Passenger volume forecasting information system for PT. KAI Daop 2 Bandung using double exponential smoothing method

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Abstract. Daop 2 Bandung is one of the Indonesian railroad operations areas, under the administration of PT Kereta Api Indonesia (Persero). Daop 2 Bandung is currently experiencing a problem in predicting the number of passenger volumes. It is common for railway transportation services to experience passengers flows that increases or decreases in the volume which in turn causes the service of the PT. KAI becomes less optimum. Therefore, a forecasting information system is needed to forecast the volume of train passengers in the upcoming period. This study applied Double Exponential Smoothing method as a forecasting method. The data used is the number of passenger volume data for two periods, i.e. 2017 and 2018 periods. For forecasting accuracy, PE (Percentage Error) and MAPE (Mean Absolute Percentage Error) were used. The passenger volume forecasting results on the Executive Class category shows 946,824 with an error percentage of 11.9962%, the Business Class category shows 221,188 results with an error percentage of 21.6714%, and the Economy Class category shows 5,144,074 with an error percentage of 10.4366%.

1. Introduction
Daop 2 Bandung is one of Indonesia's railroad operations areas, under PT. Kereta Api Indonesia (Persero). Daop 2 Bandung is currently experiencing a problem in predicting the number of passenger volumes. Passenger volume is a condition when passenger capacity exceeds previous capacity. Sometimes rail transportation services experience flows in passenger volume that increasing or decreasing which in turn results in less optimal service. The data obtained during the observations at PT. Bandung Daop 2 KAI are in the form of passenger volume data with the following categories, Executive Class, Business Class, and Economy Class. The railroad category data have a different data structure that has an increasing trend.

Based on the above reason, a forecasting system is needed to forecast the passenger volume in the upcoming period. This in turn is hope to assist in planning the services offered by PT. KAI Daop 2 Bandung. This study uses the Double Exponential Smoothing method, in which the method is classified as the team series method (sequential). The Double Exponential Smoothing method is applied twice for the smoothing process and forecasting data that has an upward trend. To measure the accuracy of forecasting, MAPE (Mean Absolute Percentage Error) calculation is used. It is also used as a search for Alfa (α) forecasting. The Data used in the forecasting process are the data from 2017-2018 periods.
2. Theoretical analysis

2.1. Passenger volume
Volume, also known as capacity, is the calculation to find out the space required to be occupied in an object. The object can be a regular object or an irregular object. Volume is an indication of the extent of usage capacity [1]. Passengers, on the other hand, is "Every person who needs to be transported using transportation services such as an airplane, train, or any other means of transportation, on the basis of the company or organization agreement that manages the means of transportation [2]. Therefore, passenger volume is the space or place required for each person to occupy in the mass transportation services provided by the particular service, which experience either an increase or a decrease to result in exceeding passenger capacity, and is influenced by the transportation service user satisfaction.

2.2. Double exponential smoothing
Double exponential Smoothing method is one of the in-depth exponential smoothing methods. Exponential Smoothing method is a continuous improvement procedure for forecasting the latest observation objects. This method focuses on decreasing the priority exponentially on prior preceding observation objects [3]. In applying the Exponential Smoothing method, there are data patterns that are required in order to determine the Exponential Smoothing method that is suitable for data patterns needed in the Double Exponential Smoothing method using data pattern trend in which the data keeps increasing from each period of time [4].

The stages of the calculation method are as follows.

- To determine the first smoothing:
  \[ S' t = \alpha X_t + (1 - \alpha) S' t - 1 \]  

- To calculate the second smoothing:
  \[ S'' t = \alpha S' t + (1 - \alpha) S'' t - 1 \]  

- To determines the \( \alpha \) constant value
  \[ \alpha_t = S' t + (S' t - S'' t) \]  

- To determines the slope value / trend \( b_t \)
  \[ b_t = \frac{\alpha}{1 - \alpha} (S' t - S'' t) \]  

- To determine the forecasting value
  \[ F_{t+m} = \alpha_t + b_t m \]  

Note:
- \( S' t \) = forecasting value for t period
- \( S'' t \) = Double Exponential Smoothing t period value
- \( \alpha \) = exponential weighting constant
- \( \alpha_t \) = constant value
- \( X_t \) = t period actual value
- \( F_{t+m} \) = forecasting value
- \( m \) = forecasted upcoming period

2.3. Forecast error measurement
Many error calculation methods are available to find out forecasting accuracy, such as MAPE (Mean Absolute Percent Error), to obtain the error percentage.

2.3.1. MAPE: Mean Absolute Percent Error (MAPE). MAPE is the average absolute process between the predicted value and the actual value. It is used to evaluate forecasting accuracy using percentage errors. The following is MAPE calculation formula stages:
• PE Calculation (Percentage Error)

\[ PE = \left( \frac{X_t - F_t}{X_t} \right) \times 100 \]  

(6)

• MAPE Calculation

\[ MAPE = \frac{\sum_{t=1}^{n} PE_t}{n} \]  

(7)

MAPE value interpretation are as follows:
- <10% = very accurate forecasting.
- 10% -20% = accurate forecasting.
- 20% -50% = fairly accurate forecasting.
- > 50% = inaccurate forecasting.

3. Algorithm analysis

3.1. System work analysis
Block diagram describes the interactions between the user and the system which includes the data input required, a set of process, and also the data output generated from the interactions. The data were retrieved from passenger volume from 2017-2018 periods.

Data input are in the form of train class options used and period (year). System output data is the prediction which is based on input data that has been processed using the forecasting method.

![Figure 1. Block diagram.](image)

3.2. The scope of the research
This research was developed an application to calculate passenger volume forecasting trend at PT. KAI Daop 2 Bandung. The focus of this study is to predict passenger volume in the following periods using exponential smoothing and the data used are from 2017 period to 2018 period. Figure 1 shows that the forecasting technique used in this study is double exponential smoothing. PE and MAPE methods are used to calculate error accuracy.

3.3. Dataset
Passenger volume data were retrieved from 2017 period to 2018 period at PT. KAI Daop 2 Bandung. The data on passenger volume are shown in table 1 below.
### Table 1. Passenger volume data.

| Month | 2017/2018 |          |          |
|-------|-----------|----------|----------|
|       | Executive Class | Business Class | Economy Class |
| Jan-17| 770526     | 573890   | 5441405   |
| Feb-17| 625956     | 268786   | 4708718   |
| Mar-17| 729011     | 305164   | 5344856   |
| Apr-17| 809453     | 346084   | 4932212   |
| May-17| 820510     | 351938   | 5207331   |
| Jun-17| 786731     | 334120   | 5127228   |
| Jul-17| 978670     | 435623   | 5913592   |
| Aug-17| 844903     | 337436   | 4905755   |
| Sep-17| 871157     | 360784   | 5128493   |
| Oct-17| 847306     | 323338   | 5141363   |
| Nov-17| 811395     | 300899   | 4976950   |
| Dec-17| 971181     | 429208   | 6340726   |
| Jan-18| 806051     | 363005   | 497227    |
| Feb-18| 752873     | 303227   | 4859475   |
| Mar-18| 873965     | 309208   | 5468888   |
| Apr-18| 908167     | 309079   | 5594764   |
| May-18| 862440     | 262802   | 5361827   |
| Jun-18| 1132510    | 409016   | 6655129   |
| Jul-18| 1120642    | 395891   | 6197117   |
| Aug-18| 1080212    | 338010   | 5674046   |
| Sep-18| 1040335    | 282054   | 5563542   |
| Oct-18| 1055891    | 264383   | 5599297   |
| Nov-18| 545635     | 132537   | 2733045   |

Based on the data, it can be seen that passenger volume data at PT. KAI Daop 2 Bandung shows an increasing trend and decreasing trend. The following graph shows both trends from 2017/2018 periods.

![Passenger volume from 2017/2018 period.](image)

**Figure 2.** Passenger volume from 2017/2018 period.

### 4. Results and discussions

#### 4.1. Optimal values evaluation

Double Exponential Smoothing method is used to show trends. Exponential smoothing with the presence of trends such as smoothing on the constants used. Trend is smoothed estimation of the average growth at the end of each period. A smoothing constant parameter ($\alpha$) must be evaluated in this method.

The $\alpha$ value will be tested from $\alpha \; 0.1$ to $\alpha \; 0.9$ weight values. The forecasting calculation is done repetitively to obtain the smallest MAPE value.
4.2. Error prediction
The Double Exponential Smoothing method accuracy depends on the selection of smoothing constant values used. In this forecasting, the α value that are tested starts from α = 0.1 to α = 0.9. The forecasting calculations are executed repetitively to obtain the smallest MAPE value.

In applying MAPE, first PE (Percentage Error) calculations are needed to be done. PE is the stage required to obtain the total PE value, the total PE value that are used to calculate the MAPE value. The total PE calculation is shown in Table 2.

Table 2. PE value (percentage error).

| ALPHA | EXECUTIVE CLASS | BUSINESS CLASS | ECONOMY CLASS |
|-------|-----------------|----------------|---------------|
| 0.1   | 275,9128%       | 584,1228%      | 240,0427%     |
| 0.2   | 280,7436%       | 498,4423%      | 256,5641%     |
| 0.3   | 305,0762%       | 520,8305%      | 269,3060%     |
| 0.4   | 319,0933%       | 529,8149%      | 283,2140%     |
| 0.5   | 324,4711%       | 530,8067%      | 298,2749%     |
| 0.6   | 331,4166%       | 553,9764%      | 321,0236%     |
| 0.7   | 347,3337%       | 598,7678%      | 344,8462%     |
| 0.8   | 366,1203%       | 636,5230%      | 371,5887%     |
| 0.9   | 397,6077%       | 681,0404%      | 401,1319%     |

PE and MAPE total values can be calculated using different smoothing constants; from the MAPE value, the smallest value will be used as a parameter of the forecasting constant. The results of the MAPE calculation are shown in table 3 below.

Table 3. MAPE results.

| ALPHA | EXECUTIVE CLASS | BUSINESS CLASS | ECONOMY CLASS |
|-------|-----------------|----------------|---------------|
| 0.1   | 11.9962%        | 25.3966%       | 10.4366%      |
| 0.2   | 12.2062%        | **21.6714%**   | 11.1550%      |
| 0.3   | 13.2642%        | 22.6448%       | 11.7090%      |
| 0.4   | 13.8736%        | 23.0354%       | 12.3137%      |
| 0.5   | 14.1074%        | 23.0786%       | 12.9685%      |
| 0.6   | 14.4094%        | 24.0859%       | 13.9575%      |
| 0.7   | 15.1015%        | 26.0334%       | 14.9933%      |
| 0.8   | 15.9183%        | 27.6749%       | 16.1560%      |
| 0.9   | 17.2873%        | 29.6105%       | 17.4405%      |

Table 2 shows that passenger volume forecasting results for the Executive Class category are 946824 using α = 0.1 with MAPE = 11.9962%, the Business Class on the other hand, shows the results of 221188, α = 0.2, MAPE = 21.6714%, and the Economy Class obtained 5144074, α = 0.1, and MAPE = 10.4366%.

The values in the MAPE range can be described as follows. The MAPE range for <10% = forecasting is very accurate, MAPE 10% - 20% = accurate forecasting, MAPE 20% - 50% = forecasting is quite accurate, MAPE> 50% = forecasting is not accurate. The following diagram shows a more detailed information.
Figure 3. MAPE percentage error testing for KAI 2017/2018 period.

Therefore, the forecasting value for each category is as follows. The Executive Class shows a forecast value of 946824 by using $\alpha = 0.1$ and obtains MAPE value of 11.9962% which shows accurate forecasting, while the Business Class shows a forecasting value of 221188 using $\alpha = 0.2$ and obtains a MAPE value of 21.6714% which shows a quite accurate forecasting. Finally, the Economy Class shows a forecast value of 5144074 using $\alpha = 0.1$ and obtains a MAPE value of 10.4366% which addresses details forecasting results accurate forecasting value. Table 3 below shows a more detailed forecasting results.

Table 4. Forecasting results.

| ALPHA | EXECUTIVE CLASS | BUSINESS CLASS | ECONOMY CLASS |
|-------|-----------------|----------------|---------------|
| 0.1   | 946824          | 248053         | 5144074       |
| 0.2   | 893420          | 221188         | 4598608       |
| 0.3   | 787445          | 182777         | 3924289       |
| 0.4   | 668147          | 143706         | 3265137       |
| 0.5   | 551362          | 110412         | 2655782       |
| 0.6   | 442300          | 83687          | 2089586       |
| 0.7   | 339651          | 61879          | 1545022       |
| 0.8   | 239672          | 42288          | 1000084       |
| 0.9   | 138905          | 22400          | 441284        |

5. Conclusion

- After testing the calculations with the Double Exponential Smoothing method can be used as information for planning services that will be held by the Operations Manager and Facility Manager.
- The results of forecasting passenger volume in the category of Executive, Business, Economy trains calculated from January 2017 to November 2018, get forecast results of
  - Alpha Executive 0.1, 946824, MAPE 11.9962%, which shows accurate forecasting.
  - Alpha Business 0.2, 221188, MAPE 21.6714%, quite accurate.
  - Alpha Economy 0.1, 5144074, MAPE 10.4366% accurate.

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