AN ANALYSIS OF SPATIO-TEMPORAL TRENDS OF ROAD TRAFFIC CRASHES ACROSS NIGERIA-2023

[1]Bitrus Eniyekenimi Daukere, [1]Enekole Esther Adeniyi, [1]Bukola Ademiloye, [2]Abdulganiyu O. Kilani and [3]Ishaya Kuku Yahaya

[1]Department of Geography and Environmental Management University of Ilorin,
[2]Defense Space Administration, Obasanjo Space Center Lugbe
[3]Department of Geography, Nigerian Defense Academy Kaduna, Nigeria

Corresponding Author's email: dauksenies2010@gmail.com

Abstract

This study investigated the spatiotemporal patterns of road traffic crashes (RTCs) across Nigeria's 36 states and the Federal Capital Territory (FCT) Abuja in 2023, using quarterly data sourced from the National Bureau of Statistics. Descriptive statistics in IBM SPSS Statistics 27 were used to examine the extent of RTCs cases, casualty levels, and causative factors while the Global Moran's I statistic in ArcGIS 10.8.2 environment was employed to test for their pattern of spatial clustering. The findings showed that the second quarter recorded the highest mean total cases at 80.19, followed by a notable decline in the third quarter, and an increase to 73.43 in the fourth quarter. Findings also revealed that fourth quarter recorded the highest mean total casualties at 282.14, while the third quarter showed the lowest mean total casualties at 187.81. Findings revealed that speed limit violations and brake failure were identified as the most important causative factors, while poor weather was the least frequent. Findings further revealed that the spatial distribution of RTC cases and casualty levels are concentrated in Kaduna, Ogun, FCT, Bauch, and Niger while Bayelsa, Akwa Ibom, Cross River, Rivers, and Abia recorded the lowest, reflecting regional disparities in crash incidence and severity. Findings also revealed a statistically significant spatial clustering of cases and casualty levels of RTCs. It was therefore recommended that high-risk states should be provided with sustained attention and tailored solutions of well-designed localized road safety programmes to reduce RTC cases and casualties.

Keywords: *Causative factors, Casualty levels, Regional disparities, Spatial clustering, Speed violations*

Introduction

Globally, road traffic crashes (RTCs) are a significant public health challenge, causing physical injuries, psychosocial burdens, and premature deaths (Ahmed et al., 2023; Rajčević et al., 2024; World Health Organization, 2023). For instance, rapidly urbanizing cities such as Jakarta, São Paulo face severe traffic congestion, causing increased travel times, pollution, economic losses, and significant loss of life, including deaths from traffic-related incidents and health impacts (Nanditho & Yola, 2022; Nurhidayat et al., 2023). Similarly, in Nigeria, RTCs have become an increasingly pressing issue amid rapid urbanization and population growth, driving a surge in vehicular traffic volumes (Adebayo, 2015). Historical data from the Federal Road Safety Commission showed that between 1960 and 2012, Nigeria recorded over one million RTCs, with fatalities exceeding 322,000 people (Oluwakoya et al., 2020). More recent estimates indicate approximately 40,000 road deaths annually, though these figures are believed to be underreported due to systemic data challenges (World Health Organization, 2023). Notably, the spatial distribution of RTCs and casualties across Nigeria, including the Federal Capital Territory (FCT) and the 36 states, remains

uneven, reflecting diverse road conditions, regulatory enforcement, and infrastructural disparities (Afolayan et al., 2022; Osayomi & Areola, 2015).

Road Traffic Crashes are unexpected events resulting from the operation of vehicles that cause injury, death, or property damage. These incidents are complex phenomena driven by multiple interacting factors including human behaviour, vehicle condition, road infrastructure, and environmental influences (Afolabi & Gbadamosi, 2017; Osayomi & Areola, 2015). In Nigeria, human factors such as speeding, reckless driving, fatigue, and non-compliance with traffic rules contribute to over 80% of road crashes (Adebayo, 2015; Osayomi & Areola, 2015). Vehicle-related issues like brake failure and poor maintenance further exacerbate crash risk, while inadequate road infrastructure characterized by poor road conditions, insufficient signage, and lighting significantly increases crash occurrence and severity (Bombom et al., 2022). Additionally, socio-environmental factors including rapid urbanization, population growth, and variable enforcement intensity create a diverse risk landscape across Nigerian states. Given the multidimensional nature of RTCs, it is crucial to apply a holistic analytical framework that captures how these overlapping human, vehicular, infrastructural, and socio-environmental factors combine to influence when, where, and why crashes occur (Ahmed et al., 2023). The spatial clustering and uneven distribution of RTCs necessitate precise identification of hotspots to inform targeted and effective road safety policies (Holmes et al., 2023; Korter et al., 2014). This study is therefore motivated by these facts regarding the spatiotemporal trends of RTC cases and casualties to providing evidence to support interventions aimed at reducing the human and economic toll of RTCs in Nigeria.

Several studies have leveraged geographic information science (GIS) to analyze the spatiotemporal dynamics of road traffic crashes in neighbourhoods. For example, Adebayo (2015) and Rukewe et al. (2014) mapped accident hotspots to depict their trend and characteristics in Nigeria using GIS. Their findings revealed spatial clustering that is consistent with Tobler's First Law of Geography; however, their focus was primarily on spatial patterns without exploring how these patterns change over time, thereby overlooking temporal trends that could offer deeper insights. Likewise, Afolabi & Gbadamosi (2017) examined the road traffic incidents in Nigeria in order to explain the contributing causes, including driver behaviour, vehicle condition, and infrastructure but did not account for how these factors might fluctuate quarterly or seasonally. Furthermore, Holmes et al. (2023) and Odusola et al. (2023) incorporated both spatial and temporal dimensions but their studies were restricted to the FCT and Lagos State, limiting the generalizability of findings to the entire nation. Additionally, these studies neglected the evolving nature of RTCs in the context of Nigeria's rapid urbanization and increasing motorization. Consequently, there remains a significant need for comprehensive, nationwide quarterly analyses that could capture both spatial and temporal variations in RTCs cases, causes, and the extent of casualty levels. Therefore, this study is motivated by the need for an up-to-date spatiotemporal assessment across all the 36 states and the FCT Abuja to enhance understanding of RTCs patterns that could be essential for effective, localized road safety interventions across Nigeria.

In Greater Melbourne Area of Australia, Soltani & Roohani (2024) examined the intricate relationships between road accident frequency and contributing factors like socio-demographics, road transport infrastructure, and the built environment. The study's application of clustering techniques serves as a model for comprehensive spatial risk assessment, supporting evidence-based resource allocation and policy formulation that was geared toward reducing RTCs and their consequential harms. Abdulwahab et al. (2021) and Abid (2024) demonstrated the value of integrating spatial statistics with temporal data to inform targeted road safety interventions. This methodology could be further explored to understand the clustering pattern of the cases and causative factors in recent Nigeria's transport system. Furthermore, Wole et al. (2024) examined the potential link between ember months and crash rates, concluding that season significantly influences crash rates, but ember months themselves do not significantly impact crash

frequency or severity. Most of these studies fail to comprehensively examine the spatiotemporal trends of the cases, causes, and casualty levels of RTCs in Nigeria for recent years. This underscores the urgent need to strengthening understanding through comprehensive data analysis of RTCs causes, which is critical to improving safety measures and saving lives on Nigeria's roads and beyond.

Against this backdrop, the aim of this study is to investigate the spatiotemporal patterns of RTCs across Nigeria's 36 states and the FCT. The objectives are to examine the RTCs cases, casualty levels (injuries and deaths), and the causative factors; analyze the spatial distribution of these factors; and determine whether RTCs cases and casualties exhibit significant spatial clustering using advanced spatial statistics.

Material and Methods

The Study Area

Nigeria the study area is located between latitudes 4° and 14°N and longitudes 3° and 15°E (Figure 1). This area is located in West Africa which spans approximately 923,768 square kilometers. The study area's road network is a layered system comprising federal highways, state roads, and local government roads. These roads serves as critical transport corridors that support the country's mobility and economic activities. Major federal highways like the Lagos-Ibadan expressway and the Abuja-Kaduna-Kano highway connect key urban centers and experience high traffic volumes. These expressways are identified as hotspots for RTCs due to factors such as heavy vehicle flow, complex intersections, and variable road quality (Oni & Oyewo, 2011; Osadebe & Quadri, 2021). State roads primarily link cities and towns within states, while local government roads provide essential access within rural and urban communities. Urban areas along these corridors typically report higher crash occurrences due to dense traffic, while rural roads often face issues like poor maintenance and limited enforcement, influencing crash severity and emergency response (Atubi, 2024). The spatial variation in crashes is therefore shaped by the road network's hierarchical structure, urban-rural differences, and infrastructure quality. This study employs advanced statistical and spatial analysis methods to pinpoint causes and crash patterns, aiming to guide targeted interventions and optimize resource allocation for improved road safety nationwide.

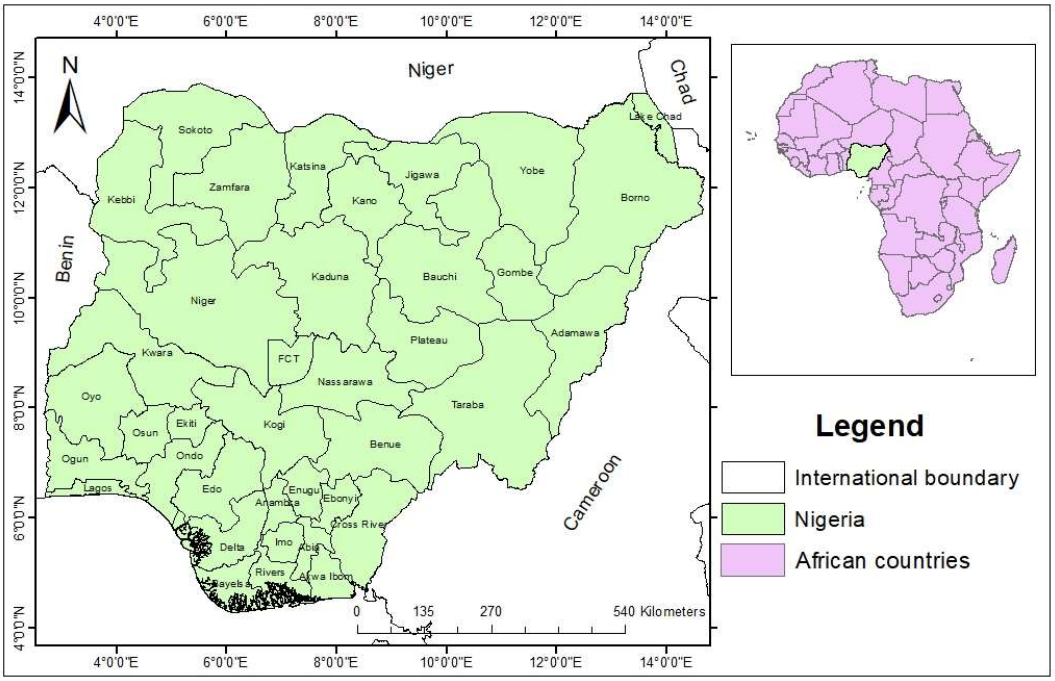


Figure 1: Nigeria

Methods

Data on RTC cases, casualty levels, and causative factors for the year 2023 classified into the four quarters of the year were sourced from the Annual Abstract of Statistics 2024, at https://www.nigerianstat.gov.ng/elibrary/read/1241582. This document provides the RTCs quarterly data based on the 36 states and the FCT. The dataset includes the year, state of occurrence, number of accidents, injuries, and deaths. The RTC cases were categorized as fatal (at least one death at the scene), serious (injuries sustained, regardless of subsequent death), and minor (no casualties). As used in this study, the summation of fatal, serious, and minor cases equal to the total RTC cases for each quarter, while casualties are classified as either killed (deaths at the scene) or injured (injuries sustained during the crash).

As a result, for assessing the cases, casualty levels and causative factors of RTCs in Nigeria during 2023, descriptive statistics such as minimum, maximum, mean, and standard deviation in SPSS Statistics 27 environment were used to analyze the data. After this, the dataset was converted to a comma-delimited format in Microsoft Excel to spatially join to the Nigerian administrative shapefile in ArcGIS 10.8.2 environment. Thereafter, the data was categorized using the attribute table in ArcGIS 10.8.2 environment to display the spatial distribution of the total cases and casualty levels of RTCs across the 36 States and the FCT. To examine the spatial clustering of the total cases and casualties of RTCs, the Global Moran's I statistic was employed using ArcGIS 10.8.2 software. This spatial autocorrelation tool was applied because the data has the relevant attribute values (such as total cases or casualties per state) which was used to define the spatial weights matrix based on distance or contiguity, which was used to run the Moran's I tool to measure the spatial autocorrelation of the feature values. Westerholt (2023) provides the following formula:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\,(X_i - \bar{X})\,(X_j - \bar{X})}{\sum_{j=1}^{n}(X_i - \bar{X})^2} \qquad (1)$$

Where:

n = total geographic units (such as the FCT plus the 36 states)

X_i = value of the variable at location *i* (e.g., total number of crashes cases and casualties levels)

$\bar{X}$= mean of the variable

W_{ij}= spatial weight between i and j locations

$\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij} =$ total sum of spatial weights.

This spatial autocorrelation measure involved creating a spatial weights matrix considering distances or contiguity, and calculating Moran's I statistic, p-values, and z-scores to determine clustering or dispersion tendencies (Bajjali, 2018). The results indicated significant positive clustering of the RTC cases and casualties, meaning that states with high incidence rates tended to be near one another—an observation consistent with Tobler's First Law of Geography. This approach permitted identification of high-risk clusters and informed targeted interventions, aligning with similar studies such as Bombom et al. (2022). Overall, this combination of descriptive and spatial analytic techniques provided a robust framework to analyze the distribution and drivers of RTCs in Nigeria.

Results and Discussion

Variation of Road Traffic Crashes cases in Nigeria - 2023

Table 1 shows the results of the quarterly RTCs cases for Nigeria in 2023. The findings in this table reveals that there is a notable fluctuations in fatal, serious, minor, and total cases recorded in the study area. In

the first quarter, findings in Table 1 record mean total of 73.86 cases, with serious injuries (mean: 48.68) and fatalities (18.3) comprising the bulk of RTC cases. The second quarter recorded the highest mean with total cases of 80.19 and fatalities of 20.43. Findings on serious injuries remained consistently high, reflecting persistent issues with road safety and enforcement during yuletide seasons. On the other hand, results in Table 1 further showed that the third quarter experienced a significant decline in total cases with mean of 59.11, fatalities of 14.38, and serious injuries of 38.35. This drop could be linked to intensified road safety campaigns and the rainy season, which influence the reduction of high-speed travel but could introduce other risks like brake failure (Afolabi & Gbadamosi, 2017). However, the fourth quarter recorded a higher resurgence of RTC, with mean total cases rising to 73.43 and fatalities reducing to 18.57. The findings of this study is consistent with those of Wole et al. (2024), who found that "Ember Months" phenomenon, where end-of-year festivities lead to increased road use, overloading, and risky driving behaviors. Overall, these trends showed that Nigeria's RTCs patterns are both cyclical and could be influenced by behavioural, environmental, and infrastructural factors. The persistently high standard deviations across the quarters also reflect the significant regional disparities, where North-Central states bear a disproportionate burden.

Table 1: Descriptive statistics for RTC cases in Nigeria -2023 - (n=37)

Cases	Minimum	Maximum	Mean	Std. Deviation
First Quarter				
Fatal	1	71	18.3	17.32
Serious	2	245	48.68	51.725
Minor	0	66	6.89	12.629
Total Cases	6	382	73.86	77.571
Second Quarter				
Fatal	2	67	20.43	16.889
Serious	5	214	51.86	49.129
Minor	0	54	7.89	12.717
Total Cases	7	320	80.19	73.073
Third Quarter				
Fatal	0	63	14.38	14.572
Serious	2	216	38.35	43.025
Minor	0	70	6.38	12.35
Total Cases	5	349	59.11	67.088
Fourth Quarter				
Fatal	0	71	18.57	16.562
Serious	2	199	47.89	44.264
Minor	0	50	6.97	11.51
Total Cases	3	296	73.43	65.84

Source: Authors' Analysis (2024)

Casualty Levels of Road Traffic Crashes in Nigeria - 2023

Table 2 displays the descriptive statistics of the casualty levels of RTCs in Nigeria – 2023. According to the results, RTCs across Nigeria's 36 states and the FCT revealed significant variation in casualties. Findings showed that the first quarter recorded a mean of 225.38 injured persons and 38.95 killed, totaling 264.32 casualties, with an average of 479.78 people involved per state. The second quarter showed a slight

increase in injuries to 226.41 and a marginal decrease in fatalities to 38.08, maintaining a similar total casualty mean of 264.49 but involving more people on average (511.51). In contrast, the third quarter experienced a notable decline, with a mean of 163.27 injuries, 24.54 fatalities, and a total of 187.81 casualties, alongside fewer people involved (378.35). The fourth quarter saw a resurgence, with injuries peaking at 246.38, fatalities rising to 35.76, and total casualties reaching 282.14, involving an average of 524.7 people. These fluctuations align with seasonal travel patterns, enforcement intensity, and environmental factors such as weather, influencing crash frequency and severity, particularly during the "Ember Months" characterized by increased travel, festivities, and risky driving behaviours as seen the findings of Wole et al. (2024). The high standard deviations and wide ranges across quarters highlight regional disparities and variability in crash severity and reporting.

Table 2: Descriptive statistics for RTCs casualties in Nigeria -2023 (n=37)

Casualty	Minimum	Maximum	Mean	Std. Deviation
First Quarter				
No. Injured	11	782	225.38	194.216
No. Killed	1	139	38.95	37.068
No. of Casualty	12	921	264.32	227.026
People Involved	28	1742	479.78	447.134
Second Quarter				
No. Injured	22	755	226.41	188.555
No. Killed	3	119	38.08	28.883
No. of Casualty	25	874	264.49	214.385
People Involved	53	1777	511.51	448.011
Third Quarter				
No. Injured	2	607	163.27	158.466
No. Killed	0	82	24.54	23.364
No. of Casualty	2	689	187.81	180.149
People Involved	21	1824	378.35	402.511
Fourth Quarter				
No. Injured	14	889	246.38	203.168
No. Killed	0	150	35.76	32.227
No. of Casualty	14	1039	282.14	231.302
People Involved	17	1838	524.7	435.056

Source: Authors' Analysis (2024)

Causative Factors of Road Traffic Crashes in Nigeria -2023

Table 3 displays the results of RTCs causative factors in Nigeria for the 2023. Findings in this table revealed that speed limit violation (SPV) consistently remain the leading causative factor throughout the 4 quarter of the year. Findings revealed that mean values of SPV ranges from 45.43 in the third quarter to 62.11 in the second quarter, accounting for nearly half of all the recorded crashes. These findings are consistent with those of Awoniyi et al. (2021), who found that speed violation, loss of control, and reckless driving are the primary contributors to RTCs in Nigeria. Other significant factors include brake failure (BFL) and tyre burst (TBT), with mean quarterly values fluctuating between 3.16 to 5.7 for BFL and 4.76 to 5.7 for TBT, reflecting persistent vehicle maintenance challenges in Nigeria. These factors could be influenced by inadequate inspections of roads/vehicles and a weak maintenance culture, which in turn contribute to the increase crash severity and frequency in the country.

Beyond mechanical and speed-related causes, traffic sign/signal violations (SLV) and wrongful overtaking (WOT) also featured prominently. For instance, findings in Table 3 revealed that SLV averaged between 5.38 and 9.46 cases per quarter and WOT maintained a steady mean around 4.7 to 5.84. These therefore reflect that both driver non-compliance and infrastructural deficits such as poor signage visibility and enforcement gaps. Dangerous driving (DGD), according to Table 3, shows existence of reckless behaviours like stunts and aggressive maneuvers, thereby revealing a moderate but consistent presence, with mean values between 3.38 and 5.7. This further emphasized that the causes of RTCs in Nigeria is the human factor. In addition, other lesser but notable factors included mechanically deficient vehicles (MDV), route violations (RTV), and overloading (OVL), which, although lower in frequency, contribute to crashes by compromising vehicle control and road safety standards. This findings call for stricter vehicle inspection regimes and targeted driver education programmes to mitigate these risks in order to improve public health.

According to Table 3, the remaining causative factors such as use of phone while driving (UPD), drunk driving (DAD), fatigue (FTQ), poor weather (PWR), and sleeping on steering (SOS) recorded at relatively low levels but remain critical for comprehensive road safety strategies. For instance, findings revealed that UPD and DAD had mean values consistently below 0.3 per quarter, yet their potential for causing severe crashes necessitates ongoing enforcement and public sensitization. The low incidence of poor weather-related crashes could be due Nigeria's favourable weather conditions for driving but does not diminish the need for preparedness during rainy seasons. Consequently, these findings show that Nigeria's RTC causative factors are multifaceted, dominated by speed violations and mechanical failures. This is also compounded by behavioural and infrastructural issues, particularly the existence of poor road infrastructure. Therefore, there is a need for an effective RTC reduction combining law enforcement, vehicle maintenance policies, driver education, and infrastructural upgrades tailored to specificities according to the 36 states and the FCT.

Table 3: Descriptive statistics for RTCs causative factors in Nigeria -2023 - (n=37)

	First Quarter				Second Quarter				Third Quarter				Fourth Quarter			
Causative Factors	**Min**	**Max**	**Mean**	**Std. Deviation**	**Min**	**Max**	**Mean**	**Std. Deviation**	**Min**	**Max**	**Mean**	**Std. Deviation**	**Min**	**Max**	**Mean**	**Std. Deviation**
SPV	4	320	57.27	72.119	2	340	62.11	71.986	5	278	45.43	62.138	0	265	57.97	63.848
UPD	0	2	0.11	0.393	0	2	0.27	0.56	0	2	0.14	0.419	0	2	0.19	0.462
TBT	0	21	4.76	5.188	0	37	5.7	6.883	0	28	5.14	5.817	0	34	5.54	7.198
MDV	0	18	2.95	4.268	0	20	2.65	4.151	0	12	1.78	2.973	0	11	2.05	2.677
BFL	0	16	3.16	4.413	0	24	4.19	6.328	0	14	3.35	3.882	0	22	4.19	5.384
OVL	0	4	0.95	1.153	0	7	0.95	1.598	0	5	0.57	1.168	0	5	0.84	1.424
DOT	0	4	0.41	0.985	0	7	0.49	1.346	0	4	0.16	0.727	0	3	0.38	0.794
WOT	0	24	5.32	6.558	0	18	5.84	4.438	0	25	4.7	5.327	0	20	5.78	4.516
DGD	0	33	5.54	7.672	0	37	5.7	8.031	0	21	3.38	4.763	0	21	4.16	5.247
BRD	0	5	0.38	1.037	0	6	0.35	1.111	0	2	0.16	0.442	0	4	0.54	1.169
RTV	0	27	3.81	5.859	0	24	4.57	5.771	0	33	4.24	7.232	0	22	4.14	5.569
OBS	0	5	0.65	1.358	0	16	1.3	2.989	0	8	0.57	1.425	0	10	0.7	2.184
SOS	0	4	0.24	0.76	0	4	0.3	0.878	0	8	0.27	1.326	0	3	0.16	0.553
DAD	0	1	0.14	0.347	0	4	0.22	0.712	0	2	0.16	0.442	0	3	0.22	0.63
PWR	0	2	0.08	0.363	0	2	0.14	0.419	0	1	0.11	0.315	0	4	0.24	0.76
FTQ	0	8	0.73	1.895	0	7	0.41	1.235	0	4	0.3	0.968	0	9	0.84	1.708
SLV	0	179	9.46	29.86	0	136	8.14	23.057	0	119	8	21.15	0	71	5.38	12.945
OTHERS	0	25	4.32	5.812	0	14	2.65	3.442	0	12	2.38	3.435	0	33	3.57	7.147
TOTAL	10	616	100.27	122.199	9	502	105.95	114.018	7	511	80.84	103.413	4	382	96.89	93.774

Note: **SPV**: Speed limit Violation, **UPD**: Use of phone while Driving, **TBT**: Tyre Burst, **MDV**: Mechanically Deficient Vehicle, **BFL**: Brake Failure, **OVL**: Overloading, **DOT**: Dangerous Overtaken, **WOT**: Wrongful Overtaking, **DGD**: Dangerous Driving, **BRD**: Bad Road, **RTV**: Route Violation, **OBS**: Obstruction, SOS: Sleeping on Steering, **DAD**: Drunk Driving, **PWR**: Poor Weather, **FTQ**: Fatigue and **SLV**: Sign Light Violation

Source: Authors' Analysis (2024)

Spatial Distribution of Road Traffic Crashes Cases in Nigeria – 2023

The spatial distribution of road traffic crashes (RTCs) in Nigeria from the first to fourth quarters of 2023 is displayed in Figure 2. Finding in this figure reveals persistent regional disparities, with the North-Central and South-West zones consistently recording the highest case numbers. Throughout the first two quarters, the FCT and Ogun State had the highest number of RTC cases, reaching 382 and 269 in Q1 and 320 and 283 in Q2, respectively, while Bayelsa, Akwa Ibom, and Abia states consistently had the lowest number of cases. This pattern persisted into the third and fourth quarters, with FCT, Ogun, Kaduna, and Nasarawa dominating the crash statistics, while much of the South-South, South-East, and far North-West (e.g., Zamfara, Sokoto) remained at the lower end of the ranges. Driven by the influence of the FCT and the Lagos-Ogun corridor, the highest concentrations of cases are in the central and southwestern states, while the lowest numbers occur in the northwestern and far southern parts of the country.

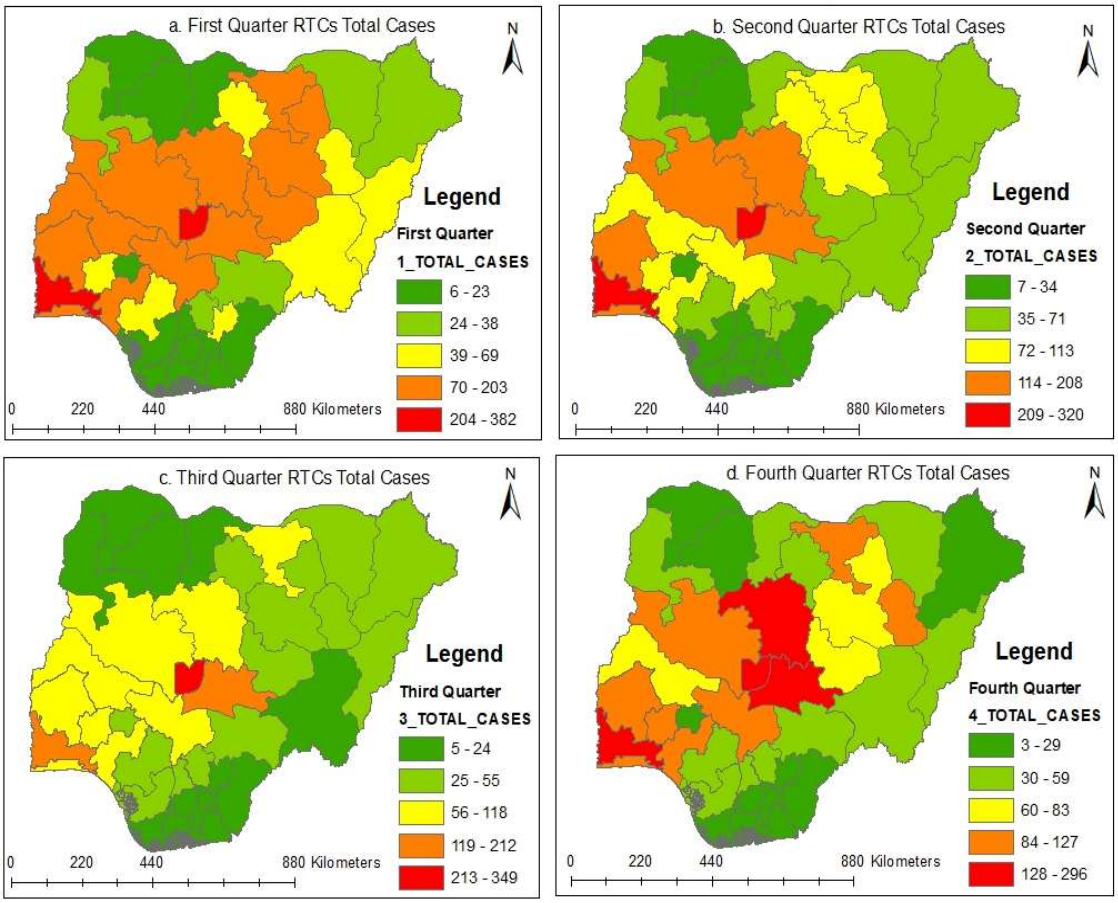


Figure 2: Spatial distribution of RTCs total cases – 2023

Source: Authors' Analysis (2024)

The spatial pattern is visually captured in Figure 2, where a gradient from green (low) to red (high) highlights the concentration of RTCs cases along major transport corridors and urbanized states. These regional variations are driven by several factors. High RTC incidence in North-Central and South-West states is attributed to dense road networks, heavy vehicular movement, and the presence of major highways connecting commercial and administrative hubs. The FCT and Ogun, for instance, serve as transit points for intercity travel and goods transportation, increasing exposure to crash risks (Odufuwa et al. 2019; Abdul, et. al., 2020). Conversely, lower RTC rates in the South-South and South-East are linked to less traffic volume, shorter intra-state journeys, and, in some cases, better compliance with local transport regulations. These findings align with those of Odusola et al. (2023), whose findings show North-Central and South-West as hotspots for RTCs, while the South-East and North-East recorded fewer incidents. The spread

and persistence of these patterns underscore the need for region-specific interventions, improved infrastructure, and targeted enforcement to address Nigeria's uneven RTC burden.

Spatial Distribution of RTC casualties in Nigeria – 2023

Figure 3 displays the spatial distribution of RTC casualties across Nigeria in 2023.

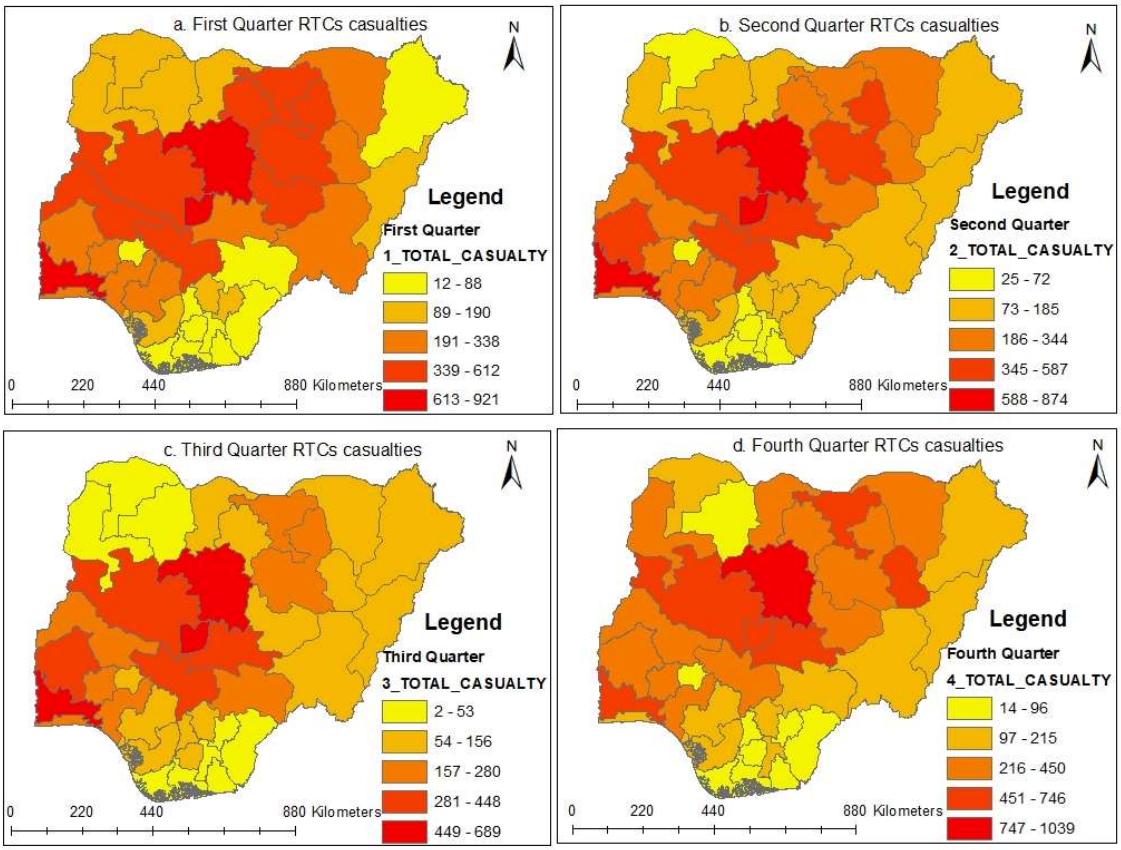


Figure 3: Spatial distribution of RTCs casualty levels – 2023

Source: Authors' Analysis (2024)

Findings in this figure reveal a pronounced concentration of injured and death in the central and southwestern regions. In the first quarter, a total of 9,780 casualties were recorded, averaging 479.78 per state, with Kaduna (921), Ogun (820), FCT (767), Bauchi (612), Niger (501), and Plateau (475) leading in the number of casualties. Conversely, states in the South-South and parts of the Southeast, such as Bayelsa (12), Akwa Ibom (19), Cross River (42), and Rivers (46), consistently reported the lowest casualty figures. By the fourth quarter, casualties increased to 10,439, with Kaduna recording the highest at 1,039, while Bayelsa remained the lowest at 14. This spatial pattern reflects the interplay of factors such as population density, road network density, and traffic volume, with central states like Kaduna and the FCT serving as major transit and commercial hubs that experience heavier vehicular flows and thus higher crash exposure. These findings align with those of Aderamo (2012), whose findings revealed that Abia, Adamawa and Akwa Ibom states recorded the lowest casualty levels, while states like Benue, Kaduna and Ogun had high level of RTCs casualties in the country.

The reasons for this uneven spread of RTC casualties' levels are multifaceted. High traffic volumes, poor road infrastructure, and inadequate enforcement of traffic laws in central and southwestern Nigeria contribute to elevated casualty rates. The FCT and Kaduna, for example, are characterized by major highways and urban centers where speeding, overloading, and risky

driving behaviours are prevalent, increasing crash severity as noted by Abdulwahab et al. (2021). In contrast, states with lower casualties often have less dense road networks and reduced commercial traffic. Studies by Olayinka et al. (2024) and Taruwere Yakubu and Muhammed (2021) corroborate these spatial disparities, highlighting that economic activities, road quality, and enforcement intensity vary regionally, influencing RTC outcomes. Furthermore, the persistence of high casualties in the "Ember Months" (Q4) underscores the seasonal risk factors related to increased travel and festive activities, which exacerbate crash severity in already vulnerable regions, as also seen in the works of Wole et al. (2024). These insights emphasize the need for region-specific road safety interventions, improved infrastructure, and targeted enforcement to reduce the disproportionate burden of RTC casualties in Nigeria's high-risk zones.

Spatial Clustering of the Total Cases and Casualties of RTCs (Global)

Table 4 presents the Global Moran's I results for the total road traffic crash (RTC) cases and casualty levels in Nigeria for 2023. These findings strongly reject the null hypothesis of spatial randomness, demonstrating statistically significant spatial clustering across all quarters. Moran's I values ranged from 0.4857 to 0.5469 for total cases, substantially exceeding the expected index of -0.0278, with z-scores above 3.9 and p-values well below 0.001. This indicates that states with high numbers of RTC cases tend to be surrounded by neighbouring states with similarly high case counts, creating contiguous hotspots, while low-incidence states cluster together. These spatial patterns align with existing studies by Bombom et al. (2022) and Holmes et al. (2023), which attribute clustering to shared road infrastructure, traffic density, and socio-economic factors. The persistence of clusters, particularly in North-Central and South-West zones, highlights the interconnected nature of RTC risks, underscoring the importance of coordinated regional interventions rather than isolated efforts to improve road safety.

Similarly, the spatial analysis of RTC casualties in 2023 reveals consistent clustering throughout the year. The Global Moran's I values for casualties ranged from 0.3778 to 0.5269, with all z-scores exceeding 3.1 and p-values below 0.002. This findings confirms that states with high casualty numbers are spatially proximate. This pattern reflects uneven distribution of the burden of road injuries and fatalities, concentrated in regions characterized by major transport corridors and varying enforcement practices. These results align with those of Soltani & Roohani (2024), emphasizing how infrastructural deficits and socio-economic disparities contribute to spatial clustering of RTC severity. Overall, the findings reinforce the need for regionally coordinated, data-driven road safety strategies to effectively address these persistent risk clusters.

Table 4: Moran's *I* Results

Quarter 2023	Moran's Index	Expected Index	Variance	z-score	p-value	Remarks
Total RTC Cases						
First	0.493896	-0.027778	0.017064	3.99355	0.000065	Clustered
Second	0.54687	-0.027778	0.016266	4.505751	0.000007	Clustered
Third	0.485667	-0.027778	0.013311	4.450375	0.000009	Clustered
Fourth	0.54494	-0.027778	0.016387	4.474011	0.000008	Clustered
Total RTC Casualties						
First	0.493896	-0.027778	0.017064	3.99355	0.000065	Clustered
Second	0.503525	-0.027778	0.017369	4.03142	0.000055	Clustered
Third	0.526957	-0.027778	0.017072	4.245584	0.000022	Clustered
Fourth	0.377821	-0.027778	0.016928	3.117385	0.001825	Clustered

Source: Authors' Analysis (2024)

Conclusion and Recommendations

The study has analyzed the quarterly variation of RTCs cases, casualty levels, causative factors, and their spatial distribution in Nigeria - 2023. Findings revealed significant fluctuations in RTCs cases, casualties, and causative factors across quarters, with the highest incidents recorded during festive "Ember Months" and the lowest during rainy seasons, highlighting the influence of behavioural, environmental, and infrastructural factors. Speed limit violations consistently emerged as the dominant cause, while mechanical failures and driver non-compliance also played crucial roles. Spatially, the North-Central and South-West zones, especially the States of Kaduna, Ogun, Bauchi, Niger, Plateau and the FCT, recorded the highest RTCs cases and casualties, while south-southern states like Bayelsa, Akwa Ibom, Cross River, and Rivers had fewer incidents due to variability in dense transport networks and heavy traffic. These results emphasize the need for state-specific road safety interventions, improved infrastructure, and stricter enforcement regimes. Future research should explore the integration of behavioural, enforcement intensity, and infrastructural variables to better understand their impacts on RTCs patterns by potentially leveraging real-time data and machine learning techniques for predictive modeling. The findings of this study call for urgent, coordinated policy action to strengthen traffic law enforcement, improve vehicle maintenance culture, and enhance public awareness campaigns. Such multifaceted strategies are essential to curb Nigeria's persistent and uneven RTCs burden in order to ensure safer roads and reduce casualties nationwide.

Based on the findings, three key recommendations emerge: (1) Intensify speed management through stricter enforcement, public awareness campaigns, and the deployment of speed-calming infrastructure in identified hotspots; (2) Enhance vehicle inspection regimes and maintenance standards, particularly for commercial vehicles, to address mechanical failures in order to reduce crash severity; and (3) Strengthen state-specific interventions by leveraging geospatial data to allocate resources and design localized road safety programmes, ensuring that high-risk states receive sustained attention and tailoured solutions. By adopting a data-driven, regionally nuanced approach, Nigeria can make meaningful progress in reducing the burden of road traffic crashes and safeguarding lives on its roads.

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