Spatial Analysis of the Hotspots of Road Traffic Accidents in Southwestern Nigeria

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DOI: https://doi.org/10.47772/IJRISS.2026.101000265

Received: 11 October 2026; Accepted: 16 October 2026; Published: 01 November 2026

ABSTRACT

Road traffic accidents represent a key socio-cultural and transport issue of concern, especially in the developing world, where a high rate of urbanization coupled with growing traffic congestion and insufficiency of infrastructure enhances the susceptibility to accidents. The proposed research is a spatial analysis of road traffic accident hotspots in Southwestern Nigeria, aiming to identify high-risk areas and analyze their spatial distribution patterns. The use of Geographic Information Systems (GIS) methods, as well as the use of sophisticated spatial analytical applications, addressed the question of how accident concentration and clustering occurred within the region along selected urban and peri-urban corridors. The details of accidents were retrieved through the pertinent traffic and safety bodies and then georeferenced to create an overall spatial database. To identify statistically significant clusters of accident incidence, spatial statistical methods of Kernel Density Estimation and hotspot analysis were used. The findings indicate the presence of significant spatial heterogeneity in the distribution of accidents and that the hotspots are present around large transportation corridors, high-volume intersections, and highly populated urban centers. These geographical concentrations are closely related to traffic levels, road network structure, land-use processes, and infrastructural limitations. The results emphasise the paramount importance of the application of spatial analytical methods in interpreting the occurrence pattern of accidents and areas with priority for intervention. The existence of statistically significant hotspots is empirical evidence of targeted road safety interventions, infrastructural enhancement, and evidence-based transportation planning. The research supports the fact that GIS-based methodologies are inevitable to the problem of road safety management and policy-making in regions such as Southwestern Nigeria and other developing economies.

Keywords: Road Traffic Accidents, Spatial Analysis, Hotspot Analysis, Geographic Information Systems (GIS), Kernel Density Estimation, Southwestern Nigeria, Road Safety Planning.

INTRODUCTION

The word transport was derived from two Latin words, trans, which means “across,” and portare, which means “carry” (Akujor, Uzowuru, Abubakar, and Amakom, 2022). Transport refers to the movement or conveyance of people, goods, and services from one geographical location to another through various modes, including road, rail, water, air, pipelines, and other means (Akujor et.al, 2022). Transport plays a significant role in our day-to-day activities, without which nothing much can be achieved; this is evident in the work of Ogunleye (2011), which asserted that Transport plays a crucial role in a region's economic development. It is the primary artery connecting communities and society's disparate sections. It has also been acknowledged internationally for its critical role in driving change in economies from the industrialized to the developing world.

Due to the increasing demand for transport in space, rapid increase in population, urbanization, and high levels of socio-economic activities, road traffic accidents have become inevitable s (Kazmi and Ahmed, 2020).

Road traffic accidents (RTAs) pose a significant and escalating global issue, primarily due to their alarming fatality rates and the profound economic and social repercussions they entail. According to the World Health Organization (WHO, 2018), approximately 1.35 million individuals perish each year as a result of these

incidents; additionally, between 20 and 50 million people sustain non-fatal injuries, many of which lead to long-term disabilities. The situation is particularly critical in low- and middle-income nations, which comprise only 60% of the world's vehicles and account for 93% of road traffic fatalities (Peden, 2004). This burden is anticipated to increase as motorization rises, urbanization expands, and road infrastructure remains underdeveloped in these areas. However, addressing these challenges is essential because the implications extend beyond mere statistics, affecting communities at large (Nantulya and Reich, 2002).

Road traffic accidents represent a pressing public health concern in Nigeria due to their considerable social, economic, and health implications. The nation grapples with poor road infrastructure, ineffective traffic law enforcement, rapid urbanization, and insufficient emergency response systems (Ibor Inah et al., 2025). These factors collectively contribute to an elevated incidence of accidents across the country. The utilization of Geographic Information Systems (GIS) for spatial analysis serves as a valuable tool; it aids in comprehending the distribution of accidents, pinpointing hotspots, and guiding targeted interventions aimed at enhancing road safety. However, by tackling the deficiencies in road safety standards and emergency response mechanisms, Nigeria can achieve significant advancements in alleviating the burden of road traffic accidents. Although the challenges are substantial, this effort is critical for improving public health outcomes (FRSC, 2024; Inah et al., 2025).

In countries such as the United States, Germany, and Japan, significant strides have been made in curtailing traffic-related fatalities through stringent enforcement of road safety regulations, the development of efficient public transportation systems, and the widespread adoption of safety technologies (Elvik and Høye, 2019). However, countries in Africa, Asia, and certain regions of Latin America have failed to maintain a comparable pace with these advancements, resulting in disproportionately high rates of road traffic deaths and injuries (Nantulya and Reich, 2002). This discrepancy highlights the urgent need for enhanced safety measures in these areas; although the challenges are complex and multifaceted, they must be addressed. Because of this, it is essential to examine the underlying factors contributing to these disparities.

In Nigeria, road traffic accidents have emerged as a significant public health crisis. Data from the Federal Road Safety Corps (FRSC) reveal that between 2015 and 2020, more than 30,000 individuals lost their lives due to road crashes; the majority of these fatalities occurred on federal highways (FRSC, 2020). The country's rapidly growing population, urbanization, and increasing vehicle ownership have not been accompanied by corresponding enhancements in road infrastructure or the enforcement of safety measures.

Many roads are poorly designed, which exacerbates the problem, and they remain inadequately maintained despite a proposed ₦229.99 billion federal road maintenance budget for 2026 aimed at patching critical "failed sections" (FERMA, 2026). These infrastructure deficits, coupled with heavy congestion and a lack of robust enforcement of traffic laws, greatly contribute to Nigeria's alarming rate of accidents; in 2025 alone, road traffic crashes increased by 9.2%, with speeding accounting for nearly 47% of all incidents (FRSC, 2026; NBS, 2024). However, this situation could potentially improve if focused efforts are made to address these underlying issues through integrated digital enforcement and improved emergency response timelines (LASTMA, 2026; Mohammed, 2025).

STUDY AREA

The study area comprises of six states namely Ekiti, Ondo, Osun, Oyo, Ogun, and Lagos states respectively as shown in fig 1. The region is approximately 78,771km2 by size and it is located between Latitude 50451 and 80351 North of the Equator and Longitude 20401 and 6051 East of the Greenwich Meridian.

The southwestern part of Nigeria lies between the northern savanna region and the coast of the Atlantic Ocean in the south. It spans approximately 79,000 square kilometers and comprises six states: Lagos, Ogun, Oyo, Osun, Ondo, and Ekiti. On its west it borders the Republic of Benin, to the north are Kogi and Kwara state while Edo State borders it on the east; on the south is the Atlantic Ocean (Afolabi et al., 2022). Trade and cultural interchanges have always been enhanced by the geographical location of southwest Nigeria which is surrounded by geographical features especially a coastal area such as Lagos one of the busiest ports in Africa (Olusola and Adewale, 2023). As a commercial hub and transit area, traffic volumes are again increased in the region due to the existence of large transport corridors such as the Lagos-Ibadan Expressway. In particular,

traffic congestion raises the probability of accidents in specific inaccessible zones, with high-speed limits and insufficient security measures (Olagunju, 2021).



Fig. 1: Political Map of Southwestern Nigeria

METHODOLOGY

The collected data were processed using GIS. The following steps were taken to ensure data quality and usability for spatial analysis. Accident records from the FRSC were compiled into a geodatabase, and location data (e.g., GPS coordinates) were standardized to ensure accurate spatial representation. Road network data were digitized and attributed with relevant information, including road classification and safety features. The compiled data layers were integrated into a GIS environment. Road network data and accident locations to facilitate spatial analysis.

Hotspot Analysis: Kernel Density Estimation (KDE) and Moran's I were used to map accident density and assess spatial autocorrelation, revealing clusters and patterns of road traffic accidents in southwest Nigeria. The results were presented as detailed maps highlighting high-risk areas in the study area.

RESULTS

Spatial Analysis of Road Traffic Accidents in Southwest, Nigeria

The spatial analysis of road traffic accidents (RTAs) in Southwestern Nigeria as shown in Fig. 2 according to FRSC records revealed significant variation in accident intensity across the region's road network. Based on annual accident frequency per kilometer, road segments were classified into four risk categories. Approximately 34% of the roads recorded fewer than 1 RTA per kilometer per year, indicating low-risk areas typically found in rural settings with lower population densities and limited vehicular activity. About 36% of the segments fell within the 2–3 RTAs/km/year range, representing moderately low-risk zones, often located in peri-urban regions and along secondary roads.

A further 22% of the network experienced 4–5 RTAs/km/year, corresponding to moderate-risk segments that generally serve as links between urban centres and regional towns. The remaining 8% of the road segments recorded more than 5 RTAs/km/year, identifying them as high-risk corridors or accident hotspots. These high-risk areas were predominantly concentrated around major urban centres such as Lagos and Ibadan, as well as along heavily trafficked intercity highways. Fig. 4.1 clearly illustrates this clustering of high accident rates, particularly in Lagos State, which displayed the highest concentration of RTAs, likely due to its dense population, commercial activity, and complex traffic dynamics.

In contrast, lower-risk zones were more prominent in states such as Ekiti, Osun, and parts of Ondo, where most road segments fell within the low to moderately low-risk classifications. These areas, characterized by rural landscapes and less congested roads, exhibited comparatively safer travel conditions. Overall, the spatial patterns suggest a strong urban–rural divide in accident risk, with elevated frequencies in high-density zones and reduced risks in less populated regions. This distribution highlights the need for targeted road safety interventions focused on urban corridors and major transport routes with persistently high accident intensities.

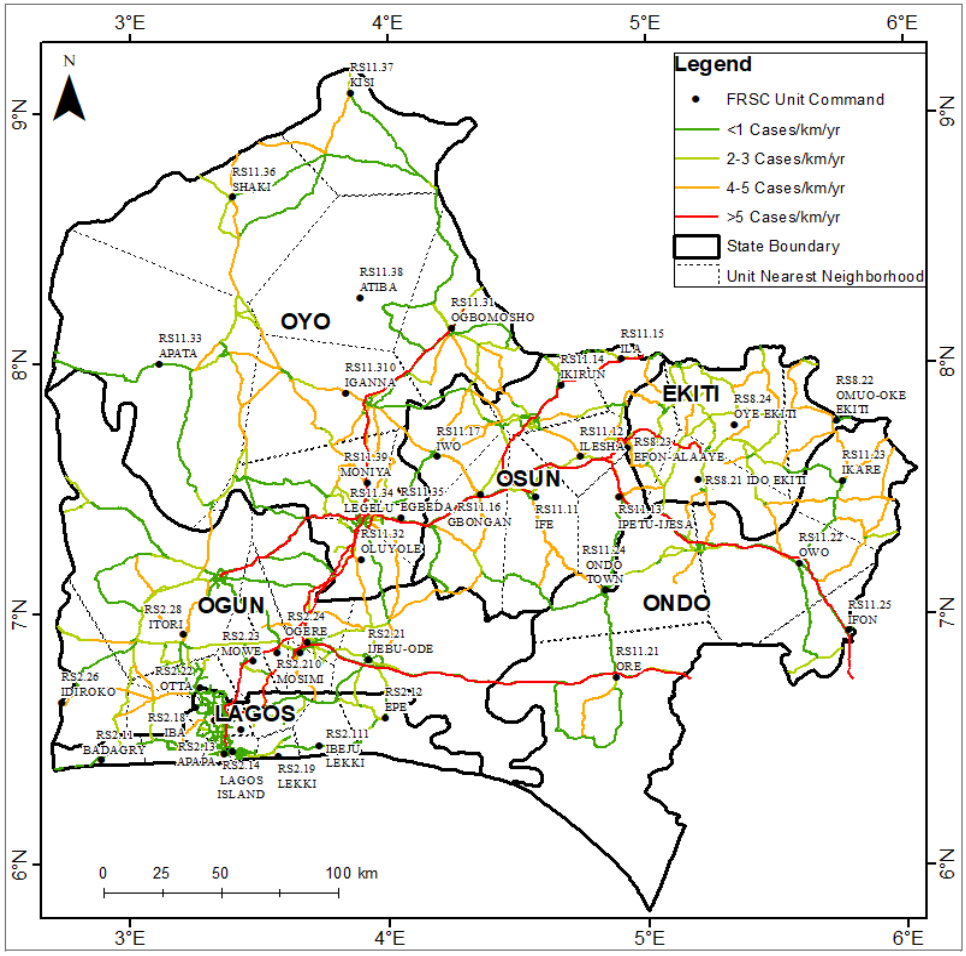


Fig. 2: Cases of Road Traffic Accidents in Southwest Nigeria.

Road Traffic Accident Hotspots

The hotspot map of road traffic accidents (Fig.3) in Southwest Nigeria clearly delineates areas with statistically significant clustering of high and low accident frequencies. Notably, prominent and continuous red zones, indicating hotspots with a 99% confidence level, are concentrated along major transportation arteries such as the Lagos-Ibadan Expressway, the Ibadan-Abeokuta Road, the Lagos-Benin Expressway (particularly within Ondo and Ogun states), and the Akure-Owo Road. These high-risk corridors, statistically unlikely to exhibit such clustering by random chance, strongly correlate with routes connecting major urban centers like Lagos, Ibadan, Abeokuta, Akure, and Benin City, suggesting a relationship between high traffic volumes and elevated accident rates. Adjacent areas, marked as hotspots with a 95% confidence level, indicate a broader influence of accident-contributing factors along these key routes. Conversely, blue-shaded regions represent statistically significant coldspots with 99% and 95% confidence levels, signifying areas with a clustering of lower-than-expected accident occurrences, typically observed in more rural settings. The grey areas are deemed statistically insignificant, displaying a more random distribution of accidents. Importantly, these hotspot and coldspot patterns transcend state boundaries, underscoring the influence of transportation infrastructure and associated human activity over administrative divisions. While the map also presents elevation data, a direct causal link to accident hotspots requires further specific analysis. Overall, the visual evidence strongly suggests a non-random spatial distribution of road traffic accidents in Southwest Nigeria, with significant clustering along major highways, necessitating targeted safety interventions and a deeper understanding of the localized factors driving these high-risk concentrations.

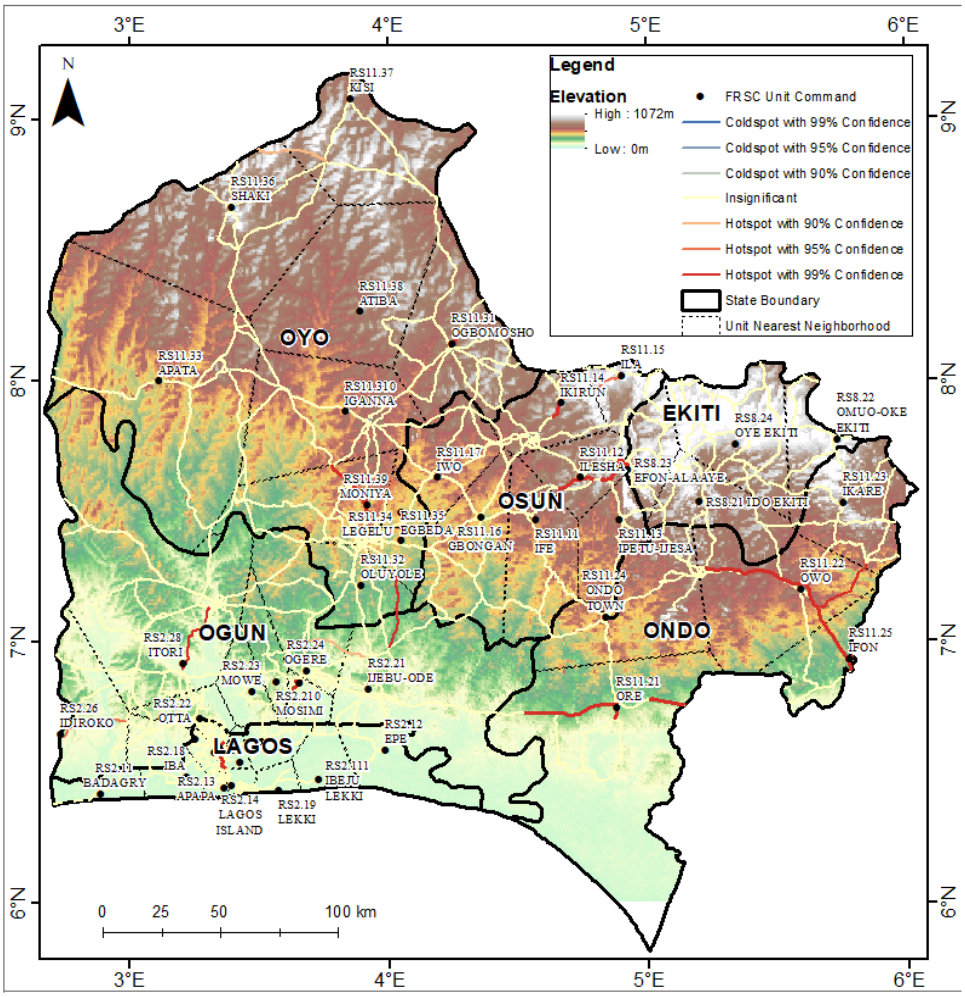


Fig. 3: Hotspots of road traffic accidents in Southwest Nigeria.

Conversely, Ondo State displayed fluctuating values, oscillating between weak positive and negative spatial autocorrelation. Positive clustering was observed in 2018 (2.38) and 2017 (0.54), yet the majority of the decade was characterized by negative values, including -2.38 in both 2015 and 2016. This inconsistency implies a dynamic spatial reorganization of road accidents, possibly influenced by localized infrastructure improvements or alterations in enforcement strategies that shifted accident-prone locales across different temporal junctures.

Osun State maintained predominantly negative autocorrelation values throughout the examined period, ranging from -0.48 to -2.34, signifying dispersed accident patterns devoid of stable clustering. This suggests that road traffic incidents in Osun were distributed more randomly across its network, likely due to the comparatively lower congestion levels of its road system and a more geographically dispersed settlement configuration.

Oyo State exhibited a mixed pattern of clustering and dispersion across the decade. While 2020 (5.52) and 2019 (2.74) reflected strong clustering tendencies, the earlier years, notably 2015 and 2016, showed moderate negative values (-1.2), indicating a transition from dispersed accident patterns to more spatially concentrated ones. This temporal shift may be linked to rapid urban expansion and the increasing volume of vehicular traffic around Ibadan, the state's capital and a significant transportation node.

Clustering of Road Traffic Accidents

The spatial autocorrelation report, utilizing Moran's I statistic in Fig. 4, revealed a statistically significant clustered pattern in the distribution of total accidents over the 10-year study period. The calculated Moran's Index of 0.700642, substantially higher than the expected index of -0.021739 under spatial randomness, indicates a strong positive spatial autocorrelation. This signifies that geographical areas experiencing a high number of total accidents tend to be located adjacent to other areas with similarly high accident counts, and conversely, areas with fewer accidents are clustered together. The extremely low p-value of 0.000000,

associated with a highly significant z-score of 7.445239, effectively dismisses the possibility that this observed clustering is a random occurrence. In fact, there is less than a 1% likelihood that such a distinct spatial pattern could arise purely by chance. This strong rejection of spatial randomness implies that underlying spatial processes or factors are likely contributing to the concentration of high and low accident areas. These factors could include variations in road infrastructure, traffic volume patterns, enforcement levels, socio-economic characteristics of the areas, or even environmental conditions that exhibit spatial dependencies. The visual representation in Fig.4 further reinforces this conclusion, illustrating how a high positive z-score corresponds to a clustered spatial arrangement, where similar values tend to aggregate geographically rather than being randomly dispersed. Therefore, the analysis strongly suggests that interventions and further investigations should consider the spatial context of accident occurrences to identify and address the localized factors driving these patterns.

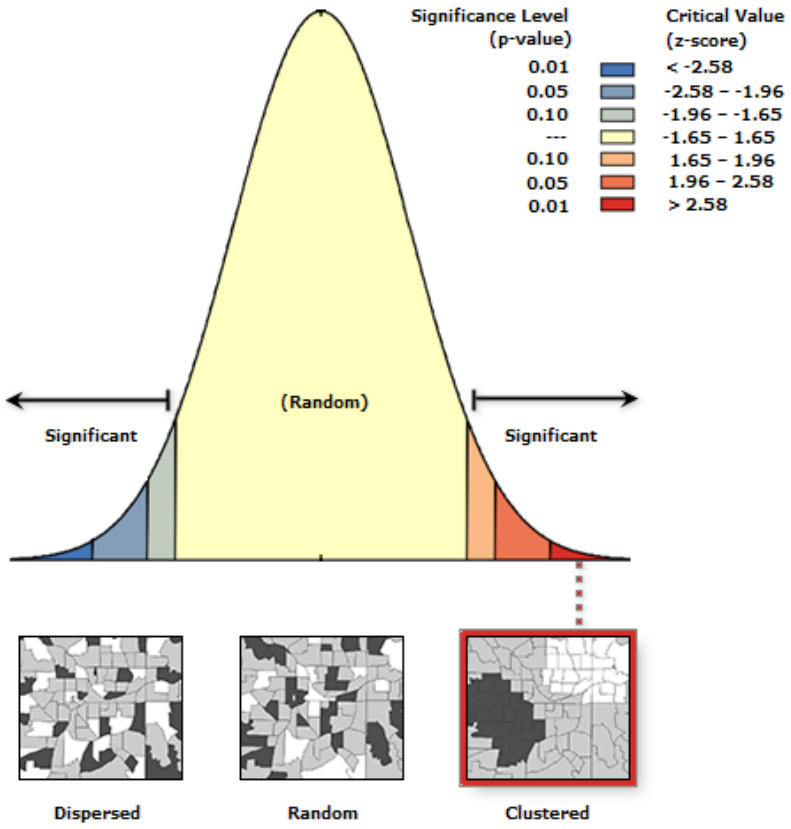
Table 1: Spatial autocorrelation for the 10-year period across the states from 2012-2021

State	Year 2021	Year 2020	Year 2019	Year 2018	Year 2017	Year 2016	Year 2015	Year 2014	Year 2013	Year 2012
Lagos	0.12	3.58	4.24	0.52	1.9	1.46	1.46	-0.18	0.74	0.12
Ogun	0.88	11.88	8.12	4.18	0.96	1.96	1.96	-0.64	5.06	0.88
Ondo	-0.86	0.88	0.86	2.38	0.54	-2.38	-2.38	-0.9	-0.32	-0.86
Osun	-0.48	0.64	-2.06	-1.94	-2.34	-1.28	-1.28	-1.28	-0.72	-0.48
Oyo	-0.98	5.52	2.74	1.42	0.32	-1.2	-1.2	-1.16	0.12	-0.98
Ekiti	-4.24	-4.7	-4.82	-5.18	-5.48	-5.5	-5.5	-5.4	-3.46	-4.24

Tab. 1: Spatial autocorrelation for the 10-year period across the states from 2012-2021

Spatial Autocorrelation Report

Moran's Index:	0.700642	
z-score:	7.445239	
p-value:	0.000000	



Given the z-score of 7.44523882573, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Moran's Index:	0.700642
Expected Index:	-0.021739
Variance:	0.009414
z-score:	7.445239
p-value:	0

Fig. 4 Moran's I: The total accidents for the 10 years

DISCUSSION

The Moran's I analysis revealed a strong and statistically significant spatial clustering of road traffic accidents across Southwest Nigeria during the 10-year study period. The Moran's I value of 0.700642, together with a z-score of 7.445239 and a p-value of 0.000000, indicates that accident locations were not randomly distributed but were significantly concentrated in particular areas. This suggests that factors such as road conditions, traffic volume, population density, land use, driver behaviour, and enforcement of traffic regulations influence the spatial distribution of accidents. The finding agrees with previous studies that identified clustering of road traffic accidents in major Nigerian cities, although some studies reported more dispersed patterns in areas with lower population density and wider road networks. Differences in findings may be associated with variations in data resolution, road infrastructure, urbanisation, traffic behaviour, and accident reporting systems.

The temporal analysis further showed that spatial clustering varied considerably among the six states between 2012 and 2021. Lagos and Ogun States generally recorded positive z-scores, indicating stronger clustering, with Ogun showing the most consistent and intense clustering, particularly in 2020. This may be associated with high traffic volumes and major transport corridors. Oyo State also shifted from negative to positive z-scores in the later years, suggesting increasing clustering associated with urban expansion and commercial activities. Osun and Ekiti States generally recorded negative z-scores, indicating more dispersed accident patterns, possibly due to lower traffic density and less complex road networks. Ondo State showed fluctuations between positive and negative values, suggesting changing spatial patterns that may be influenced by road safety interventions and infrastructural changes.

The findings demonstrate that road traffic accidents in Southwest Nigeria are spatially and temporally dynamic, with clustering intensity differing from one state to another. These differences reflect the combined influence of physical, socio-economic, infrastructural, behavioural, and institutional factors, as well as variations in accident reporting and road safety interventions. The use of Moran's I provides a stronger assessment of spatial dependence than simple descriptive or hotspot analysis because it considers the relationship between accident patterns and neighbouring locations.

CONCLUSION AND RECOMMENDATIONS

The research, which employed Geographic Information Systems (GIS), geo-spatial analytical tools, and inferential statistics to assess the Spatial Analysis Of The Hotspots Of Road Traffic Accidents In Southwestern Nigeria, has revealed critical insights into the geographical features, level of vulnerability, and institutional preparedness in managing road traffic accidents in the region.

The analysis of spatial distribution revealed that road traffic accidents (RTAs) predominantly take place in some urban centres and major intercity routes. Analysis in this regard, using kernel density estimation (KDE), showed that accidents tend to cluster around the vicinity of major expressways and also at intersections, which are around Lagos, Ibadan, Abeokuta, and Akure. The spatial patterns found were statistically supportive, as they had positive Moran's I indices, showing that crash hotspots are more or less clustered towards each other.

These spatial concentrations can mostly be pinned to the dynamic relations between the following conditions:

a. A large volume of traffic and inefficient flow of traffic
b. Commercial activities with roadside loading/offloading
c. Lack of pedestrian infrastructure
d. Inadequate traffic control measures

The result of the findings supports the spatial epidemiology theory, that geographic patterns usually emerge from differences in exposure and infrastructure.

Based on the findings of the spatial analysis of road traffic accident hotspots in Southwestern Nigeria, several strategic measures are recommended to reduce accident occurrences and improve overall road safety across the region.

i. Installation of intelligent traffic management systems: Intelligent traffic management systems should be installed along major highways and high-risk corridors such as the Lagos-Ibadan Expressway and other heavily used intercity roads. The use of speed cameras, traffic monitoring systems, and real-time surveillance will help regulate traffic flow and reduce reckless driving.

ii. Development of pedestrian bridges and crossings: pedestrian infrastructure should be improved in urban areas where accident hotspots have been identified. The construction of pedestrian bridges, sidewalks, and clearly marked crossing points will reduce conflicts between vehicles and pedestrians, particularly in densely populated commercial areas.

iii. Improved road signage and intersection: dangerous road intersections and junctions should be redesigned and upgraded. Improved road signage, traffic lights, proper road markings, and roundabouts should be introduced to enhance traffic control and reduce collision risks at these critical points.

iv. Periodic spatial safety audits of major transport corridors: traffic law enforcement should be strengthened along identified accident corridors. Agencies such as the Federal Road Safety Corps should intensify patrols and enforce regulations related to speeding, reckless driving, and overloading.

v. Integration of GIS-based accident monitoring systems by FRSC: Geographic Information Systems

vi. should be integrated into road safety management in Nigeria. GIS-based accident monitoring systems will enable authorities to identify emerging accident hotspots and implement targeted interventions more effectively.

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