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Time Series Analysis of Cases of Road Accidents in Benue State - Nigeria.

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ABSTRACT

Vehicular accidents in Nigeria and Benue State in particular have become one of the growing concern of most Nigerians in recent times. This is as a result of the tremendous negative effects of accidents on human lives, properties and environment as well as economy at large. Many researches have come out with causes, effects and recommendations to vehicular accidents, which include drunk driving, machine failure and over speeding just to mention a few, yet there is an increase in the reported number of accidents and victims in Benue State.

This study has assessed Road accidents cases and casualties in Benue State. The Auto Regressive Integrated Moving Average (ARIMA) as popularized by Box-Jenkins was adopted because of its reliability and accuracy. The selection criterion identified ARMA(2,0) as a suitable model for forecasting traffic road accidents in Benue State while ARMA(2,2) was confirmed to be the best model for forecasting the number of road accident victims in the state from 2014 to 2020. These models minimize the errors of forecast in each case and also show that the autocorrelations were insignificant at all lags. Forecasts for both models are made as a guide to the general public and those involved in accidents prevention and management agencies for informed and intelligent policies as to minimize this ugly situation.

Key words: Time series;Analysis;Road accident;Autoregression;Moving average.

I. INTRODUCTION

Road traffic accidents is a serious issue of concern in Benue and Nigeria at large, which account for over a thousand deaths in the country yearly. The World Health Organization (WHO) classified road accidents as one of the top ten causes of deaths in the world, using International Statistical Classification of Diseases and Related Health Problems (ICD) (Organization, 2013). The Global status report on road safety 2013 presents information on road safety from 182 countries accounting for almost 99% of the world's population. The report indicates that worldwide, the total number of deaths due to road traffic remains unacceptably high at 1.24 million per year. Only 28 countries covering 7% of the world's population, have comprehensive road safety laws on five key risk factors: drinking and driving, over speeding, failing to use motorcycle helmets, failing to use seat-belts, and child restraints. Road traffic accidents are increasing in recent years in Benue State, due to nonchalant attitude of the government to road construction, and violation of traffic laws by motor users in the state. This shows that causes of road traffic accidents are multi-factorial ranging from government factors, driver factors and whether conditions. Road accidents reduces the value of goods and services upon transportation and above all risk human life.

Today, the rapid development of technology and population has greatly increased transportation. Transportation itself is vital to both rural and urban areas. However, the rapid growth of city population and corresponding vehicle kilometers of travel, commerce and transportation infrastructure has generated negative effects such as congestion, deterioration of air quality, noise, and motor vehicle crashes.

Consequently, the use of the undesirable modes such as personalized transport and intermediate public transport is growing at rapid speed, roads and footpaths today are heavily encroached by parked vehicles and roadside business forcing pedestrians to walk on the road.

However, this results not only in restricting only traffic flow, but also putting the pedestrians' life at a great risk. According to WHO (2016), each year an estimated 1.2 million people are killed in road crashes and up to 50 million injured. This scourge, if not properly addressed will be the second most common cause of disability in developing countries (Murray and Lopez, 1996). There is also a competition between different classes of road users coupled with poor road maintenance, bad and inadequate road infrastructure. All these are contributing factors to the serious road safety problems in developing countries like Nigeria. In Nigeria, about 300,000 persons lost their lives in 1,000,000 road accidents between 1970 to 2015, while over 900,000 people suffered various injuries within the same period according to FRSC and Balogun (2006). The accident situation is more serious in Nigeria because of the rapid growth of motor vehicles in the past few years and the inadequacy of many of our roads. The causes of accidents being interplay of a variety of factors, the analysis of accidents data present formidable problems .Qualitative methods of analysis of accidents can provide insight into the causes that contributes to accident and can often help to identify the black spots on the road network system.

According to a World Health Organization (WHO) and World Bank (1999) report on "The global Burden of Disease", deaths from non-communicable diseases are expected to climb from 28.1million to 49.7million by 2025. Road traffic crashes will contribute significantly to this rise. According to the report, road traffic crashes are to move from the ninth position to the third in the rank order of disease burden by the year 2025.

Table: Projected Rank Order of Disease Burden 1990 to 2020

1990			2025
Lower respiratory infections	1	1	Ischaemic heart
Diarrhea	2	2	Unipopular major depression
Perinatal	3	3	Road Traffic Crashes
Unipopular major depression	4	4	Cerebrovascular
Ischaemic heart	5	5	Pulmonary
Cerebrovascular	6	6	Lower respiratory infections
Tuberculosis	7	7	Tuberculosis
Measels	8	8	War
Road Traffic Crashes	9	9	Diarrhea
Cogenital Anornalies	10	10	HIV

Source: www.grsproadsafety.org

In assessing the magnitude of the problem of road crashes, according to WHO, 1.2 million people die through road traffic crashes annually. On the average, in the industrialized countries, and also in many developing countries, one of every ten hospital beds is occupied by road traffic crash victims (NRSC 2010).

The 1999 WHO publication on "Injury: A leading cause of global Burden of Diseases", reports that road traffic crashes are the major cause of severe injuries in most countries and the leading injury related cause of death among people aged 15-44 years. Globally, the WHOP reports that 33,848,625 people were injured through motor vehicle crashes in 1998. Out of the 5.8million people who died of injuries, 1,170,694 (20%) died as a direct result of injuries sustained in motor vehicle crashes.

The above facts reveal unacceptable levels of road traffic accidents and casualties and therefore have both global and national social and economic burden, especially in Nigeria and Benue State in particular as 1.6% of our GDP. There is therefore, need for interventions and strategies to deal with the menace especially by reducing it by 50% by the end of 2025 as recommended in the United Nations (UN) Global Plan for the Decade of Action for Road Safety.

Unfortunately, in Benue State there is an information gap in respect f population and road traffic crashes as enough research have not been conducted in this field, hence the need to analyze the accidents data statistically in relation to the population in order to bridge this information gap in Nigeria in general and Benue State in particular.

Forecasting or seeing the future has always been popular. The ancient Greeks and Romans had their priest examine the entrails to determine outcome of a battle before they attacked. Today entrails are not used in forecasting. Rather, scientific forecasts are based on sound (economic) theory and statistical methods. Many people have mixed opinions about the value of scientific research as they may often found that such forecasts are often wrong.

This opinion is due to basic misunderstanding of the nature of scientific forecasting. Scientific forecasting can achieve two ends

- Provide a likely or expected value for some outcome
- Reduce the uncertainty about the range of values that may result from a future event

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The essence of any risky decision is that one cannot know with certainty what the result of the decision will be. Risk is basically the lack of knowledge about the future. With perfect foresight, there is therefore no risk. Scientific forecasting therefore increases our knowledge of the future and thus reduces risk. However, forecasting has not and will never completely remove all risk

This research lays emphasis on accident analysis on the major roads in Benue State in the North Central region of Nigeria.

1.1 Background to the study

Vehicular accidents in Nigeria and Benue State in particular have become one of the growing concern of most Nigerians in recent times. This is as a result of the tremendous negative effects of accidents on human lives, properties and environment as well as economy at large. Many researches have come out with causes, effects and recommendations to vehicular accidents, which include drunk driving, machine failure and over speeding just to mention a few, yet there is an increase in the reported number of accidents and victims in Benue State.

According to the results of 2006 census, it is recorded that Benue State has a population of 4,253,641 covering 34,059km^2. It is noted with dismay that road traffic accident is responsible for 30% of annual deaths recorded in the last five years in the state.

Reports from World Health Organization Strategy of 2001 indicates that presently road traffic accidents are the leading cause of death and the 9th leading contributor to the burden of disease and disability. In Nigeria, there has been simultaneous increase in the number of vehicles on the road with increased road safety campaign and unfortunately, road conditions, vehicle maintenance and driver instructions have not grown accordingly.

At least 150 road accidents are recorded every year with about 90 deaths resulting from these accidents in Benue State (FRSC, 2003). Moreover, 60% of victims of this said menace are aged between 15 and 55 years. These accidents are associated with driver error, vehicle conditions, road environment, over speeding , road users and a variety of factors (Aworemi, 2010).

Little work on road accidents has been done within the context of regression analysis. A recent study employed binary and multinomial logit regression model to study the effect of posted speed limits on road accidents and found that speed limit do not have any significant effect on road accidents (Nataliya,2006). Kweon and Kockeleman (2003) used Poisson and ordered probit model to analyze road accidents and found that young drivers are far more crash prone than older drivers.

Road traffic accidents research has not extensively been considered within the framework of time series analysis in Nigeria and Benue State in particular. It is in this direction that this research is prepared to study the trends, patterns and forecast of road traffic accidents in Benue. This work therefore will analyze the number of road traffic accidents and casualties in Benue State and will use the data to forecast the near future.

1.1.1 An Autoregressive Process

An autoregressive process $AR_{(p)}$ uses the previous or prior values of a system to determine what the future values of such system are. It is defined by any of the following expressions

$$x_t - \emptyset_1 x_{t-1} - \cdots - \emptyset_p x_{t-p} = \varepsilon_t \qquad (1.1)$$

Or

$$(1 - \emptyset_1 L - \cdots - \emptyset_p L^p) x_t = \varepsilon_t \qquad (1.2)$$

Or

$$\emptyset(L) x_t = \varepsilon_t \qquad (1.3$$

Where

$$\emptyset(L) = 1 - \emptyset_1 L - \cdots - \emptyset_p L^p \qquad (1.4)$$

For an $AR_{(p)}$ process the stationary conditions may be set as follows:

Write

$$\emptyset(L) = (1 - g_1 L)(1 - g_2 L) \ldots (1 - g_p L) \qquad (1.5)$$

Stationarity conditions require

$|g_i| < 1$ for $i = 1..p$

Or alternatively

${g_i}^{-1}$ all lie outside a unit circle. Thus the autocorrelations will follow a difference equation of the form

$$\emptyset(L)\rho_k = 0, \quad k = 1, \ldots$$

Whose solution is of the form

$$\rho_k = A_1 {g_1}^k + A_2 {g_2}^k + \cdots + A_p {g_p}^k \qquad (1.6)$$

The autocorrelation function (ACF) is a mixture of damped exponential and sine terms. These will generally die out exponentially.

1.1.2 The Moving average Process

The moving average process describes the current state of a system through a linear combination of its present state and the lag errors. It is defined by:

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X_t
$= \varepsilon_t$
$+ \theta\varepsilon_{t-1}$

(1.7)

Where ε_t is white noise.

The combination of autoregressive and moving average models gave the autoregressive moving average which is basically applied for a stationary data. For an non stationary data differencing is done so as to achieve stationarity, thus Autoregressive Integrated Moving Average (ARIMA) model

1.2Objectives:

The objectives of this study are to:

i. Estimate ARIMA model parameters that minimizes error(s).

ii. Use the available data to identify a suitable model for forecasting rate of accidents and casualties.

iii. Test the stationarity of the estimated models

iv. Use the findings from the analyzed data and provide recommendations to the relevant agencies involved in road accident management and prevention.

1.3 Significance of the study

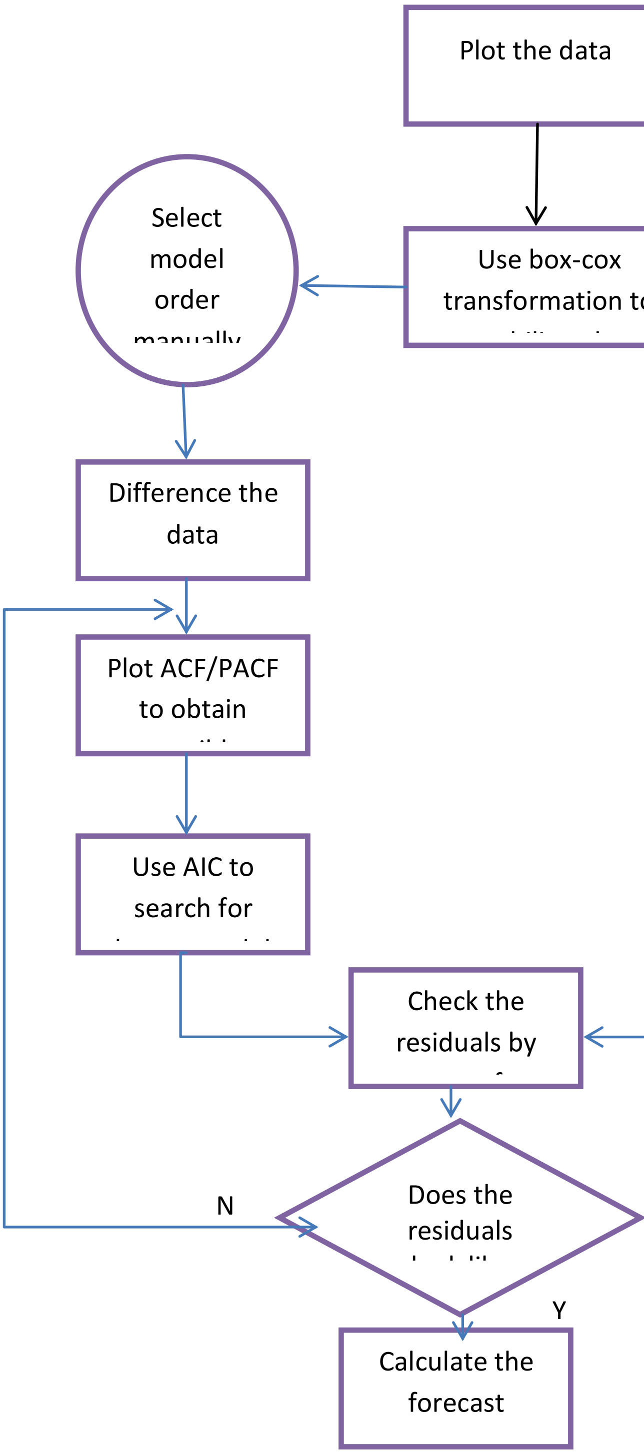
The model would serve as a guide to stakeholders within the road transport system in making informed and intelligent policies with regard to management of road traffic accidents in Benue state. With the predicted results, the general public will better be cautioned thereby reducing the menace. To the literature, it will serve as a reference material for future study on ARIMA and road accidents.

II. METHODOLOGY

A time series is defined as a set of observations arranged chronologically, that is a sequence of observations ordered in time. It describes the history of movement of a variable in a state. In this work, an Autoregressive Moving Average (ARMA) Models will be selected to identify the most suitable fit of a time series to past cases of road accidents in Benue State in order to forecast similar cases and guide both the public and accident prevention agencies in the state on immediate preventive measures.

The formulation of ARIMA or ARMA model depends on the characteristics of the time series. The data will be modeled using Autoregressive Integrated Moving Average (ARIMA) and Autoregressive Moving Average (ARMA) model, popularized by Box and Jenkins(1976). An ARMA (p, q) model is a combination of Autoregressive (AR) which shows there is a relationship between present and past values, a random value and a Moving Average (MA) model which shows that the present value has something to do with the past residuals.

ARIMA Model Flowchart: This chart presents the sequence of processes followed in this work for accurate prediction of traffic road accidents and casualties in Benue State.



2.2 ARIMA (p,d, q) Model

The Autoregressive Integrated Moving Average (ARIMA) Model which difference data to achieve stationarity is mathematically given by

$$W_t = \mu + \frac{\theta(B)}{\varphi(B)}\alpha_t \qquad (2.1)$$

Where
t = index time
W_t = Response series Y_t or a difference of the response series
μ = mean term
B = backshift operator, that is, $BY_t = Y_{t-1}$

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$\varphi(B)$ = autoregressive operator, represented as a polynomial in the backshift operator . $\varphi(B) = 1 - \varphi_1 B - \cdots - \varphi_P B^P$

$\theta(B)$ = Moving average operator, represented as a polynomial in the backshift operator. $\theta(B) = 1 - \theta_1 B - \cdots - \theta_q B^q$

α_t = independent disturbance, also called the random error.

2.3 Box Jenkins Methodology

The ARIMA or ARIMA model as popularized by Box and Jenkins (1976) is of three major stages, namely model identification, model estimation and model verification or diagnostic checking.

Model Identification

Model identification involves examining the given data by various methods to determine the values of p, q and d. These values are determined using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). This can be done by observing the graph of the data or autocorrelation partial autocorrelation function (Makridakis et, al 1998). For any ARIMA (p, d, q) process, the theoretical (PACF) has no zero partial autocorrelations at all lags. The non-zero lags of the sample PACF and ACF are tentatively accepted as the p and q parameters. For a non stationary series, differentiation determines the order of d. Thus, for a stationary data d=0 and ARIMA (p,d,q) can be written as ARMA (p,q).

Model Estimation

After an optimal model has been identified, the model estimation methods make it possible to estimate simultaneously all the parameters of the process, the order of integration coefficient and parameters of an ARMA structure. The estimators of the exact maximum likelihood proposed by sowell is the vector which maximizes the log likelihood function .

Model Verification

The last step is model verification or model diagnostic check, which involves assessing the residuals of the model to determine whether to accept the model or reject it. For methods of residual assessment, if evidence results in latter case, whether it is from inadequacies of the model or availability of additional data, the model building process will need to be repeated from step 2, or even step 1. Repeating this process may occur many times before a model is finally decided upon. Thus model is an iterative, interactive process.

So, given multiple competing models, we decide upon a final one model which satisfies the model selection criterion: Akaike's Information Criterion (AIC), Schwartz Information Criterion (SIC) and Hannan Quinn Criterion (HQC) which attempts to choose a model that adequately describes the data but in the most parsimonious way possible, or in other words, minimizing the number of parameters. In general, the chosen model minimizes the respective criterion score.

2.4 Akaike's Information Criterion

Akaike's information criterion (AIC) originally proposed by Akaike, attempts to select a good approximating model for inference based on the principle of parsimony. AIC proposes the use of the relative entropy, or the kull back-Leibler (K-L) information as a fundamental basis for model selection. A suitable estimator of the relative K-L information is used and involves two terms. The first term is the measure of lack nof model fit, while the second is a "penalty" for increasing the size of the model, assuring parsimony in the number of parameters. The AIC to be minimized is

$\mathrm{AIC} = \mathrm{NLog(SSE)}+2\mathrm{K}$

(3.5)

N is the sample size, ss_e is the residual sum of squares of error and k is the number of parameters.

2.5 Schwarz's Bayesian Information Criterion

The Bayesian Information Criterion (BIC), originally proposed by Schwarz was derived in a Bayesian Context and is dimension consistent in that it attempts to consistently estimate the dimension of the true model. It assumes that a true model exists in the set of candidate models, therefore requires a large sample size to be effective. The BIC criterion to be minimized is

$\mathrm{BIC} = \mathrm{Nlog(SSE)} + \mathrm{klogN}$

(3.7)

n is the sample size, k is the number of parameters

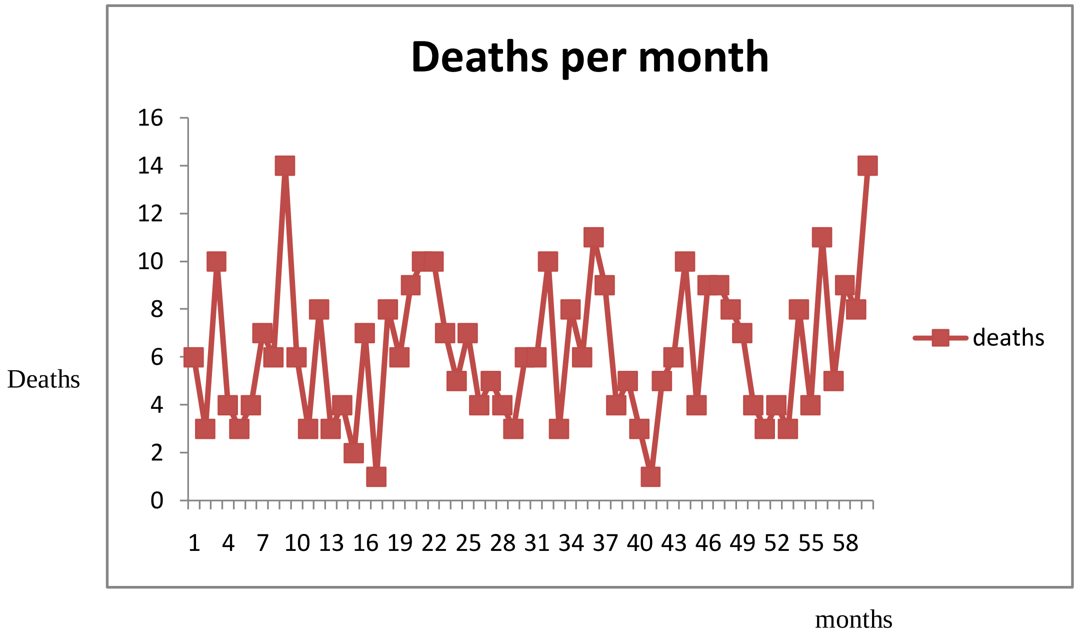

Fig 4.1: Time series plot of number of accidents In Benue State from 2014 to 2018.

MODEL	Number of parameters	Residual Sum of Errors	AIC	BIC
ARMA(1,0)	1	1411.05	701.24	712.33
ARMA(1,1)	2	2102.72	711.93	724.07
ARMA(1,2)	3	1400.98	699.05	709.97
ARMA(1,3)	4	1478.53	703.56	718.85
*ARMA(2,0)	2	*1319.16	*679.96	*691.45
ARMA(2,1)	3	1813.90	698.50	720.09
ARMA(2,2)	4	1456.07	701.32	723.81

From the table above, we observed that the optimal model is ARIMA (2,0,0) that is based on the selection criterion, number of parameters, residual sum of errors, AIC and the SIC

Thus substituting this in the ARMA(2,0,0) function

$$y_t = \mu + \emptyset_1(y_{t-1} - \mu) + \emptyset_2(y_{t-2} - \mu) + \theta\varepsilon_{t-1} + e_t$$

We obtain

$$y_t = 19.3 + 0.4561(y_{t-1} - 19.3) - 0.03595(y_{t-2} - 19.3)$$

$$y_t = 11.19 + 0.4561y_{t-1} - 0.03595y_{t-2} \quad (4.0)$$

From the bounds of stationarity for ARIMA (2,0,0)

$$\emptyset_1 = 0.4561, \qquad \emptyset_2 = -0.03595$$

$$|\emptyset_2| < 1, \qquad -1 < \emptyset_2 < 1$$

$$\emptyset_1 + \emptyset_2 < 1, \quad |\emptyset_1| < 1\emptyset_2 - \emptyset_1 < 1$$

Using similar arguments on page , we deduce that $y_t = 3.6895 + 0.4561y_{t-1} - 0.03595y_{t-2}$ is stationary.

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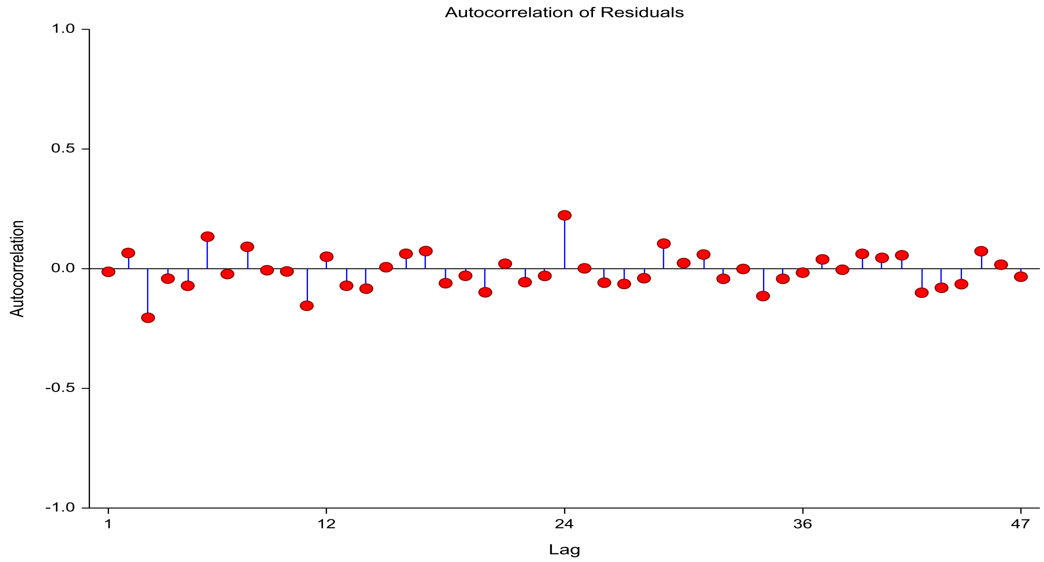

Fig.4.1 Autocorrelation Plot of Benue State Road Accidents Occurrences

It was stated earlier in this study that for a fitted model to follow a white noise process, about 95% of all sample autocorrelation values(i) to be within the range $\pm 1.96\frac{1}{\sqrt{n}}$. It therefore means that the model follows a white noise process.

III. RESULTS

(i) The models satisfy qualities of a good model according to Stephen (1998)
(ii) The model can be used to forecast future occurrence of road accidents in Benue State in particular and Nigeria in general

IV. CONCLUSION

This study has assessed the predictive capabilities of accidents occurrence in Benue State. The main contribution of this study is evaluating the performance of the various time series model in a comprehensive and systematic way. Empirical results in this work will pave way for other future research in sciences, statistics and management.

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