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Modelling Vehicle Accidents and Efficiency of Highway Geometric Design

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Abstract

This study investigates the relationship and effect of geometric variables such as curve radius (Horizontal and vertical), road width, median width, shoulder width and super-elevation on the frequency of accident in highways. Accident predictions were done for the Benin-Ore road and Benin-Agbor road using field data such as numbers of crashes, length of the route and Average Annual Daily Traffic (AADT) values etc. Poisson and Negative Binomial Regressions techniques were adopted for accident prediction modelling and model validation was done using the Statistical Package for Social Sciences (SPSS) to determine the reliability of the parameters. Where the Poisson regression model failed because of over-dispersion and under-dispersion of data, the Negative Binomial (NB) proved very useful because of its ability to cater to such shortfall. Results from the analysis show that of the designated geometric (independent) variables selected, vertical curves and shoulder-width were the most significant in influencing the probability of crash occurrence in the designated highways of the study domain. For the Benin Ore road, the shoulder width and the road width accounted for the principal causes of accident with a probability of crash occurrence of 73.6% and 8.7% respectively. The vertical alignment with a probability of crash of 19.60% accounted for the principal cause of accident along the Benin Agbor expressway. Super elevation and the horizontal curve accounted for just 1% each of the probability of crash occurrence along the Benin Agbor road. It can, therefore, be concluded that some form of checks be carried out on the shoulder width and the road width along the Benin Ore road while similar checks must be focused on the vertical alignment along the Benin Agbor road to mitigate the occurrence of accidents arising from defective geometric configuration.

1. Introduction

Road crashes have been on the increase in the last decade or so. This has led researchers to investigate the probable causes and likely solution to prevent road crashes. This field of transportation engineering is generally termed traffic safety and management [1]. Studies in traffic safety and management have led to the development and discovery of new models that predict road crashes with reasonable certainty. Road accidents are prevalent over the world and annual global road crash statistics for Africa has it that there are 26.6 deaths per 100,000 population making the continent the highest in road-related accidents in the world [2]. More than half of all road traffic deaths occur among young adult ages between 15 to 44 years. Road traffic crashes rank as the 9th leading cause of death and accounts for 2.2% of all deaths globally. Road crashes are the leading cause of death among young people ages between 15 to 29, and the second leading cause of death worldwide among young people ages between 5 to 14 years. Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030[3, 4].

According to the Federal Highway Authority Report FHWA[5], over 90% of all road fatalities occur in low and middle-income countries, which have less than half of the world's vehicles. Road crashes cost $518 billion USD globally, costing individual countries from 1-2% of their annual Gross Domestic Product. Road crashes cost low and middle-income countries USD $65 billion annually, exceeding the total amount received in developmental assistance[2, 5]. The Global Status report on Road Safety [2] also states that more than 1.2 million people die each year from vehicle accidents and an additional 50 million people are injured annually worldwide. In many countries, such as the United States (USA), vehicle crashes are the leading cause of death for people between the ages of 1 to 34 years [5]. Traffic Engineers are working to ensure that the highway systems are designed and particularly operated to drastically reduce accident rates and its severity.

Enforcement, Education and Engineering are called the 3E's factors to ensure considerable reduction in traffic accidents[6]. Traffic crashes and collisions could be prevented, and its effects minimized, by modifying driver’s behaviour, vehicle design, roadway geometry and alterations to the travelling environment. If the factors that contribute to traffic accidents are identified, it avails the opportunity to modify and improve the highway system[1, 7].

Traffic Safety and Accident studies have been in the research domain for the last two decades owing to the prevalence of accidents globally. From literature, traffic accidents are caused principally by three factors namely[1]:

a) Personal or human behavioural factors

b) Road and Environmental factors

c) Vehicle factors

Personal or human factors mainly include the age of the driver and/or victim; gender of the victim, physical, mental and psychological state of the driver etc. Environmental factors include the general conditions of the climate and ambient environment; lighting conditions of the roadway, time of the accident, pavement conditions to mention but a few. The vehicle factor deals with the state of the mechanical and electrical components of the vehicle causing mobility.

Zhang [8]analysed the relationship between highway horizontal curve and traffic safety and found that curve radius, super-elevation, pavement widening, transition curve and sight distance all influence road accidents. Aram[3] studied some safety factors on horizontal curves of two-lane highways and observed that traffic volumes and mix; road geometrics such as curve details, cross-section, road-side hazards, stopping sight distance, curve coordination, pavement friction and traffic control devices affect the safety performance of horizontal curve. It was ascertained that the degree of horizontal curve, length of the curve, super-elevation, transition length, shoulder width and ADT responses are the important independent effective variables in road accident studies. Horizontal curves is seen to have the highest influence in crash rates than straight sections of similar length and traffic composition[6].

Hassan and Easa [9]studied the effect of vertical alignment on driver perception of horizontal curves and found that the perception of the driver is an important factor and should be addressed in road design. Miaou [10]demonstrated that conventional linear regression models are not appropriate for modelling vehicle accident events on roadways, and statistics from these models are often erroneous. It was concluded that Poisson and Negative Binomial Regression models are more appropriate tools in accident modelling for highways.

Mohamedshah et al.[4] investigated traffic and geometric-related variables causing truck crashes using data from the Highway Safety Information System (HSIS). Multivariate logistic models for truck crashes on interstates and two-lane rural roads were developed considering truck crash data in Utah from 1980 to 1989.

Daniel *et al*.[6]developed a crash prediction model for truck crashes on route sections with signalized intersections. Crash data were obtained from the New Jersey accident records, and volume and geometric data were obtained by reviewing straight-line diagrams and contract drawings of the roadway. A Poisson regression model and a Negative Binomial Regression model were developed for the study. The coefficients of the Negative Binomial model were compared with those of the Poisson Regression model with some exceptions. The coefficients of both models showed significant impact based on segment length, AADT, length of vertical grade, number of lanes, number of signals within the segment, and pavement width on truck crash frequency on selected roadways.

Virginia crash data were used by Joshua and Garber [1] to determine the quantitative relationship between traffic and geometric variables, and the probability of occurrence of large truck crashes. Geometric data such as numbers of lanes, lane and shoulder width, and vertical and horizontal alignments data were collected directly from the sites at which a large number of truck-related crashes occurred. Multiple linear and Poisson regression analyses were carried out to predict the number of truck crashes, where the Poisson regression model was found to be preferable at describing the relationship between the geometric data and large truck accidents.

Lin[11] in studying flattening of the horizontal curve on rural two-lane highways found that horizontal curves are on average more hazardous than tangent sections. As their curvatures increase, horizontal curves tend to have higher accident rates. The differences between the 85th percentile speeds and the safe speeds have no statistically significant relationships with the accident rates[11].

2. Methodology

2.1 Data collection

The basic data such as the geometric features namely the width of the pavement, length of the roads, traffic data and design speed were obtained from maps, reconnaissance studies and site visits. Accident/crash data between 2015 and 2016 were obtained from the Department of Statistics in the Federal Road Safety Corp Zonal Office in Benin for the selected routes. The data were carefully observed to identify spot of accident recurrence along the designated routes (‘black spot’). These black spots are areas with critical horizontal curves, super-elevation, pavement widening etc. These details were then used to determine the frequency of accident occurrence on these routes with specific reference to the black spots. Furthermore, the Statistical Package for Social Sciences (SPSS) was employed for Parameter Estimation using the Poisson Regression and Negative Binomial techniques as bases for establishing a model to predict accidents/crashes on these routes from the collected or derived geometric variables as independent variables.

2.2 Description of the study Routes

The Benin Ore (B - O) and the Benin Agbor (B - A) expressways are high traffic truck A roads carrying both passengers and goods into and away from Benin City, the capital of Edo State. The Benin Ore road is a 150km route between Benin City and Ore City in Ondo state. The road is the major route between Lagos and Benin City. It connects Benin City to Ogun state and other states in the Western part of Nigeria.

The Benin Agbor road is over 150km from Benin City. It connects Benin City to the Eastern part of the country. The major cities between Benin City and Agbor is Asaba, the capital city of Delta State. Map showing the study area/routes is presented in Figure 1:

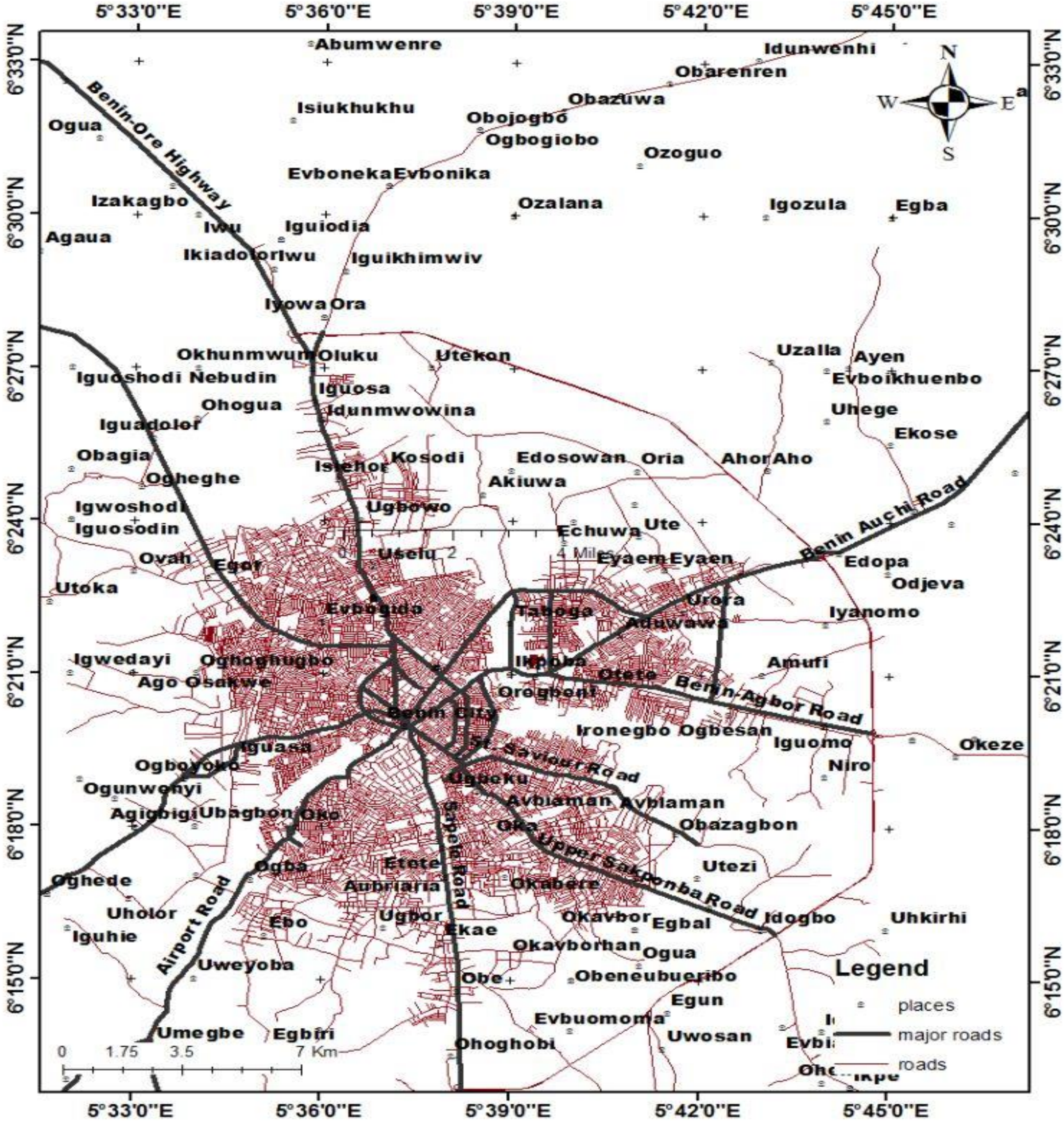

Figure 1: Map of Benin City Showing the Study Routes

2.3 Accident Rate

Accident Rate is generally expressed in crashes per million vehicle-kilometres of travel as:

$$AR = \frac{C \times 10^8}{365 \times V.N.L} \quad (1)$$

2.4 Poisson's Regression and Negative Binomial (NB) Regression model

At this stage, the Poisson's Regression and the Negative Binomial (NB) Regression Models were selected for analysis in order to generate an expression for the model.

The general form of the Poisson's Regression Model is given as:

$$P(n_{ij}) = \frac{e^{-\lambda}\lambda^{n_{ij}}}{\lambda!} \quad n = 0, 1, 2, \quad (2)$$

Where: $\boldsymbol{\lambda}$ indicates the mean of the distribution

Various statistical models could be considered for identifying relationships between numbers of vehicle crashes, geometric and traffic characteristics.

The general expression for the Negative Binomial (NB) Regression Model is given as:

$$P(Y_i = y_i) = \frac{(\lambda_i \theta_i) y_i e^{-\lambda_i \theta_i}}{y_i!} \quad (3)$$

λ_i indicate vehicle crash involvement while Θ_i is taken to be random error

Associated with each roadway segment i, x_i independent variables describe geometric characteristics, traffic conditions, and other relevant attributes. Traffic exposure, which is the amount of vehicle travel during the sample year, can be computed as:

$$\lambda_i = 365 \text{ x AADT x } T_i \text{x} L_i \quad (4)$$

Accident prediction is generally expressed as:

$$\text{AP km/year} = e^{(n+n_1X_1+n_2X_2+n_3X_3+n_4X_4+n_5X_5+n_6X_6+n_7X_7)} \quad (5)$$

Where n = intercept; X_1= Vertical grade (percent); X_2= Horizontal curvature (m); X_3= Super-elevation (percent); X_4= Design speed (km/hr); X_5= Road width (m); X_6= Median width (m); X_7= ideal shoulder width. In order to assess the adequacy of the model, the basic descriptive statistics for the event count data first need to be investigated in accordance with Pedan [12].

2.5 Model Validation

The models to be developed will use relevant statistically significant variables for testing the goodness-of-fit, using the Pearson Chi-Square statistics [13]. Pearson Chi-Square statistics was used to assess the fit of the model and the extent of Over-Dispersion. The model was calibrated and validated using the Pearson chi-square test to assess the presence of over-dispersion/under-dispersion in the model. The expression for the Pearson Chi-Square is as shown in Equation 6

$$\chi^2 = \sum_1^n \frac{(O_i - E_i)^2}{E_i} \tag{6}$$

If the value of the Chi-Squared statistics over the degrees of freedom is larger than 1, over-dispersion is implied. If on the other hand, the Pearson Chi-Square statistics is closer to 1, it indicates a better model fit. Chi-square analysis was performed using the statistical package SPSS.

2.6 Parameter Estimation (PEST)

Parameter estimation analysis involves the estimation of the most critical design parameters for accident prediction. The model developed from the Poisson's Regression and Negative Binomial (NB) Regression analysis (see Equation 5) for the stretch of the designated roads were validated by determining critical parameters to compute the rate of accidents. The number of accident (AC) was taken as the dependent parameter while the design parameters such as design speed, super elevation, median width and shoulder width constitute the independent variables. Parameter estimates were carried out for a confidence interval of 95% with the standard deviation of design parameters along the road stretch being unknown i.e. σ unknown. The hypothesis defining the statistics using t distribution is given as

$$\underbrace{\bar{X} - t_{cv}\left(s_{\bar{x}}\right)}_{\text{lower limit}} < \mu < \underbrace{\bar{X} + t_{cv}\left(s_{\bar{x}}\right)}_{\text{Upper limits}} \tag{7}$$

Where $\bar{X}$ = sample mean, t= t test results, s= sample standard deviation.

It is pertinent to note that Equation 7 is only used where the degree of freedom is 1 i.e. n-1. The selected estimator will then be used for the computation of the predicted accidents for designated the roads.

3. Results and Discussion

3.1 Results

Table 1 shows the number of accidents between 2011 and 2015 corresponding to the type of vehicles. Table 2 shows the roads lengths and Annual Average Daily Traffic (AADT) of the Benin Ore (B-O) road and the Benin Agbor (B–A) road as obtained from the records of the Federal Road Safety Corps, Benin Zonal command in 2016. Table 3 shows the number of accidents, death and the vehicles involved between 2011 and 2015 for the designated roads.

A total of 1,016 numbers of accidents at different locations have been considered on two routes with a total number of 144.80km segment of road length as shown in Tables 2 and 3. The data collected from the field studies include accident counts, traffic volume count (Annual Average Daily Traffic), horizontal and vertical alignments, horizontal arc length, super-elevation, vertical gradient, vertical curve length, shoulder width, road width and design speed.

Table 1: Number and Type of Vehicles involved in Accident, 2011-2015

	Type of Vehicle Involved													
Year	**Bicycle**	**Motorcycle**	**Tricycle**	**Car**	**SUV(Jeep)**	**Van**	**Minibus**	**Luxury Bus**	**Pick-up**	**Truck**	**Tanker**	**Trailer**	**Others**	**Total**
2011	5	78	0	215	15	5	216	5	10	156	46	84	35	870
2012	1	95	0	255	24	3	199	4	10	108	45	155	12	911
2013	0	28	0	112	10	4	110	1	9	89	37	81	1	464
2014	0	24	0	126	26	2	97	7	9	94	10	46	9	446
2015	0	30	0	112	33	1	99	6	8	91	22	64	2	471
Total	6	255	0	820	108	15	721	23	46	538	160	430	59	3162

Table 2: Length and Average Annual Daily Traffic of Selected Routes

S/N	National Highway Route	Length (km)	AADT
1	Benin-Ore (B-O)	94	1850
2	Benin-Agbor (B-A)	50.8	1826
Total	**2**	**144.80**	**3,676**

Table 3: Accident Data from 2011- 2015

Location	No of Accidents	No of Vehicles Involved	No of Persons Involved	No of Persons killed
B-O	513	870	4196	1,899
B-A	503	911	4043	1,963
Total	**1,016**	**1,781**	**8,239**	**3,862**

3.1.1 Accident Rate

The results of the accident rate analysis of the roads based on Equation 1 are presented in Table 4. The variable labels are as described in section 3.4. The accident rate expressed in crashes per million vehicles-km for the Benin Ore road and the Benin Agbor road is 161.64 and 297.13 respectively.

Table 4: The Accident Rate between 2011 and 2015.

Variables	B-O	B - A
C	513	503
V	1850	1826
N	5	5
L	94	50.8
AR	**161.64**	**297.13**

3.2 Geometric features along designated routes

3.2.1 Benin Ore road

The geometric features of the Benin Ore road such as the design speed, road width, median width and shoulder width were 100km/hr, 10.5m, 1.0m and 1.5m respectively. Other geometric parameters peculiar to the route are shown in the Table 5.

Table 5: Geometric Features along Benin-Ore Route

Chainnage (km)	No of Accidents (f_i)	Vertical Curve (%)	Horizontal Curve (m)	Super-Elevation (%)
11.5 - 13.0	25	12.4	2440.56	4.3
13.7 - 14.6	137	0	425.67	5.1
24.7 - 39.3	2	8.7	0	0
59.5 - 62.3	114	2.6	3642.47	1.5
72.8 - 73.8	80	0	2088.15	2.6
74.0 - 76.6	95	0	3290.26	1.2
78.0 - 81.0	45	1.3	5726.30	2.1
84.0 - 85.0	11	0	1022.96	0.4
86.0 - 87.0	3	0	5087.89	1.3
90.0 - 90.5	1	0	904.28	0.5

3.2.2 Benin Agbor Road

The general geometric parameters of the Benin-Agbor road such as design speed, road width, median width and shoulder width have values as 100km/hr, 10.5m, 20m and 1.5m respectively. Other values that are peculiar to each chainage are presented in the Table 6:

Table 6: Geometric Features along Benin-Agbor Route

Chainnage (Km)	No of Accidents (f_i)	Vertical Curve (%)	Horizontal Curve (m)	Super-Elevation (%)
4.5 - 5.4	52	5	958.27	1.3
5.5 - 6.5	49	6.2	852.82	5.2
7.0 - 7.5	109	3.4	322.05	6
9.0 - 9.4	30	3.0	399.90	3.1
10.0 - 10.6	169	5.8	584.33	3
15.0 - 15.7	8	5.5	851.55	5.7
16.4 - 16.8	73	2.8	429.780	4.9
29.0 - 29.4	8	4.4	418.91	6
30.0-30.7	1	4.9	486.50	6
32.0-33.0	3	4.5	2288.19	1
40.0-40.9	2	1.6	1900.62	2.5

3.3 Modelling and Parameter Estimation (PEST)

The final modelling depicting accident occurrence in the study routes is predicated upon critical parameter selection as can be obtained by the techniques of parameter estimation. The estimator for the study routes at the designated chainages as presented in section 4.2.1 and 4.2.2 for each of the geometric features and other design parameter are shown in Tables 7 and 8. The final accident prediction model as obtained from either of the Poisson regression or the binomial regression was based on the critical estimators and ordered in the manner presented in Equation 5. The results of PEST for Benin Ore road and Benin Agbor road are presented in Tables 7 and 8.

Table 7: Parameter Estimates for Benin-Ore Road

Parameter	B	Std. Error	95% Wald C.I Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	2.023	.9025	0.254	3.792	5.023	1	0.025	7.560	1.289	44.336
[X_4=100.00]	0[a]							1		
[X_5=10.50]	0[a]							1		
[X_6 =1.00]	0[a]							1		
[X_7=1.50]	0[a]							1		
X_1	-0.140	0.0891	-0.314	0.035	2.457	1	0.117	0.870	0.730	1.036
X_2	0.000	.0002	0.000	0.001	2.051	1	0.152	1.000	1.000	1.001
X_3	0.552	.2290	.103	1.001	5.810	1	0.016	1.737	1.109	2.720
(Scale)	1[b]									
(Negative binomial)	1[b]									

Table 8: Parameter Estimates for Benin-Agbor Road

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	6.165	1.9553	2.333	9.998	9.943	1	.002	475.996	10.310	21974.954
X_1	0.179	0.2202	-0.253	0.610	.658	1	.417	1.196	0.776	1.841
X_2	-0.002	0.0008	-0.004	-0.001	10.752	1	.001	0.998	0.996	0.999
X_7	-0.356	0.2564	-0.859	0.147	1.928	1	.165	0.700	0.424	1.158
X_4	0[a]	.	.	.	.	.	.	1	.	.
X_5	0[a]	.	.	.	.	.	.	1	.	.
X_6	0[a]	.	.	.	.	.	.	1	.	.
X_3	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									
(Negative binomial)	1[b]									

The output models developed from the binomial regression modelling for accident prediction based on Tables 5 and 7 for the Benin Ore road and Tables 6 and 8 for the Benin Agbor road are presented in Table 9

Table 9: Model developed for the various study routes

Route	Type of Model	Model developed
Benin-Ore	Poisson/Negative Binomial	$L(AADT \times e^{(7.560+X_1+X_2+X_3+X_4+0.870X_5+X_6+1.737X_7)})$
Benin-Agbor	Poisson/Negative Binomial	$L(AADT \times e^{(475.996+1.196X_1+0.998X_2+0.700X_3+X_4+X_5+X_6+X_7)})$

The probability of vehicle crashes occurring (as a percentage) based on the individual geometric parameters is shown in Table 10. From Table 10, it is apparent that the shoulder width plays the most significant role in accident prediction with a vehicle crash probability of 73.6% followed by road width with a probability of vehicle crash of 8.7% for the Benin Ore expressway. The highest parameter causing accidents along the Benin Agbor road is the vertical alignments in terms of the length of the curve with a probability of 19.6% followed by an equal proportion of the horizontal curve and super elevation at both approximately 1% contribution to vehicle crash along the road.

Table 10: Model Developed for the Various Study Routes

Route	X_1	X_2	X_3	X_4	X_5	X_6	X_7
B-O	-	-	-	-	8.7%	-	73.7%
B-A	19.6%	0.998%	0.700%	-	-	-	-

4. Conclusion

A combination of the Poisson regression and the Negative Binomial regression techniques was used to model vehicle accidents along the Benin Ore road and the Benin Agbor road. Accident data such as the number of accidents and the types of vehicles causing the various crashes, the number of deaths recorded were obtained from the repository of the Sector command of the Federal Road Safety Corp in Benin City for the years 2015 and 2016. The geometric features for the areas where accident are prevalent were obtained from field measurement and reconnaissance studies. While the model considered the vertical alignment, horizontal alignment, super elevation, shoulder width, road width, median width and the design speed, these parameters were together used to formulate the mathematical model for Accident prediction for the study location. The formulated models for the two roads were then validated by Parameter Estimation techniques to determine the most critical geometric feature causing accident from the different chainages where accidents are prevalent. The final model equations developed for the two roads are as presented in Table 9. Table 10 indicates that the vehicle crash probability arising from the shoulder width is 73.6% followed by the road width with a probability of vehicle crash of 8.7% for the Benin Ore expressway. It was also ascertained that the vertical alignment accounted for the highest accident-causing factor accident along the Benin Agbor road with 19.60% probability of vehicle crashes followed by an equal proportion of the horizontal curve and Super-elevation each accounting for about 1% contribution to vehicle crash along the road.

It is on this premise that it is recommended that a recheck of the shoulder width be carried out on the Benin Ore road as the accidents are usually caused by vehicle malfunction and reckless driving on the part of motorist. The road width has been greatly reduced due to the many failed portions of the road thereby causing vehicles to use only one lane for the incoming and outgoing traffic.

For the Benin Agbor, the principal cause of accident is the undulating nature of the vertical alignment of the road. This also warrants some rechecks particularly with respect to sight distances. The occurrence of some vehicles plying one-way has greatly increase accident occurrence especially at crest curve location along the road. The anomaly of vehicle crashes has greatly been facilitated by the large number of haulage trucks plying the expressway.

Nomenclature

AR	Accident Rate expressed as crashes per 100 million vehicle-km of travel (100mvkm)
C	Total number of crashes in the study period
V	Traffic volumes using Annual Average Daily Traffic (AADT)
N	Number of years of data
L	Length of the roadway in km
O_I	Observed number of vehicle crashes
E_i	Expected number of vehicle crashes, and
n	Number of road sections.
λ_i	Traffic exposure on segment i,
$AADT_i$	- Annual Average Daily Traffic (vehicles/day),
T_i	Percentage of a particular type of vehicle in a traffic stream
L_i	Length of the road segment
Θ_i	random error

References

[1] Joshua, S. and Garber, N. (2013): *Estimating Truck Accident Rate and Involvements Using Linear and Poisson Regression Models.* Journal of Transportation Planning and Technology. **15**(1): p. 41-58

[2] Global Status report on Road Safety (2018), *Summary*, Division, R., Editor, World Health Organization.

[3] Aram, A. (2010): *Effective Safety Factors on Horizontal Curves of Two-Lane Highways.* Journal of Applied Sciences. **10**(22): p. 2814-2822

[4] Mohamadshah, Y.M.*, et al.* (1993): *Truck Accident Models for Interstate and Two-Lane Rural Roads. 1407.* Transportation Research Record. **1407**: p. 35-41

[5] FHWA (2010): *Traffic Volume Trend 2009.* Federal Highway Administration. **02**

[6] Daniel, J.*, et al.* (2002): *Factors in Truck Crashes on Roadways with Intersections: Transportation Research Record.* Journal of the Transportation Research Board. **1818**(1): p. 54-59

[7] Garnaik, M.M. (2014), *Effects of Highway Geometric Elements on Accident Modelling*, in *Department of Civil Engineering*, National Institute of Technology: Rourkela-Odisha-769008, India.

[8] Zhang, Y. (2009). *Analysis of the Relation between Highway Horizontal Curve and Traffic Safety.* in *In Proceedings of the 2009 International Conference on Measuring Technology and Mechatronics Automation*.

[9] Hassan, Y. and Easa, S.M. (2003): *Effect of Vertical Alignment on Driver Perception of Horizontal Curves.* Journal of transportation engineering. **129**(4): p. 399-407

[10] Miaou, S.P. (1994): *The Relationship between Truck Accidents and Geometric Design of Road Sections: Poisson Versus Negative Binomial Regressions.* Journal of Accident Analysis and Prevention. **26**(4): p. 471-482

[11] Lin, F.-B. (1990): *Flattening of Horizontal Curves on Rural Two-Lane Highways.* Journal of Transportation Engineering. **116**(2)March 1990.

[12] Pedan, A. (2009): *Analysis of Count Data Using the Sas System." Sugi 26.* National Highway Traffic Safety Administration (NHTSA). Traffic Safety Facts 2009.No. HS-8113888. 2009. p. 22-25

[13] Agresti, A. (2007), *An Introduction to Categorical Data Analysis*. Vol. 423 ed: Wiley-Interscience.