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GEOSPATIAL ANALYSIS OF TRAFFIC CRASHES AT CURVED ROAD SEGMENTS IN OYO STATE, NIGERIA

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Abstract:

The road transport mode is the most accessible and widely utilised globally, yet it poses significant challenges to health and safety due to traffic crashes. While many studies examine the causes of road traffic crashes (RTCs), few focus on the influence of Curved Road segments using GIS-referenced data, particularly in developing countries like Nigeria. This study employs GIS and statistical techniques to analyze the impact of Curved Road segments and speed limits on RTCs in Oyo State, Nigeria, from 2020 to 2022. An ex post facto research design was adopted. Crash data sourced from the Federal Road Safety Corps (FRSC) included attributes such as date, time, location, crash type, causes, casualties, and weather conditions. Shuttle Radar Topographic Mission (SRTM) elevation data tagged crash sites, while road network and land use data from Landsat imagery were integrated using ArcGIS 10.8. The Getis-Ord G statistic identified 66 crash blackspots across 18 routes. Also, 55% of the curved road sections on the route under study are unsafe when driving at a speed between 80 and 100 km/h, while 45% are safe when driving at a speed between 60 and 80 km/h. An independent t-test confirmed a significant disparity between FRSC-approved speed limits and curvature design at curved road segments (p = 0.000). The study concludes that roadway environmental factors strongly contribute to RTCs in Oyo State. Recommendations include enhanced patrol of crash blackspots, redesigning hazardous curves, frequent road maintenance, and improved signage to mitigate crashes. These measures are vital to improving road safety in the region.

Keywords-------Traffic Crashes, Blackspot, speed limits, curved road segments, GIS.

1.0 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" [21].

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. [6] 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%)" [12].

According to Road Safety International [28], 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 [25]. What could be responsible for the development of blackspots? What could be wrong with these locations? Could it be that the roadway segments' environment which includes components like signs and symbols, surface conditions, lighting systems, prevailing weather conditions and the roadway geometry among many others are defective, hence contributing to the crash situations in these locations? What roadway environmental characteristics promote the recurrence of traffic crashes in specific locations or roadway segments? What roadway environmental element make the roadway segments unsafe in terms of vehicle speed?

According to [18]. roadway environmental elements include weather, roadway segment geometry, roadway surface condition and roadway defects, the location elevation and the road's lighting i.e., level of illumination or brightness of the environment. Every roadway is embedded with these characteristics as they majorly determine the safe usage of these roadways. The reoccurrence of road traffic crashes in specific locations or road segments may be connected to the deficiencies associated with these roadways. Road and roadway environmental element account for 18% of crashes in the Republic of Korea [16]. According to [4], "Only 3% of road crashes are due to roadway factors or the environment in the USA, but 34% of road crashes are a combination of roadway factors and any other factor". As a result, it is important to pinpoint hazardous roadway segments or portions where serious crash incidences have reoccurred with a view to investigating these locations and taking appropriate corrective measures. This aligns with the United Nations Global Plan for the Decade of Action for Road Safety 2021-2030, which emphasizes the necessity of improving the inherent safety and protective features of road networks to enhance the safety of road users [21].

The phenomenon of traffic crashes on the roads has become ingrained in societies over time, human behaviour and mistakes combined with vehicular or mechanical issues are seen as the foremost reasons for road traffic crashes on the roadways. [11] As the quest to further reduce traffic crash occurrences and ensure that the fatality level is continuously reducing, a searchlight must now be beamed on the roadway environment that is related to the roadway as efforts have traditionally been focused on educating drivers and other road users on how to prevent road crashes and technological advancements in vehicles to decrease injuries and death levels in the event of a crash.

Most of the time the effects of the road and its surroundings are not given the desired consideration when considering traffic crash occurrences.[22].

Road traffic crashes are still prevalent in the sphere of human existence, both in developed and developing societies. The impact may vary but the casualties are the same, as it leads to the death and paralysis of people and the destruction of goods and properties. Many factors have been adduced by scholars across the world to be responsible for road traffic crash occurrences [29], [2]. These includes human behaviour and failure in the vehicular system; however, not much of the road geometric factor is emphasised. Road traffic crashes remain a prevalent issue globally, significantly impacting both developed and developing societies. The casualties, including deaths and injuries, are a common consequence, with developing nations experiencing a higher fatality rate. Nigeria ranks 54th in the global index of road traffic crash with deaths reaching 41,693 [21].

Oyo State is located in the southwestern region of Nigeria, is no exception to this situation as it is ranked 4th in road traffic crash rankings [8]. The state's capital; Ibadan is one of the largest cities in Nigeria and a major transportation hub, contributing to the high volume of vehicular movement.

The higher fatality rate in the developing world than in the developed countries is another question begging and waiting for answer with 20–27% of road traffic crashes producing deaths of about 100,000 people, against the 4–9% death in developed world [22]. What could be the source of this discrepancy in the casualty of road traffic crashes? It is common knowledge that the roadway environment in developing countries is not what it should be in terms of safety. Different factors that relate to the natural environment in which the roadway is situated calls for re-evaluation to produce an improved knowledge with regards to road traffic crash occurrences.

Researchers have investigated the phenomenon of road traffic crashes in developing nations. However the developed world has been able to deploy technology in the study of the roadway environment [15], [14]; [10]. Landsat imagery data and computer simulation of the roadway environment with the aim of enhancing their understanding of the roadway so as to reduce road traffic crash occurrences; however developing countries have not been able to fully tap into some of these technologies [17]; [5]; [1]. They are stuck with the basic tools within the GIS software, which have not produced any form of additional understanding of the roadway environment, hence curved sections of the roads where traffic crashes are frequent have not be effectively investigated with a view to making these locations safer.[15],[19].

2.0 THE STUDY AREA

Oyo State is located approximately within Latitude 7° to 9^0 N and Longitude 3° to 4^0E of the Greenwich Meridian. It is positioned in the south-western part of the country and is bounded by Lagos State in the south, Kwara State in the north, and Osun State in the east. Oyo State is one of the constituent states that make up the Nigerian Federation. It is located about 145 km north-east of Lagos. As represented in figure 1:

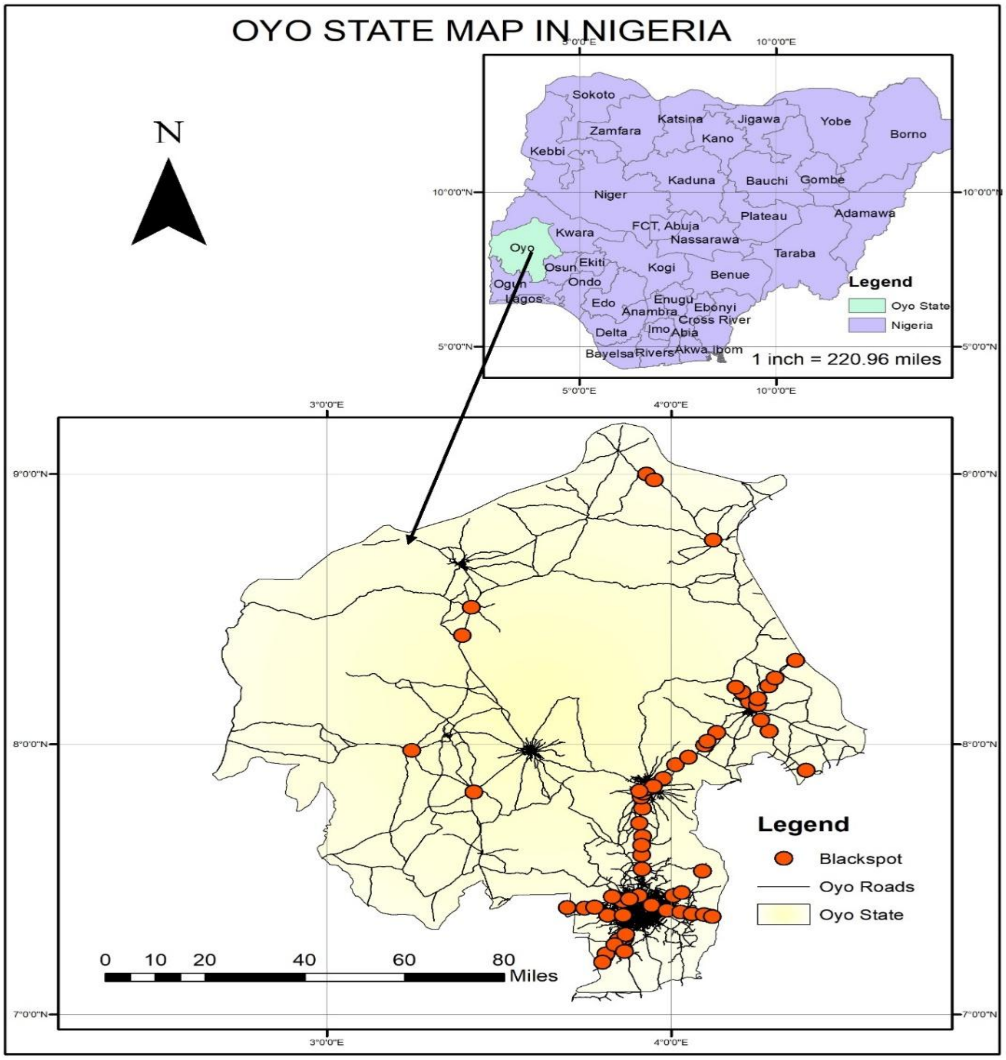

Figure 1. Map of Oyo State Nigeria showing Blackspot location.

With a western boundary with the Republic of Benin in a north-eastern direction from Lagos by the most direct route, the city is directly connected to many towns in Nigeria by a system of roads, railways, and air routes. The railway to the northern states passes through Ibadan, which has since become a major break-bulk point for trade goods from the southwest to the north, as well as from the north to the southwest.

Economic activities undertaken by the people of Oyo State include trading, public service employment, and agriculture, in decreasing order of importance. The volume and diversity of demand for food products stimulated the need for agricultural production within the vicinity of the city. In the city, many people work in agriculture. Moreover, the economic needs and knowledge of residents have transformed the land left over by urbanisation into gardens notable for their ecological richness and variety. The predominant crop production in Ibadan is staple foods such as cassava, maize, and vegetables such as Chinese spinach, okra, aubergine, cucumber, tomatoes, and pepper. Socioeconomic facilities include markets like Alesiloye and Oja-oba, shopping centres and fast food spots located in different areas within Ibadan City, and a very good road network for easy movement of people and goods.

3.0 MATERIALS AND METHOD

3.1 Conceptual Reviews

According to [29] the design speed is a chosen speed that is utilised to define the different geometric design elements of the highway. According to [7], "it is described as a speed used to create the many geometric design components of roads, including alignments". The American Association of State Highway Officials [4] accepted a modified definition of design speed in 1938 as the maximum approximately uniform speed which probably will be adopted by the faster group of drivers but not necessarily by the minority of careless people. The definition of design speed then was the highest safe speed that may be maintained along a defined segment of highway when conditions are favourable [20].

Up until the 2001 publication of the AASHTO Green Book, "maximum safe speed" was mentioned in the definition of design speed. A proposal to exclude "the maximum safe speed" from the definition of design speed was made in 1997 in response to NCHRP Report 400. In order to avoid the impression that operating speeds above the design speed are unsafe, the phrase "safe" was eliminated. It was acknowledged that operational speeds can be higher than the design speed [3]. The minimal values for highway design such as the horizontal curve radius and sight distance are expressly determined using the approved design speed. Design documentation often includes the intended design speed, which is frequently displayed on the design documentation's cover sheet.

[9] Stated that the second term used to describe design speed is "inferred design speed," which only applies to features and elements with criteria based on (specified) design speed (e.g., vertical curvature, sight distance, superelevation). When the actual value differs from the criterion-limiting (minimum or maximum) value, a feature's inferred design speed will deviate from the authorised design speed. For a radius-superelevation combination. The inferred design speed is the top speed that does not exceed the limiting speed-based side friction value for both the planned rate of super-elevation and the inferred design speed (determined through an iterative process). [23] Horizontal offsets to sight impediments on the inside of a horizontal curve may also be used to restrict the inferred design speed. The highest speed at which the required stopping sight distance does not exceed the available stopping sight distance is known as the inferred design speed for a crest vertical curve. The combination of lane width and daily traffic volume may also serve as a speed limiter for the implied design speed. The implied design speed may be higher, lower, or equal to the specified speed. In the table, the concepts and theories in relation to the objectives and hypotheses are shown.

The road plays a role in road traffic crashes and could be identified as blackspots and black lengths (a section of 1 km within a given road section). A blackspot is any site or road location with many casualty crashes. A casualty crash, which means a fatal crash or a crash in which at least one person is injured (serious or slight), could be at an intersection, short lengths or curves (a casualty crash is defined as an accident in which at least one person is critically or slightly hurt). It is one of the core issues related to road injuries and deaths. A blackspot is determined by three things: traffic crash incidence, severity and rate. [24]

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[26] Concluded that a blackspot is a place where there are a lot of RTCs, whether they are deadly, serious, or minor. It might be a crossroads or a portion of a road, but it's always a location or region where there's already difficulty or cause for concern. A blackspot is a road segment which is prone to traffic crash occurrences identified over time and where there have historically been many traffic traffic crashes when it comes to road safety. According to the Victorian (Australia) blackspot programme (1980), a road length of 1 km needs 12 fatal traffic crashes within three years to qualify as a blackspot. As a result of the programme's success over the years, it has since become the accepted method for identifying blackspots worldwide. Blackspots can happen for a number of reasons including:

1. Sharp corners in a straight road
2. Hills or winding roads that limit visibility ahead

Road traffic crash "blackspots" are places where there are more traffic crashes compared to other, comparable places on the road system, or places where there are more traffic crashes and/or have a higher accident rate than a specified minimum. Blackspots can be bridges, lengthy stretches of road or very brief parts of the road with elements like them. In order to develop a systematic and logical foundation for recognising any need for safety changes involving the building, operation or maintenance of road systems, accident blackspots must be identified. Urban and rural regions both have blackspots. They are frequently seen as problem areas with unexpectedly steep climbs and curves. [25]

Blackspots can be exacerbated by twisting routes, disguised intersections and inadequate or unreadable warning signs. Drivers are taken off guard by changes in the road when there is no clear direction. In recent years, reducing blackspots has been a top objective for government transportation organisations. In order to decrease traffic crashes and fatalities in blackspots that have been discovered and to put preventative measures in place there, some nations establish blackspot reduction efforts with deadlines. The road user, the road environment and the vehicle are the three potential causes of motor vehicle collisions, which are multi-causal occurrences. Concerns about blackspots are typically related to certain characteristics of the road environment. To adapt to the constantly shifting demands of road conditions and their surroundings, drivers must constantly juggle their driving standards. The phrase "blackspot" denotes a specific place, although it is also frequently used to describe stretches of dangerous roadways. [25]

3.2 Research Design and Methodologies

The researcher based the data on the traffic crash database of the Federal Road Safety Corps (FRSC) in Oyo State Sector 2020–2022. Geographic data relevant for this work includes a geo-referenced map of Oyo State, a road network map, a satellite image (Landsat or Google Maps), shuttle topographic mission data (SRTM) for terrain analysis, and geographic data obtained from the road segments. Identified traffic crash blackspot coordinates were picked using the hand-held GPS to record these locations.

3.3 Sources and Data Collection Instruments.

The data collection processes are as follows:

Personal Observation:

A field survey of the identified road segments in the study area was conducted in order to identify the road geometric was them measured in the GIS environment as shown in figure 2 and stated in Radius of the Curvature section in table 2.

Secondary Data

The GIS process was used to convert FRSC secondary data on road traffic crashes. The data used for this study include the satellite imagery of Landsat and Google Earth with spatial resolutions of 30 and 5 metres, respectively, which was acquired and used to extract the route for the study area; the coordinates of the accident locations was obtained with the aid of GPS; the elevation the blackspot location in the study area was extracted from shuttle radar topographic mission data using ArcGIS version 10.8 and used to create the relief map using the 3D analyst tool; and the crash record of the study area obtained from the Federal Road Safety Commission (FRSC) with the attribute data below:

1. Location or route of the accident
2. Number of vehicles involved
3. Type of crash (fatal, severe, major, or minor)
4. Causes of the crash
5. The number of people involved in the accident

GIS Data Processes

The imagery interface covering the study area was imported into the ArcGIS 10.8 environment using the Arc2Earth extension tool. The study route, the road, and its characteristics were digitised with the aid of ArcGIS. The creation of a database of all raster data (i.e., line and point features) needs to be arranged in a separate attribute table and the road labelled with its name. Similarly, the crash segment attribute table contains records from the Federal Road Safety Corps. Types of data, characteristics, and sources 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	1:25,000	2020		Office of surveyor general Oyo state.
Satellite image (Landsat)		2020		United State Geological Survey (USGS)
shuttle topographic mission data (SRTM) for terrain analysis		2020		United State Geological Survey (USGS)
Blackspot road segments	Geo-coding and Data Extraction location/route description	2020/22	Field Survey	Federal road safety corps traffic crash records as a guide.
Road/Street Network Map	Geo-coding and Data Extraction (Road Network)		Vectoring from Imagery	Regional Centre for Training in Aerospace Surveys (RECTAS)
Road traffic crash data		2020/22		FRSC.

Source: Field Survey 2022

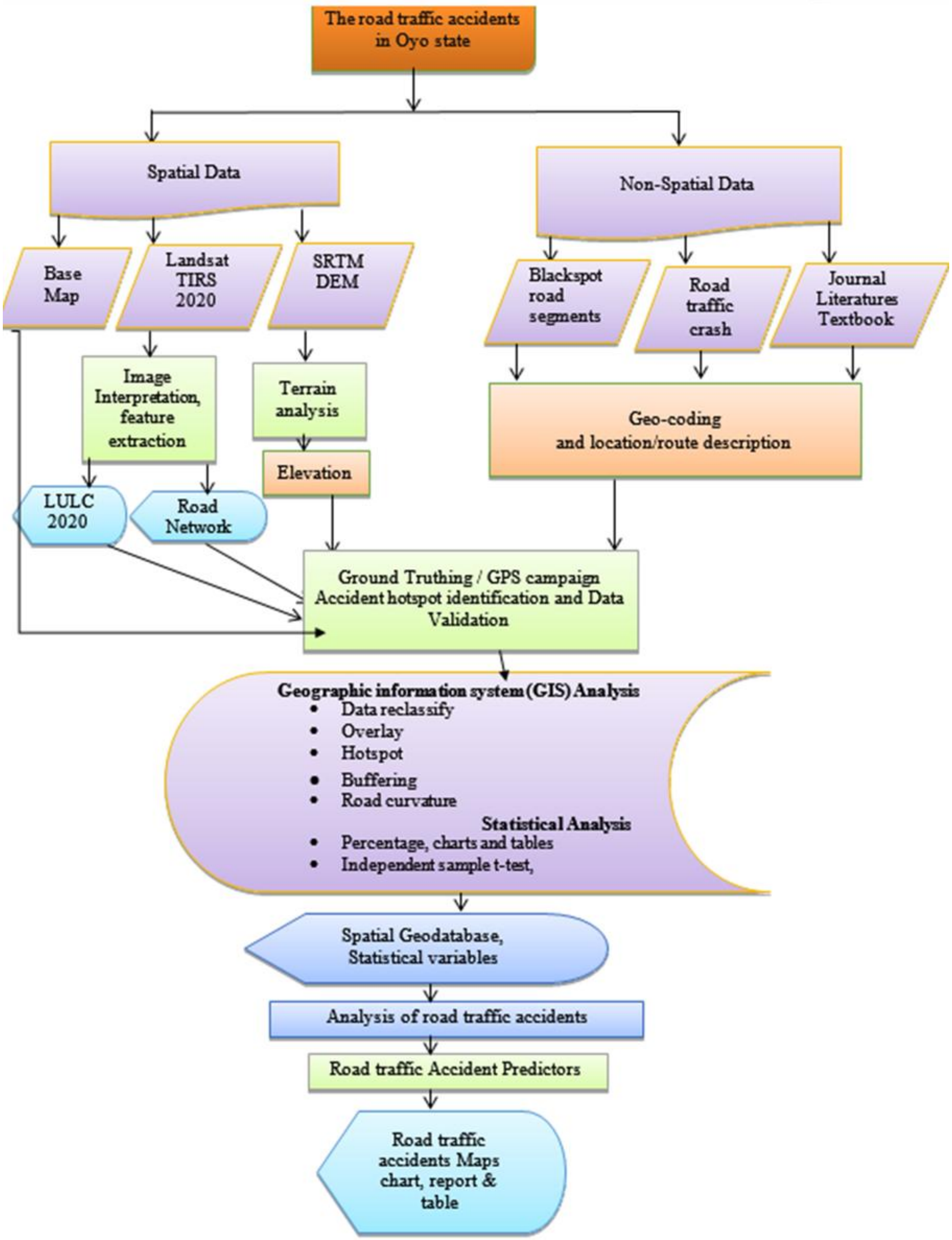

Figure 2: Methodological flow chart

3.4 Data analysis, Interpretation of Results and discussion of findings

Road Curvature/Geometric Analysis

The roadway curvature was analysed to determine the radii of the curved roadway segment within the blackspot area. Every radii in degree has a speed limit associated with it, called the Designed Curvature Speed Limit. 56 curved sections were identified along the 64 federal routes investigated in the study.

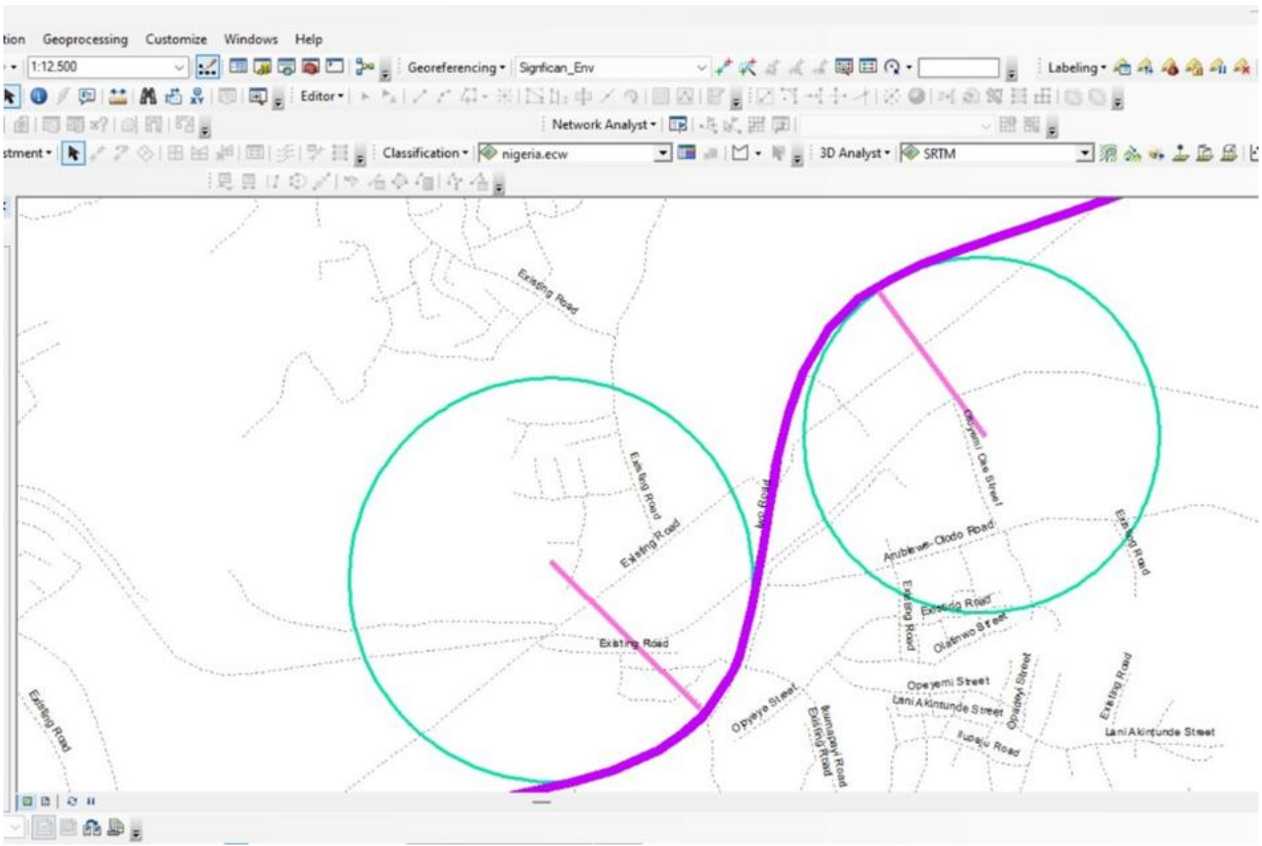

Fig. 3 Curvature analysis in the GIS environment (Arcgis 10.8) Author2023

Figure 3: is the Curvature analysis of the road segment curves as displied in the GIS environment Arcgis 10.8 the resultant table in represented in table 2.

4.0 RESULT AND DISCUSSIONS

The results in this study are shown in forms of discussions, maps, tables, and charts, to enable traffic crash occurrence and the influence of road curvature processes to be visualized. To achieve a reliable, effective, efficient road safety management in Oyo state Nigeria. Table 2 shows the route, the number of blackspot in the location and the year under study.

Table 2: Showing Roads and Location with Traffic Crash Blackspots.

S/n	ROUTE	Location Of Black spot (road sections)	Number of Black spot	Year 2020	Year 2021	Year 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**

Source: FRSC 2022

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From table 2 eighteen route were identified to have 66 blacspot location, 51 of these blackspot are located on a curved road segment. The road curvature analysis, the radii of the curved blackspots segments are presented in table 3.

4.1 Crash Difference between FRSC and Curvature Speed Limits.

The roadway curvature was analysed to determine the radii of the curved roadway segment within the blackspot area. Every radii in degree has a speed limit associated with it called the Designed Curvature Speed Limit. Fig. 2 is a representation of how the roadway curvature in this study is determined.

Table 3 available curves on the blackspot road segments and traffic crash frequency (2020-2022)

S/n	Route	Designed Radius of the Curvature (m)	Curvature Perimeter (m)	Curvature Speed Limit (Km/h)	FRSC Approve Speed limit (Km/h)	Report
1	ELEBU (4)	45.13	.4915	40	100	inconsistent
		466.52	.2704	100	100	consistent
		191.58	.7006	60	100	inconsistent
		173.25	.6830	80	100	inconsistent
2	IBADAN – ABEOKUTA (3)	342.82	2.6836	100	100	consistent
		258.22	1.3656	80	100	inconsistent
		131.22	1.5465	60	100	consistent
3	IBADAN METRO (3)	136.18	.6218	60	60	consistent
		197.01	.9311	60	60	consistent
		113.43	.8831	60	60	consistent
4	IBADAN-IFE (2)	170.23	1.3439	80	100	inconsistent
		256.25	1.6232	80	100	inconsistent
5	IBADAN-IJEBU ODE (2)	176.75	2.1263	80	100	inconsistent
		102.24	1.6733	60	100	inconsistent
6	IBADAN-IWO (5)	566.85	4.6158	100	100	consistent
		576.24	2.0739	100	100	consistent
		258.86	1.6916	80	100	inconsistent
7	IBADAN-LAGOS (6)	192.10	1.5023	80	100	inconsistent
		212.45	2.1245	80	100	inconsistent
		424.95	2.9587	100	100	consistent
		86.34	.5643	60	100	inconsistent
		425.11	5.0783	100	100	consistent
		268.12	3.9084	100	100	consistent
8	IBADAN-OYO (1)	354.87	2.4130	100	100	consistent
9	IGANNA – OKEHO(3)	86.45	2.2867	45	100	inconsistent
		153.42	4.3220	60	100	inconsistent
		325.12	10.4639	100	100	consistent
10	KISI-IGBETI (3)	295.11	3.4094	100	100	consistent
		425.23	2.6228	100	100	consistent

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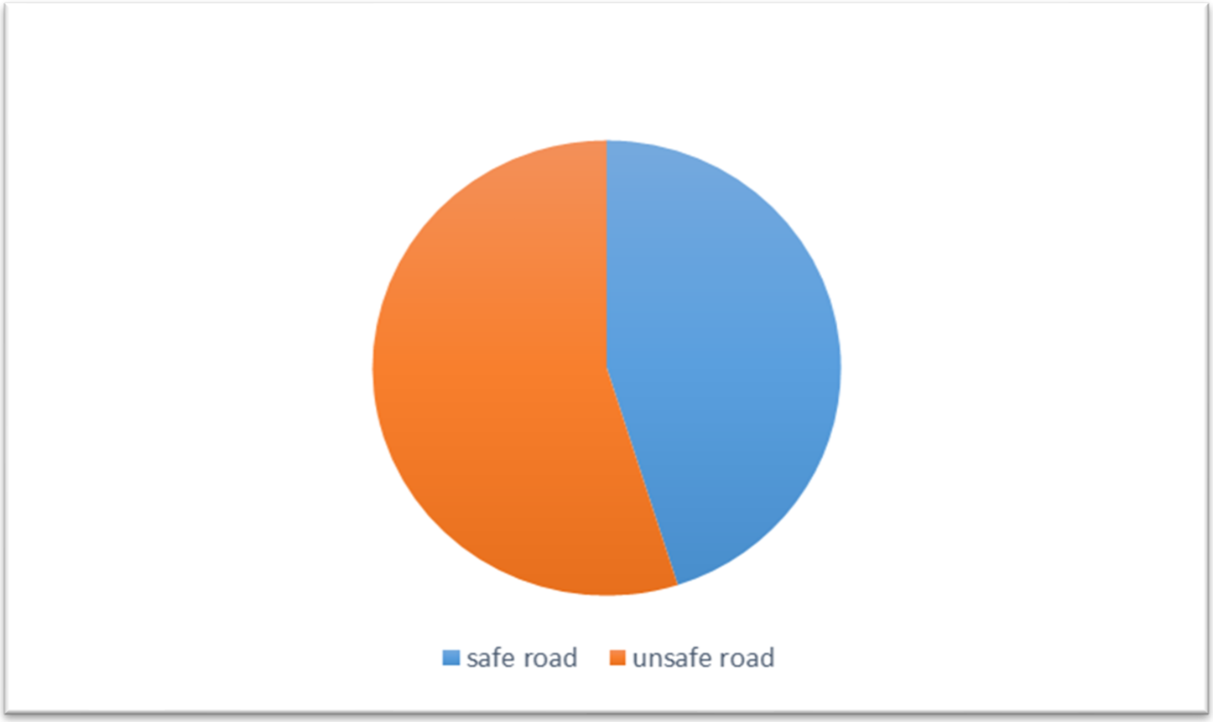
		395.63	3.9470	100	100	consistent
11	KISI-ILORIN (3)	68.26	8.2386	40	100	inconsistent
		112.23	16.4927	80	100	inconsistent
		127.36	6.9443	80	100	inconsistent
12	OGBOMOSHO-IKOYI (2)	5.32	3.5412	15	100	inconsistent
		5.32 75.08	3.55412 2.8292	40	100	inconsistent
13	OGBOMOSHO-ILORIN	31.58	1.4004	30	100	inconsistent
		426.00	4.6785	100	100	consistent
		139.23	.9039	80	100	inconsistent
14	OGBOMOSHO-OSHOGBO	68.42	2.6129	40	100	inconsistent
		72.41	7.3921	40	100	inconsistent
		288.13	5.8311	100	100	consistent
		0	0	0	0	0
15	OGBOMOSHO-OYO	427.08	1.5305	100	100	consistent
		109.10	2.0495	60	100	inconsistent
		434.79	2.6057	100	100	consistent
16	OYO-ISEYIN	55.98	9.9308	40	100	inconsistent
		122.40	7.6894	60	100	inconsistent
17	OYO-METRO	118.38	.4849	60	100	inconsistent
		43.60	.9374	40	100	inconsistent
		529.36	.9971	100	100	consistent
18	SAKI-AGO AREA	728.42	4.6931	100	100	consistent
		436.47	5.2578	100	100	consistent
		328.26	14.7178	100	100	consistent

Source: Authors Compilation 2023

The roads' curvature analysis identified 51 curves sections. The curvature speed limit (Km/h) is the actual speed that should be adopted at those curved and bent road locations based on the design radii. The cause of traffic crash at these curved sections of the read is connected to the violation of these curvature speed Limits. Hence, this speed limit is not really enforced by the drivers of the regulatory agency, as some speed limit at these location are not consistent with the designed curvature speed Limits. Out of the 51 curves sections, 28 of these curves are inconsistent with the approved FRSC speed limit, while twenty-three are consistent. This implies that 55% of the curved road sections in the study area are safe for driving at a speed that is below 100 km/hr, while 45% of the curved road sections are safe for driving at or below 100 km/hr.

The chart representation of Table 3 is shown in Figure 4



Source: Authors Compilation 2023

Fig 4 shows an analysis of curved road sections. Author 2023

Twenty-eight of these curves are inconsistent with the approved FRSC speed limit, while twenty-three are consistent. This implies that 55% of the curved road sections on the route under study are unsafe when driving at a speed between 80 and 100 km/h, while 45% are safe when driving at a speed between 60 and 80 km/h. This is represented in the chart.

The table 4, shows some of the identified route with curved section and the designed speed attached to each curved road section.

Table 4: Some curved road sections and designed speed limits

ROUTE	CURVED ROAD SEGMENT WITH BLACK SPOT	DESIGN SPEED ALLOWED in (Km/h)
IBADAN METRO	BODIJA JUCTION, IWO ROAD ROUNDABOUT, ELEYELE BAPTIST CHURCH ADEGBAYI	60 60 60
ELEBU	BENJAMIN AREA, OLOGUNERU POLICE OUTPOST, MOBIL FILLING STATION, IYANA IJOKODO	40, 100 60 80
IBADAN -ABEOKUTA	IDA VILLAGE, ONIGBAGBO VILLAGE, OMI AREA	100 80 60

IBADAN-IFE	IDI OMU AREA, OLORUNSOGO Area	80 80
IBADAN-IJEBU ODE	TOP ONE AREA, IDI AYUNRE ROUND ABOUT	80 60
IBADAN-IWO	ALAGBEDE,	80
IBADAN-LAGOS	GURUMARAJI, AJANLA FARMS, NASFAT	80 60
IBADAN-OYO	IROKO VILLAGE	100
IGANNA - OKEHO	OKE AFIN IGANNA	45 60
KISI-IGBETI	OJUKOTO	100
OGBOMOSHO-IKOYI	ODO ORU, IDI ARABA,	15 40
OGBOMOSHO-ILORIN	AASELEKE, IGBIN VILLAGE, KARA EXPRESS,	30 100 80
OGBOMOSHO-OSHOGBO	OKIN APA. ABEDE, GOMAL	40 40 100
OGBOMOSHO-OYO	ONIGARI BUSARI VILLAGE, SEKONA, ASANI,	100 60 100
OYO-METRO	OLIVET SCHOOL DURBAR, OWODE,	60 40
OYO-ISEYIN	ELEEKARA, ADO AWAYE AREA,	40 60
KISI-ILORIN	IREPO JUNCTION, OLORUNSOGO AREA	40 80 80
SAKI-AGO ARE	ALJASSAS RD,	100

Source: Authors Compilation 2023

4.2 Descriptive Statistical Analysis.

The descriptive statistical analysis (percentage) of the number of road with susceptible curve was conducted. The curvature analysis showed 53 curved sections which was subjected to percentage analyses The outcomes is tabulated in Table 5, and a graphical representation in Fig. 5 which shows the distribution of the section curve's along the study route.

Table 5. The number of curved segments along each sampled route in the Study Area.

Route	Curved sections	Percentage
ELEBU	4	7.5
IBADAN -ABEOKUTA	3	5.7
IBADAN METRO	3	5.7
IBADAN-IFE	2	3.8
IBADAN-IJEBU ODE	2	3.8
IBADAN-IWO	3	5.7

IBADAN-LAGOS	6	11.3
IBADAN-OYO	1	1.9
IGANNA - OKEHO	3	5.7
KISI-IGBETI	3	5.7
KISI-ILORIN	4	7.5
OGBOMOSHO-IKOYI	2	3.8
OGBOMOSHO-ILORIN	3	5.7
OGBOMOSHO-OSHOGBO	3	5.7
OGBOMOSHO-OYO	3	5.7
OYO-ISEYIN	2	3.8
OYO-METRO	3	5.7
SAKI-AGO ARE	3	5.7

Source: Author's Compilation, 2023

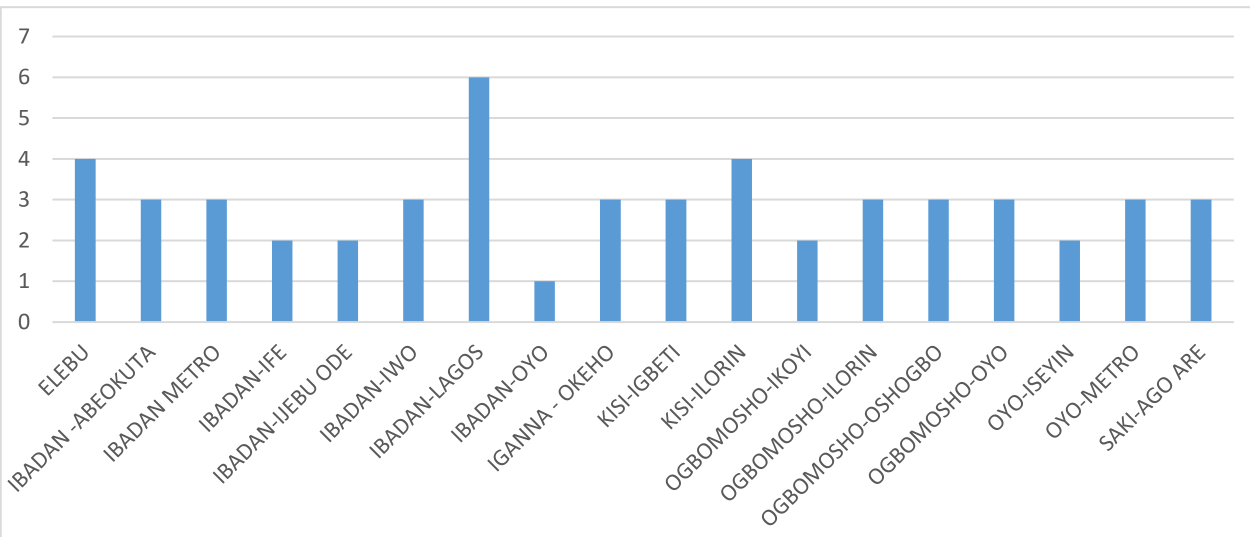


Fig. 5 statistical distribution of roadway curve location along the study corridor.
Source: Author's Compilation, 2022

4.3 Route Curved segments visualization.

The chart and the table above reveal that the Laguna-Ibadan roadway has the highest number of curved sections; this is followed by Elebu Road and the Kisi-Ilorin roadway. The spatial analysis of the road segment curve location within the blackspot location was achieved by using curvature analysis of the radius, the perimeter and the venerability of the curvature in the ArcGIS environment. The sampling curve along the eighteen routes under study was analysed using a spatial analysis tool in ArcGIS. Figure 5 reveals the spatial location of the roadway curve along the route under study. In this thematic map, locations that are curved road segments of the roadway are identified with the purple colour, while the red colour represents a straight section of the roadway.

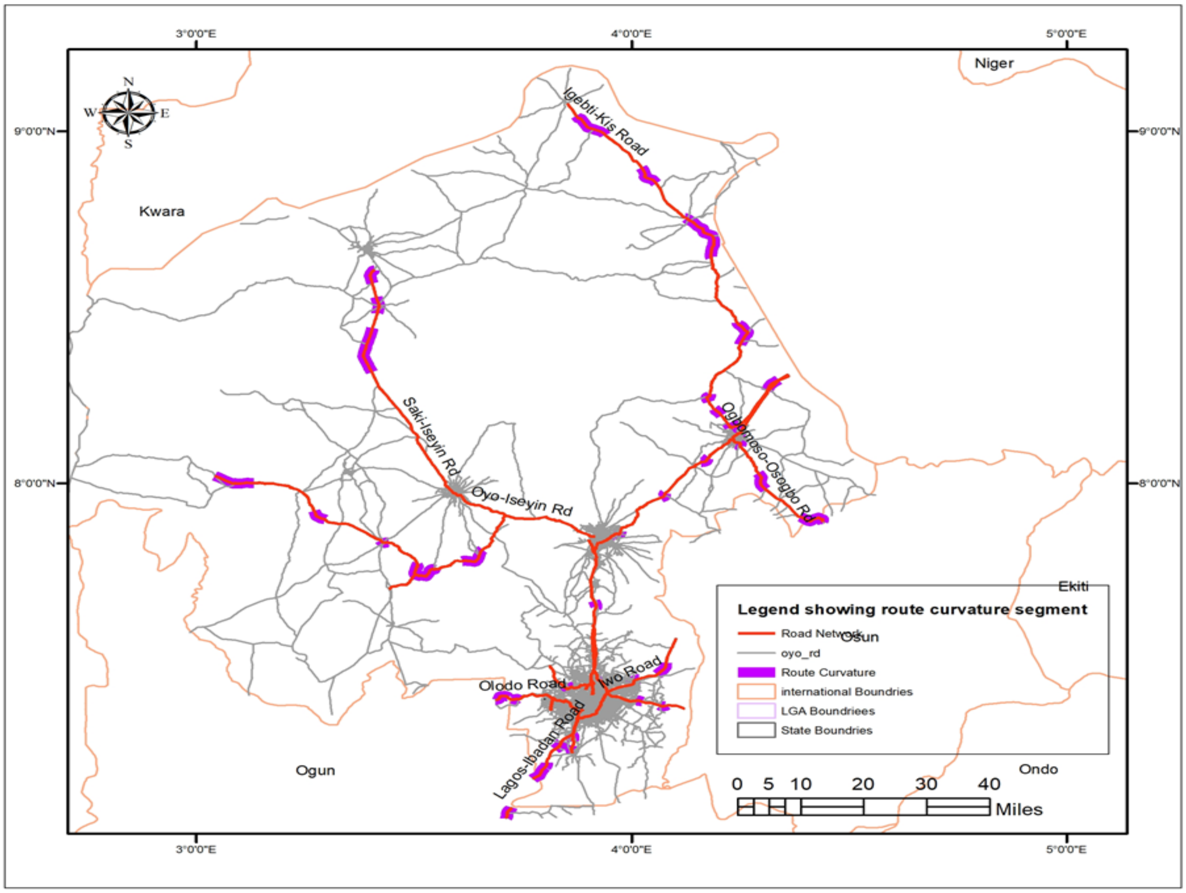


Fig. 6: shows Route Curved segments in the study route
Source: Author's Compilation, 2023

4.4 Speed limit of the road curvature on segments

The curvatures on the roadway promote venerability to road traffic crashes as the design speed limit varies with the curves. The roadways with curvature that are prone to traffic crashes imply the susceptibility of 18 routes determined by using two factors: environmental element and speed limits.

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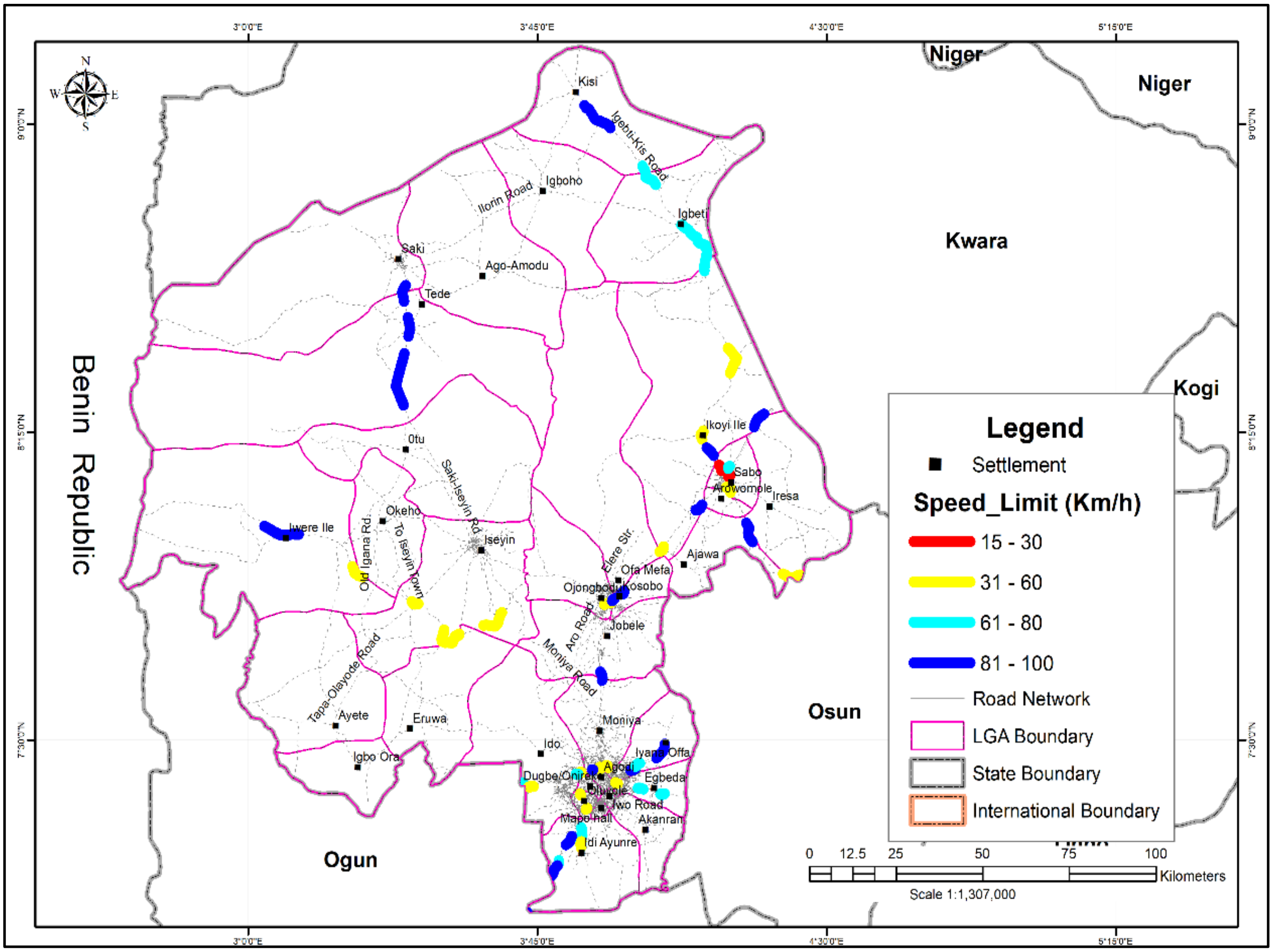

Fig. 7: Speed limit of the road curvature on segments
Source: Author's Compilation, 2023

4.5 Associated radius of the curvature

A further analysis of the curved sections of the roadway shows that various curve radii were observed and the associated design speed limit was identified. In this thematic map, the blackspot route curvature and the speed limit are symbolised with the different colures. The curve with the red colour is expected to accommodate 15–30 km/h, which makes that roadway section the most likely to crash while driving above 30 km/h, while the curve with the yellow colour is expected to accommodate 31–60 km/h, the next likelihood of a roadway traffic crash driving above km/h, a and the curve with the maya blue colour is 61–80 km/h, this is third in the ranking driving above 80 km/h and the curve with the blue colour is allocated the last driving above 100 km/h.

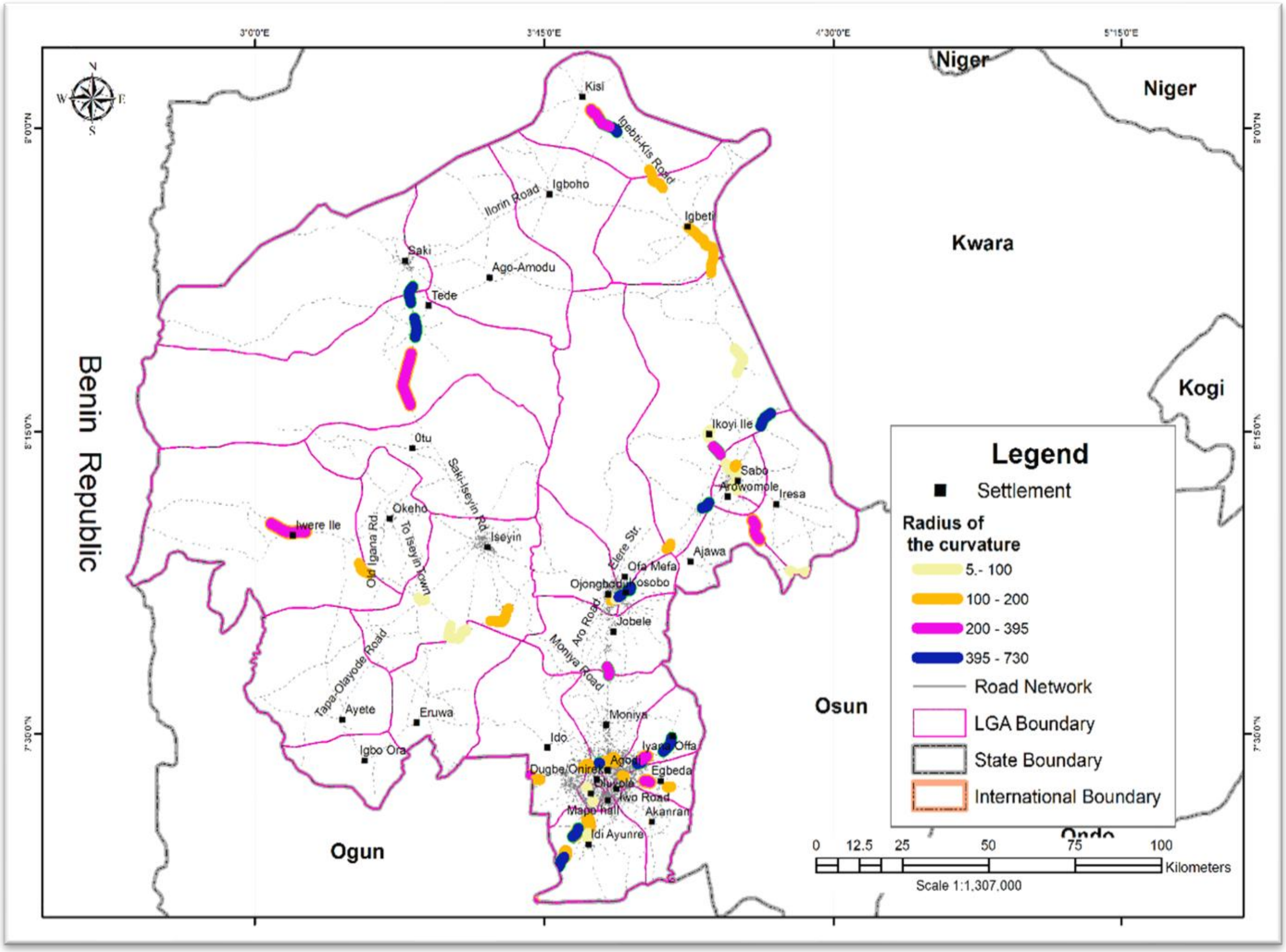

Fig 8 Associated radius of the curvature
Source: Author's Compilation, 2023

This map represented in fig 8 describes the radii of curve within the roadway segment blackspot, the colours in the key shows the variation or difference in their radius from the lower range to the highest. The lower the radii the more likely crash can occur when the speed limit is exceeded.

4.6 Susceptibility of the roadway curve segments

The susceptibility of the road way curves to road traffic crashes involves an overlay analysis of the risk factors for the study road way curve location as well as the entire route. The overlay analysis tool in ArcGIS is a powerful modelling tool that integrates different factors which are the radii of the curved sections, the designed curvature speed limit and the approved FRSC speed limit, as could be seen in the maps Figs.6, 7 and 8. When brought together or superimposed, an output showing a thematic map showing the level of risk the roads are in terms of curvature and speed limit.

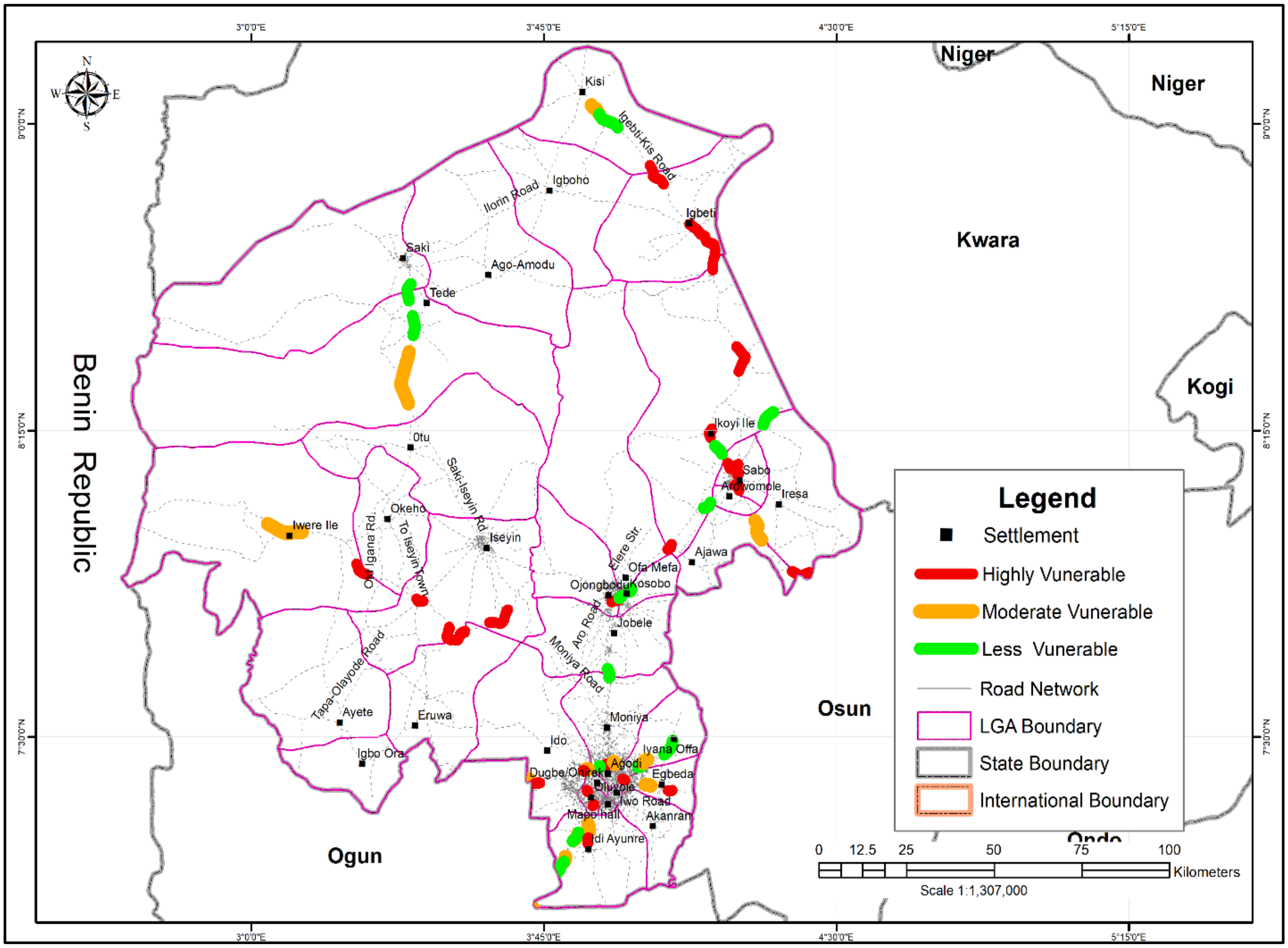

Fig. 9 Susceptibility of the roadway curve segments to road traffic crash
Source: Author's Compilation, 2023

The curves were ranked along the route in order to see the vulnerability of the roads, as shown in figure 9 the levels of road vulnerability are represented by the different colours of red, orange and green. The curved section with red represents areas with high vulnerability, followed by orange, which is a moderate vulnerability and green which is associated with a very low vulnerability. In testing the hypothesis.

4.7 Analysis of the Difference in the Speed Limits

Investigating the difference in the speed limits of the approved FRSC and designed curvature roadways at the blackspots shows that there is a level road safety challenge. Curve road sections along the sampling route in the study are identified and subjective to both statistical and spatial analysis. Considering the designed curvature speed limits and the approved FRSC speed limit for the same location, referring to Table 1 above, the results from the curvature analysis in terms of speed limits. An independent sample student t test was conducted to find the difference between the

Designed Curvature Speed Limit (Km/h) and the FRSC Approve Speed Limit (Km/h) in this table to test the hypothesis.

H1: There is no significant difference between the approved FRSC speed limit and the designed curvature speed limit at curved blackspot roadway segments.

The independent sample Student t-test were conducted, which is used to find the average difference between two variables in this case:

Variable 1 is designed curvature speed limit

Variable 2 is FRSC speed limit.

The table shows the result

Table 4. Group Statistics

Group	N	Mean	Std. Deviation	Std. Error Mean
Score 1	52	75.1923	24.39386	3.38282
2	52	97.6923	9.41742	1.30596

Table 5 Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	lower	upper
Equal variances Assumed score	69.687	.000	-6.205	102	.000	-22.50000	3.62616	-29.69246	-15.30754
Equal variances not assumed			-6.205	65.872	.000	-22.50000	3.62616	-29.74012	-15.25988

Source: Author's Compilation, 2022

Since the p-value is.000 (which is less than the common alpha level of 0.05), we reject the null hypothesis and conclude that there is a statistically significant difference in speed limits between Group 1 and Group 2. The standard deviations for the distributions of the two groups are different: 24.39386 for the design curvature speed limit and 9.41742 for the approved FRSC speed limit. From the table above, we reject the null hypothesis, which states that "there is no significant difference between the FRSC-approved speed limit and the designed curvature speed limit at curved blackspot road segments' and conclude that "there is a significant difference between the FRSC-approved speed limit and the designed curvature speed limit at curved blackspot roadway segments.". The difference in means offer insights into potential reasons for crashes, but it does not directly indicate causation. Instead, it suggests correlations or associations that require further investigation to understand the underlying reasons for crashes. This is because the p-value is less than 0.05. Meaning that group 1 (the designed curvature speed limit) is different from group 2 (the approved FRSC speed limit). We then reject the null hypothesis that states that "there is no significant difference between the approved FRSC speed limit and the designed curvature speed limit at curved blackspot roadway segments," Since the p-value is less than 0.05, the null hypothesis is rejected, and we conclude that there is a significant difference between the approved FRSC speed limit and the designed curvature speed limit at curved blackspot roadway segments.

5.0 CONCLUSION

Like in most cities across the world and in Oyo State, Nigeria the task of ensuring roads are safe is enormous road infrastructures lack functional street lights, road signs and symbols, road markings, etc., which must be put in place to ensure these roads do not become death traps for the user. The current road traffic crash situation is less desirable and urgent steps must be taken to reduce the rate of traffic crash occurrence and the associated severity. Curved road sections and road traffic crashes in Oyo State. The study achieved several objectives and revealed several critical issues relating to road traffic crashes in Oyo State. Based on the results from the field,

The study investigated the difference in speed limit between designed speed limit and approved FRSC speed limit. Surprisingly, road curvatures did not have a significant impact on crash occurrences in this study however when the designed speed limit is violated. The study pointed out discrepancies between the Federal Road Safety Corps (FRSC) approved speed limits and the designed curvature speed limits. This situation have an important safety implications. The discrepancies between the FRSC-approved speed limits and the designed curvature speed limits highlight the need for a reevaluation of speed regulations. Ensuring that speed limits are appropriately set according to road design and conditions could reduce the incidence of crashes.

Policymakers can use these findings to develop more effective road safety policies and planning strategies. By focusing on the identified key findings, resources can be allocated more efficiently to areas that will have the most significant impact on reducing road traffic crashes. Awareness campaigns and driver training programmes should incorporate these findings. The government should empower the road safety agencies to enhance better patrol of the blackspot locations.

The study recommends that the designed curvature speed limit should be enforced at curved roadway geometry by the regulatory agencies using road signs and symbols indicating the appropriate speed limit recommended by the designer of such a curved roadway segment. Ongoing education and monitoring for drivers are essential to ensure compliance with traffic signs and safety symbols, as the information communicated by these elements is vital for the safety of both drivers and other road users. Engineering solutions such as better guardrails and road leveling could be considered in areas with significant geometry or curve changes.

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