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Road traffic crashes trends of severity and injuries in Osun state, Nigeria

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ABSTRACT
Road traffic accidents (RTA) have been of concern both in developed and developing nations of the world. This study examined the road accident trends in Osun State, Nigeria, over 7 years (2015 to 2021). The dataset used is secondary data obtained from the Federal Road Safety Commission (FRSC), Osun State, Nigeria. This includes the number of cases (fatal, serious, and minor), the number of people dead, and the number of people injured. Multivariate Time Series analysis shows that an average of 243 and 44 people were injured and killed, respectively, quarterly. For the total of 1859 reported cases, 6809 and 1232 people were injured and killed, respectively, for the 7 years. The Vector Autoregressive (VAR) model was applied to study the underlying patterns and forecast future values for the number of deaths and injuries for the year 2022. Based on the value of Akaike's Information Criteria (AIC) and Bayesian's Information Criteria (BIC), the model with the constant was the best of all. The result of the forecast indicates that 245 people are predicted to be injured in the first quarter of 2022 and 243 people in the second, third, and fourth quarters. 44 people are predicted to be killed in the first quarter of 2022 and 45 people in the second, third, and fourth quarters, accident occurrence for the 7 years has a low severity index. According to the findings, it was discovered that the number of people injured and killed in traffic accidents has been rising over time. This is the outcome of several variables, including environmental, human, and road-related factors. Therefore, to decrease traffic-related deaths and injuries, the government and concerned non-governmental organizations must embark on educating drivers about defensive driving, enforcing road traffic laws, and traffic education to the populace.

Keywords: traffic, crashes, severity, injuries, multivariate time series, road

1. INTRODUCTION
Road traffic accident (RTA) is the top cause of death for people between the ages of one and twenty-nine worldwide (WHO, 2015). By 2030, it is anticipated that two million people will die in motor vehicle accidents annually if current trends continue. Road accidents are currently the ninth most serious cause of mortality worldwide, and if no new steps are taken to increase road safety, fatal accidents will certainly move up to the third spot (WHO, 2015).

Nigerians are increasingly concerned about traffic accidents; this is because it affects all societal groups in the nation. The International Statistical Classification of Diseases and Related Health Problems has listed road traffic accidents as one of the top 10 global causes of death (Samuel et al., 2016). Odugbemi (2010) defined road traffic accidents as something that happens unexpectedly, unintentionally, or by chance. Road traffic accidents have been reported to have globally growing incidence, morbidity, and fatality rates, with the majority of these deaths and injuries taking place in developing nations like Nigeria (Eze, 2012; Agbonkhese et al., 2013). According to Sanusi et al. (2016), the government's casual approach towards road construction and motor vehicle users' violations of traffic laws are the main causes of Nigeria's rising trend in road accidents. Infractions of traffic laws committed by drivers include overloading vehicles, mechanical problems, driving while intoxicated, utilizing out-of-date vehicles, and exceeding the posted speed limit. Given the severity of the problem it poses to every road user in Nigeria, road traffic accidents have been regarded as a highly significant issue requiring a comprehensive approach to lowering their frequency.

Past studies have examined road traffic accident occurrences and formulated a model for accidents. Adreinlewo and Afolayan (2019) established an accident prevention model for the Akure-Owo highway and concluded that the model can help reduce the number of accidents. In another study, Aderinlewo and Afolayan (2017) developed an accident prediction model for the Akure-Owo highway and inferred that the model could accurately predict the number of accidents on highways with similar geometric characteristics. Afolayan et al. (2022) also identified accident hotspots on the Lokoja-Abuja-Kaduna highway using the Geographical Information System. Their study provided necessary countermeasures for accident occurrence in the study area. With the growing number of studies on accident occurrence, only a handful of studies have established accident trends using the vector autoregression model. Based on the foregoing, this paper is aimed at examining the trends of severity and injuries in road traffic accidents in Osun State, Southwestern, Nigeria with the underlying objectives of establishing the trends of accident occurrences over seven years (2015-2021) in the state, modeling the number of people injured and killed in RTA using the vector autoregressive model, and forecasting the number of people that would be injured in the year 2022.

2. METHODOLOGY

The data collected for this study is for the total number of road traffic accidents in Osun State for the years 2017 to 2021. These were sorted into four quarters (i.e. Jan-Mar-1st quarter, Q1; Apr-Jun-2nd quarter, Q2; Jul-Sept-3rd quarter, Q3; and Oct-Dec.-4th quarter, Q4). These include the number of persons injured and the number of persons killed for the same period. All these were obtained from the FRSC, Osogbo office. In addition, past studies on road traffic accidents were consulted, and data were sourced from the Internet. The data were analyzed using multivariate time series and modelled using the vector autoregressive (VAR). The Statistical Package for the Social Sciences (SPSS) was used for the analysis.

2.1 The study area

The study area is Osun State, Southwestern Nigeria. The state was created on August 27, 1991, from the eastern part of Oyo state, with its capital in Osogbo City. It has a square area of 9,251 km2, the nineteenth most populous with an estimated population of about 4.7 million as of the 2016 census. Geographically, the state is bounded by Kwara in the Northeast, Ekiti and Ondo in the East, Ogun in the South, and Oyo in the West and Northwest. The Yoruba Hills run through the northern part of Osun State. The state has a covering of tropical rainforest, and the Oshun River is the most important. It is inhabited mainly by the Yoruba people (Britannica, 2006) and lies at the coordinates of 7°30' N and 4°30'E.

Osogbo, the state capital city, has a textile industry, a food-processing plant, and a steel rolling mill. The state tourist attractions include the Mbari Arts Centre at Oshogbo, the residential palaces of Yoruba rulers in Ilesha and Ile-Ife, and the Osun-Osogbo Sacred Grove, a forest that contains several shrines and artwork in honour of the Yoruba deity. The grove was designated as a UNESCO World Heritage site in 2005. This allows for the inflow of traffic yearly within the state as tourists visit the sites. The state is linked by road and railway to Ibadan in Oyo state. Figure 1 shows the GIS road network map of the study area.

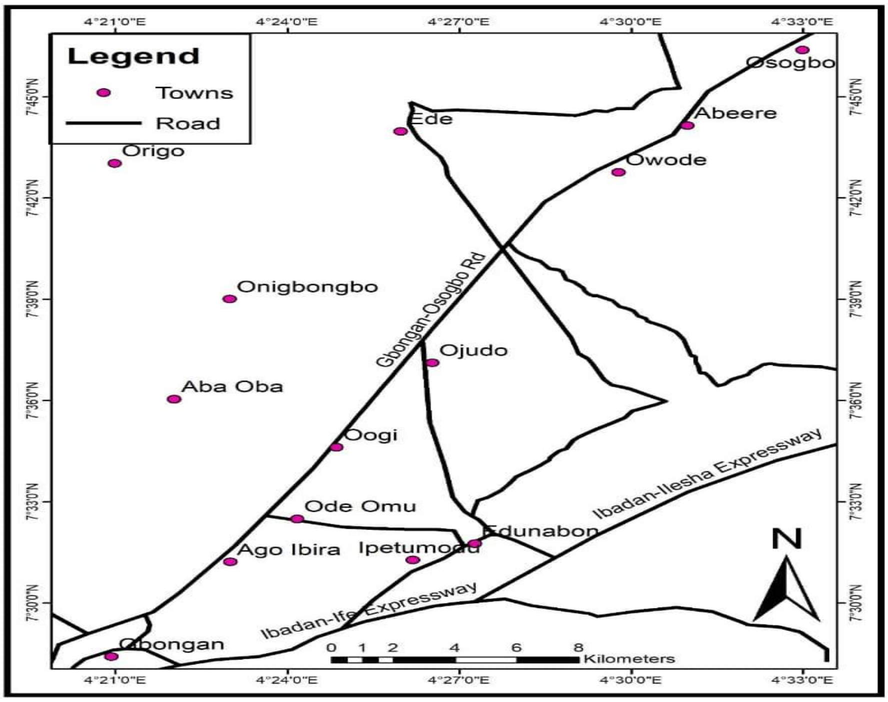


Figure 1. GIS road map of the study area

2.2 Multivariate time series

A time series is a sequence of observations (P_t) ordered in time. That is P1, P2, P3, ….., PN or $\{P_t\}$, $_{TN}$ where the time steps are denoted by 1, 2, 3. Mostly, these observations are collected at equally spaced, discrete time intervals. When there is only one variable upon which observations are made, then we call them a single time series or, more specifically a univariate time series, but if there is more than one variable, then it is called a multivariate time series. A basic assumption in any time series analysis/modelling is that some aspects of the past pattern will continue to remain in the future. Also, under this setup, often the time series process is assumed to be based on past values of the main variable but not on explanatory variables, which may affect the variable/system.

Time series models have advantages in certain situations. They can be used easily for forecasting purposes because historical sequences of observations upon study variables are readily available from published secondary sources. These successive observations are statistically dependent, and time series modelling is concerned with techniques for the analysis of such dependencies. Thus, in time series modelling, the prediction of values for future periods is based on the pattern of past values of the variable under study but not generally on explanatory variables which may affect the system. The Vector Autoregressive model (VAR) was used to analyze the multivariate time series.

2.3 Vector autoregressive (VAR) model

The VAR model is one of the most successful, flexible, and easy-to-use models for the analysis of multivariate time series (Gupta, 2021). It is a natural extension of the univariate autoregressive model to a dynamic multivariate time series. The VAR model has proven to be especially useful for describing the dynamic behaviour of economic and financial time series and forecasting. Forecasts from VAR models are quite flexible because they can be made conditional on the potential future paths of specified variables in the model. The VAR model is utilized not just for data description and forecasting but also for structural inference and policy research. In structural analysis, particular assumptions are made regarding the causal structure of the data being investigated and the ensuing causal implications of unforeseen shocks or innovations to defined variables in the model. Typically, forecast error variance decompositions and impulse response functions are used to summarize these causal effects. A stationary test must be conducted initially for a VAR model. Forecasting for Vector Autoregressive (VAR) Model (Gupta, 2021).

Vector Autoregression forecasting models are used when two or more series influence each other, i.e. the association between the time series affected is bi-directional. Each time series (variable) is modeled as a function of the past values, that is the independent variables (predictors) are time-delayed values of the series. In the study, future accident occurrences are predicted quarterly using the model.
The VAR model is defined as follows:

$$q_t = v + \sum_{j=1}^{p} A_j \, q_{t=f} + u_t \quad (1)$$

Where $t = 1, 2, \ldots \ldots .., T$

The assumption made is that q_t = stationary K-variable vector, V= K constant parameters vector, A_j = K by K parameters matrix, j = 1, …., P, u_t = i.i.d. (0, Sigma). The trend may be involved i.e. delta (t), where delta is K by 1, also exogenous variable x may be included. To evaluate Equation 1, the ordinary least squares (OLS) method was employed. Following the assumption that the error value has a conditional mean of zero, the predictors in the model are stationary, with no outliers, and the multicollinearity is not perfect.

2.4 The lag selection criteria

Lag selection is a vital component of VAR model specification. In practice, a maximum number of lags, p(max), is selected to estimate the performance of the model, including P = 0, 1,…., p(max). The optimized model is then the model VAR (p), which reduces some lag selection criteria as follows:

$$q_t = a + A_1 Q_{t-1} + A_2 Q_{t-2} + \cdots + A_p Q_{t-p} + \mathcal{E}_t \quad (2)$$

where: q_t = (q1t, q2t,….., qnt) is an (n*1) vector of time series variables, a = an (n*1) vector of intercepts, A_i (i = 1, 2, …, p) = (n*n) coefficient matrices, and $\mathcal{E}_i$ = an (n*1) vector of unobservable i.i.d. zero mean error term. The Akaike's Information Criteria (AIC), Bayesian Information Criteria (BIC), and Hannan-Quinn Criteria (HQC) were used for the lag selection criteria in this study.

The VAR models were used to generate accident forecasts in this study using the iterative forecasting algorithm as follows:

- Evaluation of the VAR model using OLS for each expression
- Computation of the one-period-ahead forecast for all variables (i.e. number injured and the number of deaths)
- Estimation of the two-period-ahead forecasts using the one-period-ahead forecast.
- Iterating until the h-step ahead forecasts are estimated.

2.5 Accident severity index

The accident severity index is the proportion of deaths that result from road accidents. For the analysis, accident rates are computed based on the previous work of Vitus (2014), who ranked the level of severity of accident cases as shown in Table 1.

Table 1. Accident severity index (Vitus, 2014)

Range of Values	Descriptions	Severity
0.00 - 2.99	If the proportion lies between the range	low
3.00 – 5.99	If the proportion lies between the range	medium
6.00 – 8.99	If the proportion lies between the range	high

The severity Index is equal to the ratio between the number of people killed and the number of fatal crashes.

3. RESULTS AND DISCUSSION

3.1 Descriptive statistics of the study area

The data obtained from FRSC were analyzed to determine the average value of accidents. As shown in Table 2, out of the 1859 reported cases of accident, the average number of persons injured between 2015 to 2021 six years was 243 people, while 44 people lost their lives. A minimum of 8 people had severe accidents, while 52 people sustained injury. The maximum number of deaths is 82 people, while 496 people sustained injury within the period under consideration. Based on the reported accidents, 95% of the reported cases had 72 people having a severe accident with 328 people with injury. The coefficient of variation of the number injured and death is 37% and 42%, respectively; this implies that 37% of factors associated with accident injuries are included in the analysis and 42% for death. The difference between the coefficient of variation of people injured and death was 5%. Some of the factors include road, vehicle, environmental, and human factors.

Table 2. Descriptive statistics of accident data (2015-2021)

Description	No. Injured	No. Death	No. Reported Cases
Mean	243.00	44.00	66.00
Median	242.00	46.00	61.00
Minimum	52.00	8.00	18.00
Maximum	496.00	82.00	111.00
Std. Dev.	88.86	18.42	24.85
Coefficient of Variation	0.37	0.42	0.37
15^{th} percent	112.00	20.00	44.00
95^{th} percent	329.00	72.00	107.00
Sum	6809.00	1232.00	1859.00
Sum Sq. Dev.	221110.11	9496.00	17296.68

3.2 Vector autoregressive (VAR) model

The selection of the best VAR model was carried out using the selection criteria known as the AIC, BIC, and the HQC for the best 3 models, which are: (i) Model with Constant only (ii.) Model with Constant and Trend (iii.) Model with Constant Trend and Seasonal dummies. Therefore, the model with constant only will be considered the best VAR model for this data and will be used for forecasting. Table 3 shows the selection criteria for the VAR model. Based on the results, variations between the AIC, BIC, and HQC values for the constant-only model are insignificant compared to the other two models. This implies that the constant-only model fits the data well, which infers that the AIC, BIC, and HQC have comparable properties. Hence, the model with constant only is selected as the best VAR model for the accident data and employed for the forecasting process.

Table 4 shows the VAR model summary; the trends in accident occurrence from the 1st quarter of the year 2015 to the 4th quarter of the year 2021 gave a value of 28. This indicates that accident occurrence on the roadway within the six years considered does not increase geometrically. In addition, a negative likelihood of -537.40108 was obtained. This implies that there is a negative relationship between the two variables included in the model. This suggests that, as the number of people injured in accidents increases, the number of deaths decreases and vice versa.

The results of VAR models for the number of injured and dead are shown in Tables 5 and 6. The impact of each variable on the other is clearly shown in the table. The number of people injured in accidents contributes 88.89% to accident occurrence, while the number dead has 22.18% proportions in the model. This implies that the number of people injured in accident occurrence in the case study area is more compared to the number dead and has a great impact. This is expected as those that sustained injuries in an accident occurrence are sometimes those that are reported dead at a later day depending on the severity of the injury.

Table 3. Selection criteria for VAR model

Models	AIC	BIC	HQC
Constant only	16.3212*	16.5124*	16.3972*
Constant and Trend	16.3407	16.5956	16.4421
Constant, Trend, and Seasonal Dummies	16.7133	17.6694	17.0935

* Represents the chosen models

Table 4. VAR model summary

VAR system, lag order 1
OLS estimates, observations 2015: Q1-2021:Q4 (T = 28)
Log-likelihood = -573.40108
Determinant of covariance matrix = 35468.096
Portmanteau test: LB (17) = 57.4446, df = 64 (0.7057)

Q1 represents the first quarter, and Q4 is the fourth quarter

Table 5. Model summary for number injured

	Coefficient	Std. Error	t-ratio	p-value
Constant	60.9612	7.67709	7.9407	<0.0001***
Injured	0.0238782	0.137417	0.1738	0.8626
Dead	-0.66291	0.535823	-1.2372	0.2203
Mean dependent variable	55.88732	S.D. dependent variable		29.68913
Sum squared residual	60127.44	S.E. of regression		29.73596
R-squared	0.025505	Adjusted R-squared		-0.003157
F (2, 68)	0.889848	P-value (F)		0.415446
Rho	-0.017190	Durbin-Watson		2.021792

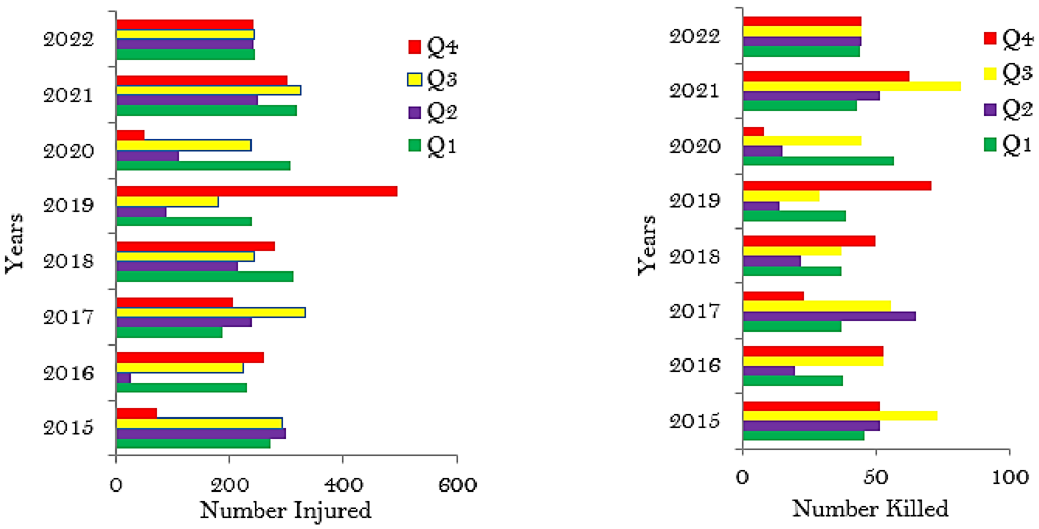
*** significance at 2-tail

Table 6. Model summary for number dead (killed)

	Coefficient	Std. Error	t-ratio	p-value
Constant	10.5369	1.97367	5.3387	<0.0001***
Injured	-0.023440	0.0353279	-0.6635	0.5092
Dead	0.0519781	0.137752	0.3773	0.7071
Mean dependent variable	9.732394	S.D. dependent variable		7.559210
Sum squared residual	3973.986	S.E. of regression		7.644669
R-squared	0.006482	Adjusted R-squared		-0.022739
F (2, 68)	0.221843	P-value (F)		0.801619
Rho	0.013063	Durbin-Watson		1.966993

3.3 Accident forecasting

The primary objective of the multivariate time series analysis is forecasting. Forecasting from a VAR model is similar to forecasting from univariate models. The models in Tables 5 and 6 were used to forecast for 4 data points i.e. 1st quarter- Jan.-Mar. (Q1), 2nd quarter- Apr.-June (Q2), 3rd quarter-Jul.-Sept. (Q3), and the 4th quarter- Oct.-Dec.(Q4) for the year 2022. Figure 2(a and b) shows the forecasted accident occurrence for the year 2022 and the previous accident from the year 2015 to 2021. The result in Figure 2a shows a uniform number of people forecasted that will be injured in road accidents in the year 2022. An average value of 243 people is projected by the model to be injured in each quarter of the year 2022. This shows a reduction in the number of injured people in accidents. This is expected as precautionary measures are envisaged to have taken place in the study area before the forecasted year. A downward trend is noticed in the number of people injured from the year 2015 to 2022. The year 2019 had the highest number of persons injured in the 4th quarter (Oct.-Dec.). This happens to be the festive period in which there is a high volume of traffic. The 1st and 3rd quarters of the year 2020 witnessed the lowest number of people injured in accident occurrence, this can be ascribed to the restriction of movement due to the global pandemic experienced in that year. Based on the number of people killed in a road accident (Figure 2b), the model forecasted an average number of 45 people will be killed in the year 2022 in each quarter. A significant reduction is noticed in the number of people to be killed in accidents compared to the previous years. This is expected as the reduction in the number to be injured greatly has an impact on the number to be killed within the same year. The 3rd quarter of the year 2021 witnessed a significant number of people killed compared to the other years, this can be attributed to the surge in traffic flow after the global pandemic period.



(a) Forecasted Chart for the number Injured (b) Forecasted Chart for the number Killed

Figure 2. Forecasted and previous accidents for the year 2015-2022

3.4 Trends of road traffic crash

Figure 3 shows the trend in crashes and fatalities from 2015 to 2021. An average 0.2% and 25% decrease were recorded in the number of crashes and fatalities, respectively, from the period outlined, However, on a year-by-year basis, in 2016, 2017, 2018, and 2019, a reduction was recorded in crashes and fatalities using 2015 as the base year. In 2020, there was a 2% increase and 44% reduction in crashes and fatalities. In 2021, a 52% increment in crashes was recorded which was the highest within the years outlined, and an 8% increase in fatality from the base year of 2015.

The total number of RTCs recorded in the year 2015 was 266 cases, which resulted in the deaths of 223 persons and injury to 938 people. In the following year, which was 2016, a significant decline was witnessed in the trend of road crashes in Osun State, Nigeria. A comparative analysis with the preceding year revealed that a total of 245 crashes were recorded with resultant fatalities of 164 deaths and injury of 949 persons, the percentage change over this period in road crashes and fatality showed a reduction of 8 and 27 per cent, respectively. However, a 1 per cent increase was recorded in the total number of persons injured.

The next year (2017), recorded a reduction in RTC. Total crashes came down from 245 to 213, reflecting a decline of 13 per cent, the number of persons killed increased from 164 to 181, indicating a 10 per cent increment, while the number of people injured also increased from 949 to 963, which is a 2 per cent increase. The year 2018 witnessed an upward trend with 233 RTC cases, representing an increase of 9 per cent from the previous year. Similarly, the number of people injured increased from 963 to 1053, signifying a 9 per cent increment, while the number of persons killed was reduced by 17 per cent.

The year 2019 witnessed a downward trend with 227 RTC cases, representing a reduction of 3 per cent from the previous year. Similarly, the number of persons injured also declined from 1053 to 1004 persons, indicating a 5 per cent reduction. However, a 5 per cent increase was recorded in number of people killed. A significant increase in RTC was recorded in the year 2020, with 271 cases, indicating a 19 per cent increase from the year 2019. But fatalities came from 152 to 125, reflecting a decline of 18 per cent, and the number of persons injured also declined from 1004 to 709, representing a 29 per cent reduction.

The year 2021 witnessed a surge in RTC, which was the highest in study years, with 404 cases signifying an increase of 33 per cent from the previous year. Similarly, the number of persons injured from 709 to 1193, indicating a 68 percent increment, while the number of people killed also increased to 240 from 125 which signifies a 90 percent increase.

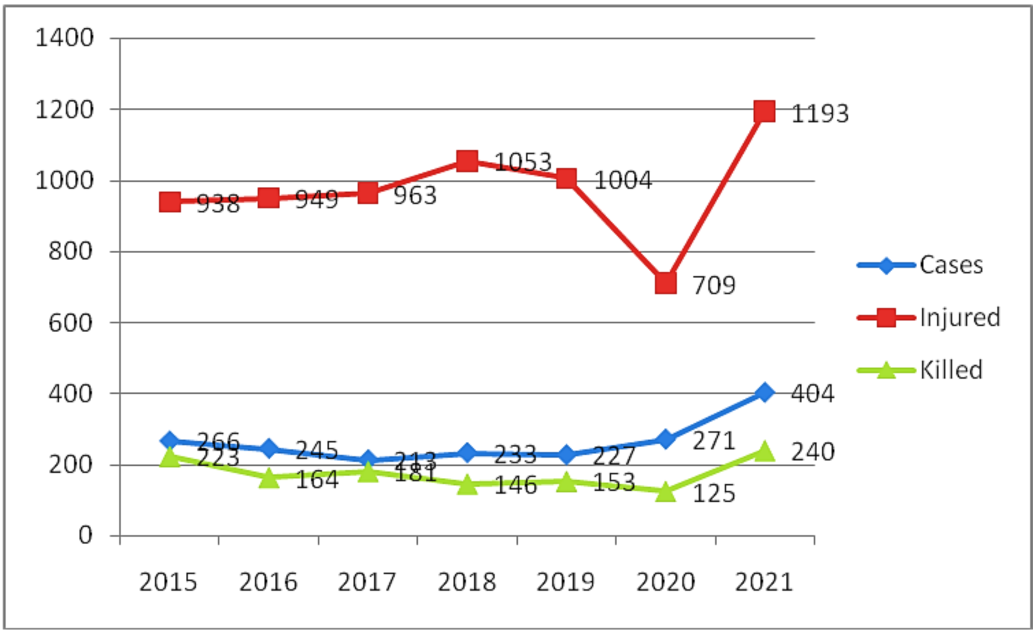


Figure 3. Trends of accident occurrence in Osun State, Nigeria (2015-2021)

3.5 Severity index of road accidents

The severity index of accidents along the study route was computed by dividing the number of fatal accidents for each year by the total number of people killed in the year. The index was then ranked according to Vitus's (2014) ranking system. Low severe accident was obtained for all the years; the forecasted accidents for the year 2022 also indicate that fatal accidents within the year would not be severe.

Table 7. Severity index of fatal road accidents in Osun State, Nigeria (2015-2021)

Years	Fatal Crashes	Number Killed	Severity Index	Ranking
2015	85	233	2.69	low
2016	78	164	2.10	low
2017	82	181	2.21	low
2018	84	146	1.74	low
2019	82	153	1.87	low
2020	76	125	1.65	low
2021	89	240	2.70	low
2022	65	45	1.4	Low-forecasted

4. CONCLUSIONS

This study presents the trend of road crashes in Osun State, Southwestern Nigeria, using the multivariate time series analysis approach. The vector autoregressive model with a lag length of order 1 was employed for the multivariate analysis. The constant-only model was found suitable for the accident forecasts. Average forecasted values of 45 dead persons and 244 injured persons were obtained for each quarter of 2022. Furthermore, a reduction in accident occurrence was noticed from the year 2015 to 2021. The number of people injured has a great impact on the other variables in the model.

To allow for a decrease in the number of accidents in the study area, government and non-governmental organizations are encouraged to show concern through sensitization of motorists over reckless driving, rehabilitation of the roadway, enforcement of legislation on speed limits on both urban and rural roads, strict compliance with the procedures for obtaining driving licenses so that only qualified and responsible people receive the license, enforcement of the use of seat belts, routine breath testing of drivers on the roads to detect drivers who drive under the influence of alcohol, funding of traffic safety research.

5. ACKNOWLEDGMENT

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