International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 5 Issue 11, November 2018

ISSN: 2394-4404

Modeling Of 85th Percentile Speed At Selected Mid-Curves On Ondo-Ife Two-Lane Rural Highway In Southwestern Nigeria

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***Abstract:** The 85th percentile operating speed of vehicles at selected mid-curves along Ondo – Ife two-lane rural highway in southwestern Nigeria was modeled using regression approach. Ten horizontal curves were selected and the spot speed measured using stop watch method, after which the 85th percentile speeds were evaluated. Geometric elements perceived to influence operating speed at mid-curves were extracted from the database of Federal Ministry of Transportation, Abuja, Nigeria. Multiple linear regression equation was developed using the 85th percentile as dependent variable and length of curve (Lc), radius of curve (Rc), preceding tangent length (Pt_L) and super-elevation (e) as independent variables. The coefficient of determination R was found to be 0.994, which infers that 99.4% linear relationship exists between the dependent and independent variables. The model developed in this study is useful for designing, redesigning and improving the safety performance and geometric consistency of horizontal alignments of two-lane rural highways in Nigeria.*

***Keywords:** Operating speed, horizontal alignment, regression model*

I. INTRODUCTION

Researchers have established that horizontal curves have a significant effect on vehicle operating speeds. Significant relationship exists between design speed and geometric design elements such as radius and length of curves, super-elevation, and length of preceding tangent. The 85th percentile of the distribution of observed speed is the most frequently used measure of the operating speed associated with a particular location or geometric feature.

Nigeria experiences significant number of road crashes yearly, some of which result in fatal, serious or slight injuries. The number of road related crashes from 1960 – 2016 is reported to be 1125377, resulting in 350961 fatalities and 1,208,890 injuries [1]. 39.9 % of these crash cases were attributed to speed violations. Majority of these crashes occur on two-lane rural segments characterized with diverse geometric elements and weak speed limit enforcement. The safety of these roads has become a public health concern, considering the number of traffic crashes recorded on them annually. Horizontal alignment curve is a very important feature of road geometry. The knowledge of the relationship between operating speed at curves and the geometry features influencing them is very important for road designers and policy makers to be able to improve their safety performance.

The main objective of this study is to develop regression models to predict V_{85} percentile operating speed of vehicles at mid-curves along Ondo-Ife two-lane rural highway in Nigeria. The regression approach takes into consideration roadway horizontal alignment characteristics in developing the models.

Previous research for 85th percentile speed prediction on two-lane rural highways indicate that several geometric elements such as curve radius, length of curve, super-elevation, deflection angle, length of tangent etc. are important in determining speed on horizontal curves. Several researchers have developed 85th percentile models using these elements as explanatory variables to explain the variation in operating speed at curves. [2] developed a regression model to predict 85th percentile speed along Bode Saadu – Jebba road in Kwara state, Nigeria. They reported that the operating speed of vehicle depends on the Radius (R), Length of curve (Lc), Tangent Lengths (Tl), Gradient (G) and Super-elevation (e). [3] developed a series of regression models to predict speed on horizontal curves for two-lane rural highways in northern Iraq.

In order to study the combined effect of curve radius and grade on the 85th percentile curve speed, they separated the grades into four groups, i.e. < 3% upgrade, ≥ 3% upgrade, < 3% downgrade, and ≥ 3% downgrade. The speed prediction equations performed well, in that the mean absolute percent error ranged from 7 -9 % and there was an overall mean absolute percent error of 8%. [4] in their work developed the 85th percentile operating speed model at mid-curve that can be integrated based on shoulder width, degree of curve, length and radius of simple horizontal curves on kerala two-lane highway conditions. Prediction and estimation of operating speed on two-lane rural highways are of great importance to planners and designers. In a developing country like Nigeria with high traffic volume and poor speed compliance, only a few studies are documented along this line. It is therefore important to develop 85th percentile models that will reflect local conditions and that will be useful in improving the safety performance of horizontal alignments of similar geometric and traffic characteristics.

II. METHOD

A. STUDY AREA

Ondo-Ife, 63km federal road which begins at Ondo city in Ondo State and ends at the ancient city of Ife in Osun State in southwestern Nigeria has been selected for the study. The road corridor is a single carriage two-lane highway with an average traffic volume of 2,500 vehicles per day. The selection of this road segment is based on availability of geometric design data. 10 horizontal curves were selected for investigation at different locations along the segment. The criteria used for the selection include: (i) No influence of intersections (ii) No physical features or activities adjacent to, or in the course of the roadway that may create abnormal hazard such as speed reducer, narrow bridge, schools or factories etc. (iii) The road surface must be smooth and in dry condition. The horizontal curves selected are simple curves, and the length of approaching and exit tangents are long enough for vehicles to move at their desired speed.

B. COLLECTION OF GEOMETRIC DATA

Relevant geometric data for the ten curve sections selected for investigation was extracted from the database of Federal Ministry of Transportation, Abuja. The horizontal alignment features considered in this study are: length of curve (Lc), radius of curve (Rc), length of preceding tangent (Lpt) and super-elevation (e). Table 1 presents the statistical analysis of these variables.

C. COLLECTION OF SPEED DATA

Vehicles were considered to be traveling in both directions on the selected horizontal curves. 100 spot speeds were measured for all vehicle type at mid-curve on weekdays. The speed data were collected under free flowing conditions with minimum headway of 6 seconds using stop watch method. The 85th percentile speeds were computed and the statistics presented in Table 2.

	Lc	Rc	Lp_T	e
Valid	10	10	10	10
Mean	221.925	710.500	189.659	0.037
Std. Dev.	55.618	370.963	67.609	0.142
Min	158.67	375.000	105.000	0.0100
Max	330.460	1405.000	325.700	0.0500

Table 1: Relationship between V_{85} and LC, RC, LPT and e.

Variable	Min	Max	Mean	Std. Dev.
85th Percentile	122.00	93.00	105.20	9.06

Table 2: Statistical Analysis of 85th Percentile Speed at Mid-curve

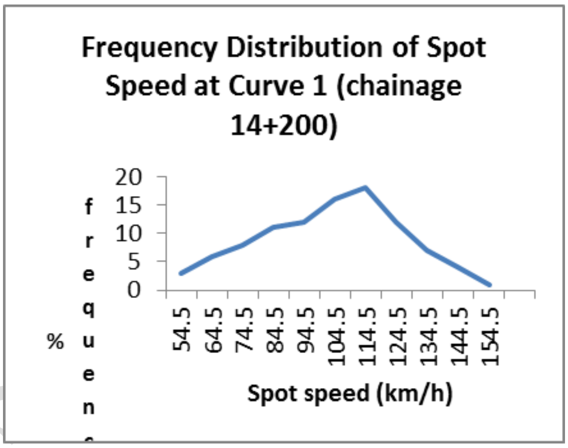

Figure 1: Frequency Distribution Curve of Spot Speed at Section 1 (chainage 6+200)

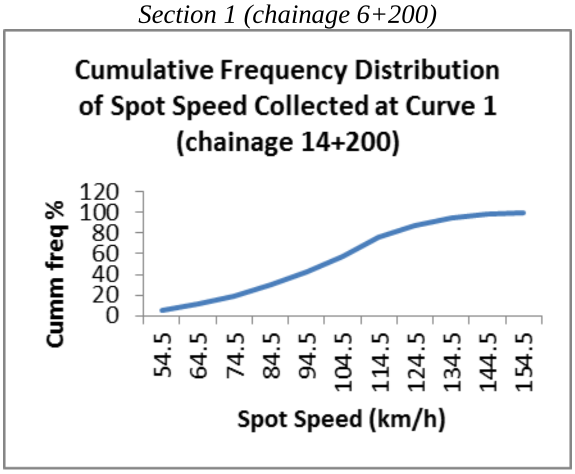

Figure 2: Cumulative Frequency Distribution Curve of Spot Speed at (chainage 6+200)

III. RESULTS AND DISCUSSION

A. STATISTICAL ANALYSIS OF INDEPENDENT VARIABLES

The statistical analysis of the horizontal alignment selected for this study was done using SPSS software and the result presented in Table 1.

B. DESCRIPTIVE ANALYSIS OF OPERATING SPEEDS AT MID-CURVES

Looking at the information presented in Table two, the 85th percentile speeds at mid-curves vary from section to section with a maximum of 122 km/h and a minimum of 83 km/h, though the posted speed limit is constant at 80 km/h throughout the study segment. This infers that the speed limit may not be the appropriate one in the study segment. The percentages and cumulative percentages of spot speed collected at chainage (6+200) were plotted against the mid-class of the various speed groups as shown in Figures 1 and 2.

C. CORRELATION ANALYSIS

Correlation may exist between certain geometric and traffic variables associated with a two-lane rural highway. A bivariate (Person) correlation matrix was developed using the road geometry parameters namely: Lc, Rc, L_{PT} and e, using SPSS (Statistical Package for the Social Sciences) software and the result presented in Table 3. The independent variables are found to be significantly correlated at 95% confidence level.

D. REGRESSION ANALYSIS

Regression analysis was employed to investigate the relationship between 85th percentile speed and the four horizontal alignment features considered in this study, and to develop a model that predicts operating speed at mid-curves of two-lane rural highway. The relationship between the operating speed (V_{85}) and Lc, Rc, L_{PT} and e, at mid-point of horizontal curve is presented in Table 4. Table 4 indicates that the 85th percentile speed of the vehicles at mid-curves has a linear relationship with the length of curve (Lc), radius of curve (Rc), Length of preceding tangent (L_{PT}) and super-elevation (e).

The R^2 values (0.018, 0.759, 0.234 and 0.471) from Table 4 above indicates that Lc, Rc, L_{PT} and e, are significant parameters influencing 85th percentile speed at mid-curves. However, no single parameter is responsible for change in 85th percentile speed, hence the need to investigate the influence of the four geometric parameters combined. The model summary is presented in Table 5. The relationship between 85th percentile operating speed and the four geometric parameters is shown in Table 6.

From Table 6, it can be concluded that there is a linear relationship between 85th percentile speed at mid-curves, length of curve (Lc), radius of curve (Rc) and length of preceding tangent (L_{PT}). The coefficient of determination R is 0.994 indicates that there is 99.4% linear relationship between the dependent and independent variables. The coefficient of determination R^2 (0.987) signifies that 98.7% of the dependent variable (V_{85}) is explained by the independent variables.

	V_{85}	Lc	Rc	Lp_T	e
V85	1	0.133	0.871	0.484	-0.686
Lc	0.133	1	-0.162	-0.544	-0.123
Rc	0.871	-0.162	1	0.464	-0.853
Lp_T	0.484	-0.544	0.464	1	-0.243
e	-0.686	-0.123	-0.853	-0.243	1

Table 3: A Person Correlation Matrix between V_{85} of and independent Variables

Geometry parameter	Relationship	R^2
LC	V_{85} = 100.393 + 0.022 LC	0.018
RC	V_{85} = 90.073 + 0.21 RC	0.759
LPT	V_{85} = 92.895 + 0.065 LPT	0.234
e	V_{85} = 121.431 – 438.674 e	0.471

Table 4: Relationship between V_{85} and LC, RC, LPT and e.

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.994[a]	0.987	0.977	1.377

a. *Predictors: (Constant), e, Lc, L_{PT}, Rc*

Table 5: V_{85} Model Summary

Model	Equation
V_{85} = 37.404 – 0.099 LC + 0.032 RC + 0.047 LPT + 380.585 e	1

Table 6: V_{85} Model equation

IV. CONCLUSION

The relationship between 85th percentile speed at mid-curve and some horizontal alignment features have been explored in this study. The following conclusions can be drawn:

- ✓ The speed distribution along mid-curves of horizontal alignment follow a normal distribution
- ✓ The maximum 85th percentile operating speed observed from this study was 122 km/h while the minimum was 93 km/h.
- ✓ The length of curve, radius of curve, length of preceding tangent and super-elevation are important horizontal alignment features that influence the operating speed on horizontal curves.
- ✓ There is a 99.4% linear relationship between the 85th percentile operating speed at mid-curve and length of curve, radius of curve, length of preceding tangent and super-elevation.
- ✓ The model developed in this study is useful for predicting 85th percentile operating speed at mid-curves of horizontal alignment. Road planners and engineers can also find it helpful in improving the design consistency and safety performance of horizontal alignments of rural highways.

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