SPATIOTEMPORAL ANALYSIS OF ROAD TRAFFIC CRASHES IN METROPOLITAN AREAS OF LAGOS

Ajala Abdul-Rahman Taiwo
Department of Transportation Planning and Management,
The Federal Polytechnic Ilaro, Ogun State, Nigeria
abdulrahman.ajala@federalpolyilaro.edu.ng

Abstract

This study examined spatiotemporal analysis of road traffic crashes with the objective of examining their causes and distribution pattern in metropolitan areas of Lagos state. Secondary data were collected from Federal Road Safety Corps, Lagos State Command for ten years (2013 – 2022). The data were updated by generating coordinates of the crash location, and these were cleaned and screened before use. Thereafter, descriptive analysis using MS Excel pivot table and spatial distribution pattern was carried out. Nearest Neighbor Analysis (NNA) and map visualization was generated using Kernel Density Estimation. Results revealed that speeding contributed 30-50% of crashes, brake failure 12-20%, and dangerous driving 11-18%. The NNA revealed that road crash clusters existed for all the years with 340m as the highest observed mean distance. Ikeja Local Government Area is the black spot zone with a cluster of an average of 200 crashes. The study concluded that the achievement of safer speed is a very crucial measure to ameliorate the increasing crashes, and recommends speed advocacy and control, the use of posted speed limit on all roads as well as installation of speed-monitoring cameras to be backed up with a system of enforcement and correction of erring drivers. Also, road safety workshops focusing measures and interventions to curb over-speeding were recommended to be organized across Lagos Meropolis.

Keywords: *Black-spot, Road Crash, Road Traffic, Safety, Speeding.*

1.0 Introduction

The global status report on road safety published in 2018 revealed an increase in global fatalities to 1.35 million yearly from previous 1.2 million (Khaniabadi et al., 2022; Athiappan et al, 2022) with an addition of 20 – 50 million people sustaining different degrees of injuries resulting in many people becoming permanently disabled (Umair, et al., 2022). Injuries from road accidents have risen to the eighth leading cause of death for all age groups globally (WHO, 2015; Mphekgwana, 2022). It was also an acknowledged killer of more people than HIV/AIDS and tuberculosis (WHO, 2018). Reports also had it that children and young adults - aged 5 to 29 years – constitute the most affected and with the highest fatality (93%) coming from low and medium-income countries (Jalilian et al., 2019; Harith & Mahmud, 2019).

Between 2017 and 2019, road traffic crashes was on the increase in Nigeria, as revealed by the Road Transport Data report (NBS, 2020). The showed an increase in road fatality between 2017 and 2019, specifically in 2017 there was an increase of 1.35% in road fatalities, in 2018 it was 1.17% and by 2019 it was 5.83%. Similarly, in 2020 there was a death toll of

41,693 translating to a road fatality rate of 27.25 per 100,000 population amounting to 2.82% of deaths in Nigeria (WHO, 2020). This figure revealed that an average of 114 people died daily on the road within the country in 2020.

Lagos State is one of the major contributors to the national statistics on road traffic accidents. The record revealed that Lagos is the 4th leading of the 36 States with a high occurrence of traffic crashes (542), and the number of people involved in the crashes between 2020 and 2022 stood at 3895 (FRSC, 2020, 2021 and 2022). While FCT Abuja, Kaduna, and Ogun were leading respectively. Hence, the need to identify the determinant of road traffic crashes that influence the high occurrence of road traffic crashes in the core metropolitan area of Lagos.

Some research has been carried out on the traffic situation in Nigeria and in Lagos State particularly. Iyanda (2018) investigated the distribution of accident severity in Nigeria and the study found that between 2012 and 2016, Lagos was one of the States with low (0.2339-0.3722) road-crashes severity rate. Similarly, Daniel et al (2017) studied the spatial epidemiology of road traffic crashes and mortality in Nigeria for a period of nine years (2007-2015) and found out that Lagos State has 3.4/100,000 population of road traffic crashes and a mortality rate of 2.7/100,000 population during the period. Bombom et al., (2022) in a study of the underlying pattern in road traffic fatality rates in Nigeria between 2005 and 2018, discovered that Lagos State has a 0.52 fatality rate per crash which is the lowest among the States of the Federation. The study further established that for 14 years, Lagos was second to Abuja in the number of recorded crashes with 10128 cases. During the period, Lagos recorded an average death of 5270, which is below the mean rate of 8900 per year, and came to a distant 7th position in the ranking of States with road fatality.

Fowode, Nwaogazie, and Anyanwu (2023) investigated the prevalence of factors causing road traffic crashes in Lagos State. The study discovered that a high prevalence (68%) of road traffic crashes is among commercial drivers, and submitted that age was an important demographic characteristic factor contributing to road crashes in Lagos. In another study, Ibrahim et al (2017) cited by Iyanda (2018) attributed road crashes fatality to poor pre-hospital care and the response time of the rescue team, stating that less than three (2.3%) percent of the accident victims brought to Lagos State Teaching Hospital received pre-hospital care and have shorter arrival time. Olusina and

Ajanaku (2017) found that accidents in Lagos are caused by the smoothness of the road, especially the expressway where the largest numbers of crashes are recorded. The study added that 3.6% of accidents are caused by pedestrians' refusal to use facilities like overhead bridges.

Mohammed et al (2023) carried out a spatiotemporal analysis of road traffic crashes by identifying black spots and examining the attributable causes of crashes between 2015 and 2019 in Qatar. Geographically weighted regression, time series, and hot spot analysis were employed in the study. Findings revealed that crashes are concentrated in central-eastern Qatar than in other parts and the major causative factor was drivers' behavior. The study further identified clusters of crashes during the weekdays in the later years as opposed to the early year of 2015. The study concluded by recommending the application of spatiotemporal analysis as a tool for sustainable transport planning in other regions.

Kernel Density Estimation (KDE) is one of the frequently used GIS tools for identifying road crash black spots because it is easy to use and access. It is a location-based data density estimator that equally creates a visualization to describe the spatial distribution pattern. Choudhary et al., (2015) define KDE as a tool for calculating the density of crashes within a specified bandwidth. The determination of the bandwidth is very important to the result. Pour et al., (2017) noted that a larger bandwidth will produce area-wide density while a smaller bandwidth will present individual point density. To determine an appropriate bandwidth, nearest neighbor analysis (NNA) can be conducted to establish the pattern and the minimum distance between points that can be obtained.

Several researchers in the field of road traffic crashes have used KDE (Atubi, 2012, Iyanda, 2017; Ziakopoulos and Yannis 2020; Shahi, et al, 2023) in the spatial analysis of crash events mostly for area-wide density estimation and with other tools such as Moran's I. Inability of the KDE to test for statistical significance of the observed pattern of distribution limits its use, and therefore Moran's I can also be used to establish the pattern of distribution. The study at hand adopted kernel density estimation to examine the spatial distribution of crashes and assess the cause over a ten-year period (2013 to 2022).

2.0 Methodology

2.1 Study Area

Lagos state is situated in South Western Nigeria within latitude 6^0 2'N to 6^0 4'N and longitude 2^0 45' E to 4^0

20'E. The State is bounded from the north and east by Ogun State; from the west by the Republic of Benin; and from the south by the Atlantic Ocean which stretches over 180 kilometers along the Guinea Coast of the Bight of Benin on the Atlantic Ocean. The State covers an area of about 358,862 hectares or 3,577 sq. km of land, which represents 0.4% of Nigeria's territorial land mass of approximately 923,773 sq. km (Lagos State Government, 2023). Lagos being a coastal region, has 22% or 787 sq. km (75.755 hectares) of its land mass as water bodies (Lagos State Government, 2023).

Lagos State is said to have about 24.6 million inhabitants as at 2015 (Lagos State Government, 2023). The rate of people living in the urban area is put at 27.4 % of the national estimate (UN-Habitat, 2006). Lagos State is statutorily divided into 20 Local Government Areas (LGA) and 37 Local Development Councils, sixteen (16) of the LGAs constituting the core metropolitan area of Lagos. This core area (covering about 37% of the land space) accommodates over 85% of the population. Thus Lagos has higher population density in Nigeria and, indeed, the entire African continent with an average of 2400 persons/km2 and an annual population growth rate of over 5% (Odeleye, 2011).

Comprehensive Road Traffic Crashes (RTC) data were obtained from the Lagos State Sector Command of the Federal Road Safety Corps. The data covered all crashes that have been recorded in ten years (2013 – 2022) for Lagos state. The dataset is organized year by year, and the crucial details for elicited for this study comprising location of crash incident and the road landmarks. To enhance the utility of the data for spatial analysis, the location coordinates were generated. Each accident's address was systematically formatted to enable decoding using the ArcGIS Online World Geocoder by Esri. After that, crash locations were plotted with the help of Google Street Map, and checked by conducting personal visits to the location. The geo-coded addresses underwent a thorough validation process to ensure accuracy and reliability. The data set was then saved in a shape-file, and thoroughly checked for error with those appearing erroneous had their correct coordinates generated using GPS at the crash address.

Thereafter, the Nearest Neighbor Analysis (NNA) was carried out for each year and stratified into three temporal periods of spatial analysis - 2013-2015, 2016-2018, and 2019-2022 – after which a cumulative analysis for the ten years (2013-2022) was carried out.

KDE was used to identify the black zone within the core metropolitan area of Lagos State. The shape-file of the Lagos geographic boundary was used as the input layer and the crash locational data as kernel points while a bandwidth of 350 meters and a cell size of 30 meters were selected to derive density estimates based on the NNA carried out. The results were saved as shape-file and imported to ArcGIS for visualization through maps, which aid identification and characterization of the crash black-spots.

3.0 Results and Discussion

3.1 Causes of Road Traffic Crashes

In the years under review, over-speeding was responsible for the largest proportion of road crash occurrences. It accounted for a proportion ranging from 25% to 50%. Next to over-speeding is break failure which accounted for a range of 12% to 20%, dangerous driving recorded 5% to 18%, while others have varying proportions of between 1% and 10%.

The result revealed that across the years the major ten (10) causes of road traffic crashes in the Lagos metropolitan area in order of ranking are over-speeding, break failure, dangerous driving, route violation, mechanical deficiencies and incidences of burst tyres on motion. Others included fire and electrical faults, overloading, wrongful overtaken and hit-and-run cases. Further analysis as presented in Table 1 revealed that over-speeding accounted for an average of about 25 to 50% of the cause of road traffic crashes in the core metropolitan area of Lagos state, followed by break failure with a range of 12% to 20% while other factors having proportions not more than 11%. Olusina and Ajanaku (2017) also found that over-speeding accounted for 45.5% of probable causes in Lagos. Awoniyi et al (2021) equally identified major causes of road crashes as speed violation, loss of control, and dangerous driving. NBS (2022) reported major causative factors of road traffic crashes to include speed violation, sign-light violation, wrongful overtaking, dangerous driving, brake-failure, defective vehicle, tyre-burst, bad roads and road obstruction. Invariably, all the earlier studies identified over-speeding as the leading cause, though the ranked position for others varied.

Table 1 Percentage contribution of risk factors to road traffic crashes (2013 – 2022)

Code	Risk Factor	Percentage contribution
SPV	Speed violation	25 – 50
BFL	Break failure	12 – 20
DGD	Dangerous Driving	5 – 18
HIT/RUN	Hit and run	6 - 10
RTV	Route violation	4 – 7
MDV	Mechanically deficient vehicle	3 – 8
TBT	Tyre burst	2 – 7
OTHERS	Other risk factors	2 – 5
WOV	Wrongful overtaking	2 – 4
OVL	Overloading	1 – 2

Source: Researchers' compilation, 2024

3.2 Temporal Analysis of the Distribution Pattern of Crash Location

The nearness neighbor analysis is to statistically understand and explain the pattern of distribution of the crash locations and determine whether it is dispersed, random, or clustered. One more reason for this analysis is to determine the average distance band obtainable for each year of the study period (2013 - 2022). Table 2 presents the nearest neighbor analysis for each year between 2013 to 2022, the NNA ratio for each of the years gives a positive value and the corresponding z score are higher negative value which suggests that there is a cluster of crash locations in each of the years. Similarly, the observed mean distance presents the average distance between the points in each year. The highest (348.2407m) mean distance is in 2013, while the lowest (186.9064m) is in 2019, and the cumulative (2013-2022) is 61.6411m. The Table also shows a negative z score, which revealed that the observed mean distance for each year is significantly below the mean distance, which also explains the cluster nature of the distribution.

The NNA indicates stronger clustering. In this case, the NNA ratios range from 0.19 to 0.37. All values fall within the typical range for clustered patterns, indicating that the points are not randomly distributed but tend to form groups or clusters. The Z score is a measure of how many standard deviations a particular data point is from the mean. Negative Z scores suggest that the observed mean distance is below the expected mean distance. In the Table, all Z scores are negative, ranging from -20.25 to -28.77. These large negative Z scores indicate that the observed mean distances are significantly smaller than the expected mean distances, reinforcing the notion of clustering.

The observed mean distance is the average distance between points in the dataset. The values range from 156.14 to 348.24 meters. The decreasing trend in

Table 2: Nearest Neighbour Analysis of the Yearly Road Crashes Distribution 2013-2022

Year	NNA Ratio	Z Score	Observed Mean Distance (M)	Expected Mean (M)	Pattern
2013	0.374095	-20.249876	348.2407	930.8885	Clustered
2014	0.348439	-19.708611	346.9264	995.6592	Clustered
2015	0.330179	-22.378930	297.6328	901.4275	Clustered
2016	0.365488	-20.954578	333.3079	911.9532	Clustered
2017	0.330145	-21.056859	316.3031	958.0735	Clustered
2018	0.251612	-22.862709	248.0517	985.8495	Clustered
2019	0.253238	-30.068701	189.4125	747.9608	Clustered
2020	0.249611	-27.275393	206.8191	828.5660	Clustered
2021	0.190782	-29.778112	156.1413	818.4268	Clustered
2022	0.232653	-28.766574	186.9064	803.3690	Clustered
2013 - 2022	0.199230	-77.947914	61.6411	309.3960	Clustered

Source: Researchers' computation, 2024

observed mean distance across the years indicates a tendency for the points to be closer to each other year by year, supporting the idea of clustering. The expected mean distance is the average distance expected under a random distribution assumption. The values range from 747.96 to 995.66 meters. The consistently high value of expected mean distances compared to observed mean distances further confirms the clustered nature of the data. However, the highest mean distance obtained over the year is 348.24, and the distance obtained for the years aggregate (2013-2022) is 309.3960. This means that the average distance band is 309.3960 and the upper limit distance band is 348.24, the highest in any particular year.

3.3 Spatial Analysis for the Period of 2013-2015

The spatial pattern of road traffic crashes in the period 2013-2015 presents the aggregate crashes for 2013, 2014, and 2015. Figure 1 presents the spatial distribution of crashes based on the frequency of crashes occurring in each local government area. The spatial pattern by frequency of crashes has Ikeja as the local government area with the highest average number of crashes (97-154), followed by Alimoso, Kosofe, Amuwo-Odofin, and Eti-Osa local government areas in the second category with average number of crash ranging between 47 and 96. The last category has an

average number of crashes ranging between 7 and 46, and the Local Government Areas in the group are Agege, Ifako-Ijaye, Ojo, Lagos Mainland, Lagos Island, Apapa, Oshodi-Isolo, Surulere, Mushin, Somolu, and Ajeromi-Ifelodun.

3.4 Spatial Analysis for the Second Temporal Period of 2016-2018

The aggregate crash frequency for the three years 2016, 2017, and 2018 is presented in Figure 2, the spatial distribution illustration map. The map shows that the Ikeja Local Government has the highest average number of crash points (62-191), followed by Amuwo-Odofin, Eti-Osa, Lagos Island, and Kosofe with an average number of crashes ranging between 36 and 61. Other LGAs with the lowest average number of crashes (6-35) are Agege, Ifako-Ijaye, Ojo, Lagos Mainland, Apapa, Oshodi-Isolo, Surulere, Mushin, Somolu, and Ajeromi-Ifelodun.

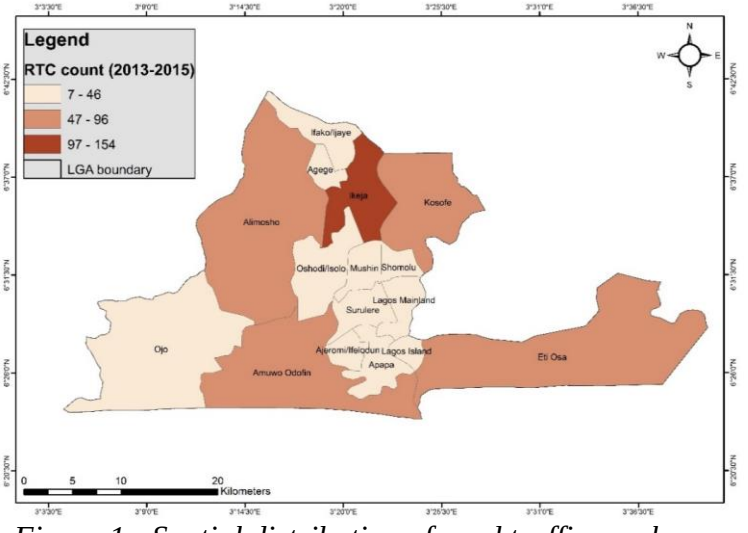

Figure 1: Spatial distribution of road traffic crashes by Local Government area for 2013-2015
Source: Researchers' computation, 2024

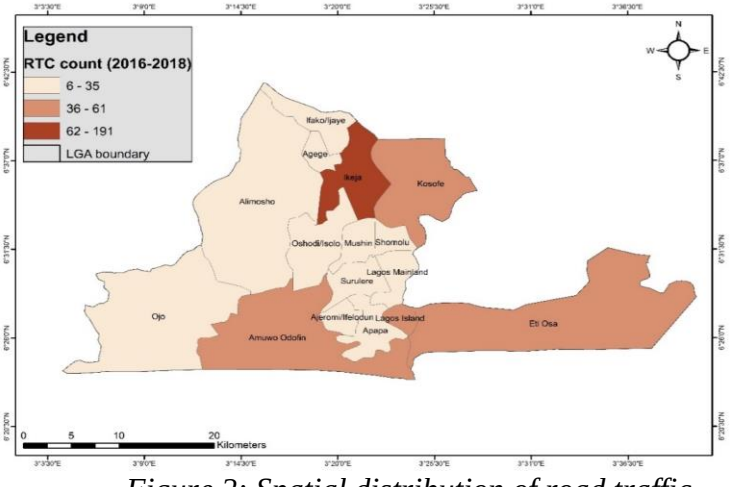

Figure 2: Spatial distribution of road traffic crashes by Local Government area for 2016-2018
Source: Researchers' computation, 2024

3.5 Spatial Analysis for the Third Temporal Period of 2019-2022

The third temporal period is made up of four years, 2019, 2020, 2021, and 2022. The period presents the recent crash situation in the study area, and the pattern of distribution is shown in Figure 3. Similarly, Ikeja has the highest average number of crashes ranging between 153 and 255 recorded during the period, followed by ten other LGAs with an average number of crashes of 65-152, the LGAs include Alimoso, Kosofe, Amuwo-Odofin, Eti-Osa, Agege, Ifako-Ijaye, Ojo, Lagos Mainland, Lagos Island, Apapa, Surulere, and Ajeromi-Ifelodun, while Agege, Ifako-Ijaye, Oshodi-Isolo, Mushin, and Somolu Local Government Areas were with low average number of crashes.

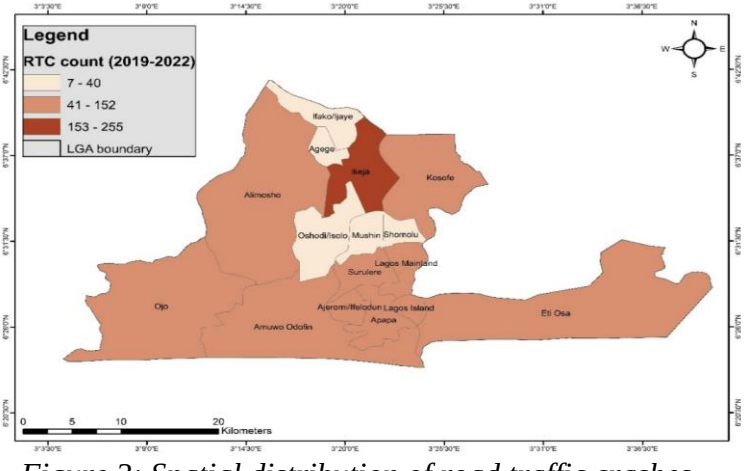

Figure 3: Spatial distribution of road traffic crashes by Local Government area for 2019-2022

Source: Researchers' computation, 2024

3.6 Analysis of the Crash Aggregate for the Ten Years

The aggregate data for the ten years is analyzed in this section, further to the distribution pattern observed in the three temporal periods, the aggregate spatial distribution pattern is presented in Figure 4. Similar to what was obtained in the three temporal periods Ikeja Local Government Area recorded the highest crash frequency with an average count of 401 to 600. Kosofe, Amuwo-Odofin, Lagos Island, and Eti-Osa were the next in the category with average of 201 to 400 crash counts, and the last group with low crash counts of 20 to 200 include Agege, Ifako-Ijaye, Ojo, Alimosho, Lagos Mainland, Apapa, Oshodi-Isolo, Surulere, Mushin, Somolu, and Ajeromi-Ifelodun Local Government Areas.

Based on three temporal periods, an area-wide spatial analysis to identify high-risk local government areas using crash counts was conducted, the KDE analysis presents the spatial distribution patterns visualized in each of the temporal maps based on the relative number of occurrences in each LGA. The LGA was chosen as the basis for spatial analysis because of the political and administrative status of governmental intervention and programmes. Interestingly and more prominently, the Ikeja LGA which happens to be the

seat of government in Lagos state is prominently identified as a black-spot zone of the sixteen LGAs in the core metropolitan area of Lagos. The analysis aimed at identifying areas with worse road safety situations and plan intervention strategies and measures to ameliorate them.

The spatial distribution analysis revealed that, all through the years Ikeja LGA recorded the highest number of crash occurrences (black-spot), and closely related is Amuwo-Odofin which also recorded the highest average counts in 2014 and 2019. The second level of crash count distribution analysis has nine (9) LGAs in the group. Four of the LGAs are in the group by chance, because they recorded the level of counts once or twice. These LGAs are Oshodi-solo, Apapa, Surulere, and Lagos Mainland. Alimosho, Eti-Osa, Lagos Island, Kosofe, and Amuwo-Odofin are recorded in this category not less than five times in the ten years.

The constantly low areas are Agege, Ojo, Shomolu, Ajeromi, Ifako-Ijaye, and Mushin LGAs. Olusina and Ajanaku (2017) also found that the Ikeja LGA leads other areas with 25% of the black-spot located, the study also identified Eti-osa and Amuwo-Odofin with 14% and 7% respectively. Two things are common to the LGAs identified as black-spots, first, they have an arterial road of high traffic and economic importance passing through the area, and the level of economic activities is high with the presence of commercial and public facilities.

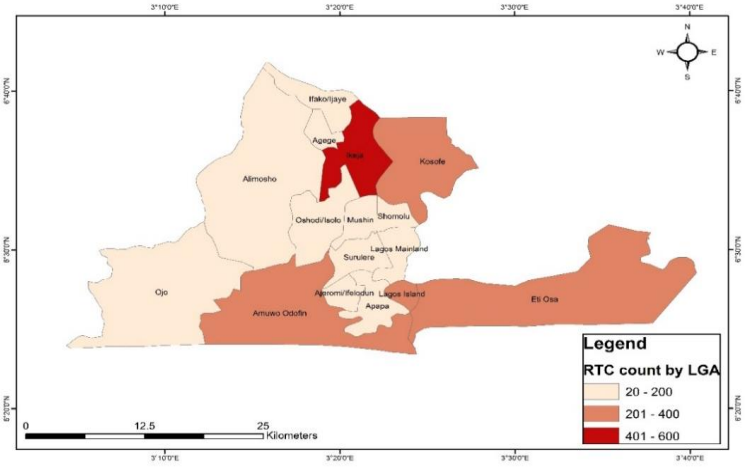

Figure 4 Spatial distribution of road traffic crashes by Local Government area for 2019-2022 Source: Researchers' computation, 2024

4.0 Conclusion and Recommendations

This study examined the causes of road traffic crashes and identified local government areas within the core metropolitan Lagos that are black-spot zones of road traffic crashes. Speed violation was found to be a leading risk factor that was responsible for road traffic crashes. The study concludes that speed advocacy and control is a very crucial measure to ameliorate the increasing crashes in Lagos State and recommends the use of posted speed limits on all roads as well as the

installation of speed cameras with a system of enforcement and correction of erring drivers. The study also established that the Ikeja LGA is the black-spot zone. Interestingly Ikeja is the administrative and economic hub of Lagos State with lots of human and material resources. It is therefore imperative that road safety attention in the form of measures and intervention to curb speeding be organized in the LGA to ameliorate road crashes and minimize waste of resources.

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