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Evaluation of the effect of highway geometric design features on truck accident on Benin-Ore road, Edo state, Nigeria

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Abstract

The project investigated roadway geometric features critical to the safe accommodation of large trucks within Edo state. Major emphasis was centered on multilane roadways plied frequently by such trucks. Accident data covering a five-year record (2011-2015) obtained from the Federal Road Safety Corps of Nigeria and also from Prime Consult Engineering services were used in the study. Geometric details such as the horizontal and vertical alignments regarding such routes were also obtained from the Federal Ministry of works of the state. Poisson Regression Method and the Negative Binomial Regression were the modeling tools employed for the project work, since the data were considered as count data and also discrete in nature. SPSS statistical software tool was used for generalized estimate of equation since it is in exponential form. Mean and variance were also used to check over dispersion and under dispersion while predictability measure of the model developed was checked using Pearson Chi-square. The result from the Negative Binomial Regression analysis showed that some of the independent variables selected were more critical than others. The results also showed that the vertical curve and horizontal curve were moderately significant with respect to accident occurrence but super-elevation played a more significant role in truck accident occurrence. Attention should be given to such sections of the road that are super-elevated to ensure that they are properly counteracted.

Keywords: Trucks crashes, Road accident, Poisson regression model, supere-levation, road geometric features, pavement design

1.0 Introduction

Highway crashes/ accidents result in high fatalities and various degrees of live changing injuries that cause huge economic loses to the country. The World Bank (2015) estimates that road crashes cost approximately 1 to 3 percent of a country's annual Gross National Product (GNP). In Nigeria, this is approximately ₦346 billion to ₦1.039 trillion, which is even more than the ₦183 billion, which forms the 2013 budget of the Federal Ministry of Works. A sizeable number of road traffic accidents occur each year in Nigeria. In 2011 alone, 4,372 people were killed and a further 17,464 suffered various injuries as a result of traffic accidents (The NATION, 2014).

The causes of road traffic accidents have been linked to human factors, road condition and vehicle types. These three features form the basis of AASHTO geometric design criteria established in the 1930's. On the aspect of vehicle types, articulated vehicles are considered more disastrous and catastrophic during accidents due to their sizes and impact they may cause when they collide with other vehicles or road users. Most of these big vehicles fail due to loss of control as a result of brake failure. Articulated vehicles which generally represent vehicles with greater wheelbase turning radii than smaller buses and passenger cars constitute significant traffic streams in Nigeria (AASHTO, 2001). These vehicles reduce roadway capacity and cause traffic congestions owing to the fact that they occupy more space and cause greater impedance to flow of traffic than passenger vehicles with their equivalents being equal to multiple passenger cars (Donnel et al, 2001).

Human factor which is often considered the dominant factor in the cause of road traffic clashes involves unhealthy behaviour from drivers, pedestrian and passengers. This behaviour include but not limited to impatience on the part of driver and passengers, over speeding, negotiating a curve at high speed, moving on the wrong lane, unhealthy lifestyle such as taking hard drugs or drinking intoxicating wines shortly before driving etc.

The road condition factor of this menace is directly linked to the geometric design features of the road. There is the need to create harmony between the human factor, the road condition factor and vehicle factor because among the three, the road condition factor seems the easiest to control. The term "geometric design" as it relates to highway infrastructure, implies the arrangement and dimensions of the physical features of a highway section (Zheng, 1997). This include: horizontal alignment, vertical alignment, cross-sections, grades, interchanges, carriageway, shoulder, median (Mohammed, 2013) and other features that significantly influence highway operation, capacity, drainage as well as safety The highway geometric design guide (Federal Ministry of Works, 2013), provided that, firstly, preliminary focus on geometric planning should indicate how user friendly the ultimate road design should be. This involves selecting the optimal site for road location, harmonization of geometric alignments with social, environmental and safety considerations. Also, there should be the assurance that design standards and guidelines used are the most appropriate for situations pertaining to route alignment. Secondly, there should be strong focus on specific geometric design measures that provide for efficient and appropriate vehicle operation on the road including provisions for specific details that make roads safe and compatible with social and environmental circumstances around the road.

1.1 Relationship between crash rates and some geometric features

Previous researches carried out show that significant relationship exist between crash rates and some geometric features of road. The Highway Capacity Manual (HCM) documents that wider lane for multilane highways result in higher free-flow speeds (Jerry et al, 2009). Generally, most studies agree that lower accident rates are attributed to wider lanes. But it seems that there is an optimal lane width around 3.5m. Studies have also noted that approaches should base on more parameters of the cross section, at least also on traffic volume.

Hearne's (1976) research results suggested that there was a marginal increase in accident occurrence with an increase in carriageway width. Hedman (1990) noted similar results of a rather steep decrease in accidents with increased width of 4m to 7m, but that little additional benefit is gained by widening the carriageway beyond 7 m. Zeger and Council (1993), and Mclean (1985) also showed that the width of 3.413 m exhibits the lowest accident rates. This is supported by the NCHRP Repot 197 (TRB, 1978) which concluded that there is little difference between the accident rate for 3.35 m and a 3.65 m lane width. However, studies on low volume rural roads indicate that accidents continue to reduce for widths greater than 3.65 m, although at a lower rate (Hughes, 1995). TRB (1987) pointed out that lanes wider than 3.70 m do not contribute to a higher safety because they may result in unsafe maneuvers such as over taking despite of oncoming traffic.

Most studies concluded that the higher the number of lanes, the higher the crash rate (Deo, 2004). In their research, Noland and Oh (2004) found that increasing the number of lanes was associated with increasing traffic crashes. In another study, Abdel-Aty and Radwan (2000) found that more lanes in urban roadway sections are associated with higher crash rates.

Garber (2000), considered flow per lane and found that there was an increase in the crash rate as the flow per lane increased. Evidence of the effect of the number of lanes can be seen when a study was done on the conversion of a two-way roadway to four or six lanes (Deo, 2004). A study by Sawalha and Sayed (2001) found that type of median and nature of land use affect crash rate significantly. Srinivasan (1982) found that on high-speed roads with two or more lanes in each direction, medians

improve safety in a number of ways, for example by reducing the number of head-on collisions.
Information from previous researchers show that there is relationship between crash rates of vehicles with the geometric design features of roads. At present, information about the quantitative relationship between the probability of occurrence of large truck crashes on Benin-Ore expressway and the traffic and geometric variables is limited. This forms the basis of this research, to evaluate the effects of both traffic conditions and site characteristics on the occurrence of large truck crashes and to develop crash prediction models to quantify the relationship between geometric characteristics and the number of crashes observed.

1.2 The zero inflated Poisson regression model

An accident prediction models is generally an algorithm pitting a dependent variable against several independent variables, each of which is assigned a constant. The dependent variable in an accident prediction model is the number of accidents, while the independent variables may be quantitative variables such as traffic flow, section length, pavement surface condition, infrastructures geometric characteristics, lighting and drivers behaviour (Rokade et al., 2010). Previous researcher like Carr (1969) have used various models and techniques for similar problems. However, our research would be based on the zero inflated poisson regression model.

The Zero Inflated Poisson (ZIP) regression model which was developed by Lambert (1992) was employed in this work since accident data are count data and are of discrete random variable in nature. The idea of the model is that it assumes that outcomes emanate from two processes. One process models zero inflation, by including a proportion 1 - p of extra zero and a proportion p exp (- X_i) of zeroes coming from the Poisson distribution; and the second models the non-zero counts using zero truncated Poisson model. Being that the independent variables are dynamic, meaning changes with time and can also be fluctuated due to estimation, this informed the choice of using the Zero Inflated Poisson. However, the major consideration which may employ the Zero Inflated Poisson is the relaxation of the constraint of over dispersion and under dispersion between the mean and the variance as well as cases of excess of zeroes which limit the use of Poisson Regression and negative binomial.
In the model, the usual starting point for modeling count data *(i.e.*, data that take only non-negative integer values) is the Poisson distribution, whose p.m.f. is given as:

$$\text{Pr. } [\, Y = y] = \exp(-X)X^y / y!\ ;\ y = 0, 1, 2, \ldots \quad (1)$$

As is well-known, X (> 0) is both the mean and variance of this distribution, so it is described as "equi-dispersed". In contrast, many data are "over-dispersed", in that their variance exceeds their mean, so this reduces the usefulness of the Poisson distribution. Allowing the variance to be modeled in turn by a gamma distribution, leads to familiar Negative Binomial (NegBin II) distribution. The latter can capture over-dispersion in the data.

The ZIP model can, then, be formulated as follows:

$$P\,(Y_i = y_i\ x_i\ z_i\ ) = 0(z_i) + (1 - 0_i(z_i)\ \text{Pois}\ (X_i;0|x_i)\ \text{if } y = 0 \quad (2)$$
$$(1 - 0_i(z_i)\ \text{Pois}\ (X_i;\text{yi}|\text{xi}) \qquad \text{if } y > 0$$

With z_i as a vector of covariates defining the probability 0_i, Pois (X_i;0|x_i) = exp (- X_i) and Pois (X_i;y_i|x_i) $e{\sim}^M\ Xiy*$.
The mean and the variance of ZIP are E(y_i|x_i,z_i) = (1 - 0_i) X_i and Var(y_i|x_i,z_i) = (1- 0_i)(X_i + 0i tf)

1.2 Study area and scope

The study area is Benin City located in the southern part of Nigeria, Benin City lies between Latitude 6° 14' 00" North to 6° 21' 00" North and Longitude 5° 34' 00" East to 5° 44' 00" East and an average of 80 meters elevation above sea level. It comprises of six local government area with an estimated population of 1,147, 188 people (NPC 2006). It is 40km north of the Benin River and 320km by road east of Lagos. Benin City experiences a tropical weather.

2.0 Methodology

Data collection, route location and variable selection are presented in the following sections.

2.1 Data Collection

Data relating to truck haulage on roadways as well as crash related data were obtained from Federal Road Safety Corporation (FRSC) within the last five (5) years (2011-2015). This data set also comprised of the Police and National Emergency Management Agency (NEMA) reported crashes that occurred within the entire period. For this study, exclusive truck crash records on limited access roads (express ways) were extracted by making a query on the FRSC vehicle crash data- base from 2011 to 2015 for Edo state. The types of truck vehicles included in this analysis were vehicles whose classification on the crash data-base included single unit trucks including other converted long vehicles with less than nine (9) seats used for commercial business, tanker- trucks and trailer-truck combinations with weight value greater than 4500 kilograms, number of axles greater than or equal to two 920.

From the source database (FRSC), three kinds of vehicles were classified under the truck vehicle category, namely: single unit (SU) trucks, tankers and trailers. Table 1 below provides information on the various truck involvements in road traffic crash for Benin-Ore road within the years in consideration.

Table 1: Detail of the crashes involving large trucks in Benin-Ore road (FRSC, 2016)

Route	Truck Crash Data from 2011 - 2015			
	Single Unit Truck (SU)	Tanker Truck	Trailer Truck	Total
Benin-Ore road	103	95	121	319

Within the five (5) year period observed, a total of **319** large trucks were reported by the FRSC to be involved in crashes along all limited access highways in Edo State regardless of their severity.

2.2 Route Location

For the purpose of the study, only roadways with significant truck haulage were considered for analysis within the study area. By so doing, the geometric data pertaining to such roads were evaluated in their adequacy to effectively and safely accommodate large trucks. The roadways assessed for distribution of horizontal curvature, grade alignments as well as other important geometric features were in general, limited access roads with relative homogeneity across sections, i.e, roads with reduced entry and exit terminals otherwise referred to as expressways. These roads were selected on the basis that they represent major routes which permit the movement of large volumes of traffic at high speed and connect major points of traffic generation within industrial areas. Furthermore, these routes (Figure 1) harbour roadway sections with deficient geometrics for which truck crashes have been prevalent over time. The selected route which was analyzed was: Benin-Ore expressway, a 94km road.

Figure 1: Benin-Ore expressway (online image)

2.3 Variable Selection

The traffic volume and risk factors (geometric elements) are the explanatory variables of the model. Ideally, the choice of explanatory variables used in the crash modeling ought to be based on theory. However, variables were selected based on data availability. Selected variables were considered on the following basis:

a. Their relevance as determined from previous studies as a major influence on crash rates.
b. The feasibility of measuring such variables in a reliable manner.
c. Degree of correlation with other explanatory variables included.

A total of twelve (12) geometric variables presented below were considered for the roadway model analysis. They include the following:

a) Highway sectional length: This was defined by changes on the roadway to any of the collected variables.
b) Highway number of lanes: Denoted by the total number of lanes in a section.
c) Roadway/Lane width: The width of each roadway excluding shoulder width.
d) Left shoulder: The total width of the left shoulder.
e) Right shoulder: The total width of the right shoulder.
f) Median: Indicator variable for the presence of a divided way.
g) Functional class: Designated for the class or type of roadway investigated.
h) AADT: Average annual daily traffic per lane.
i) Percentage Truck AADT: Truck percentage in the traffic stream
j) Horizontal Curvature (HC): Measured in degree of curvature or as curve radius. k) Vertical Grade (VG): Denoted by grade change across a highway section.

However, due to data availability, consistency and relevance over measured road sections, highway sectional length, lane width, truck AADT per lane, horizontal curvature, vertical grades and yearly dummy variables were subjected to the final testing and analysis using Poisson regression modeling method.

3.0 Results and Discussion

The outcome of the research was discussed in the following sections.

3.1 Highway Variable Selection and Definitions

Upon final testing and analysis, three (3) geometric design elements were outlined as critical to the accommodation and safety of trucks on plied roadways. They include the horizontal curvature, vertical grade and lane width. Sections of each roadway for which truck mishaps have been reported to be relatively prevalent as well as those with poor geometric configuration were investigated. Tables 2 and 3 highlights crucial findings for horizontal curvature and vertical grades for each roadway.

Table 2: Chainages indicating vertical grade for selected sections of the road

Chainages		Slope (%)	Description
From	To		
10.8	15.2	12.4	Ovia River
24.7	39.3	8.7	Before Ugbogui
58.6	62	2.6	Ofosu
79.6	82.7	1.3	Before Ore

Table 3: Chainages indicating horizontal curvature for selected sections of the road

Chainage (km)		Linear Radius (m)	Degree of horizontal curvature (^{0})	Co-ordinate X to the centre of curve radius	Co-ordinate Y to the centre of curve radius
From	To				
11.5	13	2440.56088341	2.347657064795	778035.865071	722523.802574
13.7	14.6	425.665810998	13.46032463017	777815.492368	725390.389969
59.5	62.3	3642.46861241	1.572999141428	735510.790936	743843.462495
72.8	73.8	2088.1476373	2.743867290632	725082.351825	751491.457534
74	76.6	3290.26412501	1.741379956839	722665.043024	746657.516803
78	81	5726.2979934	1.000576638974	721256.943249	743695.131911
84	85	1022.96254336	5.600987091062	714298.141967	747264.383158
86	87	5087.88893568	1.126125210756	711559.632587	751159.910103
90	90.5	904.280841527	6.336084695021	708922.278273	746911.851437

Based on the independent variables explained above, a Poisson regression model was developed. The relationship between truck crashes and roadway geometric design features is visible in the magnitude of the exponential effect for each variable at 0.05 significance level (i.e. 95% confidence interval). Estimated coefficients greater than one (1) indicated an increase in crash frequency with corresponding increase in variable size while, coefficients less than one (1) indicated a decrease in the frequency with relative increase in variable size. On the other hand, estimates equal to one (1) meant no effect of contributing variable on crash frequency. Shown below are the exponential effects of each contributing variable for the roadway sections examined.

3.2 Analysis of Accident Rate Versus Geometric Variables

Total number of accidents was obtained from Federal Road Safety Corps zonal office in Benin City within appropriate range of radius and then, the profile/map of each of the route as well as accident spots (black spot) were captured and represented in map as shown in Figure 2. Table 4 shows the geometric features along the road.

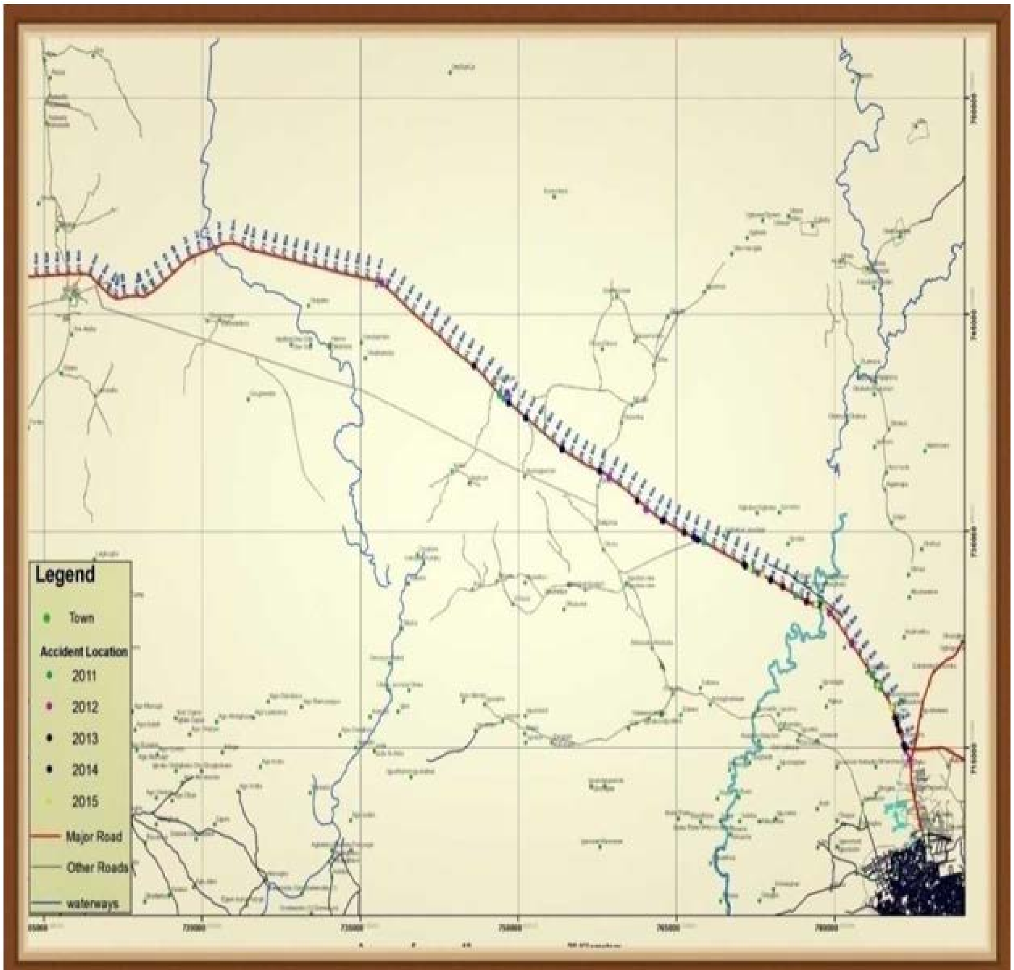

Figure 2: Profile of Benin-Ore road

Table 4: Geometric features along Benin-Ore road

Chainages, d (km)	No of accidents (A)	Vertical Curve (%)	Horizontal Curve (m)	Super-elevation (%)	Design Speed (km/hr)	Road Width (m)	Median Width (m)	Shoulder Width (m)
11.5-13.0	19	12.4	2440.56	4.3	100	10.5	1.0	1.5
13.7-14.6	96	0	425.67	5.1	100	10.5	1.0	1.5
24.7-39.3	1	8.7	0	0	100	10.5	1.0	1.5
59.5-62.3	72	2.6	3642.47	1.5	100	10.5	1.0	1.5
72.8-73.8	46	0	2088.15	2.6	100	10.5	1.0	1.5
74.0-76.6	52	0	3290.26	1.2	100	10.5	1.0	1.5
78.0-81.0	24	1.3	5726.30	2.1	100	10.5	1.0	1.5
84.0-85.0	8	0	1022.96	0.4	100	10.5	1.0	1.5
86.0-87.0	1	0	5087.89	1.3	100	10.5	1.0	1.5
90.0-90.5	0	0	904.28	0.5	100	10.5	1.0	1.5

3.3 Evaluation of statistical relationship

The statistical relationship between the accident crash rate and geometric features were evaluated using the following tools presented below.

3.3.1 Kolmogrov-Smirnov Test

Table 5 shows the result of one sample Kolmogrov-Smirnov Test while Table 6 shows the case processing summary which indicates the sample size and the percentage of included, excluded and total analysis carried out at each intersection.

Table 5: One sample Kolmogrov-Smirnov Test

One-Sample Kolmogorov-Smirnov Test		
		Accident
N		10
Poisson Parameter[a,b]	Mean	31.9000
Most Extreme Differences	Absolute	.509
	Positive	.509
	Negative	-.389
Kolmogorov-Smirnov Z		1.610
Asymp. Sig. (2-tailed)		.011
a. Test distribution is Poisson		
b. Calculated from data		

Table 6: Case Processing Summary

Case Processing Summary		
	N	Percent
Included	10	100
Excluded	0	0
Total	10	100

3.3.2 Descriptive Statistics

Table 7 shows the mean and variance. The results indicate that the value of variance is far apart from the mean, that there is over-dispersion in the data. Hence, we follow the rule earlier stated that for over and under-dispersions, we assume that the data does not follow a Poisson distribution, hence we use negative binomial model, which takes care of over and under dispersion of parameters.

Table 7: Descriptive Statistics

Descriptive Statistics			
	N	Mean	Variance
Accident	10	31.9000	1116.322
Valid N (list)	1**0**		

3.3.3 Goodness of Fit

Table 8 shows the goodness of fit test results. The goodness of fit result shows that the deviance value/df of 31.704 and Pearson chi-square value/df of 31.922 indicated that the predictability measure of the model developed was low.

Table 8: Goodness of Fit test outcome

Goodness of Fit[a]			
	Value	**df**	**Value/df**
Deviance	190.222	6	31.704
Scaled Deviance	190.222	6	
Pearson Chi-Square	191.533	6	31.922
Scaled Pearson Chi-Square	191.533	6	
Log Likelihood[b]	-115.979		
Akaike's Information Criterion (AIC)	239.957		
Finite Sample Corrected AIC (AICC)	247.957		
Bayesian Information Criterion (BIC)	241.168		
Consistent AIC (CAIC)	245.168		
Dependent Variable: Accident Model: (Intercept), VC, HC, Super-elevation, DS, RD, Median, SW			
a. Information criteria are in smaller-is-better form			
b. The full log likelihood function is displayed and used in computing information criteria			

3.3.4 Negative Binomial

Since there was a case of over-dispersion, we had to employ negative binomial to help us collapse the effect of the over-dispersion. The analysis of the negative was presented in the Table 9.

Table 9: Negative Binomial test results

Parameter Estimates										
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)	1.486	.9272	-.331	3.304	2.570	1	.109	4.421	.718	27.215
VC	-.132	.0912	-.311	.047	2.091	1	.148	.876	.733	1.048
HC	.000	.0002	.000	.001	1.745	1	.186	1.000	1.000	1.001
Super-elevation	.588	.2352	.127	1.049	6.254	1	.012	1.801	1.136	2.856
DS	0[a]							1		

RW	0[a]							1		
Median	0[a]							1		
SW	0[a]							1		
(Scale)	1[b]									
(Negative binomial)	1[b]									
Dependent Variable: Accident Model: (Intercept), VC, HC, Super-elevation, DS, RD, Median, SW										
a. Set to zero because this parameter is redundant										
b. Fixed at the displayed value.										

Table 9 contains the negative binomial regression coefficients for each of the predictor variables along with their standard errors, Wald chi-square values, p-values and 95% confidence intervals for the variables (dependent and independent) for Benin-Ore road. From the relationship developed it can be observed from the coefficients of the estimates that the horizontal curve, design speed, road width, median and shoulder width, were all adequate and had no significant impact in the likelihood of accident occurrence. Whereas vertical curve and super elevation had some significant effect on the probability of accident occurring. Vertical curve by 0.876% and super-elevation by 18.01%.

3.4 Model Relationship Development

Geometric features shown in the Table 5 were input in SPSS software for statistical analysis of the variables (dependent and independent) used. From the analysis, a parametric l K-sample test for the generalized linear model was carried out and then input values for the dependent variable which is accident and the independent variables which includes, vertical curve, horizontal curve, super-elevation, design speed, road width, median width and shoulder width for each accident location or black spots used. The models developed for this study route was presented in Table 10 below.

Table 10: Model developed for the study routes

Route	Type of model	Model developed
Benin-Ore road	Negative Binomial	$L\ (PHVX_{e}\,(4.421+0.876X1+X2+1.801X3+X4+X5+X6+X7))$

From the model, the coefficient of the variables showed how each of the variables selected play a significant role in the model. For example, those whose coefficients are one (1), means no impart was felt for that variable selected, hence parameters selected and used for design were adequate.
However, for those with coefficients greater or lesser than (1), the values are interpreted in percentages. For example, for Benin-Ore road, for road width (X1), the coefficient was 0.876; this simply means 8.76% probability influence on causing crash.
For the shoulder width (X3), the value for the coefficient from parameter estimate was 1.801, which when interpreted is 18.01% probability influence of causing crash. The same principles apply to all other variables selected as well as their coefficients gotten from parameter estimates.

3.4.1 Model Validation

The model validation was carried out with the help of the values of the deviance and Pearson chi-square. If these values are 1 or not far from one, it shows that the values obtained in the exponential column can be used for prediction. From the Table 11, most of these values were close to 1.

Table 11: Goodness of fit from Negative Binomial

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	12.876	6	2.146
Scaled Deviance	12.876	6	
Pearson Chi-Square	6.923	6	1.154
Scaled Pearson Chi-Square	6.923	6	
Log Likelihood*[5]	-		
Akaike's Information Criterion (AIC)	90.344		
Finite Sample Corrected AIC (AICC)	98.344		
Bayesian Information Criterion (BIC)	91.555		
Consistent AIC (CAIC)	95.555		
Dependent Variable: Accident Model: (Intercept), VC, HC, Super-elevation, DS, RD, Median, SW			
a. Information criteria are in smaller-is-better form.			
b. The full log likelihood function is displayed and used in computing information criteria			

3.4.2 Model Ranking

Based the parameter estimates for each of the coefficients selected, the ranking for each of the variables as to the levels of impact or significance in the model developed are shown in Table 12. From the ranking, only super elevation was significant while VC and HC were moderately significant.

Table 12: Ranking

Variables	Rank
VC (X1)	Moderately Significant
HC (X2)	Moderately significant
SE (X3)	Significant
DS (X4)	Not significant
RW (X5)	Not significant
MW (X6)	Not significant
SW(X7)	Not significant

4.0 Conclusion and Recommendations

4.1 Conclusion

The relationship between crash rate of large trucks and geometric features of Benin-Ore road was sought in this research work. A total of 329 truck crashes between 2011 and 2015 involving single unit trucks, tankers and trailer truck vehicles were used. It was established that large trucks, due to their physical and performance attributes contribute significantly to undesirable effects and road mishaps especially when such roads are deemed structurally and geometrically deficient. The following major problems relating to geometric inadequacies for these routes were identified:

1. Narrow or reduced lane width especially at interchanges or intersections truncated roadway capacity thus leading to congestion especially during peak travel hours.
2. Poor roadway geometric alignments along some sections were also a contributing factor to haulage difficulties and crashes. Where sharp curves were present, trucks were unable to complete maneuvers with ease due to their length and crashes were imminent. On steep vertical grades, truck vehicles travelled at slower speeds increasing the tendency of smaller faster vehicles to overtake more frequently resulting to mishaps.

4.2 Recommendations

In implementing geometric design features for roadways, it is important for large truck vehicles to be given adequate consideration. For limited access roadways, proper combination of curve tangents, grades and effective median types allows for effective accommodation of trucks, improved safety and roadway aesthetics.

A review of the existing design guides is necessary in order to take into account current truck dimensions and vertical grade considerations. Also, regular crash assessment on multi-lane roadways with significant truck haulage represents an effective countermeasure for evaluating the safety of horizontal alignments.

In order to mitigate the effect of increasing truck traffic and reduce the proportion of large truck vehicles in the traffic mix on multi-lane and limited access roadways, exclusive truck lanes are required to be implemented during roadway rehabilitation and reconstruction. The introduction of express lanes, barrier separated lanes and managed lanes proffer effective ways to reduce conflicts associated with increased number of lanes.

From previous literature reviews, other statistical testing model methods such as, Zero-inflated Poisson (ZIP) and negative binomial (NB) regression present more flexible analytical approaches while dealing with count data of discrete and random nature by eliminating the constraint of variance and mean equality resulting in over or under-dispersion. Therefore, it is suggested that these methods be given due consideration for further research purpose in the near future.

Conflicts of Interest

There is no conflict of interest associated with the work

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