An Intervention Theoretic Modelling Approach on the Performance Assessment of Federal Road Safety Corps in Road Traffic Casualty Reduction in Nigeria

Benjamin Ufuoma Oreko, *Member, IAENG* and Stanley Okiy, *Member, IAENG*

Abstract— In this work, intervention theoretic model technique was employed to assess the performance of Federal Government of Nigeria in road traffic casualty (injury and death) reduction through the institution of Federal Road Safety Corps, FRSC. Time series intervention model was used to analyze 55 -year (1960-2014) road traffic casualties in Nigeria. It was observed that a combination of Autoregressive Integrated Moving Average model, ARIMA 0,1,0, and first order type of intervention function amply captured the pattern of road traffic casualties in Nigeria. From the result obtained the multiple policy intervention measures introduced by Road Safety agencies are effective in whittling down road traffic casualties in Nigeria.

Index Terms — Intervention theoretic model, Road traffic casualties, ARIMA, FRSC

I. INTRODUCTION

Road traffic accidents have resulted in the loss of lives, untold injuries and unaccounted loss of goods in Nigeria. In Nigeria, an effort had been made to evaluate road traffic accident situations using various statistical methods. However, little work has been done in assessing the performance and efforts of Federal Government of Nigeria in road traffic casualty reduction. Available studies that had been carried out in Nigeria employing mathematical models on road traffic accident situations were either limited to towns, States or the entire country with a limited number of years [1, 2, 3, 4, 5, 6]. Although [7] applied intervention model in assessing the impact of FRSC on road traffic accident occurrences, their work was limited to the Edo State of Nigeria for a period of 5 years (1994-2000). The result from their study indicated that road traffic accidents in that area were on the decreasing trends. However, their works in part may not reflect well on road traffic casualties in Nigeria and the effort of Federal Government of Nigeria in whittling down road traffic casualties. Hence, this work intended to develop a mathematical model capable of assessing the intervention of Federal Government of Nigeria through the institution of Federal Road Safety Corps, FRSC in the reduction of road traffic casualties (injuries and deaths) in Nigeria.

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II. METHOD

A. Research Design

The main focus of this research was to develop a model capable of evaluating and assessing the impact of intervention measures implemented by Federal Road Safety Corps (FRSC) and other safety agencies on road traffic casualty reduction in Nigeria. Intervention Model was developed and fitted to road traffic casualties (injuries and deaths) in Nigeria. SPSS 16.0 version and Excel 2010 software were used for the analysis. Also, C++ software program was used to developed code to compute the intervention model response. A statistical test was done to confirm the adequacy of the ARIMA models. Also, the sampling unit is geographical, involving the 36 State

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structures and the Federal capital, Abuja, Nigeria. The technique adopted in this research is the non-experimental research design concept. This concept deals mainly on data collections. A Fifty- five (55) year road traffic casualty data (1960 to 2014) were collected from the Department of Planning, Research and Statistics, Federal Road Safety Corps Headquarters, Abuja [8]. This agency, apart from the obligation to prevent or reduce road traffic accident occurrences in Nigeria, it is also saddled with the responsibility of recording and keeping data observed from the scene of road traffic accidents [9].

B. Method of Data Analysis and Model Employed

Tables, scatter plots, autocorrelation functions (ACFs) and partial autocorrelation functions (PACFs) were employed in the analysis of data in order to determine the pattern, trends and other statistical features for robust model building methods. In this work, we employed intervention model technique of [10] in assessing the impact of FRSC in minimizing road traffic casualties in Nigeria. Generally, intervention model constitutes two main components namely, an intervention function, $f(I_t)$ and an Autoregressive Integrated Moving Average (ARIMA) model, N_t as stated in [10]. Mathematically, the First-Order Intervention model, according to [10, 11] could be expressed as;

$$Y_{(t)\ intervention} = f(I_t) + N_t \quad (1)$$

and it consists of the following components;

(a) Gradual and permanent impact- which could be expressed as,

$$Y_{(t)Intervention} = \theta_0 + \frac{\omega_0}{(1-\delta_1 B)} I_t \quad (2)$$

(b) Abrupt and Temporary impact - which could be expressed as,

$$Y_{(t)Intervention} = \theta_0 + \frac{\omega_0(1-B^5)}{(1-\delta_1 B)} I_t \quad (3)$$

where, $f(I_t)$ = The intervention function; N_t = ARIMA and

$$I_t = \begin{cases} 1, & when\ intervention\ occurs \\ 0, & otherwise \end{cases} \quad (4)$$

According to [10], ARIMA components model in equation (5), (6) and (7) could be combined to obtain other components of the ARIMA models.

i. ARIMA (1,0,0) or AR(1) model could be expressed as;

$$Y_{(1,0,0)} = \theta_0 + \emptyset_1 Y_{t-1} + e_t \quad (5)$$

where, $\theta_0, \emptyset_1$ are constant and coefficients, respectively chosen to minimize the sum of squared errors;

$|\emptyset_1| < 1$= bound of stationarity;

Y_t = Actual values; Y_{t-1} = previous values;

e_t = residual errors

ii. ARIMA (0,1,0) could be expressed as

$$Y_{(0,1,0)} = Y_{t-1} + e_t \quad (6)$$

iii. ARIMA (0, 0, 1) could be expressed as

$$Y_{(0,0,1)} = \mu + \theta_1 e_{t-1} + e_t \quad (7)$$

C. Basis for Model Selection

In this work, ARIMA models were analyzed. An attempt was made to consider Bayesian Information Criterion (BIC), as the first criteria (performance measures) in selecting the best ARIMA model that would be employed in forecasting road traffic casualties. Whenever ties exist in BIC, the Coefficient of determination (R^2), Root Mean Squared Error (RMSE) and Mean absolute percentage error (MAPE) would be considered sequentially in the model fit selection.

D. Pre-Intervention Analysis

To model the impact of FRSC, other safety agencies and government policies (interventions), it is imperative to model the time series data of road traffic casualties when there was no established institution to intervene in road traffic casualties (interventions). Here, we assumed that prior to the establishment of FRSC, there were no well-coordinated governmental agencies saddled with the responsibility of reducing road traffic accidents to the barest minimum, thus resulting to little effect or impact that could be neglected. This required that we model the pre-intervention period which exists as ARIMA noise, N_t in the equation (1). Hence, the pre-intervention period for road traffic casualties in Nigeria was computed from 1960 to 1987, before the establishment of FRSC in 1988.

III. RESULTS AND DISCUSSIONS

A time series plot of road traffic casualties from 1960 to 1987 and from 1960 to 2014 was plotted in Figures 1 and 2, respectively. It appears that the plot shows no specific trend in road traffic casualties from 1960-1987, but an irregular increasing pattern. However, a discernible decline was

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noticeable in 1988, which shows an irregular decreasing and increasing pattern from 1988 to 2014 in figure 2. In order to determine whether there was an existence of ARIMA components, autoregression functions, and partial autoregression functions were evaluated and plotted in Figures 3 and 4, respectively. The plots indicated an existence of ARIMA components model. The result of model adequacy for the various components of ARIMA models was tabulated in Table 1.

Table1 Model Adequacy of ARIMA Components

Road Traffic Casualty Model	**BIC**	**R^2**	**RMSE**	**MAPE**
ARIMA (0,0,0)1	17.261	0.784	$4.970x10^3$	17.423
ARIMA (1,0,0)1	16.637	0.901	$3.430x10^3$	11.665
ARIMA (0,1,0)1	16.901	0.890	$3.663x10^3$	12.443
ARIMA (1,1,0)1	16.772	0.886	$3.652x10^3$	12.190
ARIMA (1,1,1)1	16.901	0.890	$3.663x10^3$	12.443
ARIMA (0,1,1)1	16.772	0.886	$3.652x10^3$	12.189
ARIMA (0,0,1)1	16.929	0.868	$3.968x10^3$	14.135
ARIMA (1,0,1)1	16.780	0.903	$3.470x10^3$	11.746
ARIMA (1,0,0)	16.893	0.851	$4.135x10^3$	15.021
ARIMA (0,1,0)	16.460	0.885	$3.529x10^3$	11.666
ARIMA (1,1,0)	16.621	0.885	$3.598x10^3$	11.623
ARIMA (1,1,1)	16.747	0.889	$3.598x10^3$	11.623
ARIMA (0,1,1)	16.621	0.885	$3.598x10^3$	11.623
ARIMA (0,0,1)	17.948	0.571	$7.009x10^3$	31.405
ARIMA (1,0,1)	17.047	0.851	$4.209x10^3$	15.068

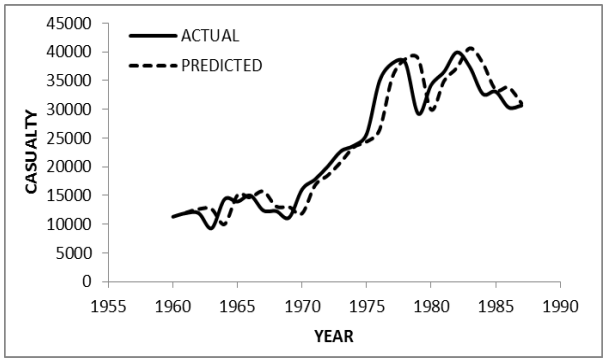

Fig. 1. Plot of actual and fitted value of Road traffic casualty from 1960-1987 (Pre-intervention period).

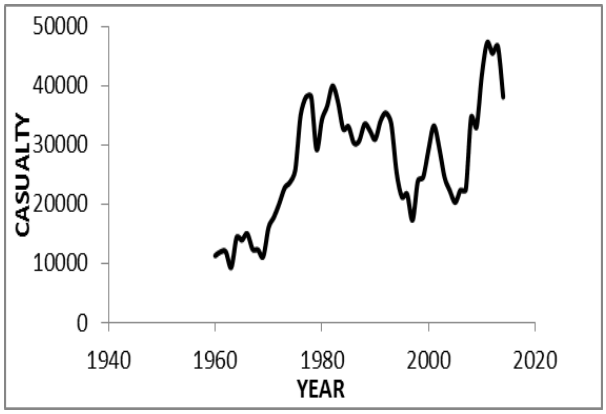

Fig. 2. Plot of actual values of Road traffic casualty from 1960-2014.

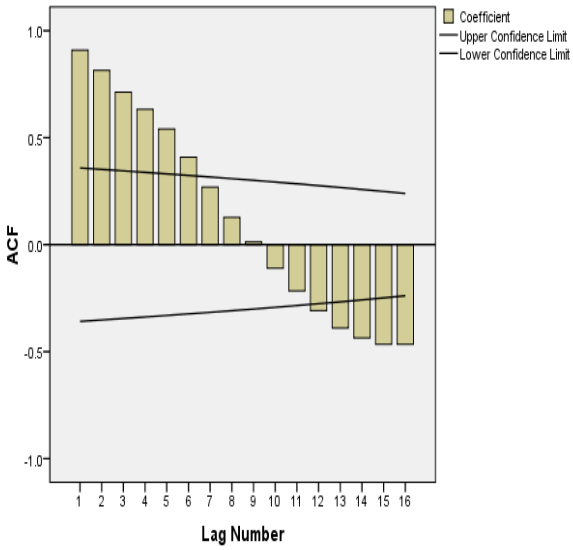

Fig. 3. Autoregression function ACF for road traffic casualty in Nigeria from 1960 – 1987.

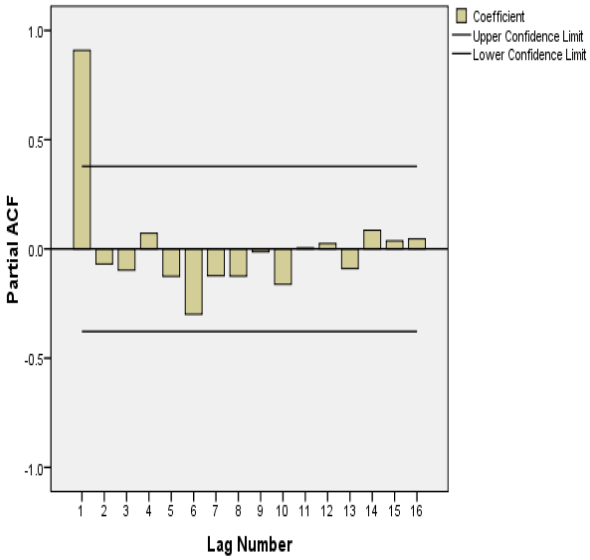

Fig. 4. Partial Autoregression Function (PACF) for road traffic casualty in Nigeria from 1960 – 1987

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A close examination of Table 1, for the pre-intervention period of road traffic casualties in Nigeria, suggested a random walk process of ARIMA (0,1,0) model which has the lowest BIC value of 16.460. From figure 2, the impact of the intervention was noticeable from 1988 with an exponential decreasing and increasing profile. We observed that the pattern was of gradual - temporal impact of the first order intervention functions. Therefore, applying equation (4), we have,

$$I_t = \begin{cases} 1, on\ and\ after\ 1988,\ when\ FRSC\ was\ established \\ 0, before\ 1988, when\ FRSC\ was\ not\ established \end{cases} \quad (8)$$

From equation (6) the fitted model for ARIMA noise is

$$Y_{(0,1,0)} = \theta_0 = Y_{t-1} \quad (9)$$

From equation (9), the previous actual value of road traffic casualties best predicts future value. Hence applying equation (3), where θ_0 = N_t = normal central value (which represents road traffic casualties in Nigeria obtained from ARIMA analysis); ω_0= Effect of the intervention on road traffic casualties. We have,

$$Y_{(t)Intervention} = \delta_1 Y_{t-1} + (1-\delta_1)\theta_0 + \omega_0(1-B^5)I \quad (10)$$

And taking δ_1 = 0.5, chosen for model stability. The intervention model for road traffic casualties in Nigeria for 1960 to 2014 is developed as;

$$Y_{(t)Intervention} = 0.5Y_{t-1} + 0.5\theta_0 - \omega_0 I_t + \omega_0 I_{t-5} \quad (11)$$

A code was developed with a computer program written in C++, for easy computation of the intervention result. The result of the actual value of road traffic casualties against the fitted intervention model response developed from 1960-2014 is shown in figure 5. We observed that total road traffic casualty occurrences in Nigeria are on the decreasing profile especially from the inception of Federal Road Safety Corps in 1988 as in figure 5, which shows a temporal reduction of road traffic casualty occurrences from one period to another, occasioned with a significant increase in some period especially from 2008 to 2014. This increment might have been as a result of an upsurge in the number of vehicles on Nigeria roads, poor road networks, road traffic rules violation and rapid population growth in recent times. Overall, the impact of intervention measures had to a considerable level resulted in the reduction of road traffic casualties in Nigeria. This impact is as result of the multiple policy interventions introduced by road safety agencies in reducing road traffic accidents occurrence in Nigeria. Some of these policies include the presence of FRSC and police staff on the road to enforce compliance of road safety rules, penalties for road traffic rules violators, road safety education programs, maintenance of existing roads and construction of new ones etc. If road safety agencies in Nigeria would continue to build on the existing structures, policies and synergy and the Federal Government of Nigeria could adequately maintain existing road, new road networks and alternative means of transportation (such as railway and waterways) are adequately provided to meet the growing demands and pressures on the roads, there would be a systematic reduction of road traffic casualties in Nigeria [8].

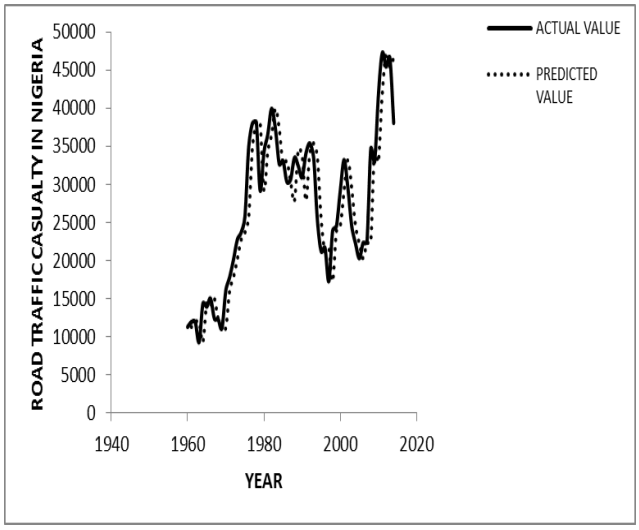

Fig. 5. Plot of actual value of road traffic casualty with intervention measures versus fitted model response

IV. Conclusion

The model developed could assist Federal Government of Nigeria and its established safety agencies such as the Federal Road Safety Corps, the Nigeria Police Force, other stakeholders and the general public to assess the impact of government efforts on road traffic casualty reduction in Nigeria.

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