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Tracking and Appraisal of Road Traffic Accidents: An Analysis for Anambra State, Nigeria

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Abstract

Increasing number of road traffic accidents with its resulting deaths and injuries have become an issue of great concern in recent times in Nigeria. Various intervention efforts have been designed to reduce accident rates and traffic mortality level. This study applied autoregressive integrated moving average (ARIMA) time series modelling approach to appraise the trends and pattern of road accidents in Anambra State, Nigeria over 132 months as well as made forecast of road traffic accidents in the State. Out of the various ARIMA models examined, ARIMA(1,1,1) model with the lowest Bayesian Information Criterion, Mean Absolute Percentage Error and Root Mean Square Error, was selected as the most suitable model for the total number of accident cases in the State and ARIMA(0,1,1) model was selected for the fatal accident cases . The autocorrelation and partial autocorrelation plots of the residuals of the models, and the Ljung-Box statistics revealed that the models are free from serial correlation, hence adequate and fit well for accidents data in the State. The forecasts showed a slight decreasing pattern in the total number of accident cases and a slight increasing pattern in the fatal accident cases in Anambra State.This study will help road safety agency in the State to understand the trends and patterns of road traffic accidents in the state and be able to take proper safety measures to curtail accidents occurrences and severity in the state.

Keywords: ARIMA model, Road traffic accidents, Forecasting, Anambra State, Nigeria

1. Introduction

Road transportation is the primary means of mobility in Nigeria and this has led to overdependence and much pressure on the available road infrastructure. The much pressure on the available road infrastructure has contributed immensely to the increasing cases of road traffic accidents in Nigeria and other parts of the world, with its attendant deaths and injuries to many people.

According to Global Status Report on Road Safety 2015 (WHO, 2015), more than 1.2 million people die each year on the world's roads, and up to 50 million others incur non-fatal injuries as a result of road traffic accidents. The current trends show that if urgent action is not taken, road traffic injuries could be the seventh leading cause of death by the year 2030, and ninety percent of these deaths occurring in low and middle-income countries (WHO, 2015). The major victims of these traffic collisions were people between 5 and 44years of age; and the cost of these collisions represented 2 to 3 percent of countries GDPs (Peden et al., 2004).

According to Odero (1998), nearly three-quarters of deaths resulting from road accidents occur in developing countries, and this problem appears to be increasing rapidly in these countries (Jacobs et al., 2000). The WHO (2013) adjudged Nigeria the most dangerous country in Africa with 33.7 deaths per 100,000 population every year. According to the report, one in every four-road accidents, deaths occur in Nigeria. International comparison indicates that the chance of a vehicle killing someone in Nigeria is 47 times higher than in Britain (Atubi, 2010).

In order to properly understand the road traffic accidents situations in Anambra State, Nigeria, Ihueze and Onwurah (2017) analyzed road traffic accident(RTA) data in the state from 2005 to 2015 and found that 1675 cases of RTA were recorded which resulted to 711 deaths and left 4299 persons injured. Thestudy also discovered that although the number of cases of road accidents in the State is decreasing from the year 2012, the number of casualties (killed or injured) in the accidents is increasing. This agreed with the result of Atubi (2012), which found an increasing trend in the number of injuries from RTA in Lagos State.

Many researches have been carried out on road traffic accidents in a bid to understand and predict its occurrence using different modelling techniques. For instance, Linear regression models (Aworemi et al., 2010; Oyedepo and Makinde, 2010; Atubi, 2012; Aderamo, 2012; Aderinola and Aiyewalehinmi, 2015); Generalized linear models(Kweon and Kockerlman, 2004; Eisenberg, 2004; Kockerlman and Ma, 2007; Wan et al., 2012) and Autoregressive integrated moving average models (Quddus, 2008; Adu-poku et al., 2014; Avuglah et al., 2014; Balogun et al., 2015; Sanusi et al., 2016; Salifu, 2016). According to Quddus (2008), ARIMA model is the best accident predictive model for aggregated time series count data.

Although, researchers have been modelling vehicular accidents with crash prediction models in various parts of the world, however, it is extremely difficult to just apply models which worked somewhere to data obtained from different country due to the variations in the various factors pertaining to different countries or locations (Fletcher et al., 2006).

Hence, this study aims at appraising and developing robust models for forecasting of road traffic accidents cases in Anambra State, Nigeria.It presents autoregressive integrated moving average (ARIMA) models for both the total number of accident cases and the fatal accident cases in the State. This study will help road safety agency in the State to understand the trends and patterns of road traffic accidents in the state and be able to take proper safety measures to curtail accidents occurrences and severity in the state.

2.0 Material and methods

2.1 Data Sources

The road traffic accidents Data used in this study were obtained from Anambra State Sector Command of the Federal Road Safety Corps (FRSC). The Federal Road Safety Corps is a lead agency saddled with the responsibility of ensuring safety on Nigerian highways. Among the various roles of FRSC are giving prompt attention and care to victims of crashes, carrying out thorough investigation on the remote and immediate contributing factors to road accidents and filing their reports. They gather the accidents information through on the spot assessment of accident scenes, vehicle, environmental conditions, and thorough interviews of the accident victims (drivers and passengers or pedestrians) and onlookers.

For this study, FRSC Anambra State Sector Command supplied data about road traffic accidents in the State for the period 1st January 2005 to 31st December 2015 (a total of 132 months). During this period, 1675 accident cases were recorded; 18.84% involved minor injury, 57.30% involved serious injury and 23.86% involved fatal accident cases. In this study, an aggregated monthly count dataset of minor, serious and fatal accidents (total number of accident cases) and fatal accident cases were used in the analysis. The accident dataset used was divided into two parts in each case. The first part (accident data from 2005 to 2014) was used to estimate the model parameters and the other part (2015 data) was used to validate the model using the estimated model parameters.

2.2 Autoregressive Integrated Moving Average (ARIMA) Models

The data were modelled using Autoregressive Integrated Moving Average (ARIMA) model in SPSS version 22, and XLSTAT 2016 version was used for the Augmented Dickey-Fuller test. ARIMA (p, d, q) model combines autoregressive, (AR) and moving average (MA) models, and explicitly includes differencing in the formulation of the model suitable for univariate time series analysis. Specifically, the three types of parameters in the model are the autoregressive parameter (p), the number of differencing (d), and the moving average parameter (q). The general form of ARIMA model is expressed as;

$\varphi(L)\nabla^d y_t = \theta(L)\varepsilon_t$ (1)

Where y_t is the actual value

ε_t is random error (white noise)at a time period t, $\varphi_i (i = 1,2,\dots p)$ are autoregressive model parameters and p is the order of the autoregressive part,

θ_j (j =1, 2,...q) are the moving average model parameters and q is the order of the moving average part,

$\varphi(L) = (1 - \varphi_1 L - \varphi_2 L^2 - \cdots - \varphi_p L^p)$

$\theta(L) = (1 - \Theta_1 L - \Theta_2 L^2 - \cdots - \Theta_q L^q)$ L is lag operator defined by $L^k y_t = y_{t-k}\nabla$ represents the integrated process

d is order of non-seasonal difference needed to achieve time series stationarity

Differencing (d) is generally given as;

$\nabla^d y_t = (1 - L)^d y_t$ (2)

The first difference ($y_t{}^I$) of any time series data is,

$y_t{}^I = y_t - y_{t-1}$ (3)

The statistical significant and adequate ARIMA (p, d, q) model for time series modelling and forecasting is formulated following Box-Jenkins methodology (Box and Jenkins 1976). Box and Jenkins (1976) proposed a three-step iterative process of model identification, parameter estimation and diagnostic checking to determine the best parsimonious model.

The first step in developing an ARIMA model is to determine if the time series is stationary or not. A stationary time series is one whose statistical properties such as mean, variance or autocorrelation are all constant over time. The Stationarity or otherwise of the accidents time series data used in this study was checked by examining the time series plots of the data and using the Augmented Dickey-Fuller test. The Augmented Dickey-Fuller regression equation is given in Eq.(4) (Dickey and Fuller 1979).

$y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \beta t + \varepsilon_t$ (4)

Where y_t represents the number of accident cases, Δy_{t-i} is the lagged change in the number of accident cases, ε_t is white noise error term, t is time trend. In Augmented Dickey-Fuller test, if the computed p-value is greater than the significance alpha value, one cannot reject the null hypothesis, which says there is a unit root for the series. The presence of unit root shows non-stationary series and this could be made stationary mostly by differencing the series. Once the stationarity is achieved, the next step is to determine the orders of the autoregressive (AR) and moving average (MA) terms using the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF).

The maximum likelihood approach was used to estimate the parameters of the identified model and the t-statistics were used to check if the model generated is statistically significant or not. In this study, many ARIMA models were examined and lowest Bayesian information criterion (BIC), mean absolute percentage error (MAPE) and root mean square error (RMSE) were used to select the best model from the significant ARIMA models generated. The BIC is expressed as (Priestly 1981);

$BIC = n.\ln(RSS/n) + k.\ln(n)$(5)

Where n is the number of effective observations used to fit the model, k is the number of parameters in the model and RSS is the residual sum of square.

The adequacy of the model, considering the properties of the residuals, was checked using the residuals ACF and PACF, and the Ljung-Box statistics (Q^*). Q^* is obtained using (Ljung and Box 1978),

$Q^* = n(n+2)\sum_{j=1}^{P} r_j{}^2/n - j$ (6)

Where: r_j = residual autocorrelation at lag j, n = number of residuals,
p = number of time lags in the test. If the p-value associated with Q^* statistic is small (that is, $p<\alpha$), the model is inadequate.
The model can be modified or a new one can be considered until a satisfactory model is determined.

3.0 Results and Discussions

Figure 1 and figure 2 show the time series plots of the total number of accident cases and the fatal accident cases in Anambra State, Nigeria from January 2005 to December 2015 (a period of 132 months). The time series plots in figure 1 and figure 2 exhibit a systematic change, therefore giving an evidence of trends in the data. The total number of accident cases in Anambra State, Nigeria increased from 2005 to 2012 and decreased from 2012 to 2015. The fatal accident cases increased from 2005 to 2015.

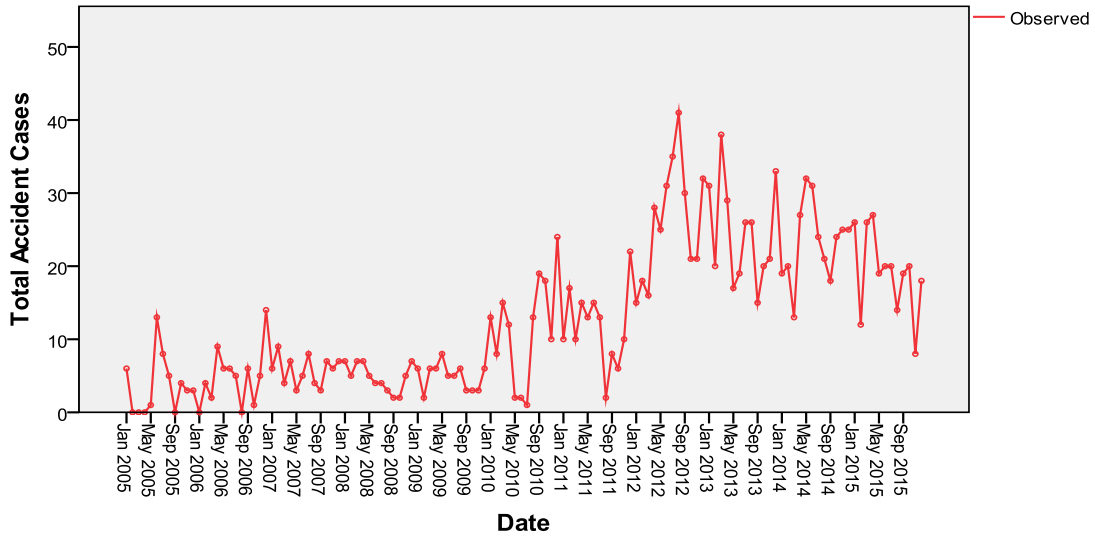

Figure 1: Time Series Plot of the Total Number of Accident Cases in Anambra State

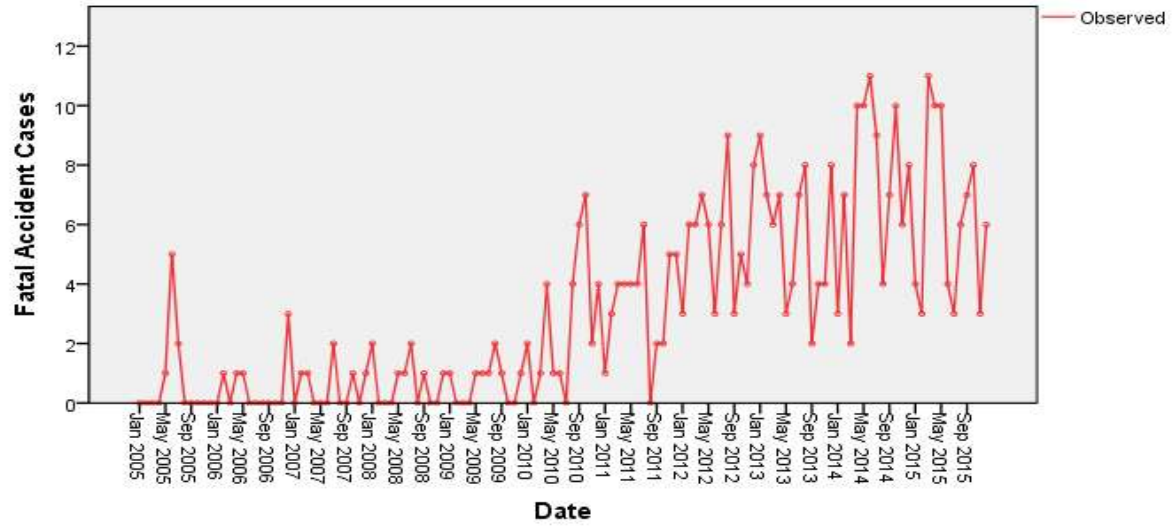

Figure 2: Time Series Plot of Fatal Accident Cases in Anambra State

Table 1 shows the Augmented Dickey-Fuller test for the total and the fatal number of accident cases. The p-value for the total number of cases is 0.444 and that of the fatal cases is 0.066. In each case, the computed p-value is greater than the significance alpha level ($\alpha = 0.05$), which shows that the two time series are not stationary and require differencing to achieve stationarity.

Table 2 shows the Augmented Dickey-Fuller test for both series after the first order differencing of the time series. The p-value for both the total number of accident cases and the fatal cases is less than 0.0001, which is less than the alpha value; hence, the two time series are stationary after the first order differencing.

Table 1: Augmented Dickey-Fuller Test for Total and Fatal Accident Cases

Parameter	Total Number of Accident Cases	Fatal Cases
Tau (Observed Value)	-2.251	-3.310
Tau (Critical)	-0.801	-0.801
p-value (one-tailed)	0.444	0.066
Alpha	0.05	0.05

Table 2: Augmented Dickey-Fuller Test of the Differenced Accidents Time Series

Parameter	Total Number of Accident Cases	Fatal Cases
Tau (Observed Value)	-6.811	-6.886
Tau (Critical)	-0.812	-0.812
p-value (one-tailed)	<0.0001	<0.0001
Alpha	0.05	0.05

Figure 3 and figure 4 show the time series plots of the total number of accident cases and the fatal cases respectively after the first order differencing. From the figures, it can be observed that there is no systematic change in the series, which shows that the trends have been removed from the original series.

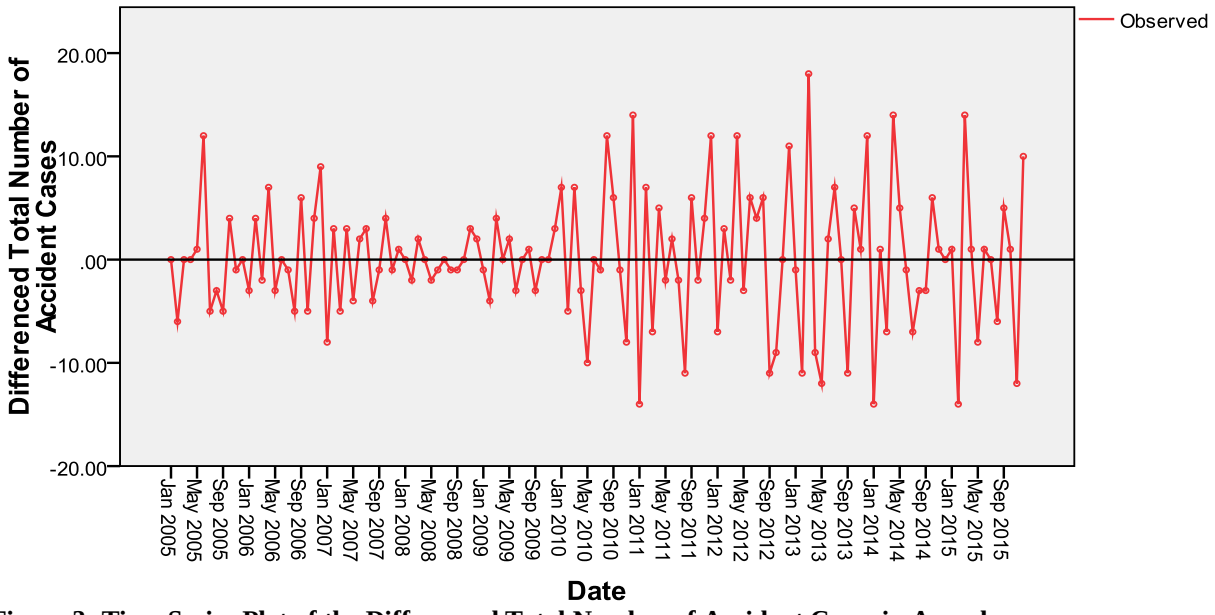

Figure 3: Time Series Plot of the Differenced Total Number of Accident Cases in Anambra

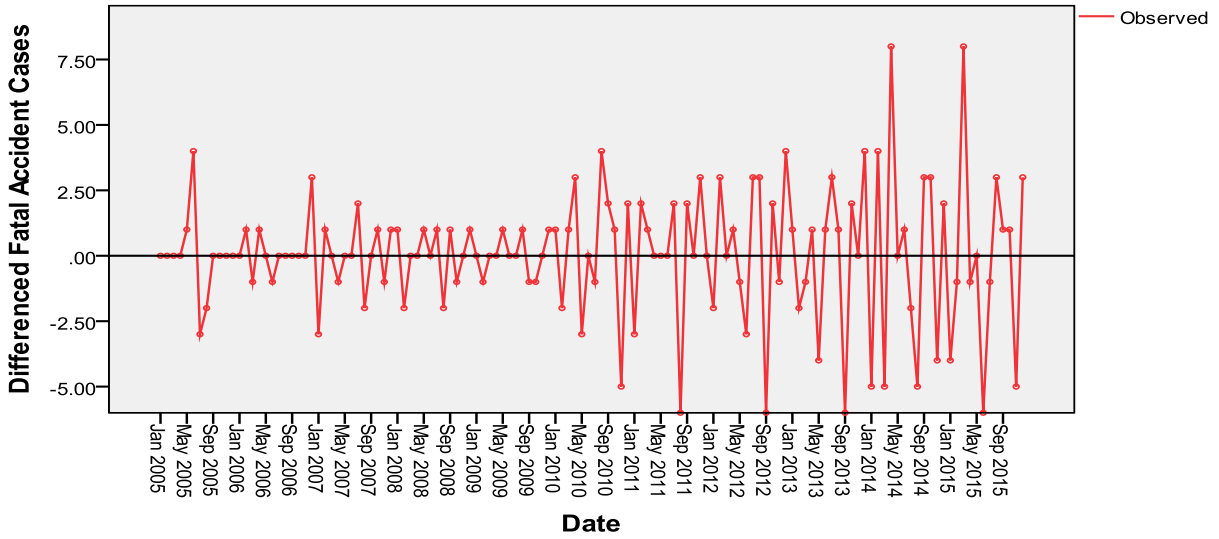

Figure 4: Time Series Plot of the Differenced Fatal Cases in Anambra State

Figure 5 and figure 6 show the autocorrelation functions (ACF) of the differenced total number accident cases and fatal accident cases respectively. It can be seen that the graphs of the ACF of the differenced time series decay very quickly, showing that the two time series were made stationary after the first order non-seasonal differencing. The total number of accident cases has only one significant spike at first lag showing the presence of white noise, which is a moving average component. The ACF of the fatal cases has significant spikes at lags 1 and 3.

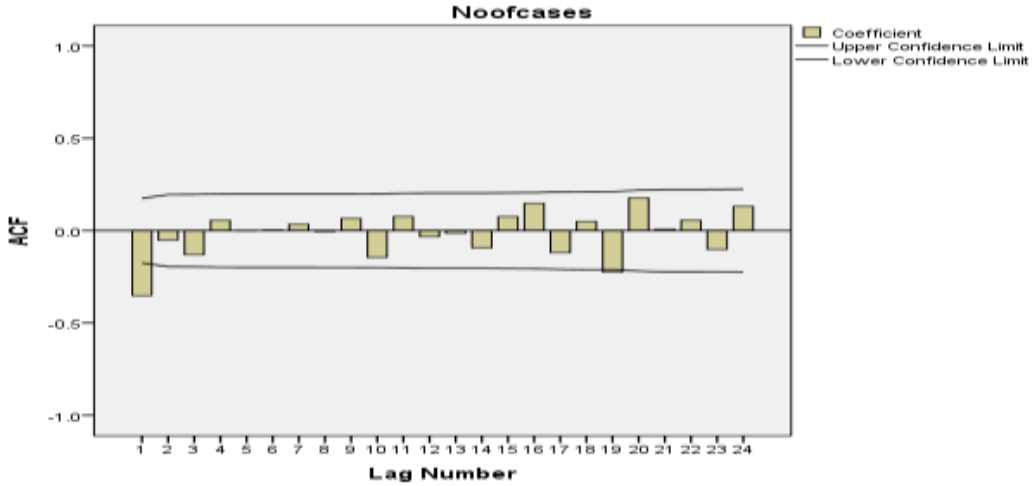

Figure 5: Autocorrelation Function of the differenced Total Number of Accident Cases

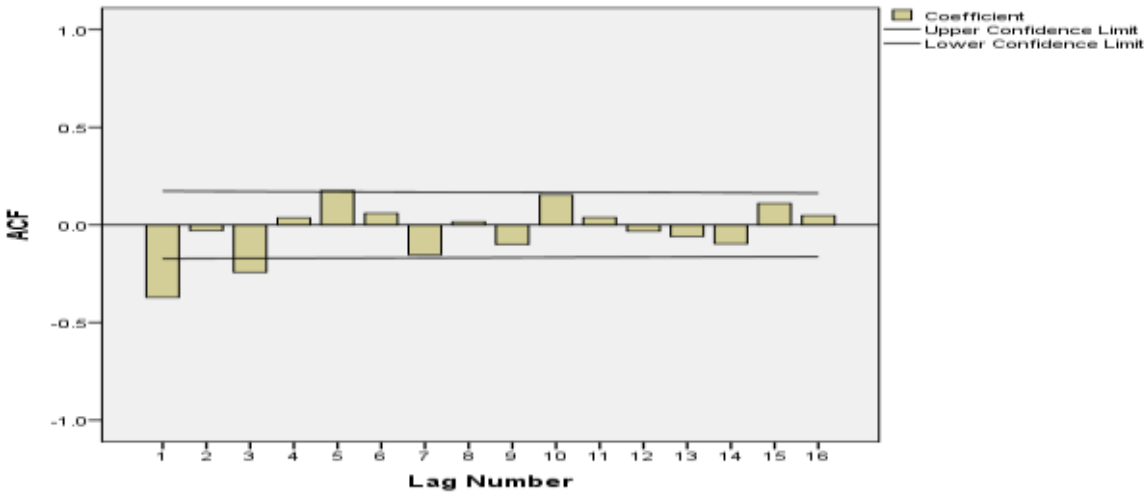

Figure 6: Autocorrelation Function of the differenced Fatal Accidents Cases

To ensure accurate Orders of autoregressive (AR) and moving average (MA), different ARIMA (p,d,q) models were examined; their parameters estimated at 95% confidence interval, their t-statistics were used to determine the significant models and lowest Bayesian information criterion, root mean square error and mean absolute percentage error were used to determine the best model among the tentatively significant models. A significant model is the one, which all its parameters at 95% confidence interval are all significant. The results for the total number of accident cases are summarized in Table 3. From Table 3, ARIMA (0,1,1) has the lowest Bayesian information criterion of 3.444 followed by ARIMA (1,1,1) with BIC of 3.451, hence, both of them are good models for the total number of accident cases among the significant models examined. But, considering the root mean square error and mean absolute percentage error, ARIMA (1,1,1) with lowest RMSE of 5.394 and MAPE of 49.854 was preferred over ARIMA (0,1,1) with RMSE of 5.483 and MAPE of 51.793 for the total number of accident cases in Anambra State. Hence, ARIMA (1,1,1) was selected for diagnostic checking to determine its adequacy for forecasting the total accident cases in the State. Table 4 shows the summary of the results of various ARIMA models for the fatal accident cases. From the table, ARIMA (0,1,1) has the lowest BIC of 1.317, RMSE of 1.893 and MAPE of 46.917 among the significant models examined. Hence, it was selected for diagnostic checking to ensure that is free from serial correlation and adequate for forecasting the fatal accident cases in the State

Table 3: Summary of Parameter Estimation ARIMA Models for the Total number of Accident Cases

Model	Parameter	Estimate	Standard Error	t-statistic	Bayesian Information Criterion	Root Mean Square Error	Mean Absolute Percentage Error
[b]ARIMA(1,1,0)	AR 1	-0.327	0.087	-3.767	3.530	5.724	50.713
[a]ARIMA(2,1,0)	AR 1	-0.375	0.092	-4.094	3.557	5.689	52.608
	AR 2	-0.143	0.091	-1.560			
[c]ARIMA(0,1,1)	MA 1	0.609	0.074	8.265	3.444	5.483	51.793
[a]ARIMA(0,1,2)	MA 1	0.525	0.091	5.742	3.459	5.415	51.114
	MA 2	0.162	0.091	1.774			
[b]ARIMA(3,1,0)	AR 1	-0.421	0.088	-4.780	3.500	5.419	51.763
	AR 2	-0.263	0.093	-2.815			
	AR 3	-0.314	0.088	-3.548			

[c]ARIMA(1,1,1)	AR 1	0.307	0.133	2.307	3.451	5.394	49.854
	MA 1	0.805	0.084	9.560			
[a]ARIMA(2,1,1)	AR 1	0.310	0.139	2.234	3.499	5.417	49.703
	AR 2	0.010	0.115	0.087			
	MA 1	0.810	0.104	7.807			
[a]ARIMA(1,1,2)	AR 1	0.189	0.105	1.809	3.529	5.417	49.810
	MA 1	0.952	0.336	2.831			
	MA 2	-0.065	0.258	-0.251			

a. Insignificant Model (t-statistic <2). b. Significant model (t-statistic ≥2). c. Selected model (significant model with lowest Bayesian information criterion).

Table 4: Summary of Parameter Estimation of ARIMA Models for the Fatal Accident Cases

Model	Parameter	Estimate	Standard Error	t-statistic	Bayesian Information Criterion	Root Mean Square Error	Mean Absolute Percentage Error
[b]ARIMA(1,1,0)	AR 1	-0.386	0.085	-4.550	1.630	2.215	56.967
[b]ARIMA(2,1,0)	AR 1	-0.483	0.089	-5.395	1.584	2.121	55.534
	AR 2	-0.248	0.090	-2.763			
[c]ARIMA(0,1,1)	MA 1	0.833	0.054	15.496	1.317	1.893	46.917
[a]ARIMA(0,1,2)	MA 1	0.714	0.092	7.747	1.346	1.883	46.740
	MA 2	0.125	0.092	1.363			
[b]ARIMA(3,1,0)	AR 1	-0.541	0.090	-5.988	1.504	1.998	50.257
	AR 2	-0.359	0.098	-3.661			
	AR 3	-0.228	0.091	-2.512			
[a]ARIMA(1,1,1)	AR 1	0.126	0.113	1.113	1.348	1.885	47.023
	MA 1	0.850	0.065	12.983			
[a]ARIMA(2,1,1)	AR 1	0.129	0.114	1.132	1.388	1.884	46.466
	AR 2	-0.077	0.107	-0.719			
	MA 1	0.843	0.073	11.536			
[a]ARIMA(1,1,2)	AR 1	-0.036	0.708	-0.051	1.396	1.893	46.442
	MA 1	0.683	0.698	0.979			
	MA 2	0.161	0.580	0.278			

a. Insignificant Model (t-statistic <2). b. Significant model (t-statistic ≥2). c. Selected model (significant model with lowest Bayesian information criterion).

The diagnostic check to confirm the adequacy of ARIMA (1,1,1) model showed that the model is adequate for time series forecasting of the total number of road accidents in Anambra State as can be seen in the plots of residuals ACF and PACF shown in figure 7. From the figure, the ACF and PACF of the residuals are not significant at any lag, meaning that serial correlation is not significant between the error terms. Hence, the model is adequate. Also, from Table 5, the overall adequacy of the model checked using Ljung-Box statistics (Q = 16.070 with degree of freedom = 17) confirmed that the model is adequate and good fit for the time series data, since the p-value (p = 0.448) computed is greater than the alpha value ($\alpha = 0.05$). From the model fit statistics, the low RMSE of 5.538

shows that the model is fit for forecasting road accidents in the State. Also, the high R-squared value of 0.713 shows that over 71% of variations in the current aggregated monthly road accidents count were explained by the immediate past accidents and the past random shock of the series. The positive coefficients of AR(1) and MA(1) in Table 3 show that there is positive relationship between the total number of accidents and the time lagged observation and the lagged random shock of the series, which implies that a unit increase in any of them, will increase the number of accidents while other parameters remain constant.

The diagnostic check for the fatal accident cases model showed that ARIMA (0,1,1) is adequate for forecasting of fatal cases of road accident as can be seen in the residuals ACF and PACF shown in figure 8. The residuals are not significant at any lag, meaningthat serial correlation is not significant between error terms. Ljung-Box Statistics (Q = 16.324) with degree of freedom of 17 for the fatal accident cases in Table 5 confirmed the adequacy of the model. In Table 5,the computed p-value of the fatal accident cases is 0.501 which is greater than the alpha value ($\alpha = 0.05$), showing that the model is adequate. The R-squared of 0.587 shows that over 58% variations in the current aggregated monthly fatal accidents count were explained by the immediate past fatal accident and the past random shocks of the series. The low RMSE of 1.893 is very satisfactory and shows that the generated model is fit for forecasting of fatal accident cases in the State.

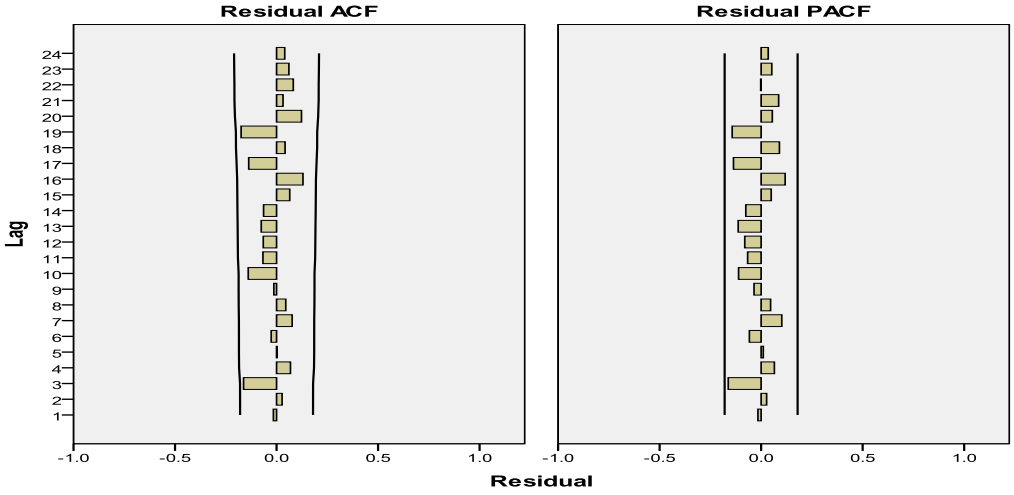

Figure 7: Residuals ACF and PACF of the Total Number of Accident Cases

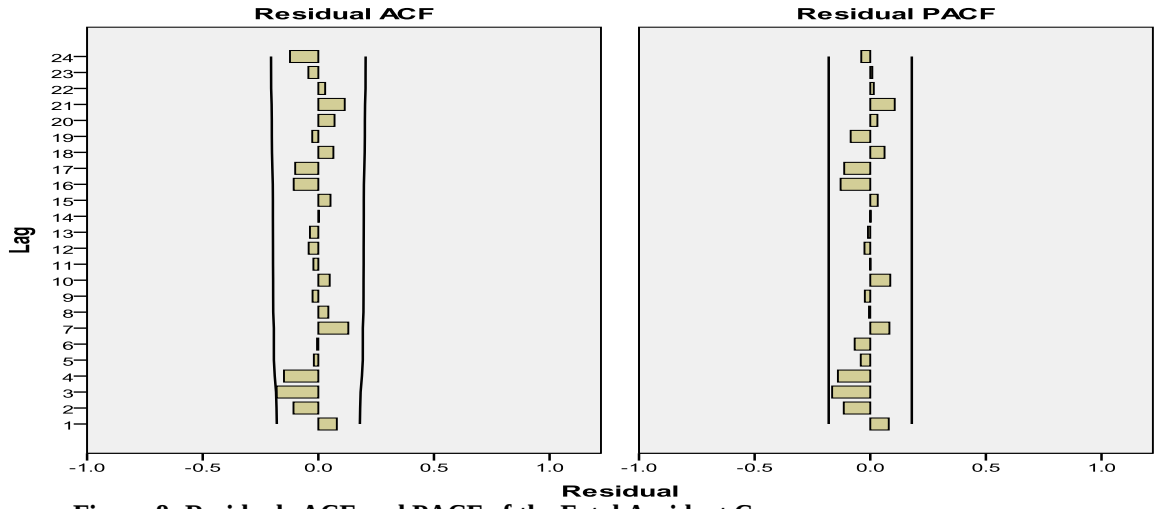

Figure 8: Residuals ACF and PACF of the Fatal Accident Cases

Table 5: Model Fit and Ljung-Box Statistics of the Total and the Fatal Accident Cases

Model	Model Fit statistics		Ljung-Box Q(18)		
	Root Mean Square Error	R-Squared	Statistics	Degree of Freedom	p-value
ARIMA(1,1,1) for the Total Accident Cases	5.394	0.713	16.070	16	0.448
ARIMA(0,1,1) for the Fatal Accident Cases	1.893	0.587	16.328	17	0.501

The essence of fitting an ARIMA model is to properly understand the system and be able to make future predictions based on the historical pattern of the time series. The statistical significant and adequate ARIMA (1,1,1) generated for the total number of accident cases and ARIMA (0,1,1) for the fatal accident cases are mathematically represented as;

ARIMA (1,1,1) for the total number of cases:

ARIMA (1,1,1) is represented as;

$$Y_t - Y_{t-1} = \varphi_1(Y_{t-1} - Y_{t-2}) + \varepsilon_t - \theta_1\varepsilon_{t-1}$$

$$Y_t = (1+\varphi_1)Y_{t-1} - \varphi_1 Y_{t-2} + \varepsilon_t - \theta_1\varepsilon_{t-1} \quad (7)$$

From Table 3, the value of AR(1) is 0.307 and the value of MA(1) is 0.805, substituting the values in Eq.(7), the ARIMA model for the total number of accident cases in the State becomes;

$$Y_t = 1.307Y_{t-1} - 0.307y_{t-2} + \varepsilon_t - 0.805\varepsilon_{t-1} \quad (8)$$

ARIMA (0,1,1) for the fatal accident cases:

ARIMA (0,1,1) is represented as;

$$Y_t = Y_{t-1} + \varepsilon_t - \theta_1\varepsilon_{t-1} \quad (9)$$

From Table 4, the value of MA(1) is 0.833, substituting the value in Eq.(9), the ARIMA model for the fatal accident cases in the State becomes;

$$Y_t = Y_{t-1} + \varepsilon_t - 0.833\varepsilon_{t-1} \quad (10)$$

12 months forecasts were made in each case for the year 2015 using the models and the results are shown in figures 9 and 10. The red line shows the actual values (observed), the thin green line shows the fit, and the thick green line shows the forecast made. Figure 9 for the total number of accident cases shows a little decreasing pattern from January to April and remains steady from May in the projected months. While in figure 10 for the fatal accident cases, there is increasing pattern in the projected months. The results agreed with the submissions of Atubi (2012) and Ihueze and Onwurah (2017) that fatal accident cases are still increasing in Nigeria. The forecasts made in each case were validated using the actual accidents count of the year 2015 as shown in Table 6. In some months, the forecasted values are very close to the actual values observed.

This study provides useful information about road traffic accidents in Anambra State, Nigeria and shows that the fatal accident cases will continue to grow if serious actions are not taken by all the stakeholders to curtail road accident menace. To ensure the accuracy of the forecasts made, the models generated will be useful for short-term forecast.

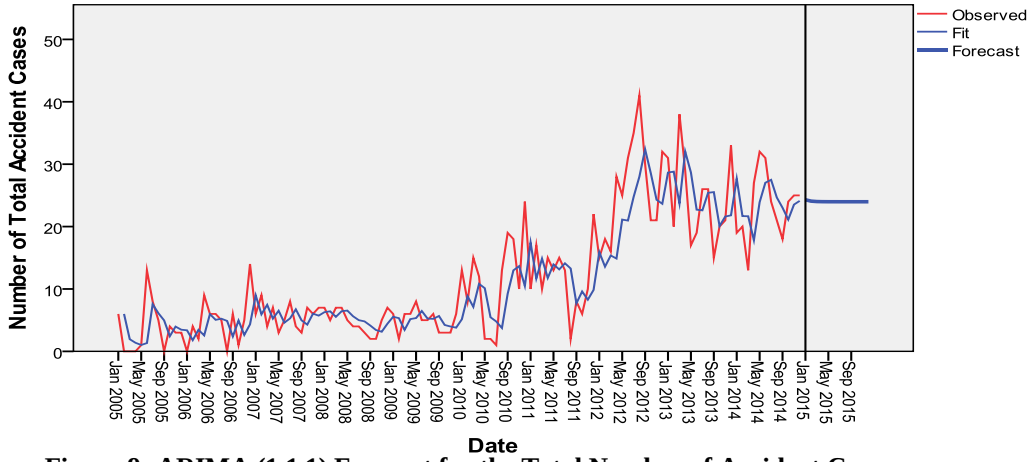

Figure 9: ARIMA (1,1,1) Forecast for the Total Number of Accident Cases

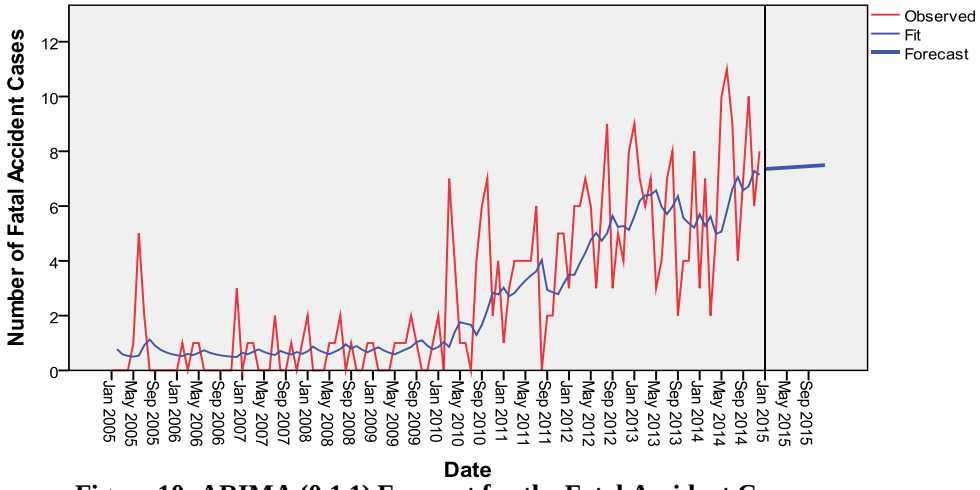

Figure 10: ARIMA (0,1,1) Forecast for the Fatal Accident Cases

Table 6: Comparison of the Actual Accident Data and the Forecasted Values

Month	Total Accident Cases		Fatal Accident Cases	
	Actual	Forecast	Actual	Forecast
Jan	26	24.29	4	7.35
Feb	12	24.08	3	7.37
Mar	26	24.01	11	7.38
Apr	27	23.99	10	7.39
May	19	23.98	4	7.41
Jun	20	23.98	4	7.42
Jul	20	23.98	3	7.43
Aug	14	23.98	6	7.44
Sep	19	23.98	7	7.46
Oct	20	23.98	8	7.47
Nov	8	23.98	3	7.48
Dec	18	23.98	6	7.49

4.0. Conclusion

Time series analysis of road traffic accidents in Anambra State using Autoregressive integrated moving average modelling approach considering both the total number of accident cases and the fatal accident cases has been carried out. The results revealed that the total number of accident cases showed an increasing pattern from 2005 up to the year 2012, then decreasing pattern to the year 2015, and the fatal cases showed an increasing pattern. Out of the various ARIMA models examined, ARIMA(1,1,1) for the total number of accident cases and ARIMA (0,1,1) for the fatal accident cases were selected as the most suitable models for prediction of road accidents in the State based on the lowest BIC, RMSE and MAPE values. The plots of residuals ACF and PACF, and the Ljung-Box statistics showed that both models generated are adequate and good fit for accidents data in Anambra State. The forecasts made with the models showed a slight decrease in the projected total number of accident cases and a slight increase in the projected fatal accident cases in the State.This study will help road safety agency in the State to understand the trends and patterns of road traffic accidents in the state and be able to take proper safety measures to curtail accidents occurrences and severity in the state.

5.0 Recommendation

This study provides useful information on road accidents in Anambra State, Nigeria and suggests to the road users, FRSC and other stakeholders that if urgent actions are not taken, the road accident fatality rate in the State will continue to increase. Hence, this study recommends that various stakeholders (government, road safety commission, drivers, transport companies, road users, etc) should invigorate their efforts in fighting the menace of road accidents in the State. Road Safety Commission should intensify efforts in enforcement of various safety rules, safety education and campaign that will help to reduce road accidents in the State to the barest minimum. Mobile clinics should be stationed along various highways to minimize the number of deaths arising from road accidents.

The future research effort in this regard should involve incorporating various accidents contributing factors observed over the same periods in the ARIMA model (multivariate ARIMA model) and comparing the results with that of solely aggregated accidents count (univariate ARIMA model).

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