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Modelling of Operating Speed in Horizontal Alignment of Two-Lane Rural Highway

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Abstract: Road accidents are most frequent and cause damage to human life and property. One of the main causes of road accidents is lack of geometric design consistency. Design consistency is defined as the relationship between the geometric characteristics of a highway which is comfortable for safe driving. The objective of this project is to develop a new operating speed model in which geometric features of alignment are considered and also to evaluate design consistency with operating speed. Geometric survey was carried out on the study stretch. Then spot speed data collection was conducted manually. From the spot speed data collected, 85th percentile speed was computed for all type of vehicles. Database include radius of curvature, curve length, deflection angle, width of road, level difference, degree of curvature, superelevation, tangent length, traffic volume, sight distance and skid number. Scatter plot was plotted to find out relationship between operating speed and various geometric parameters. Then a correlation matrix was formed from the database using the software SPSS. Significant variables found to be different for different types of vehicles. Multiple linear regression analysis was performed. Models having greater R2 value for each vehicle type were identified. Then validation was performed and selected model with least root mean square error value. Also, consistency evaluation was done based on Lamm's criteria. Based on the criteria curves were identified as relatively good, fair and poor for all type of vehicles. This criterion makes a designer to make suitable modifications in the design from the safety point of view.

Keywords: Design consistency, Operating speed, Geometric parameters, Consistency.

I. INTRODUCTION

A growing concern has brought more attention to road safety to the fact that traffic collisions have increased tremendously in recent years. Road fatalities are complex events involving a variety of factors such as highway geometry, driver behaviour, weather conditions, speed limits and human factors. As the number of accidents increasing day by day the design consistency evaluation is an important component in highway design and an important tool in evaluating road safety. Design consistency refers to the conformance of highway geometry with driver expectancy. Identifying any inconsistency on a highway and treating them in a better way can significantly improve its safety performance. Mainly design consistency depends on four factors. They are operating speed, vehicle stability, alignment indices and driver workload.

The operating speed method is most common for evaluating the design consistency of highways. The operating speed on a highway is the speed at which the vehicles generally operate on that highway. Operating speed is generally represented by the 85th percentile speed, denoted as V85. Speed can be described as one of the most important factors that road users consider in evaluating the efficiency of a certain route. In addition, along with other factors such as travel time and cost, speed may affect decisions made by drivers in selecting between different route alternatives.

II. OBJECTIVES

The main objective of the project is to develop operating speed models to evaluate the consistency of horizontal alignment designs for rural two-lane highways.

The core objectives are listed below;

- To assist the practitioners towards the best practice in highway geometric design.
- To analyze and develop the operating speed model for two lane rural highways.
- To identify most geometrical design features that affect operating speed.
- To evaluate design consistency with operating speed.

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III. METHODOLOGY

A. Study Stretch Identification

A handheld GPS was used for preliminary data collection and identification of study routes. The horizontal curves in the selected stretch having a tangent distance of 100m or more were selected. The study stretches identified includes 20 curves in SH 74 (Vazhakkode to Pazhayannur route), 16 curves in SH 39 (Kulapully to Perumbilavu route) and 12 curves in SH 50 (Ottupara to Pannithadam route).

B. Data Collection

The detailed geometric data collection for the curves in the identified study stretch was accomplished with the help of total station survey. Skid resistance for each curve are measured with the aid of British Pendulum skid resistance tester. The tangent distance was measured using an instrument called rodometer. Data from total station were later exported to AutoCAD software for generating plan and profile. Details like radius of curve, length of curve, rate of super elevation, gradient and tangent length were extracted from the drawings. Accident data are generally maintained by Police Department.

In the survey, spot speed was done manually. By manual method, spot speed may be estimated by measuring the time it takes a vehicle to travel between two defined points on the roadway a known distance apart. The observer is positioned higher than the study area and was looking down. When the front wheels of a vehicle cross a mark at the beginning of the predetermined study length, the observer starts the stopwatch. The stopwatch is stopped when the front wheels of the vehicle passes the reference line in front of the observer. The time taken to pass this fixed distance was recorded. The categories of vehicles considered are two wheelers, three wheelers, LCV, LMV and MCV.

C. Data Analysis

Bar chart diagrams and pie chart diagrams are prepared using the accident data collected from police stations. Preliminary analysis of accident data includes yearly variation of accidents, hourly variation of accidents, vehicle wise variation of accidents, driver's age wise variation of accidents. Yearly variation of number of accidents is goes on decreasing from year to year and the accident case are more coming under grievous one that is under IPC section 338. So, the improvement of geometrical features and safety measures helps to reduce the number of accidents. The number of accidents is also analysed in percentage. The monthly variation shows that on some specific months the rate of accidents is very high. From the chart it can be seen that on January, April, August, December months the rate of accidents is high. It is because of the periodical changes like vacation time, religious trip time the rate of accidents may vary.

A quantitative relationship between design consistency and operating speed is an important tool in the evaluation of the design consistency in road safety. In this study, several trials were undertaken in order to predict most consistent speed model on two lane rural highways with different significant variables. To explain relationship between various geometric as well as traffic volume parameters and operating speed, scatter plots has been plotted. One of such scatter plots is shown in Fig. 1. It helped to know the relation which can be used for the development of speed models. For this purpose, 85th percentile speed for each category of vehicle in every curve was calculated by plotting graphs. The various parameters selected for consistency evaluation are radius of curvature, superelevation, level difference, deflection angle, degree of curvature, tangent length, width of pavement, shoulder width, traffic volume, sight distance and skid number. From the graphs that were plotted helped to understand various geometric relations that exist between the operating speed and various geometric parameters.

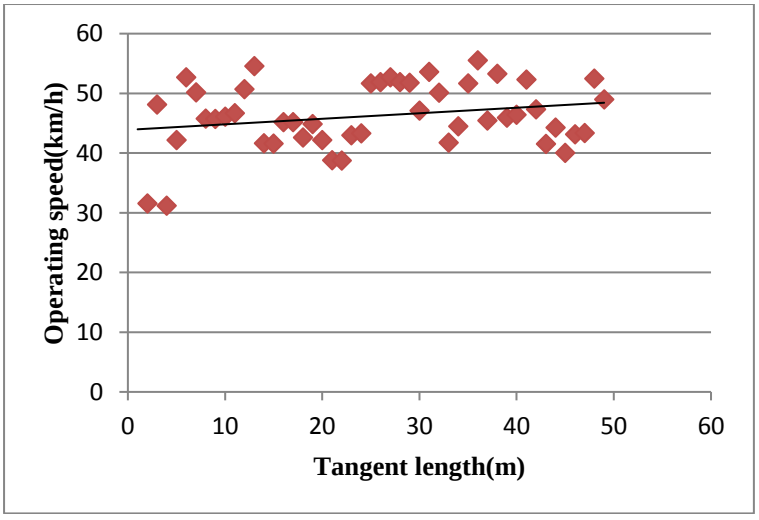

Fig. 1. Operating speed Vs tangent length for two-wheeler

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D. Model Development

The speed models were developed using multiple linear regression method. For that the assistance of SPSS (statistical package for social science) software was taken. For finding the correlation between the significant variables, correlation matrix is developed using SPSS software. The correlation matrixes for each category of vehicles are considered. It helps to find the most significant variable among them and it helps for modelling. In this study operating speed is taken as dependent variable and others as independent variables. Some of the key features of regression analysis is that it can use unlimited number of independent variables for a single dependent variable. It is the best analysis for predicting the future demand and optimization of the obtained sample. Data of about 48 horizontal curves was collected. Several trails were performed and the most significant one is only presented. For the better models, following conditions were adopted in the analysis. There should not be multi collinearity between the independent variables. The coefficient of determination (R2) must be significant. The t statistic value should be significant. It must have a value of at least '2' for significance to be established.

From the 48 data collected, analysis is performed by taking 38 samples and remaining 10 is taken for validation. Graphical plots were drawn with observed and predicted values and a 45 degree line is drawn through the origin. One of such validation graph is shown in Fig. 2. If the model is good the values of dependent variable lie on the 45 degree line. The following Table 1 shows the model with the corresponding R2 value and RMSE value.

Table I Models with Their R2 and RMSE Values

Type of vehicle	Model	R^2	RMSE
Two-Wheeler (2W)	V_{85} = 48.595 + 0.012RC -0.031TL	0.279	3.647291
Three-Wheeler (3W)	V_{85} = 46.828 - 0.112DC - 0.096SD	0.238	3.654951
Light Commercial Vehicle (LCV)	V_{85}= 53.132 + 0.001RC^2 - 0.041 TL	0.206	6.791195
Light Motor Vehicles (LMV)	V_{85}= 53.034 - 1.226SE + 0.008TV	0.201	6.613435
Medium Commercial Vehicles (MCV)	V_{85}= 46.062 + 0.001 RC^2 + 0.255$\sqrt{V}$ - 1.060$\sqrt{SD}$	0.216	4.917229

From the validation graphs it can be seen that most of the equations are very close to 45-degree line so it means that the models are capable to predict the future operating speed. All are good models to predict the operating speed.

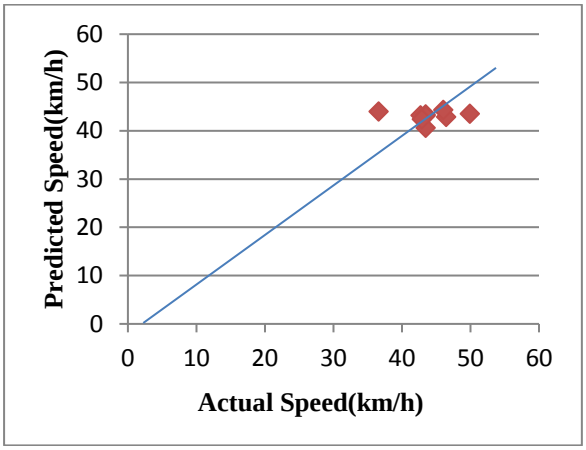

Fig. 2. Validation graph for three-wheeler

E. Evaluation of Design Consistency

Consistency evaluation was done based on Lamm's criteria in which a design is "good" if the magnitude of difference in 85th percentile speeds from approach tangent to the curve is less than 10 km/h ; a design is "fair" if the magnitude of difference in 85th percentile speeds is between 10 km/h and 20 km/h ; a design is "poor" if the magnitude of the difference in 85th percentile speed is greater than 20 km/h. Based on the above criteria, the number of good, fair and poor curves in each stretch is shown in Table 2.

Table II Evaluation Result

Stretch	State Highway	Good	Fair	Poor
Kulapully to Perumbilavu	50	8	6	1
Ottupara to Pannithadam	39	7	4	0
Vazhakkode to Pazhayannur	74	11	5	2

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IV. CONCLUSION

Data collection of almost 48 curves is done in this study. The operating speed of two wheelers, three wheelers, LCV, LMV and MCV are taken. The geometric parameters influencing operating speed are different for each category of vehicles. The speed models were developed using multiple linear regression method. By observing the models of each category, traffic volume, radius of curvature, sight distance, tangent length, super elevation and degree of curvature are the large influencing parameters with the operating speed. The models that are developed through this study will be a helpful measure for the future design projects and their significance level can also be identified from the results. Speed variation is one among the criteria which causes accidents. Results of design consistency evaluation show that twenty six sections were under good design, fifteen sections were under fair design and three sections were under poor design. By improving different techniques to control the operating speed, the number of accidents can be limited to a certain extent.

V. SCOPE AND RECOMMENDATIONS

Better models can be developed including the road parameters, camber, shoulder width and type etc. Also, good models can be generated for all type of vehicles by incorporating more number of samples.

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BIOGRAPHY

Dona Joy is born and brought up at Ernakulam District of Kerala. She was born on 17th April 1996. After schoolings, she took Bachelor of Technology in Civil Engineering from Mar Baselios Institute of Technology and Science, Kothamangalam, Ernakulam in the year of 2018. She is pursuing Masters Degree in Transportation Engineering in Jyothi Engineering College, Cheruthuruthy, Thrissur, which will be completed by the year of 2020.