

VEHICLE VOLUME FORECASTING SYSTEM ON TOLL ROADS USING DOUBLE MOVING AVERAGE AND DOUBLE EXPONENTIAL SMOOTHING METHODS (CASE STUDY AT JASAMARGA PANDAAN TOLL ROAD)

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ABSTRACT

Forecasting has become one of the considerations, especially in business and economics. This is done so that company losses can be minimized and company profits can be maximized. Therefore, a system is needed to make it easier to get accurate forecasting results. However, in real cases, the procurement of IT consultants is quite expensive. So that research provides a solution to design a vehicle volume forecasting system on a website-based toll road conducted at PT Jasamarga Pandaan Tol. This system is expected to facilitate the Traffic Collection team in projecting the future volume of vehicles on the toll road. The double Moving Average and Double Exponential Smoothing methods are used in forecasting the volume of vehicles. The Double Moving Average method is one of the time series methods whose results are influenced by the order or time. The Exponential Smoothing method is one of the time series methods whose results are influenced by the alpha parameter. The results of these two methods will be compared based on the data's accuracy so that users can see the results of forecasting future vehicle volumes. Mean Absolute Percentage Error (MAPE) is the average percentage error in multiple (absolute). Understanding Mean Absolute Percentage Error is a statistical measurement of the accuracy of estimates (predictions) in forecasting methods. The accuracy results from the application of the Double Moving Average method provide an average MAPE value of 30.124%, and the Double Exponential Smoothing method provides an average MAPE value of 5.368%.

Keywords: *Double Exponential Smoothing, Double Moving Average, Forecasting, Toll Road, Forecasting.*

1. INTRODUCTION

East Java is a province that is quite dense. Based on data from detik.com (06/12/20) East Java has a population of 40,963,227 people, the second largest population after West Java. This affects the density of traffic flow [1]. This density is caused by the growth rate of road facilities not proportional to the increase in the number of vehicles which leads to congestion.

Congestion like this must be addressed immediately using an appropriate system to facilitate community activities and support smooth mobility with other areas. Research with long field studies involving road variables is relatively inefficient because it relies on human observations with limitations in observation and calculation studies [1].

Procurement of IT consultants is one of the solutions to company system problems that can be resolved through identifying technical issues, initiation, analysis, and implementation. However, the procurement of IT consultants requires a relatively expensive cost. Therefore, the vehicle volume experience system is expected to provide convenience to the Traffic Collection in determining the projected volume of vehicles passing through the Gempol - Pandaan section. The results of the projected vehicle volume obtained will help Finance determine the company's revenue in the coming month.

This study's appropriate method for forecasting road density is forecasting [2]. Forecasting is usually based on historical data that is analysed with certain methods. By using time series data for prediction that has trend and seasonal properties [3], the Double Exponential Smoothing method and the Double Moving Average method are used in this study. The comparison will be seen from the Mean Absolute Percentage Error (MAPE) value and the forecasting results of the number of vehicle volumes.

2. LITERATURE REVIEW

In a study entitled "Comparison of Exponential Smoothing and Moving Average Methods in Forecasting Motor Vehicle Testing Levies at the Blitar City Transportation Office" in 2022, the research compares 2 methods on the same data, the data is analysed using exponential smoothing and moving average methods and calculates errors in forecasting using MAD, MSE and MAPE, and draws conclusions. In this study, it was found that the appropriate method for forecasting the amount of motor vehicle testing fees of the Blitar City Transportation Office is the single exponential smoothing method $\alpha = 0.3$ with forecasting the amount of motor vehicle testing fees in September 2020 of Rp. 49,995,278. [4].

In 2022 research entitled "Application of the Stock Availability Forecasting System at Abadi

Jaya Furniture Store Using the Single Moving Average and Exponential Smoothing Methods" the method used in this study is based on the error rate using MAD, MSE, and MAPE accuracy with the results of the Moving Average method used because it has a low error rate when compared to using the Exponential Smoothing method. The comparison process gets the smallest results using the exponential smoothing method alpha 0.5 with the result that is 17.06% (good category) [5].

2.1. Forecasting

Forecasting is the art and science of predicting future events. This forecasting requires taking historical data and forecasting into the future. Forecasts made are usually based on past data analysed using certain methods [18]. With this forecasting, it can be seen how much the growth in vehicle volume will cross the toll road in the future.

2.2. Vehicle Group

Taken from the Decree of the Minister of Public Works Number 370/KPTS/M/2007, it is explained that the vehicle Group is divided into 6 groups [6]. The list of vehicle type groups includes:

1. Group 1, namely Jeeps, Pick Ups, Sedans, Small Trucks, and Buses
2. Group 2 is Truck with two (2)
3. Group 3 is Truck with three (3)
4. Group 4 i.e. Truck with four (4)
5. Group 5 i.e. Truck with five (5)
6. Group 6, namely two-wheeled vehicles (2)

2.3. Website

A website is a collection of pages used to provide text, animation, sound, images or a combination thereof, both static and dynamic, forming a coherent whole. [20]. In this era, websites are not only limited to exchanging information but also have very broad benefits. Currently, the website has become an important communication tool, because we can connect with each other without any time and space limitations.

2.4. MySQL Database

A database is a collection of data files that are interconnected and organized in such a way that the data can be accessed quickly, easily, and processed into useful information [14]. MySQL is a Database Management System (DBMS) that uses Structured Query Language (SQL) commands and is widely used to build applications and websites.

2.5. Double Moving Average Method

A double moving average is a moving average that takes data from a single moving average over a period of time and can make adjustments to the simple moving average and double moving average and make changes to the trend value.

The equation in the Double Moving Average method:

7. Calculating the single moving average

$$S'_t = \frac{X_t + X_{t-1} + X_{t-2} + \dots + X_{t-k-1}}{k} \quad (1)$$

8. Calculating *Double Moving Average*

$$S''_t = \frac{S'_t + S'_{t-1} + S'_{t-2} + \dots + S'_{t-k-1}}{k} \quad (2)$$

3. Calculating the constant value

$$a_t = 2S'_t - S''_t \quad (3)$$

4. Calculating the trend coefficient

$$b_t = \frac{2}{k-1}(S'_t - S''_t) \quad (4)$$

5. Determining the size of the forecasting value

$$f_{t+p} = a_t + b_t m \quad (5)$$

Note:

S'_t = single moving average

S''_t = *Double Moving Average*

a_t = constant

b_t = trend coefficient

f_{t+p} = forecasting

k = time order

2.6. Double Exponential Smoothing Method

Exponential smoothing is a time series method that uses the weight of historical data to make predictions. The weight varies according to previous information. The parameter used in this method is the α parameter whose value is between 0 and 1.

Equation in Double Exponential Smoothing method:

1. Calculating single exponential smoothing

$$S'_t = \alpha X_t + (1-\alpha)S'_{t-1} \quad (6)$$

2. Calculating *Double Exponential Smoothing*

$$S''_t = \alpha S'_t + (1-\alpha)S''_{t-1} \quad (7)$$

3. Calculating Constant Value

$$a_t = S'_t + (S'_t - S''_t) = 2S'_t - S''_t \quad (8)$$

4. Calculating trend coefficient

$$b_t = \frac{\alpha}{1-\alpha}(S'_t - S''_t) \quad (9)$$

5. Determining the size of the forecasting value

$$f_{t+p} = a_t + b_t p \quad (10)$$

Note:

S'_t = single exponential smoothing

S''_t = *Double Exponential Smoothing*

X_t = demand data in a period

a_t = constant

b_t = trend coefficient

f_{t+p} = forecasting

α = alpha parameter

2.7. Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) is a method used to calculate the accuracy of a forecast or prediction. MAPE provides information about the degree of forecast error compared to the actual value of the series. The smaller the MAPE

percentage error, the more accurate the prediction results.

The MAPE value can be found using the formula in the equation below:

$$MAPE = \frac{\sum_{t=1}^n \frac{|X_t - Y_t|}{X_t}}{n} \times 100\% \quad (11)$$

Note :

- X_t = Actual Value
- Y_t = Prediction Result
- N = Number of data tested

2.8. Framework Laravel

Laravel is a PHP framework released under the MIT license with source code provided by Github, like other frameworks, Laravel is built using the concept of MVC (Model, View, and Controller), Laravel also comes with a command line tool called "Artisan", with which packages and install packages from the command prompt [16].

3. RESEARCH METHODOLOGY

3.1. System Block Diagram

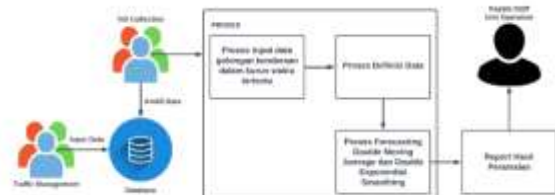


Figure 1. System Block Diagram

From the block diagram in Figure 1, the Traffic Management team will input data into a database that stores all vehicle data. the Toll Collection team will retrieve the data then perform the projection process on the existing data. The process starts when the Toll Collection team will input vehicle data based on vehicle classes within a certain period of time. Then the data that has been inputted will be defined and processed again using the Double Exponential Smoothing method and the Double Moving Average method as a form of forecasting.

3.2. Menu Structure



Figure 2. Menu Structure

In Figure 2, it is illustrated that this website has 4 main menus, namely the home menu which contains brief information about the website, vehicle volume data which has a CRUD feature in it, forecasting data to see the results of processing vehicle volume data with predetermined methods, and a report menu to provide a good report.

3.3. Flowchart System

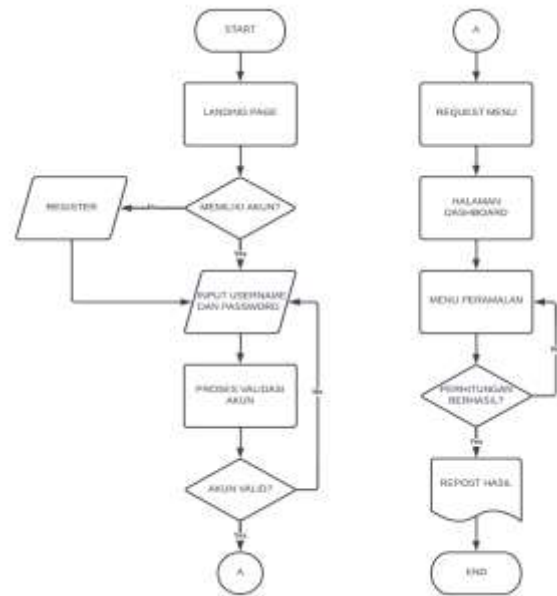


Figure 3. Flowchart System

Figure 3 is a diagram to access the existing menu, the user is asked to enter a username and password. If it is not appropriate, then the user will be returned to the login view and if it is correct then the user is directed to the dashboard page.

3.4. Flowchart of Moving Average Method



Figure 4. Flowchart of Double Moving Average

Figure 4 is the calculation of the value of the forecasting results and starts when the user inputs the data used as training data. In the forecasting process using the Double Moving Average method, the user is asked to input the order value which will be used as the value in calculating the average value.

3.5. Flowchart of Exponential Smoothing Method



Figure 5. Flowchart of *Double Exponential Smoothing*

Figure 5 shows the completion of predicting the forecast value using the Double Exponential Smoothing method, starting from user input to the data used as training data. In the calculation process using the Double Exponential Smoothing method, the user is asked to enter the parameter value α .

4. RESULTS AND DISCUSSION

4.1. Interface Implementation

The interface implementation uses the Laravel framework that applies the MVC concept. The interface implementation has a Landing Page, Login, Dashboard, Vehicle Volume Data, and Forecasting.

4.2. Dashboard Page



Gambar 6. Desain Tampilan Dashboard

Figure 6 shows the display for the Dashboard page. The dashboard displays the name of the user who is logged in and there is a display of the

vehicle volume menu, forecasting menu, and data report menu that can be accessed by the user.

4.3. Landing Page

Figure 7 shows the display for the landing page. The landing Page is the first display that appears when a user visits the website.



Figure 7. Landing Page Design

4.4. Login Page

Figure 8 shows the display on the Login page. Users are asked to enter their email and password correctly in order to enter the dashboard page.



Figure 8. Login Design

4.5. Vehicle group page

Figure 9 shows the display for the vehicle group page. On this page serves to display all the data that has been created.



Figure 9. Vehicle Group Page Design

4.6. Forecasting Page

Figure 10 shows the display for the Forecasting page. This serves to display all forecast variables.



Figure 10. Forecasting Design

4.7. Calculation of Double Moving Average

In the calculation of the Double Moving Average Method, the author takes data from January 2016 to September 2022 at PT Jasamarga Pandaan Tol. The data taken is the volume data of all classes of vehicles from 2016 to 2022.

Table 1. Vehicle Volume

	Gr.1	Gr.2	Gr.3	Gr.4	Gr.5
Jan 2016	451493	13050	1899	525	221
Feb 2016	419554	14268	2128	534	269
...
Aug 2022	1442704	114455	49931	16385	10685
Sep 2022	1384271	109407	37762	11279	7464

Table 2 is the calculation of the volume of class 1 vehicles whose data are taken from Table 1, with column S' as the first forecasting column calculated by equation 6, S'' is the second forecasting column calculated by equation 7, it is the constant column calculated by equation 8, bt is the trend coefficient column calculated by equation 9, and ft + p which is the prediction result column calculated by equation 10.

Table 2. Calculation of Moving Average Method

Gr I	Actual	S'	S''	at	bt	ft+p
Jan 2016	451493					
Feb 2016	419554					
Mar 2016	429102					
Apr 2016	419846	433383				
May 2016	493527	422834				
Jun 2016	389432	447492				
Jul 2016	570838	434268	434570	433966	-302	433664
Aug 2016	444455	484599	434865	534333	49734	584067
...
Sep 2022	1384271	1579365	1658384	1500346	-79019	1421327

4.8. Calculation of Double Exponential Smoothing

In the calculation of the Double Exponential Smoothing Method, the author took data from January 2016 to September 2022 at PT Jasamarga Pandaan Tol. The data taken is volume data on all classes of vehicles from 2016 to 2022.

Table 3 is the calculation of the volume of class I vehicles whose data are taken from table 1, with column S' is the first forecasting column calculated by equation 1, S'' is the second forecasting column calculated by equation 2, at is the constant column calculated by equation 3, bt is the trend coefficient column calculated by equation 4, and ft + p which is the prediction result column calculated by equation 5.

Table 3. Calculation of Metode Exponential Smoothing

Gr I	Actual	S'	S''	at	bt	ft+p
Jan 2016	451493	451493	451493	451493	0	451493
Feb 2016	419554	433927	441832	426022	-9662	416360
Mar 2016	429102	431273	436025	426521	-5808	420713
Apr 2016	419846	424988	429955	420021	-6071	413950
May 2016	493527	462684	447956	477412	18001	495413
Jun 2016	389432	422395	433897	410893	-14058	396835
Jul 2016	570838	504039	472475	535603	38578	574181
Aug 2016	444455	471268	471811	470725	-664	470061
Sep 2016	468815	469919	470770	469068	-1040	468028
...
Sep 2022	1384271	1463109	1524993	1401225	-75636	1325589

4.9. MAPE Moving Average Testing

Table 4 displays the vehicle volume accuracy test on all classes of vehicles, it is found that the MAPE value for Group I is 26.99%, the MAPE value for Group II is 20.586%, the MAPE value for Group III is 33.131%, the MAPE value for Group IV is 38.969%, the MAPE value for Group V is 30.943%.

Table 4. Calculation of MAPE Moving Average

	MAPE	Forecasting Results
Gr I	26.99 %	1421327
Gr II	20.586 %	126167
Gr III	33.131 %	47978
Gr IV	38.969 %	14783
Gr V	30.943 %	8693

4.10. MAPE Exponential Smoothing Testing

Table 5 shows the accuracy test of vehicle volume in all classes of vehicles obtained that the MAPE value for Group I is 4.673%, the MAPE value for Group II is 3.794%, the MAPE value for Group III is 5.959%, the MAPE value for Group IV is 6.652%, the MAPE value for Group V is 5.76%.

Table 5. Calculation of MAPE Exponential Smoothing

	MAPE	Forecasting Results
Gr I	4.673 %	1325589
Gr II	3.794 %	113741
Gr III	5.959 %	42917

	MAPE	Forecasting Results
Gr IV	6.652 %	13065
Gr V	5.76 %	8283

4.11. Comparison of MAPE Values

Table 6 displays the forecasting results and MAPE values of the two methods and from this table it can be concluded that the Exponential Smoothing method is a better method in providing forecasting results in the coming month producing an average MAPE value of 5.368% compared to the Double Moving Average method producing an average MAPE value of 30.124%.

Table 6. Comparison of Method Calculation

	Moving Average		Exponential Smoothing	
	MAPE	Results	MAPE	Results
Gr I	26.99 %	1421327	4.673 %	1325589
Gr II	20.586 %	126167	3.794 %	113741
Gr III	33.131 %	47978	5.959 %	42917
Gr IV	38.969 %	14783	6.652 %	13065
Gr V	30.943 %	8693	5.76 %	8283
Avarege	30.124%	-	5.368%	-

4.12. System Testing Using Black Box

This is done to test the features of the Toll Road Vehicle Volume Forecasting System. The results of system functional testing are shown in Table 7

Table 7. Black Box Testing

Testing Scenario	Testing Cases	Expectation	testing Results	Conclusion
Login Page	Email, password matches validation and succeed	Log in to the Dashboard page	As Expected	Valid
Login Page	Email, password does not match validation and fails	A message box appears with an incorrect email or password	As Expected	Valid
Dashboard Page	User who have logged in successfully	Show the Username dan Email user	As Expected	Valid
Dashboard Page	Total of Vehicle Groups	Show the totla of vehicle groups	As Expected	Valid
Vehicle Group Page	Button Add Vehicle Group Data	Enter the add data page with the form ready for input	As Expected	Valid
Vehicle Group Page	Button Edit Vehicle Group Data	Enter the data edit page with a form that contains the previous data and is ready to be replaced	As Expected	Valid
Vehicle Group Page	Button Delete Vehicle Group Data	Vehicle group data is deleted from the table	As Expected	Valid
Vehicle Group Page	Button Print Vehicle Group Data	Redirected to print-ready PDF page	As Expected	Valid
Comparison Page Method	Comparison of Sidebar Method	Redirected to the comparison page of the two methods with graphs	As Expected	Valid
Logout	User Logs out	User is returned to the Landing Page	As Expected	Valid

5. CONCLUSIONS AND SUGGESTIONS

The accuracy testing with MAPE on the Double Moving Average method shows that the MAPE value for Group I is 26.99%, the MAPE value for Group II is 20.586%, the MAPE value for Group III is 33.131%, the MAPE value for Group IV is

38.969%, the MAPE value for Group V is 30.943%. Based on the results of accuracy testing with MAPE on the Double Exponential Smoothing method shows that the MAPE value for Group I is 4.673%, the MAPE value for Group II is 3.794%, the MAPE value for Group III is 5.959%, the MAPE value for

Group IV is 6.652%, the MAPE value for Group V is 5.76%. Based on the accuracy testing results with MAPE, the Double Exponential Smoothing method has better forecasting calculations with an average MAPE value of 5.368% compared to the Double Moving Average method with an average MAPE value of 30.124%. Based on the research that has been done, there are several suggestions for the Vehicle Volume Forecasting System on Toll Road. It is hoped that further research can do forecasting using other Forecasting methods, including Autoregressive Integrated Moving Average (ARIMA), Weighted Moving Averages, Linear Regression, and other methods. It is hoped that further research can be made and developed on a mobile basis. It is hoped that further research can provide data import features to make it easier for users to input data. It is hoped that further research can integrate counting vehicle volumes based on groups in units of periods.

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