RESEARCH ARTICLE OPEN ACCESS

Comparative Study of Operating Speed of Vehicles on Horizontal Curve using ANN & Regression Models

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ABSTRACT
The poor relationship between geometric elements of a road can cause unsafe speed. This study assesses the effects of geometrical features of horizontal curves on operating speed by using speed prediction models. Geometrical elements of 40 horizontal lineaments identified are collected using total station and spot speed data are stored using the speed app. Geometrical features include the width of the carriageway, radius of curvature and super elevation. Speed data comprise the speed of two-wheeler, three-wheeler, and four-wheeler vehicles. The model for forecasting operating speed is generated using SPSS software and Artificial Neural Network. In the SPSS system, a linear regression model is created by analyzing the correlations. For creating an ANN model python programming language is used. By comparing both the models, it is clear that ANN model is more efficient than the Linear Regression model to predict the operating speed of vehicles on horizontal curve
KEYWORDS - Horizontal curve, Operating speed, Radius of curvature, Super elevation, Carriageway width, Speed data.

Date of Submission: 02-06-2021 Date of Acceptance: 15-06-2021

I. INTRODUCTION

Safeguarding the road is a vital concern of transportation engineers. Adopting protective measures in one or more areas like the vehicle, the driver and the roadway can help to improve road safety. Countermeasures regarding the road are regulative and warning signs, guard rails, breakaway signs, lighting supports, speed division, and varied construction techniques. Speed is a traffic character that is directly related to both driver and speed. Speed is also an important factor used to assess the convenience and efficiency of roads. The operating speed of the vehicle is affected by the geometrical elements of the road on Horizontal Curves. With higher knowledge of the geometrical layout factors which affect operating speed; designers might be capable of making extra powerful layout choices for foremost arterials. According to different studies horizontal curve greatly influences the operating speed of vehicles. To ensure safety it is necessary to predict and evaluate the operating speed of vehicles on the horizontal curve. As per this, the standard speed is expressed as a performance of the radius of curvature and superelevation. Also, other geometric parameters like the width of the carriageway, deflection angle and degree of curvature have influenced operating speed. Superelevation and extra widening needed on the curve are ruled by the speed of the vehicle. If the variation of speed on the curve for a given information processing system condition is assumed, comfortable superelevation and widening could also be given which may enhance the safety of the vehicle.

II. OBJECTIVES

- To identify the major geometrical elements that influence the operating speed of vehicles on a horizontal curve.
- To develop a model for predicting the operating speed of vehicles along a curve of known geometry using an Artificial Neural Network.
- To analyse the applicability of the model for varying vehicle types.
- To validate the obtained model.
- To compare the model with the linear regression model.

III. FIELD INVESTIGATION

A wide range of parameters needs to be obtained for the creation of a model. Since this model focuses on predicting the operating speed, several geometrical parameters that influence the speed of vehicles are collected. The speed of vehicles passing through the section is also taken into account.

3.1 Road Geometric Data

Road geometry greatly influences the operating speed of vehicles. Some of the more prominent parameters are Road width, Super elevation, Radius of curvature, Degree of Curvature, and Deflection Angle. Road width could be easily measured by a tape. Factors such as super elevation, Radius of curvature could be obtained by a total station. The degree of curvature is then found by using suitable formulas.

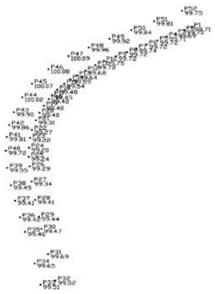

Figure 1- Curve Plotted on AutoCAD

With the help of data collected using total station, curves are plotted on AutoCAD. By using Dimension tool, radius of curvature can be measure directly. Super elevation can be calculated using taking level differences between inner and outer curves. Deflection angle and Degree of Curvature is calculated with the following equations:

Degree of Curvature =1746.38/Radius (1)

Deflection Angle = 57.29 x Arc Length/ Radius (2)

3.2 Speed Data

The speed of vehicles passing at each curve could be calculated by an application named 'Speed App'. A section of the curve with a short distance is fixed by the observer and the time taken for the vehicles to pass through this section is noted. Speed of vehicle could then be calculated by using the formulae:

Speed= Distance/Time (3)

IV. METHODOLOGY

4.1 Regression Model

The model consist of certain variables termed as predictors. These variables might be dependent or independent. Suppose our model uses variables X_1, X_2 which are independent of each other. Let Y be the required output variable, it can be mathematically written as,

$$\mathbf{Y = f(X_1, X_2)}$$

It can be noted that any change in value of X_1, X_2 will have some significant impact on the output Y.

Figure 2- Simple linear Regression Model

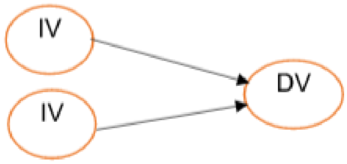

Figure 3- Multiple Linear Regression Model

Multiple linear regressions are the broadening of simple linear regression. Two or more independent variables are used to predict the change in the dependent variable. Two problems are arise during multiple regressions. They are over-fitting and multicollinearity.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_n x_n + \epsilon \qquad (4)$$

The given above equation is the general form of regression model equation.

ϵ - error

β - Linear parameters

$x_1, x_2, \ldots x_n$ – independent variables

For conducting multiple regressions analysis requires the following steps are adopted;

- The required variables are identified and values of each variable is gathered.
- These identified variables are checked for interdependency among themselves.
- Those variables which are found to be interdependent are omitted from the model creation,
- A relationship between these selected variables are checked by correlations,
- The model created with these variables are then used for prediction

4.2 ANN Model

An ANN or Artificial Neural Network model has 3 layers – input, hidden and output layers which are essential for their functioning. Its basic working principle is that the input layers are fed with the input data, which are transferred to the hidden layers where they get processed and a suitable relationship is formed. The final output required is then transferred to the output layer. For obtaining this relation between the input and output data, a process called training is done before the development of the model. A set of known input data and required output data is fed for this purpose and the model develops a suitable relation. This relation and training help to formulate the required model. Here input data are the independent variables and the output data is dependent variables.

The ANN model was created by using 'python' programming language on software named 'jupyter notebook'. The data set was then splitted into training data and testing data by a function called 'train test-split.' About 20% data were used for testing and the remaining 80% for training. The loss function taken into consideration was 'Mean Absolute Error'. It measures the average magnitude of errors in our predictions. Generally, for regression models, MAE is used as the loss function. The training is done in 500 epochs with batch size of 32. After each iteration the MAE is calculated and the least value of MAE is saved by using certain checkpoints. When the value of MAE becomes constant or nearly zero, our training process is said to be over. The test data is evaluated and the model will then be ready for validation.

V. DATA ANALYSIS, RESULTS & FINAL MODELS

5.1 Data Analysis

Analysis of data include creating a list of potential variables i.e., independent and dependent variables. For analyzing a horizontal curve, primary geometrical elements like radius(R), width of the carriage way (W), super elevation (e), degree of curvature (D) and deflection angle (D_A) are selected as the independent variable. Speed of two-wheeler, three-wheeler, four-wheeler and operating speed (O_S) are taken as dependent variable. These data are collected by using total station and an app called speed app.

By conducting correlation analysis among each independent variable, the results show that deflection angle and degree of curvature are interrelated with the radius of curvature. So they are excluded from the final set of data to avoid multicollinearity.

The next step is to conduct a correlation analysis between the selected independent variables (Radius of curvature, width of the carriageway, and super elevation) and dependent variables (operating speed of 2, 3 and 4 wheelers and in general). The graphical representation of these correlation analysis are given below;

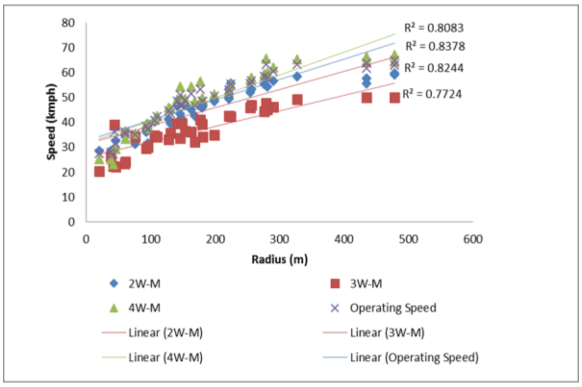

Figure 4- Speed (kmph) vs. Radius (m)

Correlation analysis between different speed and radius indicates a positive correlation i.e. when the radius increases all the speed (speed of 2, 3 and 4 wheeler, operating speed) increases accordingly. From the graph, trend line of operating speed vs radius indicates a higher correlation with R^2 value of 0.837.

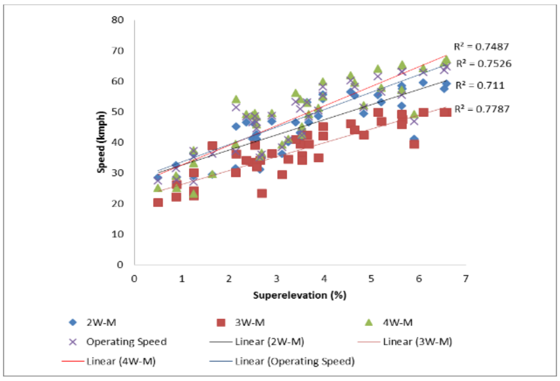

Figure 5- Speed (kmph) vs. Super elevation (%)

The correlation between superelevation and different speeds indicates a positive trend and therefore when the superelevation increases speed also increases. Trend lines show that operating Speed have a greater correlation with superelevation with a R^2 value of 0.778.

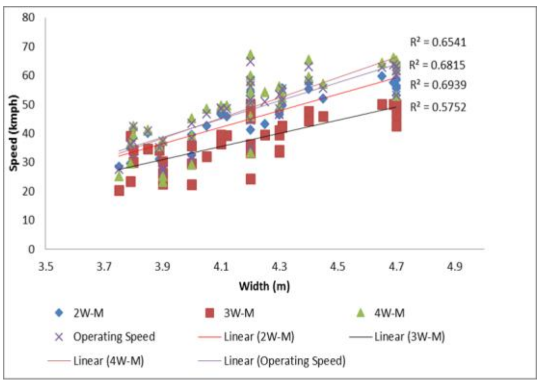

Figure 6- Speed (kmph) VS Width (m)

The correlation between width of carriageway and dependent variable is also a positive trend. Therefore whenever the width increases speed also increases. Trend line of operating speed indicates a higher value of R^2 0.693. Correlation matrix for all the independent variable and dependent variables are given below;

Table 1- Correlation matrix between Geometrical elements & Operating Speed of 2W

	W	R	e	2W-M
W	1			
R	0.792	1		
e	0.697	0.855	1	
2W-M	0.832	0.907	0.843	1

Table 2- Correlation matrix between Geometrical elements & operating speed of 3W

	W	R	e	3W-M
W	1			
R	0.792	1		
e	0.697	0.855	1	
3W-M	0.758	0.878	0.882	1

Table 3- Correlation matrix between independent variables & speed of 4W

	W	R	e	4W-M
W	1			
R	0.792	1		
e	0.697	0.855	1	
4W-M	0.808	0.899	0.865	1

Table 4- Correlation matrix between Geometrical elements & operating speed

	W	R	e	Op.Speed
W	1			
R	0.792	1		
e	0.697	0.855	1	
Op.Speed	0.825	0.915	0.867	1

5.2 Results and Comparison

Regression Model Equations are given below;

$-70286 + 0.041R + 1.946e + 9.700W = Op.\ Speed$ (5)

$-9.00 + 0.039R + 1.331e + 10.022W = 2W\text{-}M$ (6)

$6.496 + 0.025R + 2.453e + 4.250W = 3W\text{-}M$ (7)

$-11.901 + 0.042R + 2.537e + 10.439W = 4W\text{-}M$ (8)

Table 5- Actual Operating Speed Measured

Curve No.	Observed Operating Speed			
	General	2W-M	3W-M	4W-M
1	43.5	39	35.7	46
2	49	46.5	39.1	49.3
3	35.1	33.2	21.5	34.3
4	36.2	32.3	35.1	36.2
5	44.3	40.1	36.1	46.2
6	38.1	37.2	31.3	38.4
7	48.6	46.8	36.2	49.3
8	43.1	39.9	36	46.4
9	27.8	28.1	26.7	25.9
10	65.1	59.9	50.2	66.3

Table 6- Predicted Operating Speed using Regression Model

Curve No.	Predicted Operating Speed by Regression Model			
	General	2W-M	3W-M	4W-M
1	43.4	40.59	35.25	44.01
2	45.12	42.8	34.81	45.23
3	35.68	33.49	29.75	35.34
4	38.94	36.7	31.55	38.88
5	43.77	40.86	35.56	44.36
6	37.46	35.98	28.96	36.64
7	43.3	40.81	34.33	43.5
8	43.53	40.63	35.42	44.1
9	34.22	33.07	26.56	33.13
10	65.01	60.41	50.29	67.75

Table 7- Predicted Operating Speed by ANN

Curve No.	Predicted Operating Speed by ANN Model			
	General	2W-M	3W-M	4W-M
1	44.02	40.21	33.86	43.85
2	47.48	45.92	36.18	46.04
3	32.34	31.09	26.6	30.48
4	35.31	34.05	28.81	34.37
5	45.77	41.18	34.54	45.42
6	37.86	35.61	28.01	36.86
7	46.60	42.46	34.39	46.25
8	45.2	40.83	34.29	44.9
9	29.82	29.22	23.52	26.68
10	62.15	59.13	56.33	60.25

VI. CONCLUSION

The effects of geometrical features of horizontal curves on the operating speed of vehicles are studied. The correlation between the various parameters and the operating speed are displayed in the form of correlation graphs. For the purpose of creating a model, only those parameters which are independent needed to be used .Factors such as Degree of curvature and deflection angle were found to be correlated with radius of curvature. These were hence expelled at the time of model creation. The two models were created and compared for their accuracy. The regression model was found to have a prediction accuracy of +/- 7%, 12%, and 9% for two, three and four wheelers. The prediction accuracy of all the vehicles in general was +/-6%.On the other hand, the ANN model had an accuracy of +/- 4%, 10%, 5.46% for two, three and four wheelers. The prediction accuracy of all the vehicles in general was comparatively high, with an accuracy of +/-3.94%.Hence it can be concluded that though both these models were able to predict the operating speed, the ANN model was found to be more accurate.

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Lins Paul Kuriakose, et. al. "Comparative Study of Operating Speed of Vehicles on Horizontal Curve using ANN & Regression Models." *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (6), 2021, pp 01-05.