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An Assessment of the Roadway Segment Environment influence on Traffic crash in Oyo State Nigeria

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Abstract Traffic crashes remain a critical global issue. Governments have introduced measures such as legislation, driver education, and improved road design to address this challenge. This study examines highway traffic collision data from Federal Road Safety Corps (FRSC) records (2020–2022), integrating georeferenced maps, road networks, satellite imagery (Landsat, Google Maps), Shuttle Radar Topography Mission (SRTM) data, and field survey data from blackspot road segments. Analysis, which was done in ARCgis 10.8 environment, identifies 66 blackspots across 18 federal routes, with 56 curved sections linked to these routes. The findings reveal a strong correlation between environmental terrain and crash occurrences. The study advocates for the strategic placement of road signs and symbols and highlights the necessity of leveraging Global Positioning System (GPS) and Geographic Information System (GIS) technologies for accurate traffic data collection and analysis, particularly in complex terrains. These recommendations aim to enhance roadway safety and inform evidence-based policymaking.

Keywords Traffic Crashes, Blackspot, Geo-reference, Roadway environment

JEL L91, O18, R42

1. Introduction

Transportation by road is the most available mode of transportation available to mankind. It provides services at door step level unlike other modes such as air, rail, maritime and pipeline as such road network is the most intensely utilised globally, effort to organise movements on the roadways lead to improvements such as tarred roads, markings and signage's among other rules and regulation that guides its safe operation. In spite of these efforts road traffic crashes (RTCs) represent a significant worldwide challenge causing substantial morbidity and mortality, "an average of 1.19 million people die each year from road traffic crashes globally" (WHO, 2023).

Movements along the roadway may be loosely divided into two categories; people and cargo, the categorisation of these movement types is ensured in many nations by permit requirements and safety laws. Just as a horse or an ox can go down a road, so can a car, truck or motorbike. While passengers may be transported by car or bus for mass transit, cargo can be delivered by trucking firms. Modern roadways are calibrated to accommodate these various types of movement and are often distinguished by well-marked lanes, signs and other roadway characteristics to enhance road safety. "Nigeria has the largest road network in West Africa, with a national network of roads currently estimated to be about 194,200 km of which 129,580 km (or 66.7%) are local and rural roads, 30,500 km (15.7%) are state-owned roads, and the federal government owns 34,120 km (17.6%)" (Lamidi, et al 2022).

Where road traffic crashes repeatedly occur at a specific location on the roadway segments, such a location is referred to as blackspot. The Victorian blackspot programme, which started in Australia in 1980 defined blackspot as a location or a roadway segment where at least 12 casualties of road traffic crashes have occurred in 3 years. (Road Safety International 2020) What could be responsible for the development of blackspots? What could be wrong with these locations? Could it be that the roadway segments.

Roadways are constructed across different types of landforms and land uses; some roadway sections could be hilly or valley-like or undulating and some on straight, flat land. Blackspots are also formed along these different terrains. The purpose of this study is to determine whether there is a relationship between roadway traffic crash occurrences and the physical condition in terms of the terrine on which these roads are constructed.

1.1. Study Area

Located in the southwestern region of Nigeria, Oyo State is notable for its agricultural significance, cultural diversity, and historical importance. It is bordered to the north by Kwara State, to the east by Osun State, to the south by Ogun State, and to the west by the Republic of Benin. The capital of Oyo State is Ibadan, which stands as one of the major cities in Nigeria. The terrain of Oyo State is varied, with rolling hills in the north and west and fertile plains in the south. The undulating landscape in the northern Oke-Ogun region is well known. The Oyan River is a major river, while the Ogun River makes up a section of the state's northern frontier. Oyo State's tropical climate results in distinct wet and dry seasons. In general, the rainy season runs from April to October, while the dry season runs from November to March. Oyo State is mostly an agrarian state, with a largely agricultural economy. Among the several road networks that comprise the state are major thoroughfares that link Oyo State to neighbouring states and cities.

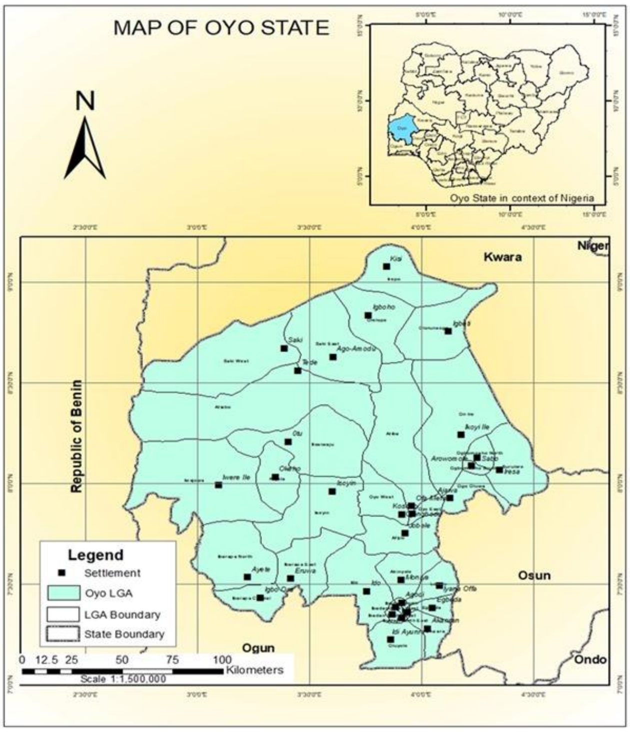

Figure 1. Oyo State Map.

According to Road Safety International 2020, when the Victorian blackspot programme started in Australia in 1980, it stated that "a blackspot is a roadway segment of 1 km with at least 12 casualty traffic crashes in 3 years." A casualty crashes means a crash that resulted in death or injuries, or a crash in which at least one person is injured (seriously or slightly). There have been great successes in traffic crash reduction over 40 years (an 85% reduction in traffic crashes, according to their definition). These blackspots may be an intersection, a curve or bend, or a straight stretch of road. To investigate these blackspots, this chapter emphasises, research design, data Characteristics, data sources and collection methods, calibration and description of variables and method of analysis.

2. Methodology

2.1. Data Procurement

This study adopted an ex post facto research design, with data obtained from Federal Road Safety Corps (FRSC) Oyo State sector (2020-2022). a secondary data derived from the (FRSC) traffic crash records spanning the years 2020 to 2022. This record was as a non-spatial data and could not be used in the GIS environment. As a result, the FRSC data was converted to spatial data and made usable in the GIS environment. A field survey was conducted at the blackspot road segments in the study area, as guided by the FRSC data, to ascertain the environmental conditions of these blackspot road segments and to create an attribute table to record the characteristics and conditions of the various blackspot road segments using GPS and locating places with goggle earth and Landsat imagery.

Information that was already captured from the roadway environment that is available in landsat imagery was used to extract the route in the study area. The elevation of the study area was obtained from a shuttle radar topographic mission. This enabled us to know the height above sea level of the blackspot segment and it was used to create the relief map. This also added to our understanding of the topography on which the roadway segment is constructed. The important data elements from this FRSC record include the following (attribute data) listed:

1. Date of traffic crash
2. Time of occurrence.
3. Location/route described in km to or from.
4. Type of traffic crash (non-injury, injury and death)
5. Causes of traffic crash.
6. Number of people involved in the traffic crash
7. Weather condition at the time of traffic crash
8. Speed limit on the blackspot segment.

The Landsat imagery of the study area was imported into the ArcGIS 10.8 environment, where geographic data essential for the research, including road networks, were digitised and extracted. The attribute table created to record the characteristics and physical condition of the various blackspot road segments during the field survey was introduced into the ArcGIS 10.8 environment in a Microsoft Excel sheet, along with the needed portion from the Federal Road Safety Commission records. The types of data, characteristics and source data for the curvature analysis are described in Table 1.

Table 1. Types of Data, Characteristics and the Sources

Types of Data	Scale	Date	Activity	Source
Geo-referenced Map of Oyo State	1:25000	2020		Office of surveyor general Oyo state.
Satellite image (Landsat)		2020		United State Geological Survey (USGS)
Shuttle topo-graphic mission data (SRTM) for terrain analysis		2020		United State Geological Survey (USGS)
Blackspot road segments	Geo-coding and Data Extraction location/route description	2022/23	Field Survey	Federal road safety corps traffic crash records as a guide.
Road/Street Network Map	Geo-coding and Data Extraction (Road Net-work)	2020	Vectoring from Imagery	African Regional Institute for Geo-spatial Infor-mation Science And Technology (AFRIGIST)
Road traffic crash data		2020/22		FRSC.

The approach offers descriptive and statistical methodologies with GIS analysis. This study fills the gaps in the use of (spatial) environmental data and methodology by using GIS to analyse road traffic crashes in blackspot locations, overcoming the limitations of using only statistical methodology. Insights into the influence of roadway environmental element on road traffic crashes were enhanced, offering valuable information for policymakers, transport planners and urban planners to improve road safety. The descriptive research design systematically describes the characteristics of the data concerning road traffic crashes and roadway environmental element. This involves identifying and categorising various environmental element and summarising the data to provide a clear picture of the current situation.

The statistical research design examined the correlational between different variables, specifically how roadway environmental elements (independent variables) are related to the frequency and severity of road traffic crashes (dependent variables). It helped to identify significant relationships and potential causal links between environmental element and road traffic crashes.

Geographic Information System (GIS) analysis enabled the spatial examination of crash data and the environmental element allowing for the visualisation and identification of spatial patterns. Maps were created as visual representations of the data to highlight key findings. For example, the maps showed crash blackspots and the visualisation of crash fatalities in relation to road surface quality. GIS analysis provided a spatial dimension to the research, revealing geographic patterns and correlations that might not be evident from statistical analysis alone. This helped in identifying the specific locations and conditions that are high-risk to inform targeted interventions.

2.2. Methods of Analysis

The method of data analysis for this study is a combination of two methods, which are:

1. Geographic information system (GIS)
2. Statistical methodology.

This study utilised a combination of Geographic Information System (GIS) analysis and statistical methods for the examination of data. The Geographic Information System method of analysis using Arcgis 10.8 software. Spatial analysis of roadway traffic crash occurrences, statistical method of analysis was used to find the correlation of relationship between road traffic crashes and the roadway environmental elements. The objectives and the associated methods of analysis are hereby linked and explained:

2.2.1. Geographic information system (GIS)

1a. Blackspot (Getis-Ord G*): This is for studying the identifiable spatial patterns, detecting spatial clustering of activities and statistically identifying significant spatial concentrations of high and low values associated with geographic features. This was demonstrated in a study by Songchitruksa and Zeng (2018), "Getis-Ord spatial statistics to identify blackspots". The Getis-Ord G* statistic is a variation that includes the point itself in the calculation making it a more localised measure. It is measured by collecting spatial data points with attribute values and their spatial coordinates, creating a weights matrix based on spatial proximity (e.g., inverse distance or binary adjacency). This is executed using ArcGIS 10.8 and the result is displayed in the form of a thematic map representation.

1b. Geographically weighted regression: This model explores the spatial relationship between the dependent variable (traffic crashes) and one or more independent variables (environmental element) using the regression analysis model. This was demonstrated by (Ali et al. 2018) in a study titled "Application of Geographically Weighted Regression Technique in Spatial Analysis of Fatal and Injury Crashes". The process involves gathering spatial data with coordinates, choosing a kernel function, selecting the bandwidth, calculating weights for nearby locations and performing a weighted least squares regression to estimate local regression coefficients. Executed using ArcGIS 10.8 and the result displayed in the form of a thematic map representation.

The two map product is then overlaid to produce a thematic map showing where environmental element is significance in the occurrence of traffic crashes in the study area.

Road curvature analysis

Road curvature analysis of the roadway was conducted using the ROCA (Road Curvature Analyst) software, integrated as an ESRI ArcGIS Toolbox. This tool facilitates the processing of vector (line) data. The identification of curves is achieved through the application of the Naïve Bayes classifier, which assists in determining the angles or radii of roadway curvature to ascertain the corresponding design speed limits. This objective stems from a classification approach for effective identification of road geometry introduced by (Andrasik et al. 2020) "Identification of Curves and Straight Sections on Road Networks from a Digital Vector Data".

In the ArcGIS 10.8 environment, the input data includes road section ID, X coordinates, coordinates of polyline vertices, Y coordinates, and geometry classification—where 0 represents a tangent and 1 signifies a horizontal curve. The analysis is performed using the ROCA analysis toolbox within ArcGIS 10.8. This software efficiently fragments roadway system data into tangents and horizontal curves, automatically calculating the circles of the horizontal curves and the azimuths of the tangents.

The overlay operation within the GIS environment was utilised. This operation is a crucial and powerful tool in GIS, as it superimposes spatial and attribute information from multiple thematic map layers to generate new insights. Curvature analysis is overlaid on elevation data (SRTM), land use data of the study area, roadway data, traffic crash blackspot data and Oyo State boundary data. The analysis produced a thematic map of roadway sections under study for the susceptibility or criticality of the roadway curve segments to road traffic crashes and proneness to road traffic crashes.

2.2.2. Statistical methodology

The Pearson Product-Moment Correlation Analysis is a statistical technique employed to assess the strength and direction of the linear relationship between two continuous variables. This statistical technique was applied to Hypotheses 5, to find the correlation between roadway segment elevation and traffic crash occurrences. The measure of correlation is called the correlation coefficient. The degree of relationship is expressed by the coefficient which ranges from correlation ($-1 \leq r \leq +1$). The direction of change is indicated by a sign. The correlation analysis enables us to get an idea of the degree and direction of the relationship between the two variables under study, it does not imply causality. Pearson's correlation analysis was applied in the study "identification of traffic accident-risk-prone areas under low lighting conditions". The study seeks to evaluate the effect of low lighting conditions on traffic accidents in the city of Cluj-Napoca. To analyse the degree of dependence between lighting and the occurrence of traffic accidents, Pearson's correlation coefficient was utilised. Furthermore, the relationship between the spatial distribution of traffic accidents and lighting conditions was assessed using the frequency ratio model. (Ivan et al., 2018). The Pearson Product-Moment Correlation Analysis was executed in the SPSS environment.

3. Locations of Traffic Crash Blackspots

The table below (Table 2) reflects the data obtained from the FRSC showing the number of blackspots on each of the location and the year respectively.

Table 2. Roads and Location with Traffic Crash Blackspots.

S/n	ROUTE	Location Of Blackspot (road sections)	Number of Blackspot	2020	2021	2022	Number of RTC
1	Ibadan Metro	Bodija Juction, Iwo Road Roundabout, Eleyele Baptist Church and Adegbayi	4	57	72	52	229
2	Elebu	Benjamin Area, Ologuneru Police Outpost, Mobil Filling Station, Iyana Ijokodo	4	70	136	101	457
3	Ibadan -Abeokuta	Ida Village, Onigbagbo Village, Omi Area	3	79	88	46	213
4	Ibadan-Ife	Best Option Egbeda, Asejire, Idi Omu Area, Olorunsogo, Egbeda,Olope Meji	6	227	393	366	1305
5	Ibadan-Ijebu Ode	Top One Area, Quarry Area, Idi Ayunre Round About	3	69	73	43	185
6	Ibadan-Iwo	Alagbede, Iyana Offa, Olodo Bridge	3	89	81	59	229
7	Ibadan-Lagos	Gurumaraji, Dominion University, Onigari, Ajanla Farms, Nasfat Junction, Oriental Foods, Sawmill	7	437	703	563	2154
8	Ibadan-Oyo	Akinyele, Iroko Village, Ilora Bridge, Jobele, Fiditi, Tose, Koladaisi University	7	350	622	522	1918
9	Iganna - Okeho	Oke Afin Iganna	1	22	12	5	39
10	Kisi-Igbeti	Ojukoto	1	1	15	3	29
11	Ogbomosho-Ikoyi	Odo Oru, Idi Araba, Oloko Produce Warehouse	3	9	14	22	69
12	Ogbomosho-Ilorin	Aaseleke, Igbin Village, Kara Express, Oja Waso, Under Bridge	5	33	67	71	206
13	Ogbomosho-Oshogbo	Okin Apa.Abede, Gomal College	3	92	87	35	214
14	Ogbomosho-Oyo	Onigari, Busari Village, Sekona, Asani, Agric, Ajaiya	6	296	223	229	748
15	Oyo-Metro	Olivet School, Durbar, Owode, Kosobo	4	157	125	142	424
16	Oyo-Iseyin	Eleekara, Ado Awaye Area, Agunrege	3	40	15	32	87
17	Kisi-Ilorin	Irepo Junction, Olorunsogo Area	2	9	3	3	15
18	Saki-Ago Are	Aljassas Rd,	1	22	9	14	46
	TOTAL		**66**	**2059**	**2738**	**2308**	**8567**

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This table 2 is further reflected in the graph or chart as shown in Figure 2.

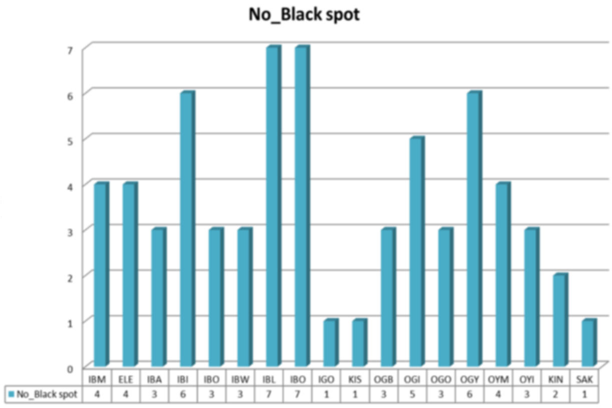

Figure 2. Blackspot Chart.

The chart shows a chart that Ibadan to Lagos, Ibadan to Oyo, Ibadan to Ife and Ogbomosho to Oyo have the highest number of blackspots and by implication, the highest number of road crash frequency.

The location of these blackspots in reality is depicted with the thematic map in figure 3, below.

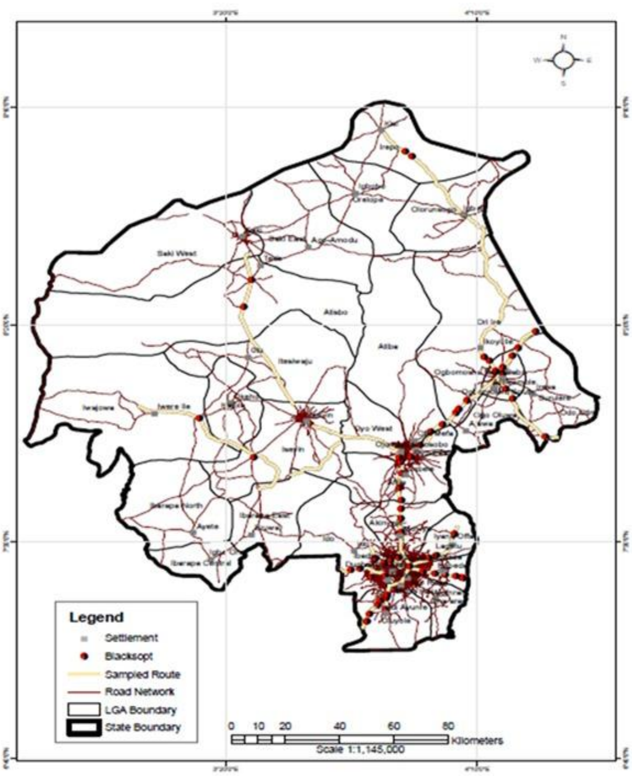

Figure 3. The Map of Oyo state showing blackspots.

The road segments with the red dots in fig.3.3 is the location this study investigated, with a view to finding out the unique conditions that have made such road segment a blackspot for road traffic crashes.

4. Results and Discussions

4.1. Land use Landcover analysis

Land use landcover plays an essential role in modelling roads that are prone to traffic crashes. On a particular axis, the probability of a road experiencing a traffic crash in built-up area is different from that of a forested area. The probability of a road traffic crash along the routes under study is modelled according to the land use and land cover. The landuse-landcover thematic map representation of the study area is shown below (Figure 4).

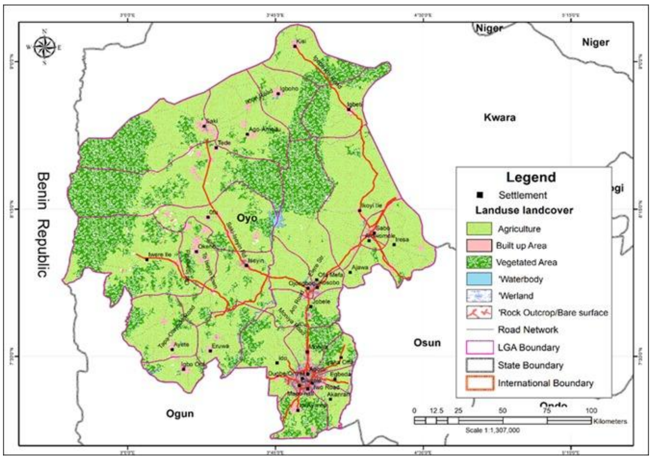

Figure 4. Land use landcover in the study area.

4.2. Terrain Analysis

Terrain analysis was carried out to identify the roadways that are prone to traffic crashes among the roadways under study. It involved the use of elevation and other topological data in order to analyse the road that is prone to traffic crashes. The elevation and slope data along with the route were obtained from the analysis of SRTM (shuttle radar topographic mission) data; in the ArcGIS environment, the elevation and slope of the study area, respectively.

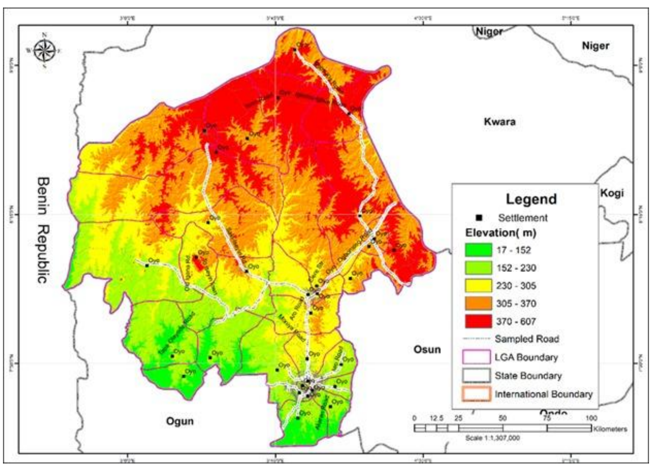

Figure 5. Elevation of study area the as generate from SRTM data

Oyo State's landscape is a gentle, rising slope, with the lowest part in the southern part between 17 and 152 meters and the highest part in the northern part at about 600 meters above sea level. With this type of terrain traffic crashes are on the rise because a large part of the road sectors that make up the state's road network are developed on sloppy terrain which means that moving from the south to the north will involve climbing the hilly terrain while moving north to the south will involve descending. In whatever direction, care must be taken and roadway countermeasures must be put in place to make the road safe.

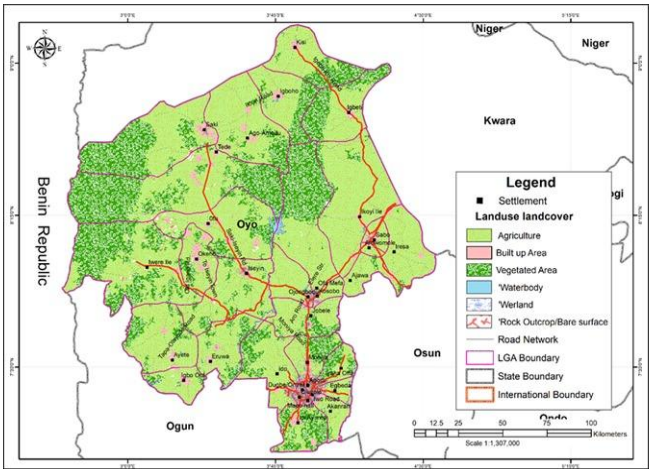

Figure 6. Slope of the study area

Slopes are the manifestation of variation in the elevation, which is a major factor that determines the design speed of roadways and hence once the speed limit for such roads is not obeyed a traffic crash is likely to occur. These roads are characterised by inadequate or lacking road shoulders as could be seen in the northern part of the state because of the elevated terrain.

4.3. Spatial Significant of environment factor on road traffic crash

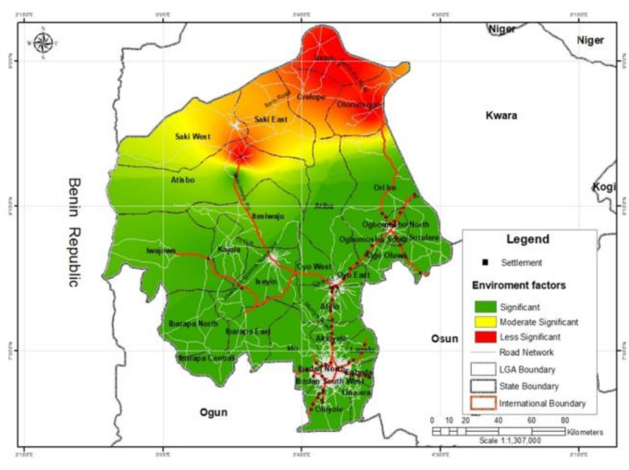

Figure 7. Spatial significant of environment element on road traffic crash

This thematic map (Figure 7) depicts the overall outlook of traffic occurrences across the study area. This is a product of the overlay operation in the GIS environment. The roadway traffic crash occurrence is superimposed on the geographic weighted regression analysis and the result shows that the effect of environment factors is significant in the southern part of the state represented by green, while environment factors are less significant in suburbs especially in the northern part of the state represented by red. A moderate region exists between the north and the south coloured yellow.

4.4. Roadways prone Traffic crash

The analysis to identify roadways prone to traffic crashes due to roadway environmental element is obtained using the weighted overlay analysis of the environmental element considered above (elevation, land use and contour). The environmental element was overlayed and reclassified according to their influence on the road traffic crash. The land use landcover ranked highest, followed by elevation and slope and the contour served as a vector back for the elevation raster. The overlay analysis results show that the sections of the route within the built-up area are less prone to traffic crashes while the sloppy and elevated areas are more prone. The plane areas are moderately prone. The outcome of the environment overlay analysis is shown below (Figure 8).

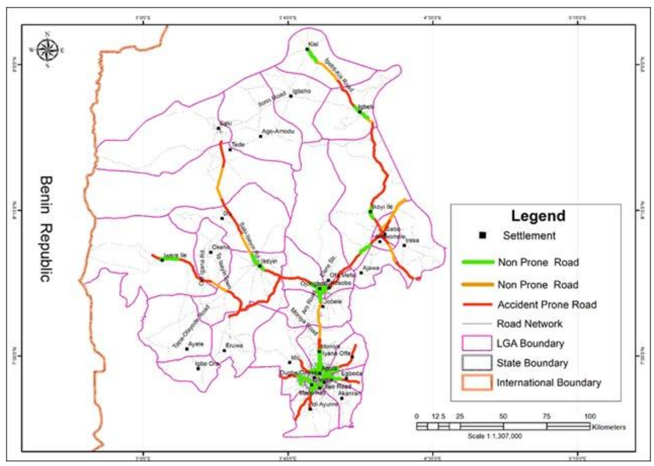

Figure 8. Roads that is prone to traffic crash in the study area

Also observed from the result in Fig. 8 is that the routes tend to be safer as they enter the buildup areas and increase in un-safeness as they move away from the buildup areas. Observing the green-coloured sections of the roadway on the map. This may be as a result of improved roadway environmental conditions due to road maintenance within the urban area, a further analysis is represented in table 3 and figure 9 respectively.

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Table 3. Analysis of the road prone to road traffic crashes in km.

S/n	Road crash probability	Length (Km)
1	Non-Prone Road	231.34
2	Moderate Prone	134.34
3	Traffic crash prone Road	461.98

Table 3 shows the total length of roads that are prone to road traffic crashes within the route study. 231.34 km is safe and not prone 134.34 km is moderately prone and 461.98 km of the route under study is prone to road traffic crashes. The graphical representation of these findings in a pie chart is shown (Figure 9):

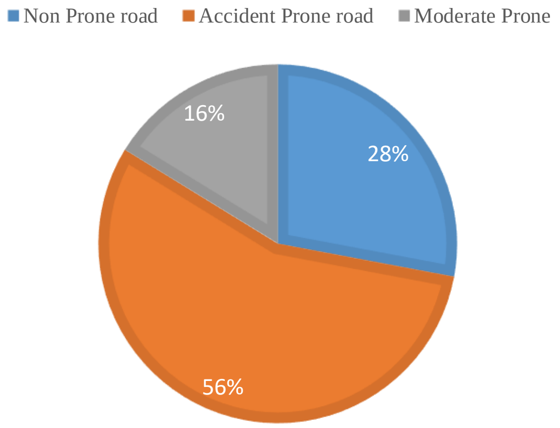

Figure 9. Analysis of road that prone to traffic crash along the study route

This suggests that more than half of the length of the route under study is not safe due to the terrain of the construction as made obvious by the colours. Segmenting the road lengths into non-prone, moderately prone and prone to traffic crash occurrences it is observed that the red colour, which is 56 percent of the total length of roads under study is found to be prone to road traffic crashes.

4.5. Relationship between roadway segment elevation and traffic

There is no significant relationship between roadway segment elevation and traffic crash occurrences. In finding the relationship between blackspot height values in metres obtained in the GIS environment using the SRTM data, which gives a slope or elevation value. This data is used to measure the correlation which is called the correlation coefficient. The degree of relationship is expressed by coefficient which ranges from correlation ($-1 \leq r \geq +1$). The direction of change is indicated by a sign. The correlation analysis gives us an idea of the degree and direction of the relationship between the two variables which are the blackspot elevation in height and traffic crash occurrence.

Table 4 shows the elevation values of roadway segments within a blackspots and the frequency of the traffic crash occurrences used for correlation analysis.

Table 4. Black spot (road sections) elevation to traffic crash frequency

Location of Black spot (road sections)	Elevation (DEM Value) in meter	Frequency of traffic crash occurrences
Bodija Juction	222	78
Iwo Road Roundabout	229	75
Eleyele Baptist Church	184	40
Adegbayi	212	36
Benjamin Area	186	160
Ologuneru Police Outpost	219	99
Mobil Filling Station	156	116
Iyana Ijokodo	207	82
Ida Village	193	70
Onigbagbo Village	189	56
Omi Area	154	87
Best Option Egbeda	185	267
Asejire,	186	301
Idi Omu Area	162	251
Olorunsogo	201	271
Olope Meji	204	321
Top One Area	129	51
Quarry Area	130	71
Idi Ayunre Round About	115	61
Alagbede	205	66
Iyana Offa	198	86
Olodo Bridge	192	76
Gurumaraji	140	307
Dominion University	148	280
Onigari	155	327
Ajanla Farms	157	324
Nasfat Junction	164	315
Oriental Foods	168	298
Sawmill	155	300
Akinyele	252	270
Iroko Village	291	298
Ilora Bridge	306	278
Jobele	277	250
Fiditi	267	274
Tose	247	268
Koladaisi University	299	280
Oke Afin Iganna	224	39
Ojukoto	384	29
Odo Oru	335	32
Idi Araba	320	28
Oloko Produce Warehouse	318	36
Aaseleke	346	35
Igbin Village	375	52
Kara Express	381	41
Oja Waso	351	47
Under Bridge	343	30
Okin Apa.	319	77
Abede	369	65
Gomal College	319	71
Onigari	320	125
Busari Village	287	138
Sekona	277	110
Asani	291	124
Agric	335	148
Ajaiya	300	100
Olivet School	311	106
Durbar	320	98
Owode	311	114
Kosobo	339	112

Eleekara	287	38
Ado Awaye Area	216	29
Agunrege	333	20
Irepo Junction	354	8
Olorunsogo Area	406	7
Aljassas Rd	329	45
Saki-Ago Are	291	46

This is a negative correlation coefficient of -0.426 between elevation and frequency of traffic crash occurrences which indicates that as one variable increases the other tends to decrease and vice versa. Although the magnitude of the correlation coefficient suggests a moderately negative relationship with the correlation coefficient at -0.426 and the p-value stated at <0.01). This suggests that higher elevations are associated with fewer traffic crash occurrences, we therefore reject the null hypothesis (H_0) which states that there is no relationship between roadway segment elevation and traffic crash occurrences and conclude that there is a significant correlation or relationship between roadway segment elevation and traffic crash occurrences; this relationship does not imply causality but a mere relationship or correlation.

Table 5. Correlation Table

	Elevation	**Traffic crash**
Elevation		
Pearson Correlation	1	- 0.426**
Sig. (2-tailed)		0.000
N	65	65
Traffic crash		
Pearson Correlation	- 0.426**	1
Sig. (2-tailed)	0.000	
N	65	65

The study systematically examined the influence of roadway environmental elements on road traffic crashes in Oyo State, fulfilling its stated objectives. Findings indicate that traffic crashes occur across all roads in the state, with 66 blackspots identified along 18 routes. Routes such as Ibadan-Lagos, Ibadan-Oyo, Ibadan-Ife, and Ogbomosho-Oyo recorded the highest crash frequencies, with blackspots concentrated on 18 sections along the Ibadan-Ife, Ibadan-Lagos, and Ibadan-Oyo routes, exhibiting crash frequencies of 21, 27, and 36, respectively.

The study highlights the significant role of environmental factors, particularly terrain, in influencing crash occurrences. The state's landscape comprises a gentle slope rising from 17–152 meters in the south to about 600 meters in the north. Roads traversing this terrain, especially on sloping sections, are prone to crashes due to the challenges of ascending and descending slopes, coupled with inadequate road shoulders, particularly in elevated northern regions.

Traffic safety is better in built-up urban areas, where enhanced roadway maintenance mitigates crash risks. Conversely, crash proneness increases in rural or vegetated areas, with 56% of the 827.66 km of roads studied classified as prone to crashes. A pie chart representation reveals 231.34 km as safe, 134.34 km as moderately prone, and 461.98 km as highly prone to crashes.

A statistically significant but moderate negative correlation ($r = -0.426$, $p < 0.01$) between elevation and crash frequency was observed, suggesting that higher elevations experience fewer crashes. However, this relationship indicates correlation rather than causation. Consequently, the null hypothesis asserting no relationship between elevation and crash occurrences is rejected. These findings underscore the need for terrain-sensitive roadway countermeasures, including improved signage, speed regulation enforcement, and enhanced road shoulder design, to mitigate crash risks across the state's road network.

5. Conclusion

This study underscores the critical influence of roadway environmental factors on traffic crash occurrences in Oyo State. The identification of 66 blackspots across 18 routes, with higher crash frequencies concentrated on key intercity routes such as Ibadan-Lagos, Ibadan-Oyo, and Ibadan-Ife, highlights the urgent need for targeted interventions. The findings reveal that sloping terrains, inadequate road shoulders, and poor road conditions significantly contribute to crash risks, particularly in northern, elevated regions of the state.

While urban areas benefit from improved safety due to better road maintenance and infrastructure, rural and vegetated areas remain disproportionately vulnerable. The analysis demonstrates a statistically significant negative correlation between elevation and crash occurrences, suggesting that while higher elevations may experience fewer crashes, the challenge lies in navigating the slope transitions.

To address these challenges, strategic recommendations include enhancing road signage and speed control measures, especially on sloping terrains, and improving road infrastructure, such as widening shoulders and implementing slope stabilization measures. The adoption of advanced technologies like GIS and GPS for precise crash mapping and data analysis is also essential for informed policy-making and proactive road safety management.

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