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# Influence of Geometric Design Characteristic on Safety Under Heterogeneous Traffic Flow

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**Abstract**: Road fatalities are complex events involving a variety of factors, including highway geometry, driver behavior, weather conditions, speed limits and human factors. As the number of accidents increasing day by day the design consistency evaluation is becoming more significant. Geometric design consistency is an important component in highway design and an important tool in evaluating road safety. Mainly design consistency depends on four factors. They are vehicle stability, operating speed, and driver work load and alignment indices. Operating speed method is the more common method for evaluating the consistency of highways. The operating speed of a highway is the speed at which motor vehicles generally operate on that highway. The geometric characteristics of plain terrain, two lane rural state highway road of Kerala, has been assessed to understand the effect on the operating speed of vehicles. Vehicles considered in the model is 2 wheeler, 3 wheeler, light motor vehicle, LCV & MCV. The effects of design elements such as horizontal and vertical curves, lane width, shoulder width, super elevation, median width, curve radius, sight distance, etc. on safety will be taken. Research related to geometric characteristics showed that few variables have significant effect on the safety of roadways. The relationship between operating speed and road geometric design is examined through results of studies made in different localities. Statistical modelling approaches by SPSS software is used for model development**.**

**Keywords**: Geometric elements, Operating speed**,** Design consistency, SPSS software

## I. INTRODUCTION

As per the World Road Statistics (2008) report of International Road Federation, India is one of the major contributor to road crash fatalities. About two-third of the fatalities that takes place in India is on National Highways and State Highways, in rural areas. Vehicles in rural highways are less interrupted by other vehicles and drivers are able to move at their desired speed, permitted by the geometry of road. Studies showed that more than 50% of fatal crashes in rural highways take place at curves. This happens when a driver encounters with an unexpected change in alignment along a highway. Many studies underlined the relationship between crashes and curve geometry. Hence, a good design of highway geometry necessitates proper coordination of straight and curved sections, so that drivers will not be surprised by a change in the alignment. In other words, any improper design of geometry leads to unnecessary speed changes. If this variability in speed demanded by the geometry is beyond safe limits, the driver may take on an inappropriate manoeuvre. As speed on highways is comparatively high, any erroneous driving manoeuvre may result in crashes of high severity. Such a road design is generally considered to be inconsistent. Evaluating the consistency of geometric design is one of the promising strategies for improving the rural highway safety as sections that lack design consistency experience high collision occurrences. The available methods for evaluating consistency are speed based, vehicle stability based, alignment indices based and driver workload based. Among the available methods, operating speed based approach can be considered as the most efficient and widely used. This is because speed is a visible indicator of consistency. Also, operating speed and speed variations can be easily observed and measured.

This paper focuses specifically on highway geometry, its effect on the speed of vehicles and its effect on safety. The operating speed of a highway is the speed at which motor vehicles generally operate on that highway. AASTHO defines the operating speed as “the highest overall speed at which a driver can travel on a given highway under favourable weather conditions and under prevailing traffic conditions without at any time exceeding the same speed as determined by the design speed on a section-by-section basis.”The 85th percentile of a sample of observed speeds is the general statistic used to describe operating speeds on a geometric feature. Thus, operating speed, usually termed V85, is defined as the 85-th percentile of the speed distribution under free flow conditions. It represents the speed scenario at a given section. Operating speeds on two-lane rural roads depend on many factors related to drivers, vehicles, roadway

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environment, radius of a horizontal curve, curvature change rate, grade, length of the horizontal curves, deflection angle, sight distance, super elevation rate, side friction factor and pavement conditions.

## 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 models are helpful for feasibility studies and for analysis of design alternatives. They can be used to analyze an existing road, detect failures, and study improvement alternatives. Geometrical data are obtained from the total station survey. And speed data required are taken by spot speed survey.

The core objectives are listed below

- To identify most geometrical design features that affect operating speed
- To analyze and develop the operating speed model for two lane rural highways

## III. METHODOLOGY

### A. Study Area Selection

The study area selected was part of three state highways in Kerala. The curves for the study are selected on some criteria's. A curve should lie in a minimum tangent length of 100m distance and the grade on the curves should be zero or nearer to zero. Radius of curve has greater importance on road safety. Accidents occur largely on sharp curves. Those curves which satisfy the requirements were selected. It is necessary to have maximum number of curves within shortest distance satisfying the requirements. Three study stretches were selected was:

- Kulapully to Perumbilavu (SH39,SH23-31KM)- 36 Curves
- Pannithadam to Ottupara (SH50-16KM)- 24 Curve
- Vazhakode to Pazhayannur (SH73-18KM)- 27 Curves

### B. Data Collection

Mainly three types of data are collected for the study, Geometric data, speed data and accident data. The geometric data collected for this study included information about the horizontal curves. For a horizontal curve, the data obtained are Radius of the curve (R), length of the curve (LH), degree of curvature (D), deflection angle (Δ) and length of the preceding tangent section (PTL), width of the road, level Difference at midcurve, superelevation, sight distance etc.

TABLE I. Summary of Geometric Details

| | Radius of Curve (m) | Curve length (m) | Deflection Angle (Deg) | Width of the road (m) | Super elevaton (m) | sight distance |
|---|---|---|---|---|---|---|
| Minimum | 899.64 | 109.68 | 63 | 13.89 | 8.10 | 41.1 |
| Maximum | 18.33 | 15.39 | 5 | 4.93 | 0.02 | 10.8 |
| Average | 200.58 | 51.09 | 20.43 | 6.86 | 3.01 | 21.25 |
| Standard deviation | 166.55 | 20.50 | 12.70 | 1.11 | 2.25 | 7.77 |

Accident data are generally maintained by the Police Department. Accident data were recorded in the First Information Report and accident data for the past three years (2013, 2014, 2015, 2016 and 2017) were collected from about 9 police stations. Spot speed survey were done by two methods. By manual method aided with an mobile application and by using TIRTL.

### C. Data Analysis

Bar chart diagrams are prepared using the accident data collected form police stations. A number of bar charts were prepared on various concept. The preliminary analysis of accident data include:- Yearly variation of accident, Distribution by type of accident, Monthly Variation of accident, Hourly variation of accident, Vehicle wise variation of accident and Driver's age wise variation of accident. Operating speed is one of the most prominent methods that can be used for the evaluation of design consistency on highways. In this chapter the geometric as well as traffic volume parameters that affect operating speed as a part of design consistency evaluation is discussed. Operating speed is a

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common and simple measure of design consistency. A quantitative relationship between design consistency and operating speed is an important tool in the evaluation of the impact of design consistency in road safety. The assessment of operating speeds affords the opportunity to assess the expected speed changes of individual vehicles traversing successive road elements. By reducing such speed changes, there is a greater chance of enhancing traffic flow and improving safety performance.

To explain relationship between various geometric as well as traffic volume parameters and operating speed scatter plots has been plotted. Almost 60 scatter plots were plotted. It helps 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(Fig.1).The plots are drawn between the operating speed and geometric details. In this study, correlation of various geometric parameters with operating speed were considered.

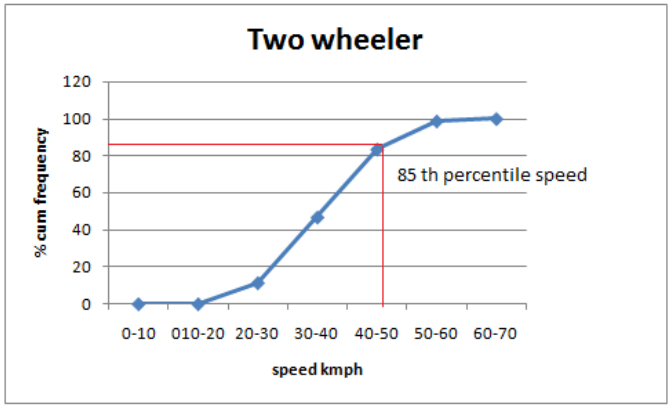


Fig.1

85thpercentile speed of every category of vehicle in each curve was calculated and tabulated. It is the operating speed parameter that was used. After the total station survey the drawings were drawn in AUTOCAD. From the drawings the values of radius of the curve, curve length, deflection angle, width of pavement, level difference is obtained. Superelevation and degree of curvature was found out by using formulas. Traffic volume is also an important factor the effects the operating speed. Traffic volume was found out by multiplying the number of the vehicles with their respective PCU factor. Fig.2 to Fig.4 provides the information about some of the variables and their justification for use in consistency evaluation.

**For two wheelers**

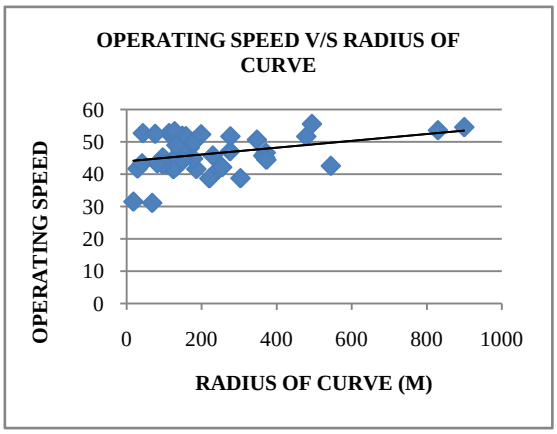


Fig.2

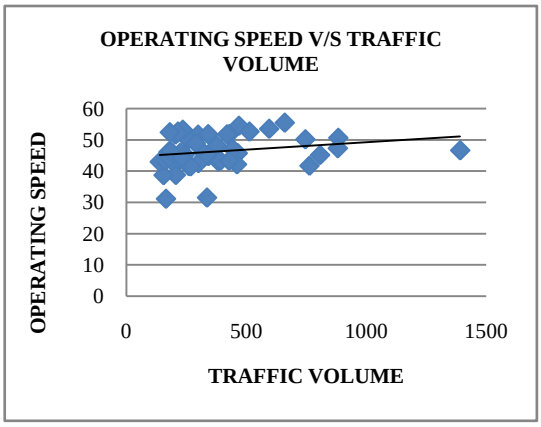


Fig.3

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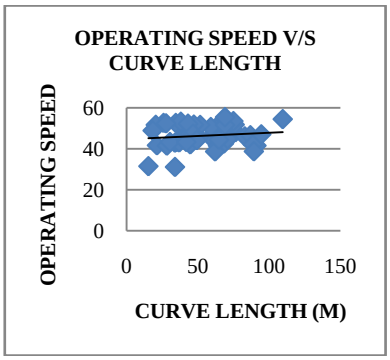


Fig.4

### D. Model development

The models were developed using multiple linear regression method. For that the assistance of SPSS software and Microsoft excel was taken. Multiple linear regression analysis helps to predict the value of a variable based on the value of two or more other variables. The variable to be predicted is called dependent variable. 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 several conditions were adopted in the analysis

a)There should not be multi collinearity between the independent variables
b) The coefficient of determination (R2) must be significant
c) The t statistic value should be significant. It must have a value of at least '2' for significance to be established. The parameters will be change according to the type of vehicle. The obtained most significant models are tabulated below and their corresponding R2 value is also given in Table 2.

TABLE II. Safety Evaluation Models

| Type of vehicle | Models | $R^2$ | RMSE |
|---|---|---|---|
| Two Wheeler (2W) | V85 = 42.44 + 0.022RC - 0.404DC - 0.199CL + 0.486DA + 0.328TV(1/2) | 0.431 | 1.625 |
| Three Wheeler (3W) | V85 = 43.673 - 0.231DC +0.96WR +0.715e - 1.243SD(1/2) | 0.338 | 2.87 |
| Light Commercial Vehicle (LCV) | V85= -72.108 + 47.701WR(1/2) +56.793e(1/2) – 1.051TL(1/2) + 0.512TV(1/2) – 219.35LD(1/2) | 0.344 | 7.2 |
| Light Motor Vehicles (LMV) | V85= -80.53+ 48.259WR(1/2) +59.743e(1/2) + 0.553TV(1/2) – 234.912LD(1/2) | 0.473 | 6.84 |
| Medium Commercial Vehicles (MCV) | V85= -42.007+ 28.494WR(1/2) +11.672e(1/2) + 0.539TV(1/2) – 70.219LD(1/2) | 0.314 | 6.95 |

## IV. CONCLUSION

Geometric details and operating speed of almost 48 curves are taken for this study. Operating speed of Two wheelers, Three wheelers, LCV, LMV and MCV are taken. For each category of vehicle the influencing geometric parameters are different. The models were developed using multiple linear regression method. By observing the general trend of the models of each category, traffic volume, width of road, super elevation and level difference are large influencing parameter 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 be also identified from the results. Speed variation is one among the criteria which causes accidents. Over speed is one of the major causes that identified. By improving different techniques to control the operating speed and geometric parameters the range of accidents can be limited to a certain extent.

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## V. FUTURE SCOPE

Studies can be further extended to vertical curves, multiple curves and combined curves.

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