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EFFECT OF HIGHWAY GEOMETRICS ON ACCIDENT MODELING

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Road accident prediction plays an important role in accessing and improving the road safety. Fuzzy logic is one of the popular techniques in the broad field of artificial intelligence and ability to improve performance similar to human reasoning and describe complex systems in linguistic terms instead of numerical values. In this study, a system was established based on Fuzzy Inference System (FIS) in which output data such as traffic Accident Rate (AR) and input data such as various highway geometric parameters. The study was conducted on two road segment from plain and rolling terrain highway and two road segments from hilly and mountainous terrain highway within the rural area of the Indian Territory. Two Highway Accident Rate Prediction Models (HARPMPRT and HARPMHMT) were developed due to the complexity of geometric parameters of rural highway on different terrain conditions which takes horizontal radius, superelevation, *K*-value, vertical grade and visibility as input variables and Accident Rate (AR) as output variables. The findings show that the proposed model can be effectively applied as a useful Road Safety tool capable of identifying risk factors related to the characteristics of the road and great support to the decision making of incident management in Intelligent Transportation Systems.

Keywords: Topographic Survey, Fuzzy Logic, Accident Rate, Digital Terrain Model, Triangulation Integrated Network, Horizontal Radius, Deflection Angle, Horizontal Arc Length, Superelevation.

1 INTRODUCTION

Motor vehicle accidents kill about 1.2 million people in a year world-wide and the number will grow to more than 2 million in 2020 unless steps are taken; a study released by the World Health Organisation (WHO) and the World Bank. [Washington: Article-Traffic accidents becoming one of world's great killers, By Matthew Wald, April 8, 2004]. Any design solution mitigating this kind of individual human behaviour cannot be predicted, only some safety rules can be enforced. Also, vehicle factors, related to mechanical behaviours of vehicles are not the scope of civil engineering study. Hence, road factors are only considered as part of this study. It is very important for the highway to establish a harmony between all the three factors at the design stage of a highway. With a geometrically good design, it is possible to compensate for the other factors and thus decrease the number of traffic accidents.

2 LITERATURE REVIEW

Lin (1990) studied on flattening of horizontal curve on rural two lane highways and found that horizontal curves on highways are on average more hazardous than tangent

sections. Hassan *et al*. (2003) found that perception of the driver of the road features ahead is an important human factor. Voigt *et al*. (2009) studied operational and safety evaluation of alternate horizontal curve design approaches on rural Two-Lane highways. Yingxue (2009) analysed the relation between highway horizontal curve and traffic safety. Aram (2010) found that degree of horizontal curve, length of curve, super elevation, transition length, shoulder width and ADT responses are the important independent effective variables. Fitzpatrick *et al*. (2010) developed horizontal curve accident modification factor (AMF) for rural four-lane divided and undivided highways. Kanellaidis *et al*. (2011) studied highway geometric design from the perspective of recent safety developments. Donnell *et al*. (2009) studied on appraisal of the interactive highway safety design model's crash prediction and design consistency modules. Choi *et al*. (2010) studied on the safety effects of highway terrain types in a crash model. Cansiz *et al*. (2011) studied artificial neural network to predict collisions on horizontal tangents of 3D two-lane highways. Mustakim *et al*. (2011) developed accident predictive models for rural roadway in Malaysia using multiple non-linear regression method with the road and traffic flow explanatory variable. Chang *et al*. (2011) developed model for identifying accident-prone spots based on the total number of accidents. Driss *et al*. (2013) studied on traffic accident prediction system based on fuzzy logic. Iyinam *et al*. (1997) studied relationship between highway safety and road geometric design elements.

3 OBJECTIVES

The high socio-economic cost of the injuries and fatalities, occurring due to road accidents, and the need for effective policies for curbing road accidents make it imperative to study the causes of road accidents. The present study aims to detect and identify the role of alignment geometric parameters on accident and prediction of accident rate through artificial intelligence system modeling.

4 EMPIRICAL DATA COLLECTION AND EXTRACTION

For this study, two roads in plain and rolling terrain National Highway (NH) 23 and 200 and two road in hilly terrain National Highway 22 and 87 were selected. Various field data such as 3D Topographic features, Accident records and Traffic volume were collected for these roads. Careful observation and collection of such data with accuracy were carried out.

4.1 Data Collection

The topographic survey has been carried out with Total Station survey equipment at accident locations. Total Station is a high precision surveying equipment to carry out 3-dimensional feature of the existing road. This survey equipment can measure distance, angle, and coordinates with relative to the known position and calculates using coordinate geometry and triangulation. All the measurements are controlled by an internal program and interfaced via computer. The captured digital data can be downloaded into a CAD program (AutoCAD) to visualize the surveying data as vector entities. Finally, this data has been analyzed later with the design application software (MX Road) which is extensively used for highway design.

4.2 Data Extraction

To find out the geometric parameters of the existing road, topographic survey points (X, Y and Z / Easting, Northing and Elevation), road center line, carriageway edge and shoulder edge line have been imported to MX Road software and a 3-dimensional digital terrain model (DTM) was developed. Then Triangulation Integrated Network (TIN) was modeled as 3-dimensional surface. After this, geometric parameters such as horizontal curve radius and Horizontal curve length, deflection angle, super elevation / cross fall, vertical grade, vertical curve length and sight distance have been extracted.

4.3 Analysis of Empirical Data and Results

Accident analysis has been carried out in order to determine the effects of different geometric elements of the highway with accident rate of the same highway. These geometric elements are horizontal radius, deflection angle, horizontal arc length, super elevation, rate of change of super elevation, vertical gradient, vertical curve length, *K*-value and visibility/sight distance. Finally, these geometric elements are statistically analyzed and considered for model development. Some of the results are shown in Figure 1.

5 PROPOSED MODEL

In the literature studies, generally the traffic accident models were developed as statistical prediction model with limited parameters. The nature of the traffic accidents required a flexible model that can accept imprecise data. For the more complex issues, fuzzy logic is very convenient in explaining traffic accidents, in which uncertainty is principal.

Here in this proposed fuzzy logic model (shown in Figure 2), an attempt has been made to predict the Accident Rate (AR) with respect to the various highway geometric parameters. Two models have been developed due to the complexity of geometric parameters of rural highway on different terrain conditions. First one is Highway Accident Rate Prediction Model for Plain and Rolling Terrain (HARPMPRT), and second one is Highway Accident Rate Prediction Model for Hill and Mountainous Terrain (HARPMHMT).

The HARPMPRT which has been proposed provide the accident rate of the highway as output variables considering radius, super elevation, *K*-value and visibility as input variables. The HARPMHMT which has been proposed provide the accident rate of the highway as output variables considering radius, super elevation, vertical gradient and visibility as input variables.

The Proposed model quantifies the accident rate considering various geometric parameters of alignment of the highway as premise variables. As mentioned earlier, two types of model (HARPMPRT and HARPMHMT) are proposed for different magnitude of parameters of highway alignment geometrics considering terrain condition. For the complexity of the formulation, fuzzy logic has been applied in the model.

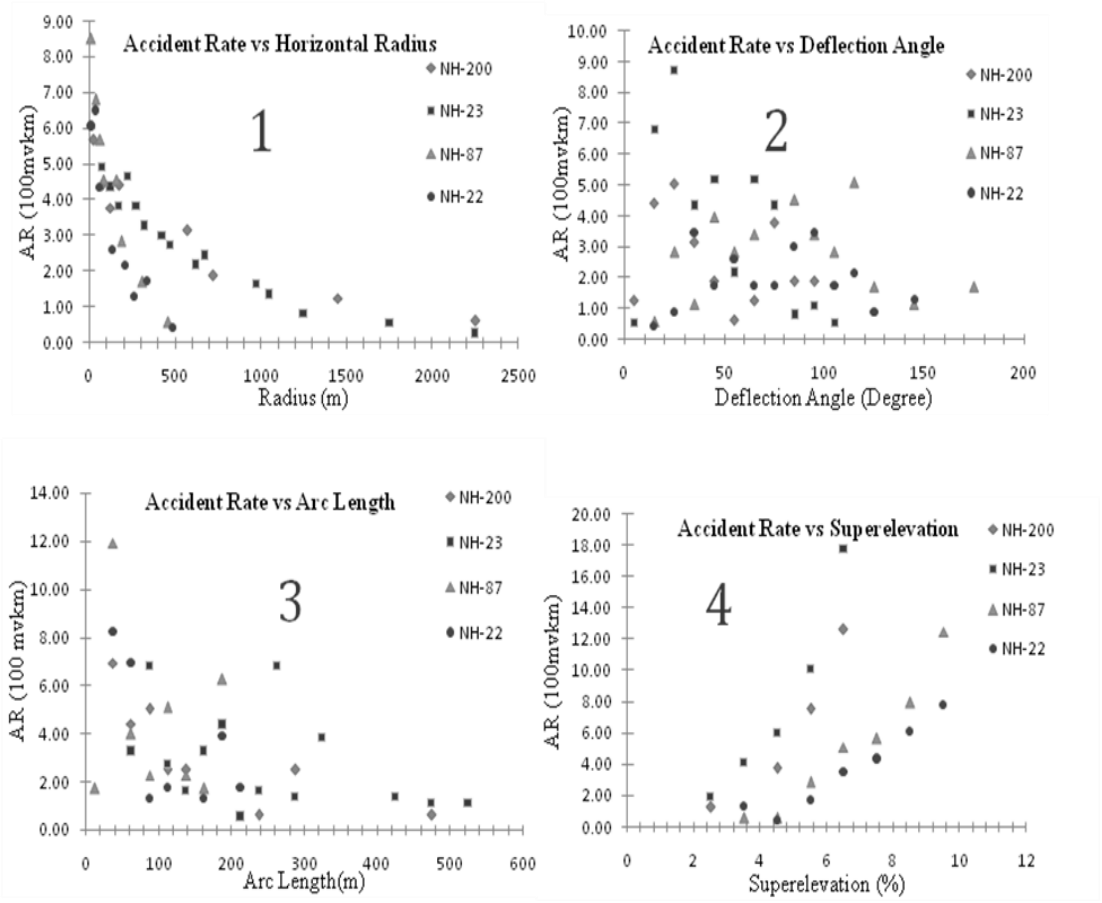

Figure 1. Accident Rates

6 VALIDATION

Here set of input data of validation set group has been entered to the Fuzzy Inference System (FIS) and each crisp output result has been taken using both Highway Accident Rate Prediction Model (HARPMPRT and HARPMHMT). Also, simulation results using the proposed model are presented.

a) The Validation of HARPMPRT and HARPMHMT: Comparison with Observation Results: the Simulation results are produced corresponding with each set of input data of validation set group and compared with the combined linear regression analysis results.

b) Model Results and Discussions: when the model results were examined in details, it was observed that as far as the simulation results are concerned, the Accident Rate (AR) value obtained from statistical analysis and obtained from the model are almost same. Hence, HARPMPRT models can be applied to predict the Accident Rate of plain and rolling terrain highway and, also, HARPMHMT model can be applied to predict the Accident Rate of hilly and mountainous terrain highway.

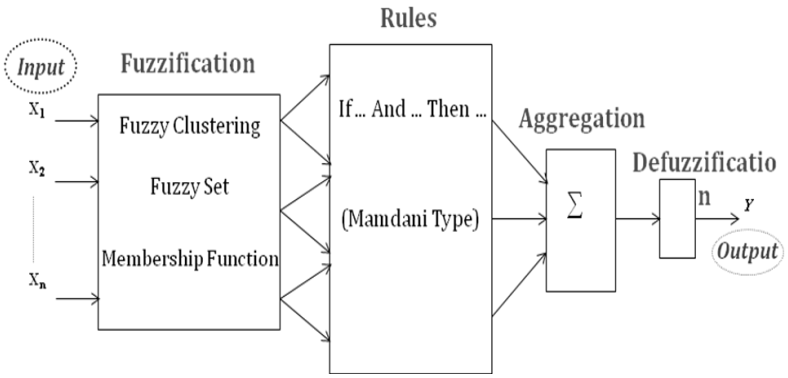

Figure 2. Schematic Diagram of Proposed Model Structure

7 SUMMARY AND CONCLUSIONS

In view of complexity of highway geometric parameters, Fuzzy Inference System (FIS) based traffic accident prediction algorithm for rural highway was proposed. Comparing to the traditional algorithms, the proposed algorithm has many advantages such as use of linguistic data set variables and apply of the expertise decisions. Two accident models were proposed which provide the accident rate of the existing highway such as HARPMPRT (Highway Accident Rate Prediction Model for plain and rolling terrain highway) and HARPMHMT (Highway Accident Rate Prediction Model for hilly and mountainous terrain highway). Simulation test shows that the detection results of the algorithm are encouraging and thus get the whole picture of traffic safety improvement based on the condition of the contributing factors.

Many developed nations have started a campaign with the motto of "vision zero" that predicted zero deaths on roads. Thus, there is so much research made on traffic accidents in developed countries. However, in India there is not enough research or study on this issue. It is suggested that more importance should be given to the Road Safety issue considering all accident causing factors and a highway safety system should be developed.

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