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(RESEARCH ARTICLE)

Traffic crashes prediction of states in Nigeria using time series analysis

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Abstract

Death and injuries associated with traffic crashes is now acknowledged to be a general phenomenon in Nigeria. The major problem for most communities in developing countries is road accident which requires serious attention in searching for preventive measures to minimize it. This study is aimed at using time series analysis to predict the number of crashes for years 2016-2018, taking Yobe, Katsina, Abia and Ogun states as case studies. The available 1999-2018 crash data were sourced from the Federal Roads Safety Corps which was used for forecasting and 2016-2018 data for validating. The three forecasting models using time series analysis for MINITAB software (that is, quadratic, growth and linear) were used. The choice of a model was made from the computed data and compared with the actual data. It was recommended that policies be made to control, enforce, regulate and educate drivers by relevant government agencies such as the Federal Road Safety Corps. Increased efforts by relevant government agencies in the provision of road infrastructures with a view to reducing traffic crashes in the cities were also recommended.

Keywords: Traffic crash; MINITAB software; Quadratic model; Growth model; Linear model.

1. Introduction

Road traffic accident is one of the prevailing causes of injuries and fatalities in the world and most especially in less economically developed countries which accounted for 93 % of the world's fatalities with only about 60 per cent of the world's vehicles. Approximately 1.35 million people die each year as a result of road traffic crashes. Between 21.35 and 51.35 million of the world's population sustain one or more forms of injuries as a result of road traffic crash yearly, out of which about 1.35 million eventually lead to death [1,2].

Nigeria, with the greatest number of deaths per 10,000 vehicle crashes in Africa, is faced with a lot of setbacks in addressing the problem of road traffic accidents. These setbacks are probably as a result of the country's level of development and practicable solutions to be provided to mitigate these problems [3,4]. According to [5], the mortality rate associated to road traffic accidents in Nigeria has increased from 38.2 per cent in 1991 to 60.2 per cent in 2001 for a period of ten (10) years. In the same vein, Lagos state, with an average fatality of 32 per 1,000 people, has been regarded as a high risk region in the whole of Africa [6]. In this research, efforts were made to forecast road traffic accident in Abia, Ogun, Yobe and Katsina states using time series analysis for the years 2016-2018 in order to avoid more occurrences.

1.1. Brief description of the study area

Abia state is a South-Eastern state in Nigeria, with a land area of 5,243.7 km^2 and a population of 2,845,380. It lies within latitudes 4°40' and 6°14'N and longitudes 7°10' and 8°00'E. It has 17 local government areas and serves as a major commercial centre for other Southeastern states in the country which enable its accumulation of 20 million when in full capacity. Its administrative capital and major commercial hub are Umuahia and Aba, with populations of 534,265 and

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359,230 respectively [7]. From January to November 2019, the state recorded 326 injuries and 25 deaths in 71 traffic crashes [8].

Ogun State, which lie within latitudes 6°12' and 7°48'N and longitudes 3°00' and 5°00'E, is in the South-Western region of Nigeria. It has an estimated population of about 5.8 million people with a land area of about 16,762 km^2 which is about 1.8 percent of Nigeria's total land area [9,10]. From January to November 2019, the state recorded over 1,723 injuries and 301 deaths in 671 traffic crashes with an increment of 23 per cent and 43 per cent respectively when compared to 2018 statistics [11].

Yobe state is a North-Eastern state in Nigeria, with a land area of 45,502 km^2 and an estimated population of 3,630,396. It lies within latitudes 4°40' and 6°14'N and longitudes 7°10' and 8°00'E. It has 17 local government areas with Damaturu as the state capital. It was reported that not less than 71 road traffic crashes occurred from January to October, 2019 with a total injuries and deaths of 344 and 202 respectively [12].

Katsina state is a North-Western state in Nigeria, with a land area of 24,192 km^2 and an estimated population of 5,801,584. It lies within latitude 11°30' and 13°N and longitudes 7° and 9°E. Its capital is Katsina, one of the thirty-four local government areas of the state [13].

Figure 1 Map of Nigeria showing the study areas with their neighbouring states (Source: [14])

2. Material and methods

2.1. Material

The data for the study was sourced from Federal Road Safety Commission (FRSC). This accident data showing the number of casualties in each state per year was analysed using MINITAB. It was in the environment of the statistical package that descriptive statistics involving frequencies, cross tabulation, development of various charts, tables and development of relationships among the variables were carried out.

One of the goals in this study is to develop time series models to analyse and predict the rate of road traffic fatalities in Nigeria. The road safety characteristics were also explored in order to determine the impact of various road safety measures and compare the results with the findings of previous studies. Statistical analysis was used to determine the descriptive statistics of road traffic casualties, which serves as the foundation for data stratification according to the type of road users and road environments.

The next step involves modelling the series of road traffic fatalities using multivariate analysis method in order to determine the statistically significant variables which influence the rate of road traffic fatalities in Nigeria and determine the impact of the interventions (road safety measures) along with the forecasted rate of fatal accidents.

3. Results and discussion

From Figure 2, it can be seen that of all the states considered, the casualties recorded for the period of 20 years (1999-2018) was in descending order of 42,839, 21,901, 10,225 and 7,478 for Ogun, Katsina, Yobe and Abia states respectively. In other word, Ogun state has the highest number of deaths and injuries of 9,476 and 33,363 respectively while Abia state recorded the lowest casualties of 1,318 deaths and 6,160 injuries.

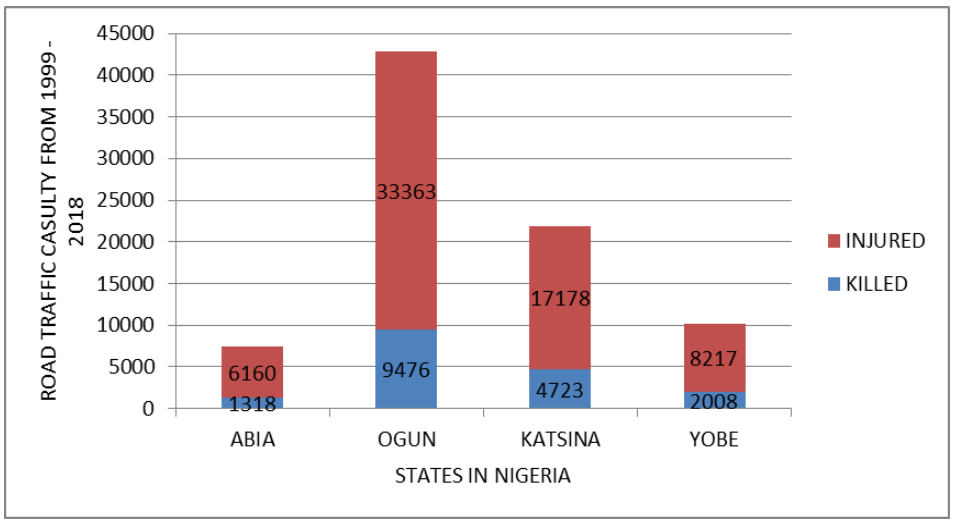

Figure 2 Graph showing the total casualties of the study area from 1999 – 2018

3.1. Time series analysis for Abia state

Figures 3a – 3c show the trend analysis plot for Abia state using linear, quadratic and growth models. The models were compared using the following accuracy measures; Mean absolute percent error (MAPE), Mean absolute deviation (MAD) and Mean standard deviation (MSD). The growth model has the least mean absolute percent error of 28.3 %. That is, the error in forecasting from the actual is 28.3 %. The mean absolute deviation, which measures the variation of the forecast from the actual value, also gives a value of 104.3. This is a clear indication that the forecast value is 104.3 away from the actual value. The Mean standard deviation gives 3097.07 for the growth model but quadratic model has the least mean absolute deviation and mean standard deviation with value of 102.8 and 13558.8 respectively.

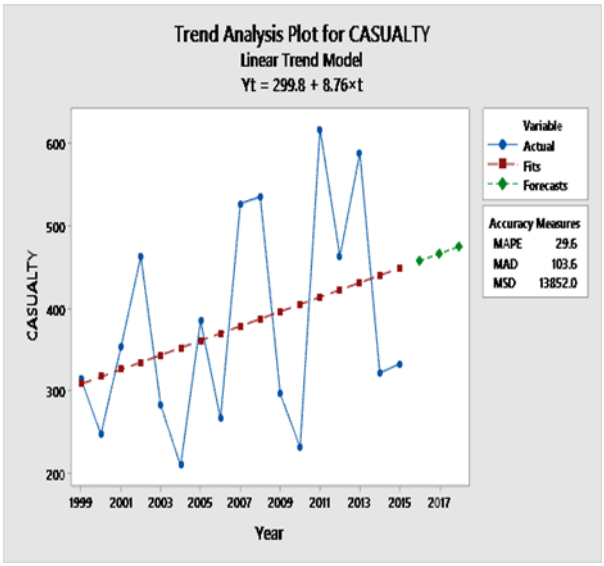

Figure 3a Linear Trend Model for Abia State

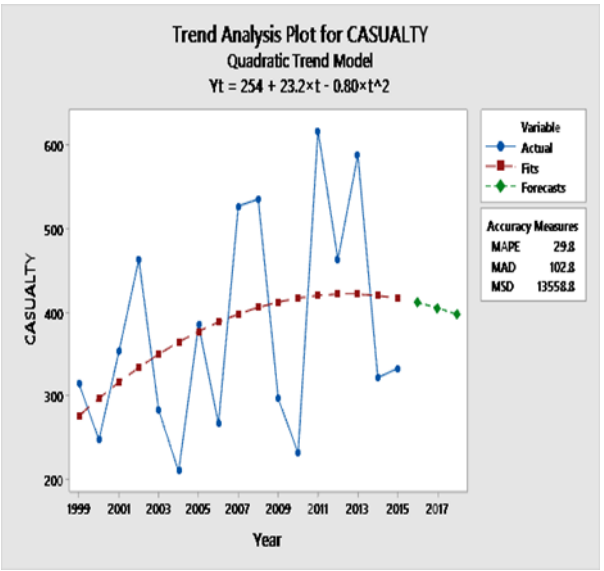

Figure 3b Quadratic Trend Model for Abia State

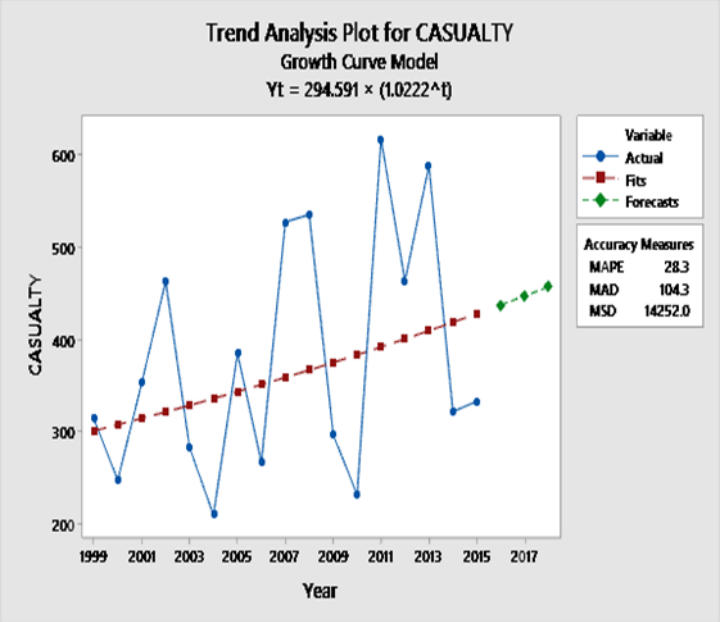

Figure 3c Growth Curve Trend Model for Abia State

Table 1 Comparison of the Actual and Predicted Data for Abia State

Year	Casualty			
	Actual	**Forecast (Linear)**	**Forecast (Quadratic)**	**Forecast (Growth)**
2016	425	458	412	438
2017	261	467	406	447
2018	355	475	398	457

Table 2 Comparison of the Actual Data and the % Errors

Year	Casualty			
	Actual	**% error (Linear)**	**% error (Quadratic)**	**% error (Growth)**
2016	425	-7.6	3.1	-2.9
2017	261	-78.6	-55.3	-71.2
2018	355	-33.8	-11.9	-28.7

From Figure 3, we observe that the quadratic model follows the pattern of the actual data than the other models, this indicates the accident rate follows an exponential distribution. Since the best model for forecasting is chosen with the least value of MAPE, MAD and MSD, therefore, the best model for Abia state is quadratic model as shown in Figure 4. In the same vein, the forecasted casualties for 2016 – 2018 were 412, 406 and 398 as against 425, 261 and 355 respectively**.**

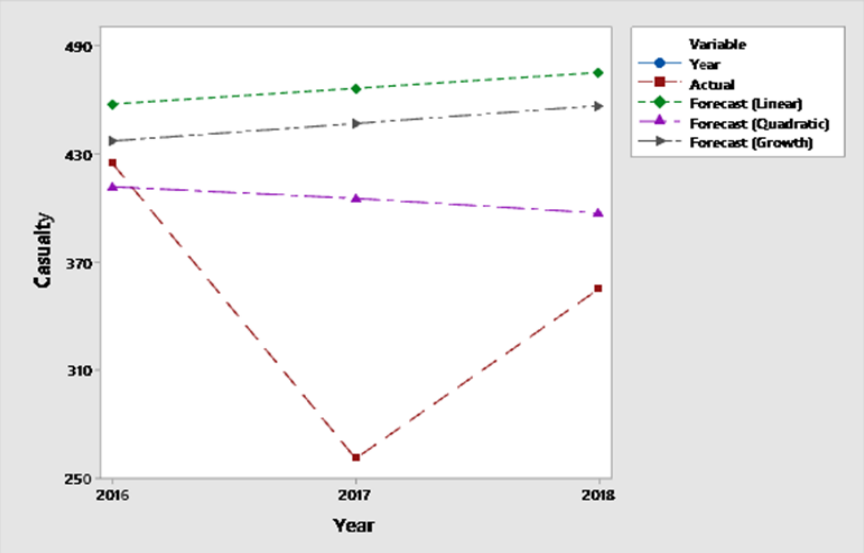

Figure 4 Time Series Plot of Actual and Forecasted Casualty for 2016 – 2018 in Abia State

3.2. Series analysis for Katsina state

From Figure 5, the linear graph shows the number of casualty keeps increasing every year, this same trend was also found in the exponential growth model. But in the quadratic model, the number of casualty decreased for the first four (4) years, that is, from years 1999 – 2003 before it eventually increased till 2018. Looking at the accuracy measure, the quadratic model has the least value for two out of the three measures. The mean absolute deviation has a value of 329 and mean standard deviation of 177157.

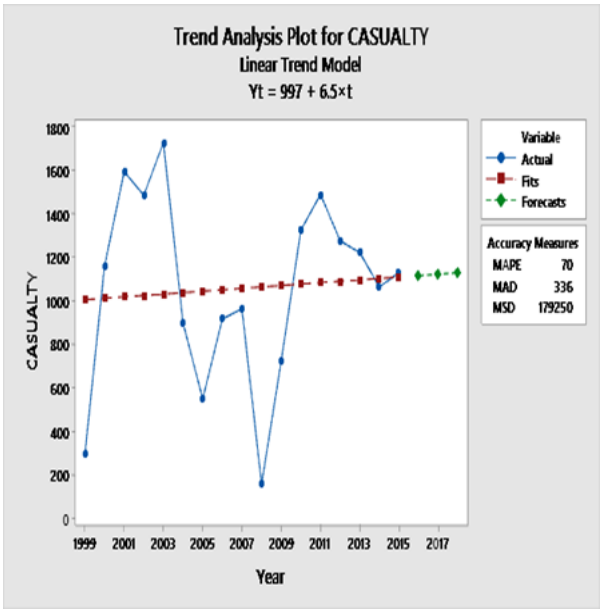

Figure 5a Linear Trend Model for Kaduna State

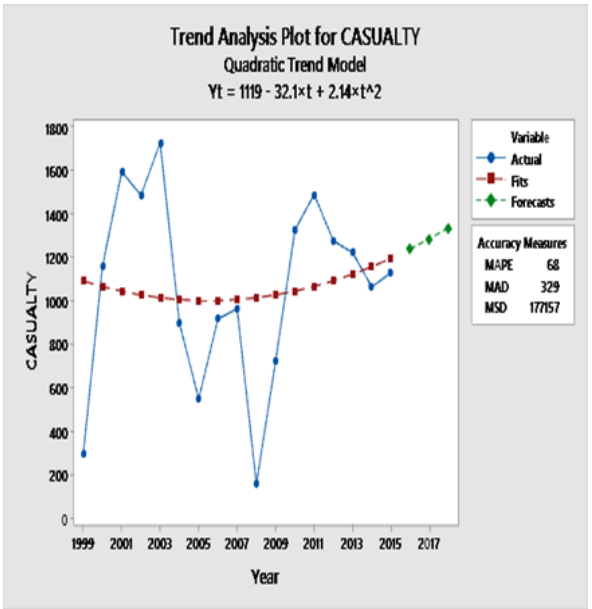

Figure 5b Quadratic Trend Model for Kaduna State

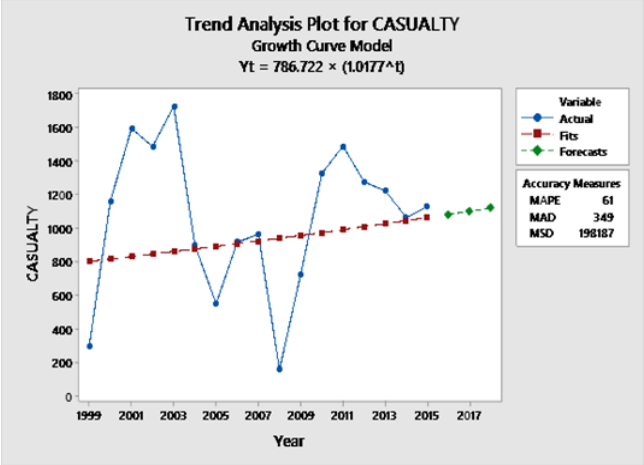

Figure 5c Growth Trend Model for Kaduna State

From Tables 3 and 4, we can clearly compare the forecast method values with the actual data values over the three years after the time series analysis has been carried out. It is observed that the quadratic forecast method best fit into the prediction because the percentage errors are quite negligible ±11% of the actual data. This implies that the traffic crashes will increase steadily along the years.

Table 3 Comparison of the Actual and Predicted Data for Kaduna State

Year	Casualty			
	Actual	Forecast (Linear)	Forecast (Quadratic)	Forecast (Growth)
2016	1114	1114	1236	1080
2017	1432	1121	1284	1099
2018	1417	1127	1335	1119

Table 4 Comparison of the Actual Data and the % Errors

Year	Casualty			
	Actual	% error (Linear)	% error (Quadratic)	% error (Growth)
2016	1114	0.0	-11.0	3.1
2017	1432	21.7	10.3	23.3
2018	1417	20.5	5.8	21.0

From the trend line in Figure 5, we observe that linear model works well in fitting the model but it performed woefully in forecasting. For forecasting, the quadratic model is the best model.

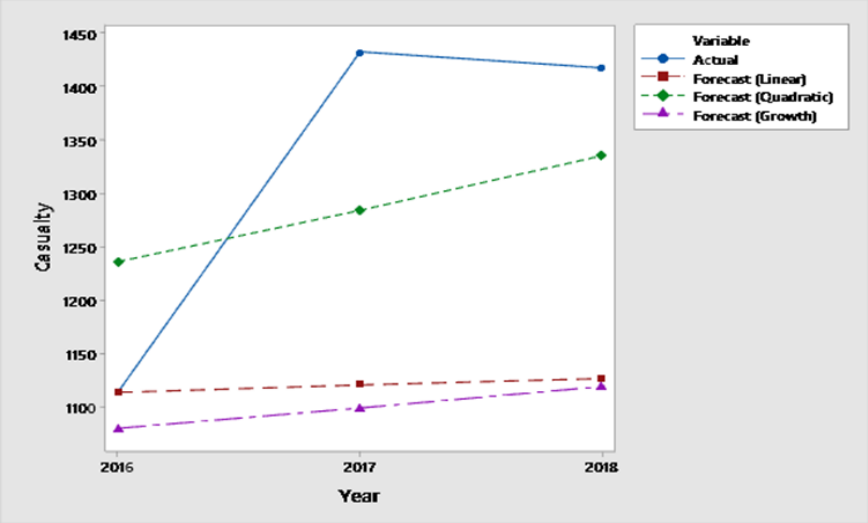

Figure 6 Time Series Plot of Actual and Forecasted Casualty for 2016 – 2018 in Kaduna State

3.3. Series analysis for Ogun state

Figure 7 shows the linear and exponential graph follows the same trend; a downward movement in the total number of accident. The quadratic model shows a rapid drop in the number of accident, it shows at a point there would be no accident after it has had an early increase for the six years, that is, 1999 – 2005. This was ascertaining by checking the accuracy measures, the quadratic model has the lowest values for MAPE, MAD and MSD of 20, 396 and 257770 respectively.

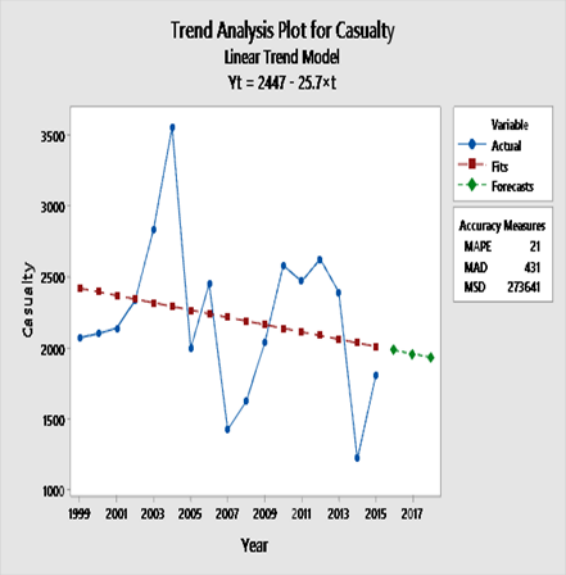

Figure 7a Linear Trend Model for Ogun State

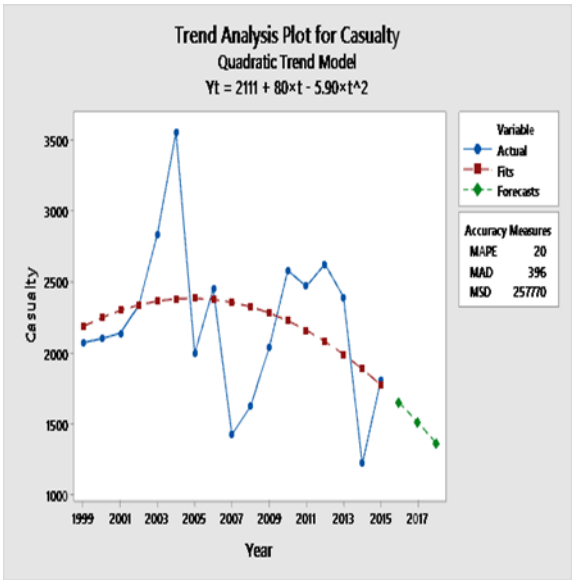

Figure 7b Quadratic Trend Model for Ogun State

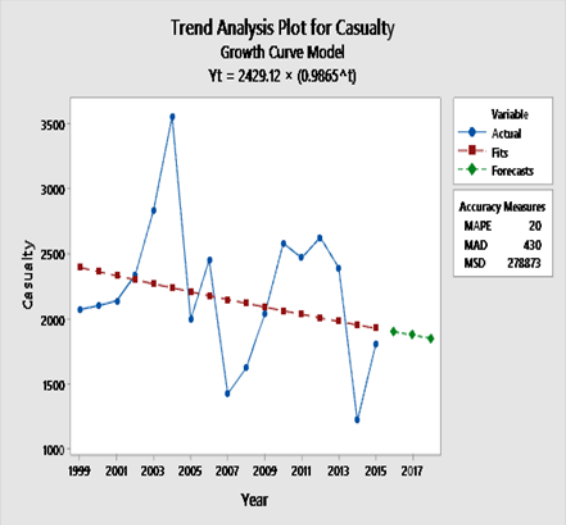

Figure 7c Growth Trend Model for Ogun State

From Tables 5 and 6, we can clearly compare the forecast method values with the actual data values over the three years after the time series analysis has been carried out. And it is observed that the quadratic forecast method best fit into the prediction because the percentage errors are quite negligible between ±30% of the actual data. This implies that the rate of traffic crashes is not constant, it will increase and decrease simultaneously over the years.

Table 5 Comparison of the Actual and Predicted Data for Ogun State

Year	Casualty			
	Actual	Forecast (Linear)	Forecast (Quadratic)	Forecast (Growth)
2016	1393	1984	1648	1901
2017	1178	1959	1510	1875
2018	1886	1933	1361	1850

Table 6 Comparison of the Actual Data and the % Errors

Year	Casualty			
	Actual	% error (Linear)	% error (Quadratic)	% error (Growth)
2016	1393	-42.4	-18.3	-36.5
2017	1178	-66.3	-28.2	-59.2
2018	1886	-2.5	27.8	1.9

Figures 7 show that none of the lines predicts the actual value correctly, the quadratic model forecast is closer to the actual value than other model. The forecast does not predict the actual value too correctly but the lines shows there is a linear trend in the forecast total accident which is also observed in the actual data. The best model for forecasting casualty in Ogun State is quadratic model with the least MAPE, MAD and MSD values as shown in Figure 8.

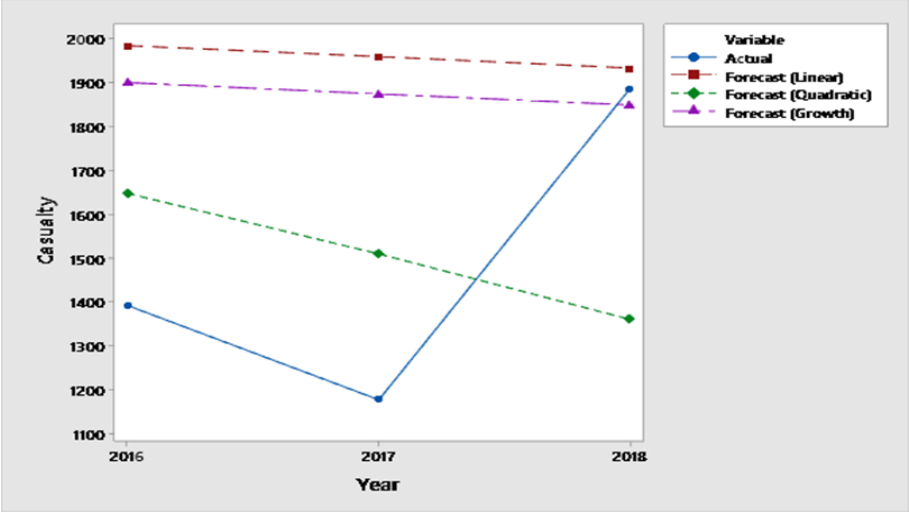

Figure 8 Time Series Plot of Actual and Forecasted Casualty for 2016 – 2018 in Ogun State

3.4. Series analysis for Yobe state

The growth model has the least mean absolute percent error of 40.4%. This is telling us the error in forecasting from the actual is 40.4%. The least mean absolute deviation, which measures the variation of the forecast from the actual value, also gives a value of 133.0 goes for the linear model. This is a clear indication that the forecast value is 133.0 away from the actual value. The least mean standard deviation gives 27266.0 for quadratic model.

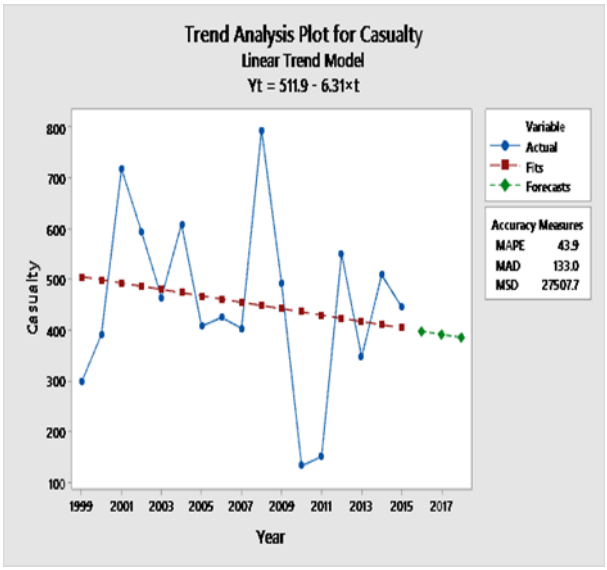

Figure 9a Linear Trend Model for Yobe State

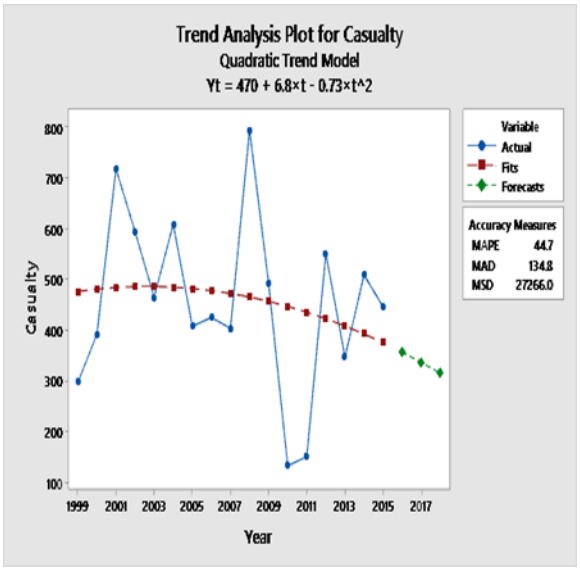

Figure 9b Quadratic Trend Model for Yobe State

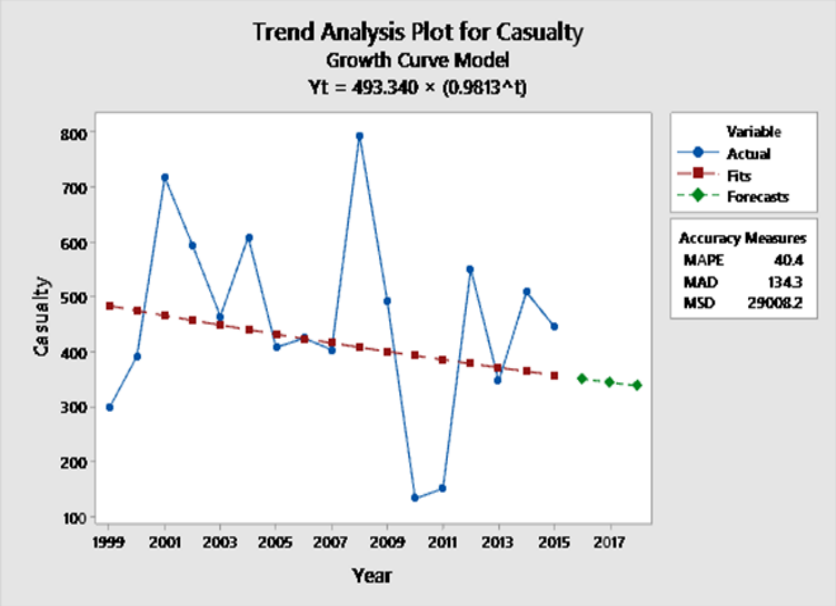

Figure 9c Growth Trend Model for Yobe State

From Tables 7 and 8, we can clearly compare the forecast method values with the actual data values over the three years after the time series analysis has been carried out. And it is observed that none of the forecast methods perfectly fit into the prediction because none of the model has more than one least accuracy measure.

Table 7 Comparison of the Actual and Predicted Data for Yobe State

Year	Casualty			
	Actual	Forecast (Linear)	Forecast (Quadratic)	Forecast (Growth)
2016	775	398	357	351
2017	633	392	337	344
2018	1081	386	315	338

Table 8 Comparison of the Actual Data and the % Errors

Year	Casualty			
	Actual	% error (Linear)	% error (Quadratic)	% error (Growth)
2016	775	48.6	53.9	54.7
2017	633	38.1	46.8	45.7
2018	1081	64.3	70.9	68.7

From figure 9, we observe that the linear model line predicts correctly than the other models by having the least percent error for the years considered. Therefore, the linear model is the best model to forecast road traffic casualty in Yobe state from 2016 to 2018 as shown in Figure 9a.

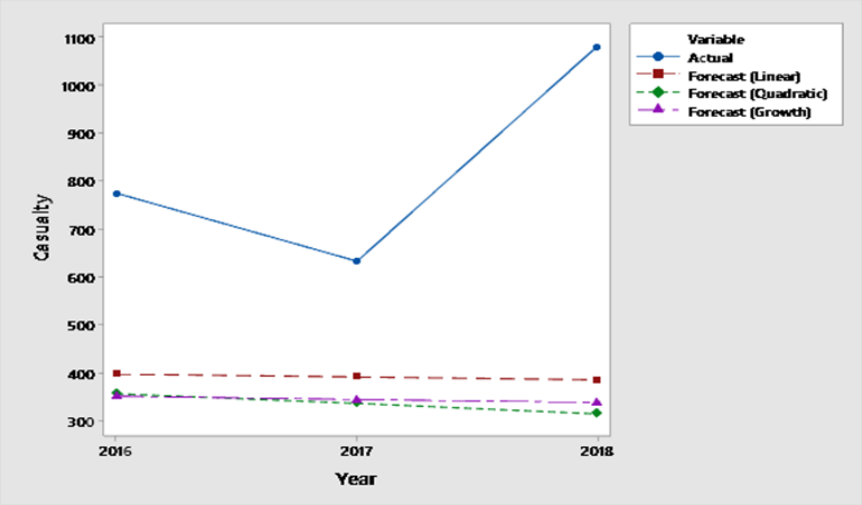

Figure 10 Time Series Plot of Actual and Forecasted Casualty for 2016 – 2018 in Yobe State

4. Conclusion

This work discusses fitting of MINITAB Model to yearly record of Nigeria accident crashes for the period January 1999 to December 2018 obtained from the Federal Road Safety Commission, while the 2016-2018 figures were used to assess the forecasting performance of the fitted model. The ultimate objective is to construct a statistical model which may be used to obtain forecasts of future values of Nigeria accident crashes necessary for policy formulation, implementation and monitoring. The result of data evaluation (for the assumptions of MINITAB models) shows that the data requires logarithmic transformation to make the distribution normal and stabilize the variance. The result of the analysis shows that the most appropriate model for Abia, Kaduna and Ogun States is quadratic model while that of Yobe state is the linear model of MINITAB 2.0.0 version. The forecast for the three years using the fitted model agreed strongly with the actual values at 95 percent level of confidence. This model has therefore been recommended for use in the study of Nigeria external reserve until further studies prove otherwise.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

We are hereby confirming that that there is no conflict of interest.

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