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IDENTIFICATION OF ACCIDENT LOCATION AND DEGREE OF VULNERABILITY ALONG OSOGBO-GBONGAN ROAD, OSUN STATE, NIGERIA

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Graphical abstract

Abstract

Road traffic accidents (RTAs) remain a significant global concern and leading cause of death of people within the economically active age-group in developing countries thereby mounting negative effect on people's health, economy and the society at large. This research aimed at developing a prediction model for accident prone areas along Osogbo-Gbongan road as past studies revealed that the study area reported the highest RTAs in Osun State, Nigeria. Four years accident data obtained from FRSC, Osogbo Branch was characterized in terms of casualty, accident causes and location and affected age-groups (Adult/Children). Geometric parameters were obtained onsite by physical measurement to estimate the vulnerability of the road at blackspot locations. The identified accident blackspots were Ogo-oluwa (02+000), Ataoja (04+000), Abeere (06+000), Owode (10+000) and Akoda (15+000) with their vulnerability indices as 53, 67, 78, 66 and 70, respectively. The obtained total occurrence of accidents in 2018, 2019, 2020 and 2021 were 144, 128, 168 and 313, respectively with speed violation as the highest causative factor. Abeere Area has the highest accident occurrence of 31 and the highest T.SPWEG-A.V.I of 78 with three other locations showing similar pattern except Owode Area. Therefore, this model showed a perfect correlation of 80% thereby ensuring the validity of the model for predicting the accident vulnerability at accident locations. This study concluded that accident in this area can be characterized as minor, serious and fatal with the fatal causing deaths. The speed violation and poor road geometry were the primary factors contributing to the severity of accident and it will continue to increase if urgent intervention is not applied. The study recommended that speed law should be enforced, presence of safety personnel at the noon part of the day and those in charge of road design, supervision and construction should uphold good practice and rehabilitate the existing road geometry so as to curtail accident reoccurrence along the study area.

Keywords: RTAs, T.SPWEG-AV Index, Blackspot, Minor, Fatal

1.0 INTRODUCTION

Transportation of goods and people is the livewire of the global economy and a key stone to civilization of which road transportation is the commonest (Wilson *et al.,* 2019). It has an enormous pivotal role in ensuring human survival and achieving sustainable development. Road transportation has an outstanding impact in any nation's developmental processes as it generates a significant employment within the economy thereby indicating economic progress and development (Oluwayemi *et al.,* 2020). However, rapid increase in road traffic activities offer negative effect on people's health, economy, society and environment at large thereby resulting to road traffic injuries, road crashes, air pollution, greenhouse gas emission, community severance, noise etc. Oluwayemi *et al.* (2020) defined road traffic accident as the collision occurring between moving vehicles and/or between a moving vehicle and pedestrian on roadways which usually leads to injuries, loss of properties, death etc. Road traffic accident or crashes is an unforeseen phenomenon occurring from the operation of vehicles. In developing countries, the incidence of road traffic crashes is of high significance as a result of increase in vehicular ownership and population explosion thereby affecting road safety targets (Antonio *et al.,* 2019). The increase in population and vehicle ownership in developing countries affect road safety targets (Antonio *et al*., 2019).

Globally, the leading cause of death of active population i.e. young adults and adolescents is road traffic accident (Ayodeji, 2018). According to the WHO (2009), the cost of global economy of road traffic crashes per year was estimated to be $518 billion (about #176 trillion) having about #34 trillion occurring in poor developing countries. Urban dwellers in Nigeria are affected by various myriads of challenges and problems such as insecurity, traffic congestions, traffic accidents, lack of shelter proper healthcare and rise in poverty etc. Road Traffic Accident is the collision that occurs between a moving vehicle and another vehicle or pedestrian on the roadway which often leads to injuries, temporary or permanent disabilities, loss of properties and death (Oluwayemi *et al.,* 2020). Road traffic accident happens as a result of malfunctioning system of driving (Katerina *et al.,* 2020). It is of great concern to health of every individual as it amounts to injuries and deaths (Muthusamy *et al.,* 2015). Ozor and Ozoegu (2020) denoted road traffic accident with two phenomena: a random and undesirable occurrence, and unforeseen events. Injury and mortality associated with road traffic accident is increasing partly due to growth in level of motorization (Ayodeji, 2018) and mainly due to difference between increase in transportation infrastructures with development investment in salient sectors (Ozor and Ozoegu, 2020).

Road traffic accident is an occurrence which happens with a cause and results from the malfunction experienced in the components of driving system which include: road users, vehicles, road infrastructures and their interaction (Katerina *et al.,* 2020). Good awareness and appreciable knowledge of the factors leading to accident would assist in its mitigation (Afolabi and Gbadamosi, 2017). The major causes contributing to road traffic crashes are classified in relation to the following factors: human (drivers) factors, vehicular factor, roadway factor and environmental/weather condition factor (Antonio *et al.,* 2019). It can be concluded that the causes of road traffic crashes are multi-factorial. Accident hotspot are locations that possess high risk of accident occurrence or places with higher number of accidents than other similar places due to risk factors (Thakali et *al.,* 2015; Yousef *et al.,* 2019). Hotspot refers to certain locatins on the road section, usually crowded intersection and sharp curves, with higher level of risk than the overall levels of risk in adjacent areas which experience significant accident counts (Yousef *et al.,* 2019). Locations are classified as accident hotspots after the identification of accident occurrence probability and level of risk with their risk level greater than the overall level of danger in the surrounding areas thereby leading to more accident occurrences.

Identification of accident hotspot involves a systematic process of detecting sections of road that are affected by unacceptable level of high risk of crashes and often known by various terms in literature which include accident-prone location, black spots, collision-prone location, dangerous sites, hazard location, hotspots or priority investment locations (Thakali *et al.,* 2015). Accident Prediction Model (APM) is a mathematical equation in which the average accident frequency of a site is expressed as a function of traffic flow and other site characteristics. This model is of great usefulness in estimating the expected number of accidents on road entities such as junctions, intersection and road sections. The results from the prediction model are useful in identifying sites in need of safety treatment. Accident prediction models have been of great use in road engineering and planning. According to Hamid *et al.* (2018), accident prediction models can be generally categorized into two major groups namely: statistical techniques which include single and multivariate deterministic models, multiple logistic models, probabilistic models, parametric models; and artificial intelligence approaches such as conventional intelligence and computational intelligence. Parametric models are used for accident prediction which takes into consideration parameters judged to be representative of road accident vulnerability.

2.0 METHODOLOGY

2.1 Study area

The study area is Osogbo-Gbongan road situated within Osun State, Nigeria. It is the linking road of Osogbo to Gbongan (Figure 1) and other cities like Ife, Ikire, Ibadan and Lagos. It is a Federal road and it spans between two junctions namely: Old garage junction of latitude 7°46'55.23"N and longitude 4°32'57.64"E to Gbongan junction of latitude 7°28'2.52"N and longitude 4°19'53.26"E and it has an approximate length of 44 km. (Google Earth Pro, 2022). Among the major junctions found on the route are Old-garage, Olaiya, Ataoja, Abeere, Owode, Aisu, Akoda, Sekona, Ode-Omu, Oogi and Gbongan with major locations like: Orisumbare, freedom park, Aregbe, Ogo-Oluwa, Ataoja Secondary School, Independent Electoral Commission (INEC) State Headquarter office, Abeere, Federal Road Safety Commission (FRSC) Station, Nigerian Police Force Zone II, Owode, Akoda, Sekona, Ode-Omu, Oogi, Gbongan etc. The main road traffic transportation modes on the road are cabs or taxis, mini-buses (korope) and motorcycles (okada) ; cabs and minibuses often ply the primary roads while motorcycles are usually used on the secondary routes (Baloye and Palamuleni, 2015). Among the most commercial and industrial parts on the road are Olaiya/Ogo-Oluwa Area; Orisumbare/Old garage Area; Abeere/Owode market Ataoja/Abeere Area.

2.2 Data Collection and Analysis

The study used parametric model known as SPCWEG-AV where S = spot speed, P = pavement condition, C = condition of shoulder, W = width of road, E = elevation (super)/cambering, G = gradient, and AV = accident vulnerability of the segment considered. The study used primary and secondary data: the records of road traffic accident data obtained from the Federal Road Safety Commission (FRSC), Osogbo command which covers the year 2018 to 2021 formed the primary data. The datasets included information on types and category of vehicles involved, route and location of occurrence, number and category of people involved, number of injured and deaths, time and date of occurrence, daily casualty count and cause of road traffic accidents. The route on which the accident occurred over the period of year under consideration were isolated from the database entries in order to determine the routes with significant occurrence. Locations with accident counts of 10 and above were considered significant, thus such locations were categorized as accident prone location.

The secondary data were measured physically and virtually on the route; the spot speed (S) was measured by direct observation of the time taken by a vehicle to cover a distance

100 m as shown in Equation 1. The average of three trials for each identified location was used.

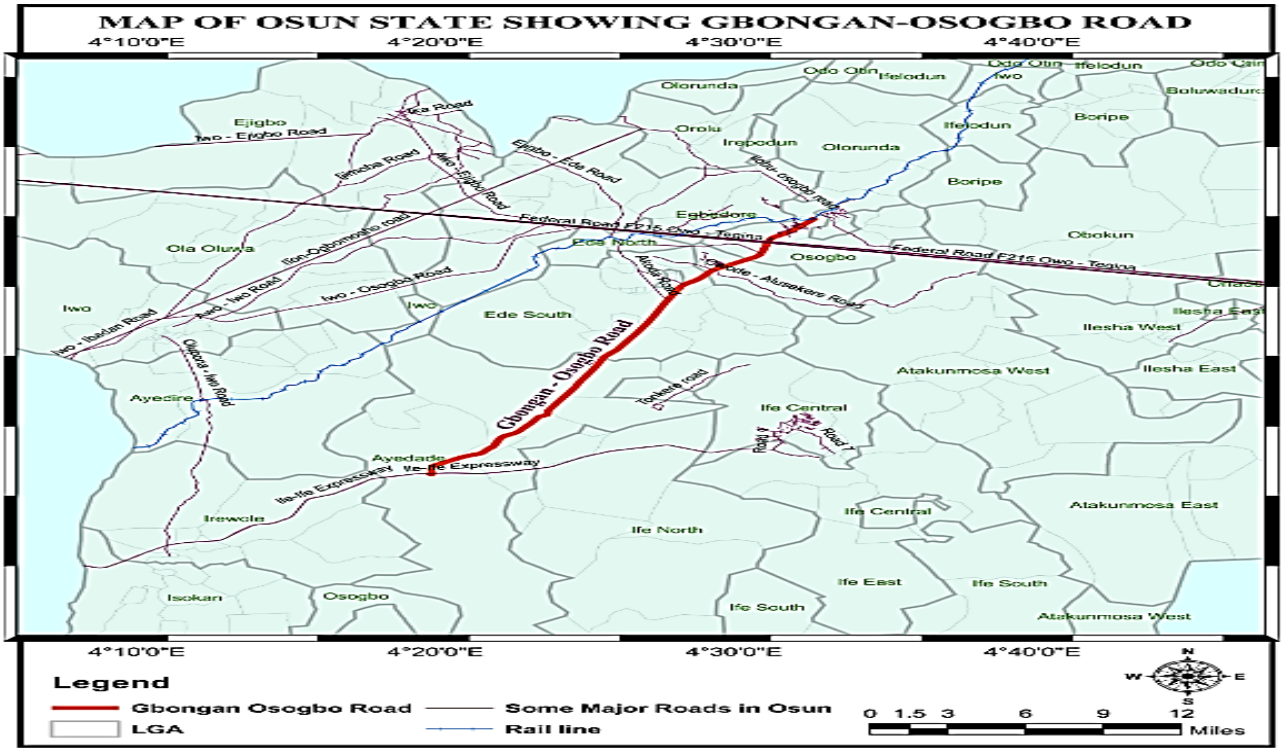

Figure 1 Osogbo-Gbongan Road (Modified and Extracted from Google Earth Pro, 2022)

$$\text{Spot speed} = \sum \frac{\text{marked distance}}{\text{measured time taken}} \quad (1)$$

The condition of road pavement (P) was assessed by visual evaluation of pavement surface and noting defects found on them. They were characterized as structurally adequate, crack/minor dents, isolated potholes, wavy/heavy surface and shear/massive failure.

The condition of the road shoulder (P) was evaluated visually and it was characterized as clean, bushy, small-sized width, eroded and absent from the location under consideration. The width of the pavement (W) was measured with a measuring tape at several locations along the route. The road elevation (E) of the road was estimated with the use of twine, plumb and measuring tape. This was done by holding the twine at the two ends of the road and ensuring a horizontal accuracy with the use of a plumb. The elevation to the stretched twine was measured at the center and at the road edges. The gradient of the pavement was determined at the location under consideration with the use of twine, plumb and measuring tape. The gradient (G) was expressed as shown in Equation 2.

$$G = \frac{road\ elevation\ at\ the\ crest\ region}{distance\ towards\ the\ edge\ of\ the\ road} \quad (2)$$

The rating and weight were associated to each of the field output in accordance to their condition and classification which depends on their position within the ranges of values for each of the aforementioned factors as presented in SPCWEG-AV Rating System and Weights (Aderinola *et al.,* 2017). The rating system adopted ranges from 1 to 5 while the weighting system ranges from 1 to 3 denoting the order of significance in contribution to road traffic crashes as shown in Table 1.

2.3 Estimation of the Accident Vulnerability

The Mathematical expression of accident model vulnerability evaluation as shown in Equation 3 was used

$$\mathbf{T.SPCWEG - AV.I} = \mathbf{S_rS_w + P_rP_w + C_rC_w + W_rW_w + E_rE_w + G_rG_w} \quad (3)$$

(Aderinola *et al.,* 2017)

Where:

S_r = Spot speed Rating; S_w = Spot speed Weight; P_r = Pavement condition Rating; P_w = Pavement condition Weight

C_r = Condition of shoulder Rating; C_w = Condition of shoulder Weight; W_r = Width of road and shoulder Rating W_w = Width of road and shoulder weight; E_r = Elevation (super)/cambering of road Rating

E_w = Elevation (super)/cambering of road Weight; G_r = Gradient of road Rating; G_w = Gradient of road Weight

AV = Accident Vulnerability

The parametric analysis was done by inputting the field data into SPCWEG - AV.I. equation and total SPCWEG-AV.I. index for each location was computed. It was further divided into six categories namely: very low, low, moderate, high, very high and dangerously high depending on the value of the index estimated at each of the locations as shown in Table 2. Therefore, the higher the value obtained using SPCWEG-AV Index, the greater the proneness of accident at the specified location.

Table 1 Rating and weighting ranges for SPEWEG-AV parameters

Parameter	Condition	Classification	Range	Rating	Weight
Spot speed (S)	Slow	Slow	0 - 30	1	
	Moderate	Moderate	30 - 60	2	6
	Average	Average	60 - 90	3	
	Fast	Fast	90 - 120	4	
	Very Fast	Very Fast	120 - 150	5	
Pavement condition (P)	Structurally adequate	Very Good	0 - 20	1	
	Crack/ minor dent	Good	20 - 40	2	5
	Isolated Potholes	Fair	40 - 60	3	
	Wavy/ Heavy Surface	Poor	60 - 80	4	
	Shear/Massive failure	Very Poor	80 - 100	5	
Condition of shoulder (C)	Clean/ Clear	Very Good	0 – 10	1	
	Bushy	Good	10 - 20	2	4
	Small Width	Fair	20 – 30	3	
	Eroded	Poor	30 – 40	4	
	Absent	Very Poor	40 - 50	5	
Width of Pavement/ shoulder (W)	Too small	Very Poor	0.0 – 2.8	5	
	Small	Poor	2.8 – 5.6	4	
	Normal	Fair	5.6 – 8.4	3	3
	Wide	Good	8.4 – 11.2	2	
	Wider	Very Good	11.2 – 14.0	1	
Elevation (super) Cambering (E)	Very Bad	Very Poor	0.00 – 0.75	5	
	Bad	Poor	0.75 – 1.50	4	
	Fair	Fair	1.50– 2.25	3	2
	Good	Good	2.25 – 3.00	2	
	Very Good	Very Good	3.00 – 3.75	1	
Gradient of Pavement (G)	Normal	Very Good	0 - 3	1	
	Moderate	Good	3 - 6	2	
	Fair	Fair	6 – 9	3	1
	High	Poor	9 – 12	4	
	Very high	Very Poor	12 - 15	5	

Table 2 Categories of Accident Vulnerability

Categories	SPCWEG-AV Index
Low	0 - 21
Very Low	22 - 31
Moderate	32 - 41
High	42 - 51
Very High	52 - 61
Dangerously High	> 61

3.0 RESULTS AND DISCUSSION

The location that experienced values above 10% of the number of road traffic accidents is presented in Figure 2; these were identified as accident prone locations. They are Chainage 07+000 (*Abeere*) with 31 counts (22.6%), 05+000 (Ataoja) with 18 counts (13.1%), (22.6%), 10+000 (*Owode*) with 18 counts (13.1%), 15+000 (*Akoda*) with 15 counts (10.9%) and 02+000 (*Ogo-Oluwa*) with 14 counts (10.2%). Hence, the locations are referred to as accident prone locations on which further analysis were conducted. The accident counts for the remaining locations were less than 10%, thus, they were neglected for further evaluation. The vulnerability of the identified accident-prone locations was estimated by carrying out road geometry survey so as to obtain the geometrical features contributing to occurrence of accident along the study. Figure 3 shows the SPCWEG-AV index of the accident-prone locations which were *Ogo-oluwa, Ataoja*, *Abeere*, *Owode* and and *Akoda* area. It shows that Ogo-oluwa area had spot speed of 65 km/h, pavement surface defect of cracks and potholes, unclean road shoulder, wide roadway (9.6 m), very bad road camber (0.1) and moderate road gradient (3.4%). The total SPCWEGAV index for *Ogo-oluwa* area was gotten by summing all the SPCWEGAV index of the individual parameters thereby resulting to 53. These procedures were repeated for other locations to obtain their respective SPCWEG-AV index; the index of *Ataoja* Area was 67, *Abeere* area was 78, *Owode* area has 66 and *Akoda* area was 70 as presented in Figure 4. In addition, a control (ideal) situation was assumed such

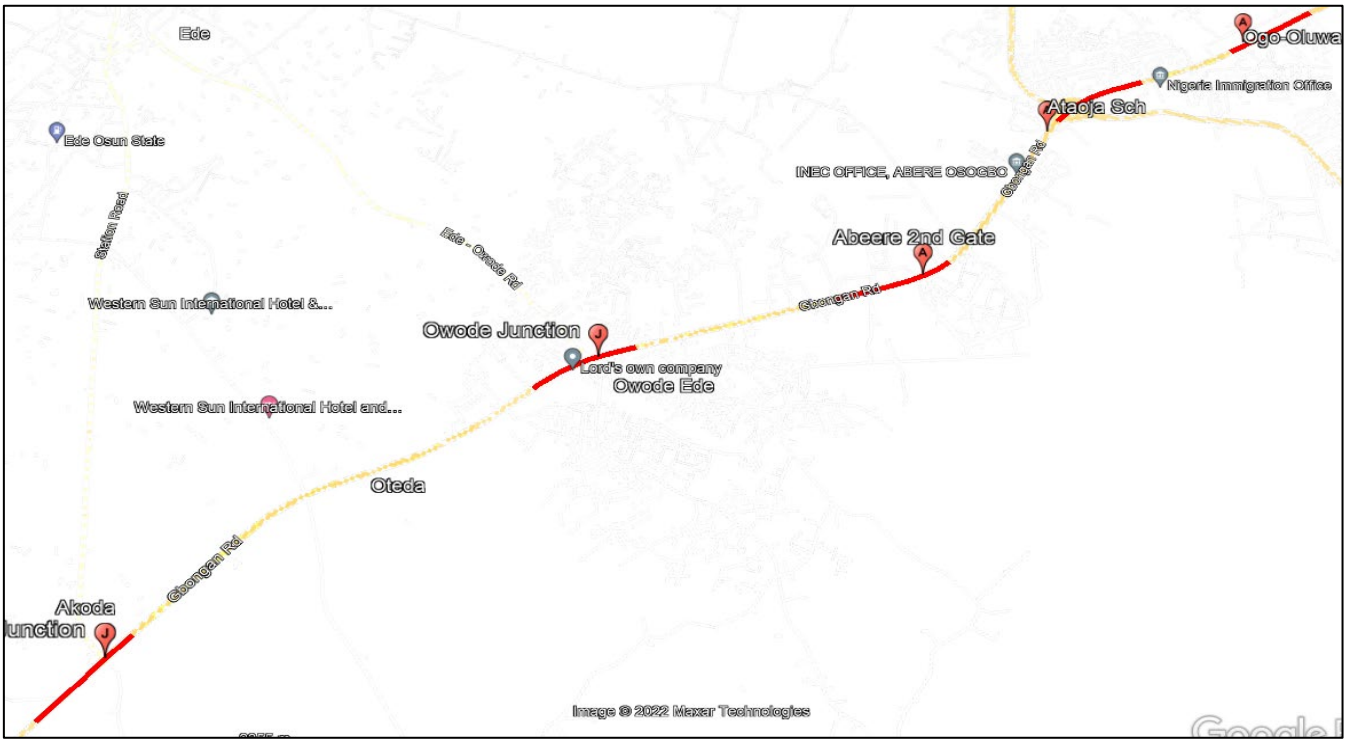

Figure 2 Accident-Prone Locations and their respective RTA Counts (Modified and Extracted from Google Map (2022))

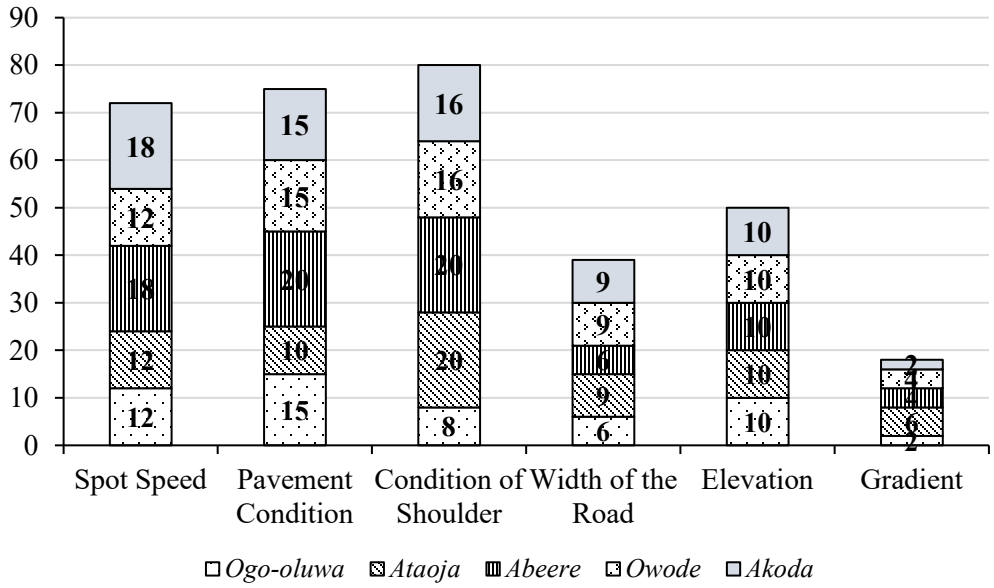

Figure 3 SPCWEG-AV Index at Accident-Prone Locations

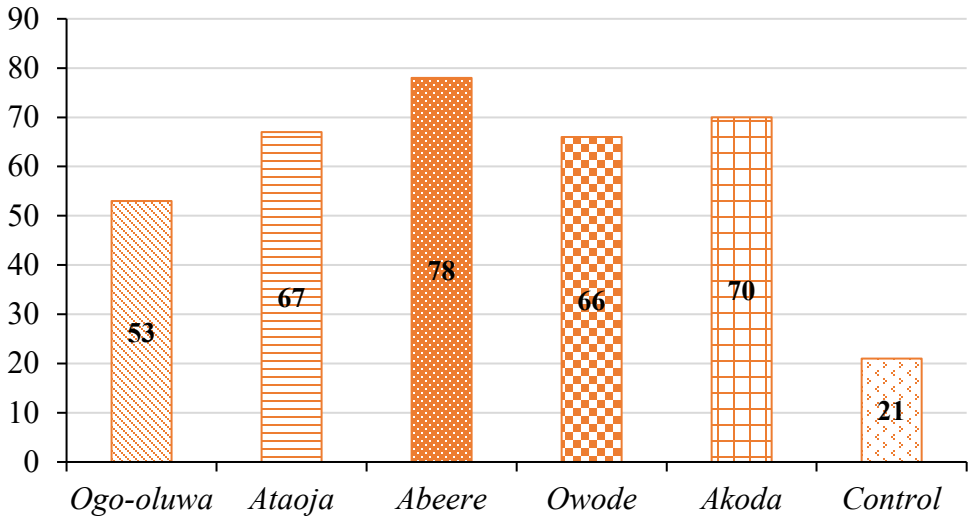

Figure 4 Total SPCWEG-AV Indices for the Accident-Prone Locations and a Control (Ideal) Location

that its SPCWEG-AV index was 21 estimated from situation whereby spot speed experienced on the roadway was 30 km/h (slow) with pavement condition being structurally satisfactory, a clean road shoulder, wider pavement width, very good camber and very high pavement gradient. Therefore, SPCWEG-AV index of 21 denotes the control (ideal) situation in which accident will rarely occur.

The vulnerability of these locations was thereby estimated such that *Ogo-oluwa* area which had the least total SPCWEGAV index of 53 is characterized to be very highly vulnerable (very high), while the remaining accident-prone locations with total SPCWEGAV index above 60 were attributed to be dangerously vulnerable to accident which is an indication for accident blackspot. According to Aderinola *et al.* (2017), the higher the more vulnerable a section of the road is, which indicate that the parametric model can replicate and predict the occurrence of accident on the road.

Additionally, Table 3 shows an existing complementary relationship between the degree of accident estimated using SPCWEG-AV.I and the frequency of accident estimated from the dataset obtained from the FRSC whereby *Ogo-Oluwa* had the least accident frequency (14), followed by *Akoda* area (15), then, *Ataoja* area and *Owode* area having the same frequency (18) and lastly, Abeere area with the highest accident frequency (31). The extent of road accidents in these areas can be attributed to factors such as spot speed, pavement condition, shoulder condition, road width, elevation, and gradient. Meanwhile, the condition of the pavement and the condition of the shoulder caused the highest percentage of accidents along the road in these areas when compared to others. However, *Akoda* area has less frequency as compared to its vulnerability to accident occurrence while others showed great correlation thereby showing that 80% of the locations showed perfect correlation, thus ensuring the validity of the model for predicting the vulnerability of accident at the accident locations. The correlations exemplified the application of the parametric model in predicting accident vulnerability at the locations under consideration thereby denoting the susceptibility of the locations to occurrence of accident. The findings of this study are consistent with those of Aderinola *et al*. (2017) and Aderinlowo and Afolayan (2019), who discovered a strong correlation between the SPCWEG-AV model indices and the frequency of accidents at the investigated points along the road.

Table 3 Degree of Accident Vulnerability and Accident Occurrence Accident-Prone Locations

S/N	Location	T.SPCWEG-A.V. I	Accident Vulnerability	Accident Occurrence
1	*Ogo-Oluwa*	53	Very High	14
2	*Ataoja Area*	67	Dangerously High	18
3	*Abeere Area*	78	Dangerously High	31
4	*Owode Area*	66	Dangerously High	18
5	*Akoda Area*	70	Dangerously High	15

4.0 CONCLUSION AND RECOMMENDATION

Osogbo-Gbongan road experienced great numbers of accident occurrence which were fairly distributed and some locations have higher percentage, thus making them accident prone areas. The identified accident-prone areas were: *Ogo-oluwa*, *Ataoja*, *Abeere*, *Owode* and *Akoda* with significant number of accidents ;14, 18, 31, 18 and 15 respectively. The degree of vulnerability to accident as determined by SPCWEG-AV Index shows blackspots of high accident vulnerability.

Also, the parametric model showed correlation between the indices and occurrences of accident at the identified locations

and *Abeere Area* has the highest accident occurrence of 31 and the highest T.SPWEG-A.V.I of 78 with three other locations showing similar pattern except *Owode Area.* Therefore, this model showed a perfect correlation of 80% thereby ensuring the validity of the model for predicting the accident vulnerability at accident locations.

The Federal Road Safety Commission (FRSC), Osun Branch should look into making a detailed accident reports which would include coordinates of places with accident occurrences and continual safekeeping of accident data with traffic volume of major locations inclusive. Also, the public at all levels of educations should be enlightened through awareness programme about road safety reinforced with continual implementation and monitoring of road safety mechanism. The identified blackspot should be given more attention likewise locations near them through correction of road geometry. The agencies charged with road constructions should direct most of their attentions to adequate design, supervision and construction of road facilities and rehabilitation of the existing roads thereby providing unavailable highway facilities such as road shoulder, side drainage, road markings, traffic signs etc.

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