

## Development of Road Accident Prediction Models for Akure-Owo Highway, Ondo State, Nigeria

Olufikayo Oluwaseun Aderinlewo<sup>1\*</sup> and Abayomi Afolayan<sup>2</sup>

<sup>1</sup>Civil Engineering Department, Federal University of Technology,  
PMB 704, Akure, Ondo State, Nigeria

<sup>2</sup>Civil Engineering Department, Federal Polytechnic, PMB 231 Ede,  
Osun State, Nigeria

\*Corresponding author: [oluade2010@gmail.com](mailto:oluade2010@gmail.com)

**Published online:** 31 December 2019

**To cite this article:** Olufikayo Oluwaseun Aderinlewo and Abayomi Afolayan (2019). Development of road accident prediction models for Akure-Owo Highway, Ondo State, Nigeria. *Journal of Engineering Science*, 15(2), 53–70, <https://doi.org/10.21315/jes2019.15.2.4>

**To link to this article:** <https://doi.org/10.21315/jes2019.15.2.4>

**Abstract:** *The aim of this study is to develop road accident prediction models for Akure-Owo highway. These relate accident numbers (as a dependent variable) with possible causes of accidents that are related to road factors (as independent variables). The study also proposes effective countermeasures to reduce the frequency and severity of traffic accidents in Nigeria. This research developed a Mathematical Accident Prediction Model using Spot Speed of Vehicles, Condition of Shoulder, Pavement Condition, Width of Pavement, Gradient of Pavement, Intersection, Drainage Condition, Stopping Sight Distance, and Overtaking Sight Distance as parameters from which the acronym SCPWGIDSO was formed. Accident data for six years (2010 to 2015) were obtained from Federal Road Safety Commission (FRSC) Akure office, which were used to identify accident prone locations along Akure-Owo highway. Twenty-four locations called “Black Spots” were identified. Field data such as Spot Speed of Vehicles, Condition of Shoulder, Pavement Condition, Width of Pavement, Gradient of Pavement, Intersection, Drainage Condition, Stopping Sight Distance, and Overtaking Sight Distance information were obtained from road condition survey. The SCPWGIDSO-AV rating system and weights produced a calibrated mathematical model, which was validated with field data.*

**Keywords:** prediction models, countermeasures, severity, mathematical, calibrated, validated

## 1. INTRODUCTION

An accident is an unpleasant or undesirable damage that happens unexpectedly or by chance. Road traffic accident occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole. Road traffic accident may also be defined as anything which happens by chance, anything occurring unexpectedly and undesigned.<sup>1</sup> Road accidents have been a threat to the safety of family members and are associated with numerous problems each of which need to be addressed separately; human, vehicle, and environmental factors play roles, before, during, and after a traumatic event. Road accidents are becoming very common and are robbing the nation of its valuable human resources; the implications of these lead to both social and economic trauma. This can be curbed mainly by educating drivers on defensive driving skills and by the enforcement of traffic laws.

Every year more than 1.17 million people die in road crashes around the world, 70% of these occur in developing countries; globally, 10 million people are crippled or injured each year, 65% of deaths involved pedestrians and 35% of the pedestrians are children. It has been estimated that a million more will die and 60 million will be injured during the next 10 years in developing countries unless urgent action is taken.<sup>2</sup> One person dies during crashes nearly every 12 min, and of that number 25,136 died in roadway departure crashes, 9,213 in intersection crashes, and 4,749 in pedestrian crashes.<sup>2</sup> It has been estimated that nearly 25% of fatal injuries worldwide are a result of road traffic crashes, with 90% of the fatalities occurring in low and middle income countries.<sup>3</sup> Road accidents cause significant social and economic costs (typically between 1% and 3% of Gross National Product [GNP]).<sup>4</sup>

Road accidents have become a re-occurring phenomenon in Nigeria, which has constituted a menace in modern times. Although both the developed and developing nations of the world have suffered from varying degrees of road accidents, the developing countries clearly dominate with Nigeria having the second highest rate of road accidents among 193 ranked countries of the world.

## 2. LITERATURE REVIEW

The dominant mode of transportation in Nigeria is the roadway and it is also the mode that records the highest number of fatalities, injuries, and number of crashes. An analysis of traffic crash data recorded over a five year period between 2000 to 2006 showed that 98,494 cases of traffic crashes were recorded out of

which 28,366 were fatal and resulted in 47,092 deaths.<sup>5</sup> The data shows Nigeria is fore front of all nations (especially the third world nations) experiencing the highest rate of road tragedies in the world. Many researchers have attempted to find the variables most highly associated with crashes.

Human error accounts for 41.50%, road condition 32.17%, vehicle 16.83%, and weather 9.50% of road traffic crashes/collisions on Ondo state roads.<sup>6</sup> Only a small percentage of road vehicle crashes/collisions can be considered unavoidable, unfortunate, and misfortune accident, this means that majority of vehicle collision/crashes on Nigerian roads are predictable and can be classified on the basis of negligence, ignorance, stupidity, being untrained, and diabolic type of action.<sup>7</sup>

Accident prediction models were developed for Akure-Ondo carriageway using multiple linear regression.<sup>8</sup> The spot speed analysis indicated that higher value of 85th percentile contributed to the accidents on the carriageway with a posted speed limit of 60 km/hr; other contributing factors stated are drivers' behaviour, poorly maintained vehicles, non-adherence to traffic rules, poorly maintained road and verges, and over-speeding.

Due to wide differences in traffic mix, road quality design and road users' behaviour, it would be either valid or useful to apply simple multiplicative factors or even devise more complex conversion formulae for models developed in one country to be applied to another country.<sup>9</sup>

Geometric structure variables such as width of lane, median barrier, curve radius, and deflection angle were studied and examined in relationship with accidents. Width of lane was shown to be an important variable through the model.<sup>10</sup>

An accident prediction model was developed according to different conditions by distinguishing separation and non-separation of left-turn lane separating roads away from median separation facilities. As a result, it was proposed that accidents were affected by Annual Average Daily Traffic (AADT), length of roads, density, and land use.<sup>11</sup>

## **2.1 Road Factors**

In 1985, a study of roadway problems in the United States showed that about 34% of serious crisis had contributing factors related to the roadway or its environment. The road or environmental factor was either noted as making a significant contribution to the circumstances of the crash. Research has shown that

careful design and maintenance, with well-designed intersections, road surfaces, visibility, and traffic control devices can result in significant improvements in accident rate.<sup>12</sup>

## 2.2 Modified “SCP-AV” (SCPWGIDSO-AV) Index Equation

The point count system called “DRASTIC” model was modified to assess accident proneness along Akure-Ondo highway.<sup>13</sup> In this particular study, other road parameters which are known to contribute to accident occurrence at the different identified locations along the road under study were added to the “SCP-AV” index equation. Spot speed of vehicles, condition of the road shoulders, pavement condition, width of pavement, gradient of the pavement, intersection, drainage condition, stopping sight distance, and overtaking sight distance were combined to produce accident proneness values for the various identified major accident-prone locations along the route. The modified “SCP-AV” model termed SCPWGIDSO-AV model is an accident proneness model for evaluating road traffic crashes using Statistical Package for Social Sciences (SPSS) software. This model also employs numerical ranking system that assigns numeric weights to various parameters which influence road traffic crashes. Nine parameters judged to be representative of accident vulnerability were selected and weighted to reflect the relationship between them and their relative importance as regards to accident impact. Each of the selected parameters has a given range, which is subdivided into discrete hierarchical intervals. Each interval is assigned a value reflecting the relative degree of accident proneness and the rating points are summed. The final numerical score is divided into segments expressing a relative degree of accident proneness.

The geometrical settings which make up the acronym SCPWGIDSO-AV are:

- S – Spot Speed of Vehicles
- C – Condition of Shoulder
- P – Pavement Condition
- W – Width of Pavement
- G – Gradient of Pavement
- I – Intersection
- D – Drainage Condition
- S – Stopping Sight Distance
- O – Overtaking Sight Distance
- AV – Accident Vulnerability

Typical ratings range from 1 to 6 and weights from 1 to 9. Ranges were attached to parametric conditions in order of their importance to road geometry and their contribution to accident proneness. This is summarised in Table 1.

Table 1: Road factors SCPWGIDSO-AV rating system and weights.

Parameter	Condition	Classification	Range	Rating	Weight
Spot speed of vehicles	Slow	Excellent	0–30 km/hr	6	9
	Moderate	Very good	30–60 km/hr	5	
	Average	Good	60–90 km/hr	4	
	Fast	Fair	90–120 km/hr	3	
	Fairly fast	Poor	120–150 km/hr	2	
	Very fast	Very poor	150–180 km/hr	1	
Condition of shoulder	Standard/clear width	Excellent	3.2–3.6 m	6	8
	Ideal	Very good	2.9–3.0 m	5	
	Narrow/bushy	Good	1.8–2.4 m	4	
	Small width	Fair	1.2–2.4 m	3	
	Eroded	Poor	1.0–0.1 m	2	
	Absence	Very poor	0.0 m	1	
Pavement condition	Very smooth	Excellent	100–85	6	7
	Smooth with few depression	Very good	85–70	5	
	Crack/minor dent	Good	70–55	4	
	Comfortable with intermediate bumps	Fair	55–40	3	
	Uncomfortable with frequent bumps	Poor	40–25	2	
	Uncomfortable with constant bumps	Very poor	25–0	1	
Width of pavement	Standard	Excellent	10.30–10.50 m	6	6
	Wider	Very good	8.24–10.30 m	5	
	Wide	Good	6.18–8.24 m	4	
	Normal	Fair	4.12–6.18 m	3	
	Small	Poor	2.10–4.12 m	2	
	Too small	Very poor	0.00–2.06 m	1	
Gradient of pavement	Flat	Excellent	0.0%–3.0%	6	5
	Rolling	Very good	3.5%–4.0%	5	
	Mountainous	Good	4.5%–5.0%	4	
	Hilly	Fair	5.5%–6.0%	3	
	Steep terrain	Poor	6.0%–8.0%	2	
	High	Very poor	9.0%–10.0%	1	
Intersection	Free-flow	Excellent	≤ 10 sec	6	4
	Sustained free-flow	Very good	10 < delay ≤ 20 sec	5	
	Speed near free-flow	Good	20 < delay ≤ 35 sec	4	
	Decline speed	Fair	35 < delay ≤ 55 sec	3	
	Non useable gap	Poor	55 < delay ≤ 80 sec	2	
	Delay	Very poor	> 80 sec	1	

(continued on next page)

Table 1 (continued)

Parameter	Condition	Classification	Range	Rating	Weight
Drainage condition	Full dried	Excellent	2 hrs	6	3
	Fairly dried	Very good	13 hrs	5	
	Partly dried	Good	24 hrs (1 day)	4	
	Surface wet	Fair	168 hrs (1 week)	3	
	Moist	Poor	672 hrs (1 month)	2	
	Flooded	Very poor	>6 72 hrs (no drain)	1	
Stopping sight distance	Levelled roadway	Excellent	38–150 m	6	2
	Crest vertical curve	Very good	150–190 m	5	
	Sag vertical curve	Good	190–259 m	4	
	Horizontal curve	Fair	259–260 m	3	
	Underpasses	Poor	260–270 m	2	
	Wet roadway	Very poor	> 280 m	1	
Overtaking sight distance	Clear gap	Excellent	335–823 m	6	1
	Safe gap	Very good	280–390 m	5	
	Manoeuvre gap	Good	150–200 m	4	
	Intermediate distance	Fair	90–100 m	3	
	Interference	Poor	50–90 m	2	
	Obstruction	Very poor	< 50 m	1	

SCPWGIDSO-AV Index, a measure of accident proneness is computed by the summation of the products of ratings and weights for each factor as follows:

$$T.SCPWGIDSO - AV = S_r S_w + C_r C_w + P_r P_w + W_r W_w + G_r G_w + I_r I_w + D_r D_w + SD_r SD_w + O_r O_w \quad (1)$$

where

$SCPWGIDSO - AV.I$  = Total Index. That is, total accident vulnerability value.

$S_r$  = Rating Assigned to Spot Speed of Vehicles,  $S_w$  = Weight Assigned to Spot Speed of Vehicles,  $C_r$  = Rating Assigned to Condition of Shoulder,  $C_w$  = Weight Assigned to Condition of Shoulder,  $P_r$  = Rating Assigned to Pavement Condition,  $P_w$  = Weight Assigned to Pavement Condition,  $W_r$  = Rating Assigned to Width of Pavement,  $W_w$  = Weight Assigned to Width of Pavement,  $G_r$  = Rating Assigned to Gradient of Pavement,  $G_w$  = Weight Assigned to Gradient of Pavement,  $I_r$  = Rating Assigned to Intersection,  $I_w$  = Weight Assigned to Intersection,  $D_r$  = Rating Assigned to Drainage Condition,  $D_w$  = Weight Assigned to Drainage Condition,  $SD_r$  = Rating Assigned to Stopping Sight Distance,  $SD_w$  = Weight Assigned to Stopping Sight Distance,  $O_r$  = Rating Assigned to Overtaking Sight Distance,  $O_w$  = Weight Assigned to Overtaking Sight Distance, AV = Accident Vulnerability.

### 3. MATERIALS AND METHODS

#### 3.1 Materials

Figure 1 shows a geographical information system (GIS) map of the highway route under study, which runs from the Federal University of Technology Akure North Gate to Rufus Giwa Polytechnic Main Gate in Owo measuring a total length of about 47.8 km.

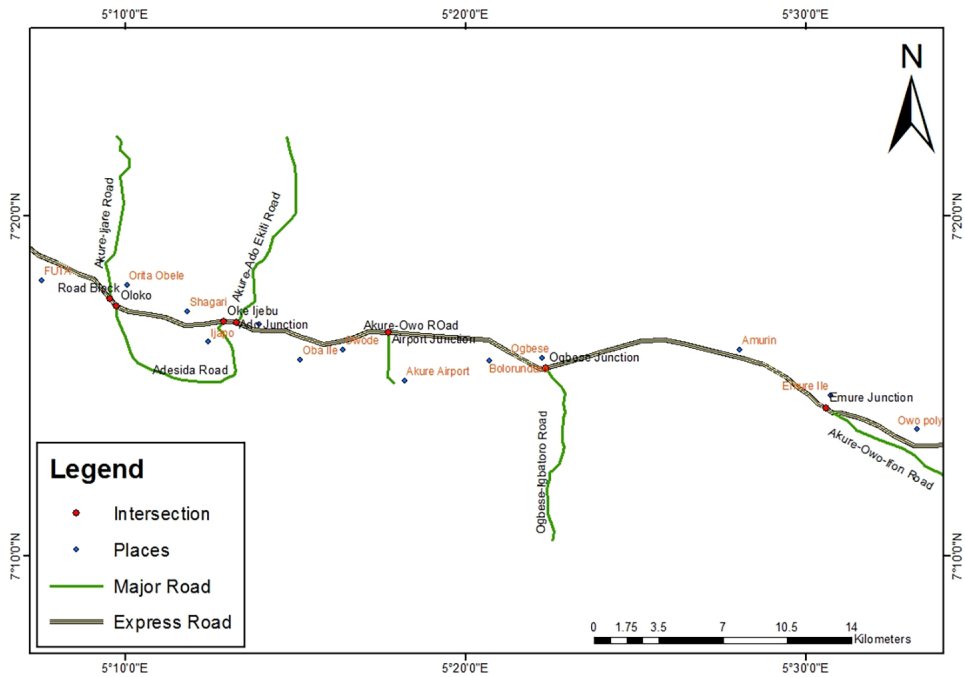


Figure 1: GIS map of Akure-Owo highway.<sup>14</sup>

The accident records on this highway for the period of 2010–2015 were collected from the Federal Road Safety Commission (FRSC) Akure office and they were used to identify 24 accident prone locations where accidents have occurred more than once. The analysis of the accident-prone locations from the FRSC records is shown in Table 2.

Table 2: Data for accident prone locations along Akure-Owo Highway from 2010–2015.<sup>15</sup>

Location	Total number of accidents	Number of persons involved	Number injured	Number killed
FUTA North Gate	8	10	5	3
Akad/Wesco Estate	4	8	6	1
Oloko/Ibadan Park	8	17	10	1
Peace Park	4	5	1	4
Oyarugbulem	9	75	36	2
NNPC Mega Station	19	116	39	1
Seebi Filling Station	8	19	5	6
Olu Foam	11	57	25	1
Mrs Filling Station	2	18	1	3
Ita Ogbolu	9	37	10	1
Benin Park	5	45	6	1
FGCC Akure	4	28	7	1
Shasha	12	107	46	2
Mobile Police Office	7	72	44	5
Airport Junction	8	199	102	6
High School Junction	7	59	69	6
Ilu Abo	8	38	24	2
Bolorunduro	12	254	48	4
Ogbese	79	594	238	76
Uso	24	196	97	23
Emure Uli	18	70	29	7
Rufus Giwa Polytechnic Gate 1	38	190	81	16
Rufus Giwa Polytechnic Main Gate	43	289	122	8

#### 4. METHODS

The rating and weight method was used to obtain the Total SCPWGIDSO-AV Index computation for the 10 locations (Tables 3 to 5) using a rating system of 1 to 6 for each variable and a weighting system of 1 to 9 in their order of significant contribution to road traffic crashes (RTCs).<sup>16</sup> SCPWGIDSO-AV accident vulnerability evaluation model is mathematically expressed as shown in Equation 1.



The lower the SCPWGIDSO-AV Index from the control, the greater the accident proneness at a location. The SCPWGIDSO-AV can be further divided into five categories: “Very low”, “Low”, “Moderate”, “High”, and “Very high”. Accident vulnerability, SCPWGIDSO-AV Index equation was analysed by imputing the field data into Equation 1. Using SPSS software, a mathematical model for accident vulnerability along Akure-Owo highway was calibrated. The value obtained from this model was validated using field data and compared with that of the parametric model obtained earlier.

## 5. RESULTS AND DISCUSSION

### 5.1 Model Validation Using Field Data

It is necessary to collect data regarding the frequency and severity of crashes at specific locations and it is also important to evaluate the success or failure of any highway improvement.<sup>17–19</sup> From the data obtained from FRSC office, it was observed that the most vulnerable points along the road are Ogbese market area where 79 accidents occurred in six years, meaning an average of about 13 accidents per annum at a point. This is followed by Rufus Giwa Polytechnic Main and Second Gate, Uso, NNPC Mega Station, Emure Uli, Road Block, Shasha, Bolorunduro Junction, and Olu Foam area.

Tables 3 to 5 show the SCPWGIDSO-AV index computation as a result of imputing field data at different accident vulnerable locations into the parametric model (see Equation 1). Table 3 shows the computation for Location 20 (Ogbese) where the spot speed of vehicles measured on site was 101 km/h, the condition of shoulder is ideal (2.93 m), pavement condition showed crack with minor dent (54), width of pavement (7 m), gradient of pavement (4.6%), intersection (0), drainage condition (950 h), stopping sight distance (120 m), and overtaking sight distance (138 m). From Table 1, the rating and weight of 101 km/h are 3 and 9, respectively. The multiplication of the two which is SCPWGIDSO-AV index gives 27. The index for the condition of shoulder, pavement condition, width of pavement, gradient of pavement, intersection, drainage condition, stopping sight distance, and overtaking sight distance using the same method are 40, 21, 24, 20, 24, 3, 12, and 4, respectively. The Total SCPWGIDSO-AV Index (T.SCPWGIDSO-AV.I) for this location, therefore, is 175. The same analysis was performed for locations 24 (Rufus Giwa Polytechnic Main Gate), 23 (Rufus Giwa Polytechnic Second Gate), 21 (Uso), 7 (NNPC Mega Station), 22 (Emure Uli), 6 (Road Block), 14 (Shasha), 19 (Bolorunduro Junction), and 9 (Olu Foam) to give the total SCPWGIDSO-AV Indices of 151, 139, 172, 184, 126, 178, 151, 157, and 172, respectively.

Table 4 acts as the control in which the spot speed of vehicles is 30 km/h, the condition of shoulder is 3.6 m, the pavement condition is 85, width of pavement is 7.5 m, gradient of pavement is 3%, intersection is 8 sec, drainage condition is 2 h, stopping sight distance is 150 m, and overtaking sight distance is 823 m with the corresponding rating of 6 for all of them. The weights are 9, 8, 7, 6, 5, 4, 3, 2, and 1 respectively.<sup>20</sup> The T.SCPWGIDSO-AV.I for the control, therefore, is 270.

Table 3: SCPWGIDSO-AV Index computation for Location 20 (Ogbese).

Parameter	Field data	Rating	Weight	SCPWGIDSO-AV Index
Spot speed of vehicles (S)	101 km/h	3	9	27
Condition of shoulder (C)	2.93 m	5	8	40
Pavement condition (P)	54	3	7	21
Width of pavement (W)	7 m	4	6	24
Gradient of pavement (G)	4.6 %	4	5	20
Intersection (I)	0 sec	6	4	24
Drainage condition (D)	950 h	1	3	3
Stopping sight distance (S)	120 m	6	2	12
Overtaking sight distance (O)	138 m	4	1	4
				T.SCPWGIDSO-AV = 175

Table 4: SCPWGIDSO-AV Index computation for control.

Parameter	Field data	Rating	Weight	SCPWGIDSO-AV Index
Spot speed of vehicles (S)	30 km/h	6	9	54
Condition of shoulder (C)	3.6 m	6	8	48
Pavement condition (P)	100	6	7	42
Width of pavement (W)	7.50 m	6	6	36
Gradient of pavement (G)	3%	6	5	30
Intersection (I)	8 sec	6	4	24
Drainage condition (D)	2 h	6	3	18
Stopping sight distance (S)	150 m	6	2	12
Overtaking sight distance (O)	823 m	6	1	6
				T.SCPWGIDSO-AV = 270

Table 5: Results of validating SCPWGIDSO-AV mathematical model for 10 accident prone locations.

Loc. no.	Location	Parameter									
		T.SCPWGIDSO-AV	S (km/h)	C (m)	P (%)	W (m)	G (%)	I (sec)	D (h)	S (m)	O (m)
20	Ogbese	171.94	101.0	2.93	54	7.00	4.6	0	950	120.0	138
24	Rufus Giwa Poly. Main Gate	150.22	81.0	0.00	63	9.00	5.8	0	672	313.9	67
23	Rufus Giwa Poly. Second Gate	134.97	82.0	1.00	20	7.30	5.0	0	672	419.3	175
21	Uso	177.50	100.0	0.00	99	7.40	3.8	0	168	255.3	290
7	NNPC Mega Station	187.73	70.0	3.00	82	7.20	6.0	33	168	217.0	25
22	Emure Uli	131.28	112.0	0.80	16	7.40	5.6	0	168	304.0	65
6	Road Block	176.44	62.6	2.22	77	6.89	5.7	17	672	260.0	175
14	Shasha	151.49	74.0	2.00	43	7.30	4.9	52	850	150.0	45
19	Bolorunduro Junction	161.32	107.0	2.13	50	7.00	4.0	0	770	225.2	35
9	Olu Foam	170.96	80.0	2.00	53	6.80	5.7	0	13	262.8	37
	Control	244.87	30.0	3.60	100	7.50	3.0	8	2	150.0	823

Table 6: Model summary and parameter estimate for spot speed of vehicles rating ( $S_r$ ).

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.625	38.392	1	23	0.000	6.303	-0.032		
Quadratic	0.659	21.222	2	22	0.000	7.748	-0.072	0.000	
Cubic	0.670	14.227	3	21	0.000	9.846	-0.181	0.002	-7.717E-006

Table 7: Model summary and parameter estimate for other parameter rating.

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
$C_r$	0.708	55.670	1	23	0.000	1.093	1.204		
$P_r$	0.977	966.718	1	23	0.000	-0.322	0.067		
$W_r$	0.250	7.650	1	23	0.011	0.751	0.469		
$G_r$	0.954	474.036	1	23	0.000	8.375	-0.902		
$I_r$	0.971	779.837	1	23	0.000	6.008	-0.064		
$D_r$	0.836	117.609	1	23	0.000	5.210	-0.005		
$SD_r$	0.840	121.043	1	23	0.000	7.705	-0.019		
$O_r$	0.707	55.381	1	23	0.000	1.705	0.007		

Equation 1 could also be re-written as Equation 2:

$$T.SCPWGIDSO - AV.I = 9S_r + 8C_r + 7P_r + 6W_r + 5G_r + 4I_r + 3D_r + 2SD_r + O_r \quad (2)$$

where 9, 8, 7, 6, 5, 4, 3, 2, and 1 are the respective weights of spot speed of vehicles, condition of shoulder, pavement condition, width of pavement, gradient of pavement, intersection, drainage condition, stopping sight distance, and overtaking sight distance.

The model summary and parameter estimates obtained from SPSS using Curve Estimation engine is as shown in Tables 6 and 7 where the dependent variable is the rating of the parameters and the independent variables are the spot speed of vehicles (S), condition of shoulder (C), pavement condition (P), width of pavement (W), gradient of pavement (G), intersection (I), drainage condition (D), stopping sight distance (S), and overtaking sight distance (O). The model equations are linear, quadratic, and cubic. Tables 6 and 7 show that linear, quadratic, and cubic equations indicate similar values with minor differences in the  $R^2$  and  $F$  values.

For the spot speed of vehicles, condition of shoulder, pavement condition, width of pavement, gradient of pavement, intersection, drainage condition, stopping sight distance, and overtaking sight distance, linear models were selected as follows:

Spot speed of vehicles rating equation ( $S_r$ )

$$S_r = 6.303 - 0.032S \quad (3)$$

$$R^2 = 0.625, P\text{-value} < 0.000, F\text{-value} = 38.372$$

Condition of shoulder rating equation ( $C_r$ )

$$C_r = 1.093 + 1.204C \quad (4)$$

$$R^2 = 0.708, P\text{-value} < 0.000, F\text{-value} = 55.670$$

Pavement condition rating equation ( $P_r$ )

$$P_r = -0.322 + 0.067P \quad (5)$$

$$R^2 = 0.977, P\text{-value} < 0.000, F\text{-value} = 966.718$$

Width of pavement rating equation ( $W_r$ )

$$W_r = 0.751 + 0.469W \quad (6)$$

$$R^2 = 0.250, P\text{-value} < 0.011, F\text{-value} = 7.650$$

Gradient of pavement rating equation ( $G_r$ )

$$G_r = 8.375 - 0.902G \quad (7)$$

$$R^2 = 0.954, P\text{-value} < 0.000, F\text{-value} = 474.036$$

Intersection rating equation ( $I_r$ )

$$I_r = 6.008 - 0.064I \quad (8)$$

$$R^2 = 0.971, P\text{-value} < 0.000, F\text{-value} = 779.836$$

Drainage condition rating equation ( $D_r$ )

$$D_r = 5.210 - 0.005D \quad (9)$$

$$R^2 = 0.836, P\text{-value} < 0.000, F\text{-value} = 117.609$$

Stopping sight distance rating equation ( $SD_r$ )

$$SD_r = 7.705 - 0.019SD \quad (10)$$

$$R^2 = 0.840, P\text{-value} < 0.000, F\text{-value} = 121.43$$

Overtaking sight distance rating equation ( $O_r$ )

$$O_r = 1.705 + 0.007O \quad (11)$$

$$R^2 = 0.707, P\text{-value} < 0.000, F\text{-value} = 55.381$$

Substituting Equations 3 to 11 into Equation 2 and collecting like terms gives Equation 12:

$$\begin{aligned} T.SCPWGIDSO - AV.I = 166.375 - 0.288S + 9.632C + 0.469P + 2.814W \\ - 4.51G - 0.256I - 0.015D - 0.038SD + 0.007O \end{aligned} \quad (12)$$

The positive constant (166.375) in Equation 12 indicates that apart from these nine variables analysed, there are other factors that might not be connected with road geometry that exacerbate the rate of accidents along this route. On the parameters analysed, the condition of shoulder and width of pavement has the highest contributing factor as per the equation because it has the highest co-efficient showing that if the pavement condition is relatively good, gradient of pavement is according to standard, intersections are well positioned and signalised, drainage of pavement is excellent, stopping sight distance and overtaking sight distances are observed by drivers and vehicles move at lower speed, say 60 km/hr, and the shoulder condition is poor, with small pavement width, accident rates would still be on the increase because there will be no refuge for the vehicle that is trying to avoid an on-coming reckless driver.

Table 8 shows the difference between the indices of SCPWGIDSO-AV (parametric) and the SCPWGIDSO-AV (mathematical) and it reveals that the indices have a difference of 1.75% for Ogbese, 0.52% for Rufus Giwa Polytechnic Main Gate, 2.20% for Rufus Giwa Poly. Second Gate, 3.09% for Uso, 1.99% for NNPC Mega Station, 4.02% for Emure Uli, 0.88% for Road Block, 0.32% for Shasha, 2.68% for Bolorunduro Junction, 0.60% for Olu Foam, and 9.31% for the control. It should be noted that none of these differences is up to 10% as stipulated by statistical packages. This therefore, shows that the SCPWGIDSO-AV mathematical model is reliable and could be used to calculate accident vulnerability indices of any road and thus predict the possible occurrence of accident along the section of road where any of the parameters used here has been investigated.

Based on accident categorisation, five categories of accident vulnerability exist, namely:<sup>21</sup>

1. SCPWGIDSO-AV Index is between 271 and above, accident vulnerability is very low.
2. SCPWGIDSO-AV Index is between 250 and 270, accident proneness is low.
3. SCPWGIDSO-AV Index is between 201 and 250, accident proneness is moderate.
4. SCPWGIDSO-AV Index is between 191 and 200, accident proneness is high.
5. SCPWGIDSO-AV Index is between 120 and 190, accident proneness is very high.

Based on the categorisation in Table 8, it can be observed that the 10 selected locations have very high possible occurrence of accidents. This fact is exemplified by the accident records collected from FRSC in which accident records for the 10 analysed locations are two times higher than the other 14 locations. It is therefore reasonable to agree that this model can logically predict the occurrence of accidents along Akure-Owo road and other roads where similar conditions of the highway occur.

Table 8: Comparison of the results of the models.

Location	SCPWGIDSO-AV index values (parametric model)	SCPWGIDSO-AV index values (mathematical model)	Difference	Percentage difference
Ogbese	175	171.94	3.06	1.75
Rufus Giwa Polytechnic Main Gate	151	150.22	0.78	0.52
Rufus Giwa Polytechnic Second Gate	138	134.97	3.03	2.20
Uso	172	177.50	5.50	3.09
NNPC Mega Station	184	187.73	3.73	1.99
Emure Uli	126	131.28	5.28	4.02
Road Block	178	176.44	1.56	0.88
Shasha	151	151.49	0.49	0.32
Bolorunduro	157	161.32	4.32	2.68
Olu Foam	172	170.96	1.04	0.60
Control	270	244.87	25.13	9.31

## 6. CONCLUSION

Road traffic accidents that have been on the increase over the years on Akure-Owo highway were due to four main factors, which are human, road, vehicle, and environmental factors. On validating the parametric and mathematical model using field data, it was revealed that road factors greatly influence accident occurrence on the route due to lack of proper caution. The most significant parameters of the road factors were spot speed of vehicles, condition of shoulders, pavement conditions, width of pavement, gradient of pavement, intersection, drainage condition, stopping sight distance, and overtaking sight distance. Relative to others, condition of shoulder and width of pavement caused the highest percentage of accidents along Akure-Owo highway. The SCPWGIDSO-AV mathematical model could assist highway engineers and other practitioners in solving the problem of road traffic crashes by forecasting possible occurrence of accidents on Akure-Owo Highway as well as on similar highways in Nigeria and abroad.

## 7. RECOMMENDATIONS

The following recommendations are made to reduce the rate of accident on Akure-Owo road based on road factors examined:

1. Road design: This should be handled by experienced personnel (engineering firms) to avoid quacks that will not meet up with required specifications.
2. Routine maintenance and rehabilitation of road pavements: The road should always be checked and areas in need of repairs should be given immediate attention. This should always include repair of shoulder whenever necessary. Federal and state governments should draw up and implement on regular basis, budgets that match the demands of the road network and its infrastructure.
3. Road information: Provision of information about routes, road geometry and give-way conditions should be carried out. This can be conveyed by means of road signs, road markings, and traffic control devices such as traffic lights and street lights.
4. Road safety plans: There should always be road safety plans (strategies for road safety and plans for safety measures) and guidelines (road user education, publicity, enforcement, safety target, and monitoring).



5. Reconstruction: Akure-Owo highway was constructed over five decades ago when the vehicular volume was very low. It is recommended that the road be dualised to be able to conveniently carry the increased traffic load and thus reduce the occurrence of accidents on the road.

## 8. ACKNOWLEDGEMENTS

We acknowledge the efforts of Mr. Afolayan Joshua Abiodun and Mr. Mobolaji Peter, who assisted in data collection. No grant or fund was received from any organisations.

## 9. REFERENCES

1. Odugbemi, O. O. (2010). *Road transportation and tourism in Nigeria*. 1st Ed. Lagos, Nigeria: Joja Press.
2. Peden, M. et al. (2004). *World report on road traffic injury prevention*. Geneva: World Health Organization (WHO). Retrieved from <https://apps.who.int/iris/bitstream/handle/10665/42871/9241562609.pdf?sequence=1> on September 2016.
3. WHO. (2015). *Road traffic injuries: Fact sheet N° 358. WHO annual road traffic accident report*. Geneva: WHO. Retrieved from <http://www.who.int/mediacentre/factsheets/fs358/en/> on 19 January 2016.
4. Ross, A. S., Lundebye, S. & Barrett, R. (1991). *Road safety awareness and commitment in developing countries. Infrastructure note RD-6*. Washington DC, USA: World Bank.
5. Federal Road Safety Commission (FRSC) (2009). *Road traffic crashes data*. Abuja, Nigeria: FRSC. Retrieved from [www.frsc.gov.ng/rtc.php](http://www.frsc.gov.ng/rtc.php). on September 2016.
6. Aiyewalehinmi, E. O. (2013). Analysis of road traffic crashes/collisions in Ondo State roads. *IOSR-JEN*, 3(8), 10–22, <https://doi.org/10.9790/3021-03841022>.
7. Aworemi, J. R., Abdul-Azeez, I. A. & Olabode, S. O. (2010). Analytical study of the causal factors of road traffic crashes in Southwestern Nigeria. *Educ. Res.*, 1(4), 118–124.
8. Oyedepo, O. J. & Makinde, O. O. (2010). Accident prediction models for Akure-Ondo carriageway, Ondo State, Nigeria using multiple linear regression. *Afr. Res. Rev.*, 4(2), 30–49, <https://doi.org/10.4314/afrev.v4i2.58286>.

9. Fletcher, J. P., Baguley, C. J., Sexton, B. & Done, S. (2006). *Road accident modelling for highway development and management in developing countries. Main report: Trials in India and Tanzania, project report no PPR095*. Berkshire, UK: Transport Research Laboratory.
10. Fitzpatrick, K. et al. (2000). *Speed prediction for two lane rural highways. Research report FHWA-RD-99-171*. New Jersey, USA: Federal Highway Administration, US Department of Transportation.
11. Bonneson, J. A. & McCoy, P. T. (2001). Effect of median treatment on urban arterial safety: An accident prediction model. *Transp. Res. Rec.*, 1581(1), 27–36, <https://doi.org/10.3141/1581-04>.
12. Jacobs, G. D., Aeron-Thomas, A. & Astrop, J. (2000). *Estimating global road fatalities*. Crowthorne, Berkshire, UK: Transport Research Laboratory.
13. Aderinola, O. S. & Aiyewalehinmi, E. O. (2015). Development of accidents prediction model on road traffic crashes along Akure-Ondo highway, Ondo State, Nigeria. *European International Journal of Science and Technology*, 4(6), 93–104.
14. Afolayan, A. (2017). Development of a framework for road accident prevention. Case study of Akure-Owo highway. MEng, Federal University of Technology Akure.
15. Federal Road Safety Commission (FRSC) (2015). Road accident data for Akure-Owo road. Unpublished data.
16. Aller, L., Bennet, T., Lehr, J. H. & Petty, R. J. (1987). *DRASTIC: A standardized system for evaluating ground water pollution using hydrological settings. US EPA document no. EPA/600/2-85-018*. Ada, Oklahoma: US Environmental Protection Agency (EPA).
17. Ismeik, M. & Jrew, B. K. (2010). Development of driver behavior's accident prediction models. *International Journal of Natural and Engineering Science*, 4(3), 61–70.
18. Aloush, M. & Jrew, B. K. (2008). Analysis of accident prediction model for Marka area in Amman. Paper presented at the *Fifth Jordanian Traffic Safety Conference. Amman, Jordan*.
19. Jrew, B. K., Al-Ani, H. M. & Salih, A. O. (2007). Development of accident prediction models for Arbil urban area. Paper presented at the *Jordanian International Conference on Decision Making in Transport Sector*.
20. Federal Ministry of Works (2006). *Nigerian Highway Design Manual*. Abuja, Nigeria: Federal Ministry of Works.
21. Nellthorp, J., Mackie, P. J. & Bristow, A. L. (1998). *Measurement and valuation of the impacts of transport initiatives. EUNET Project*. University of Leeds, UK: Institute of Transport Studies.