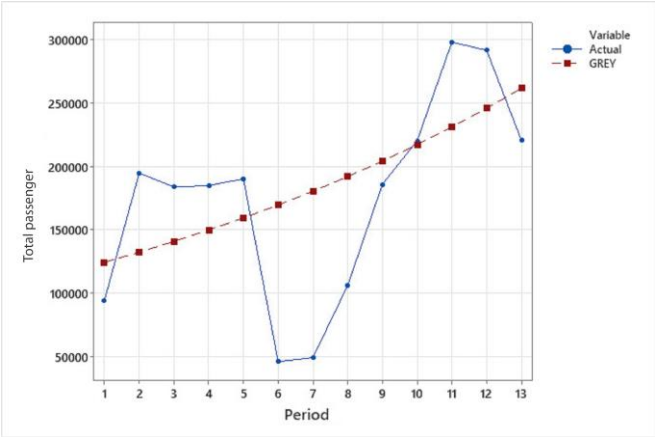

Figure 2. Comparison of Gray's Forecasting (1.1) with Actual Data

3. Moving Average Method

This study uses forecasting methods of moving averages of orders 2 and 3 to predict the number of KRL Jogja Solo passengers. The prediction results using the moving average method can be seen as follows.

Table 9. Comparison of Original Data with Moving Average Method

Period	Original Data	Moving Averages (n=2)	Moving Averages (n=3)
1	94536	-	-
2	195018	-	-
3	183935	144777	-
4	185092	189477	157830
5	190412	184514	188015
6	46340	187752	186480
7	49510	118376	140615
8	106384	47925	95421
9	186060	77947	67411
10	220388	146222	113985
11	298190	203224	170944
12	291684	259289	234879
13	220712	294937	270087

Table 10. Accuracy Value of the Moving Average Model

Accuracy Value	Moving Averages (n=2)	Moving Averages (n=3)
MAPE	63	71
MAD	63,822	73,035
MSD	5,682,822,147	7,606,377,523

Forecasting error values can be seen from the MAPE, MAD and MSD values. Based on the data above, the higher the order value used in the moving average method, the higher the error value will be. So, the second-order moving average method is preferred over the third-order moving average method.

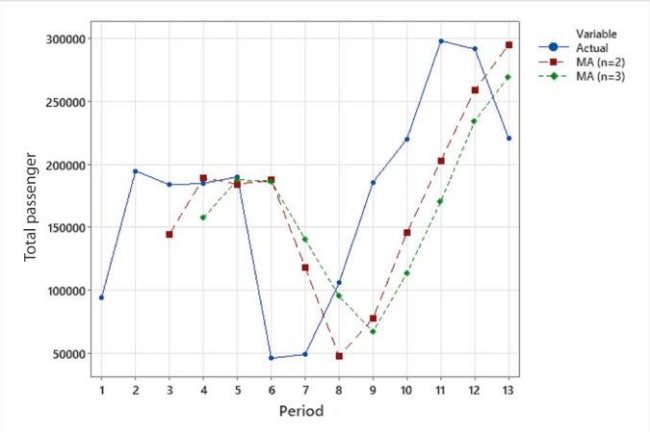

Figure 3. Comparison of Moving Average Forecasting with Actual Data

4. Exponential Smoothing Method

This study uses the forecasting method of single exponential and double exponential smoothing with smoothing measurements using optimal ARIMA (α) to predict the number of KRL Jogja Solo passengers (Susilawati & Sunendiari, 2022). The prediction results using the exponential smoothing method can be seen as follows.

Table 11. Forecasting with the Single Exponential Smoothing Method

Period	Original Data	Single Smoothing α = 1.29	Double Smoothing α = 1.29
1	94536	63914	248630
2	195018	103673	230857
3	183935	222274	260104
4	185092	172495	201532
5	190412	188851	217751
6	46340	190878	216055
7	49510	3212	6692
8	106384	63325	77709
9	186060	119232	134503
10	220388	206001	228088
11	298190	224681	244096
12	291684	320124	347483
13	220712	283198	301160

Table 12. Exponential Smoothing Model Accuracy Value

Accuracy Value	Single Exp Smoothing	Double Exp Smoothing
MAPE	51	64
MAD	50,308	61,501
MSD	3,891,632,651	6,041,280,143

The exponential smoothing forecast error value can be seen from the MAPE, MAD and MSD values. Based on the data above, the single exponential smoothing method produces a lower error value than the double exponential smoothing method.

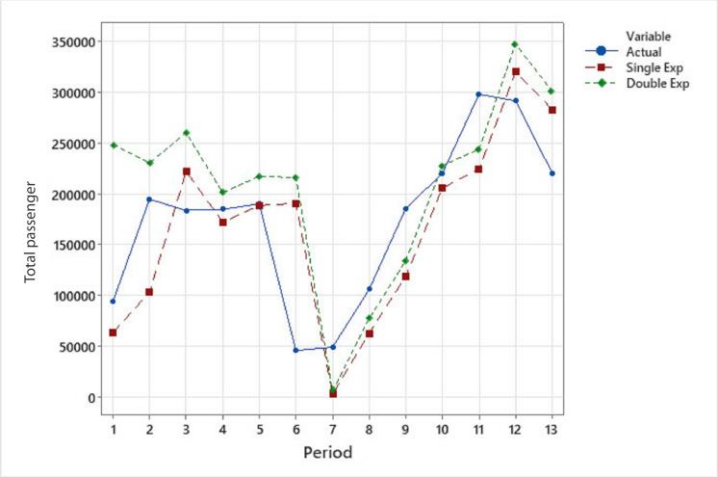

Figure 4. Comparison of Exponential Smoothing Forecasting with Actual Data

Based on the calculations that have been done and by looking at the error value of each forecasting method, it is obtained that the forecasting method is more conical in 3 methods, namely Gray (1, 1), second-order moving average and single exponential smoothing. Of the three methods, the MAPE, MAD and MSD values are compared again to obtain the most appropriate forecasting method to be used in forecasting in the next period. The results of comparing the predictions of the three selected forecasting methods can be seen in the following table.

Table 13. Comparison of Forecasting Methods

time	actual	Gray (1,1)	Moving Averages (n=2)	Single Exp Smooth α = 1.29
1	94536	124,640	-	63914
2	195018	132,589	-	103673
3	183935	141,045	144777	222274
4	185092	150,040	189477	172495
5	190412	159,609	184514	188851
6	46340	169,788	187752	190878
7	49510	180,617	118376	3212
8	106384	192,136	47925	63325

time	actual	Gray (1,1)	Moving Averages (n=2)	Single Exp Smooth α = 1.29
9	186060	204,389	77947	119232
10	220388	217,424	146222	206001
11	298190	231,291	203224	224681
12	291684	246,041	259289	320124
13	220712	261,733	294937	283198

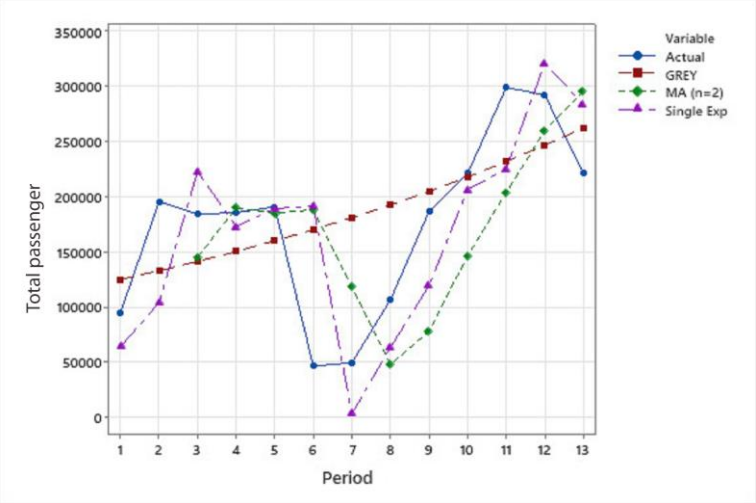

Figure 5. Comparison of Forecasting Methods

The error prediction value among the three selected methods, namely Gray (1.1), second-order moving average and single exponential smoothing, was obtained from the results of the single exponential smoothing method, which has a mirror value compared to the others. So, this method is the best method chosen to predict the number of Jogja Solo KRL passengers in the next period.

Table 14. Model Accuracy Value

Accuracy Value	Gray (1,1)	Moving Averages (n=2)	Single Exp Smooth α = 1.29
MAPE	62	63	**51**
MAD	55,111	63,822	**50,308**
MSD	4,399,133,058	5,682,822,147	**3,891,632,651**

Forecasting the next period in the single exponential smoothing method is calculated using data on the number of passengers in the previous period with α = 1.29 so that the equation can be written as follows:

$$Ft = F_{t-1} + \alpha\,(A_{t-1} - F_{t-1})$$

To calculate the number of passengers, period 14 can be calculated as follows.

$$F_{14} = F_{14-1} + 1{,}29\,(A_{14-1} - F_{14-1})$$

$$F_{14} = F_{13} + 1{,}29\,(A_{13} - F_{13})$$

$$F_{14} = 283198 + 1{,}29\,(220712 - 283198)$$

$F_{14} = 202067$

So that the prediction of the number of passengers in the 14th period is 202,067 people.

CONCLUSION

Based on a comparison of the forecasting methods that have been carried out, the single exponential smoothing method is the best because it has the mirror value, namely MAPE of 51, MAD of 50,308 and MSD of 3,891,632,651. The prediction of period 14 passengers obtained results of 202,067 people.

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