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Highway Accident Modeling Influence of Geometrics

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ABSTRACT :

This paper revisits the question of the relationship between rural road geometric characteristics, accident rates and their prediction, using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression. The goal of this paper is twofold; first, it develops a methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates and, second, it provides a straightforward, yet fundamentally and mathematically sound way of predicting accident rates on rural roads. The results show that although the importance of isolated variables differs between two-lane and multilane roads, 'geometric design' variables and 'pavement condition' variables are the two most important factors affecting accident rates. Further, the methodology used in this paper allows for the explicit prediction of accident rates for given highway sections, as soon as the profile of a road section is given

Keywords: Accident rates; rural roads; Hierarchical tree based regression

INTRODUCTION:

Road safety modelling has attracted considerable research interest in the past four decades because of its wide variety of applications and important practical implications. Public agencies, such as State Departments of Transportation, may be interested in identifying accident-prone areas to promote safety treatments. Transportation engineers may be interested in identifying those factors (traffic, geometric, etc.) that influence accident frequency and severity to improve roadway design and provide a safer driving environment. The very high cost of highway accidents paid by societies around the world makes highway safety improvement an important objective of transportation engineering. Highway safety specialists can influence traffic safety either through means such as road rules, law enforcement, and education, or by applying local traffic control and geometry improvements. An overwhelming majority of previous studies have indicated that improvements to highway design could produce significant reductions in the number of crashes. Recognizing this, the Federal Highway Administration (FHWA) promotes safety and accident investigation by encouraging States to pursue the development of Safety Management Systems (SMS). And, although SMSs are not Federally required as of 1996, most States continue to work on their development, suggesting the need for improving on existing empirical models for accident measurement. Following a long line of studies concerned with identifying major factors contributing to highway accidents, this paper revisits the problem of the relationship between rural road geometric characteristics, accident rates and their prediction, using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression (HTBR).1 The goal of this paper is not only to develop a methodology that quantitatively assesses the effects of various rural road geometric characteristics on accident rates, but also to provide a straightforward, yet fundamentally and mathematically sound way of predicting accident rates. The ability to predict accident rates is very important to transportation planners and engineers, because it can help in identifying hazardous locations, sites which require treatment, as well as spots where deviations (either higher or lower rates) from expected (predicted) warrants further examination. The remainder of the paper is organized as follows. The next section provides some background necessary for the development of the methodology used in this paper. Following this, the data and methodology that were used, the estimation results, and examine the effects of various geometric characteristics on accident rates are presented and discussed. The final section of the paper summarizes the findings and offers some concluding remarks.

2. Background Much literature exists that addresses the problem of accident rate estimation, and the identification of the various factors affecting this rate. Joshua and Garber (1990) used multiple linear and Poisson regression to estimate truck accident rates using traffic and geometric independent variables. Jones and Whitfield (1991) used Poisson regression with data from Seattle to identify the daily characteristics (traffic, weather, etc.) that may influence the number of traffic accidents. Miaou et al. (1992) used Poisson regression on traffic data from 8779 miles of roadway from the Highway Safety Information System (HSIS) to establish quantitative relationships between truck accident rates and highway geometric characteristics. Their results indicate that surrogate measures for mean absolute curvature (for horizontal alignment) and mean absolute grade (for vertical alignment) are the most important variables for accident rate estimation. In a study of approximately seven thousand miles of roadway logs in Utah, Mohamedshah et al. (1993) used linear regression to predict truck accident involvement rate per mile per year, based on average Average Annual Daily Traffic (AADT) and truck AADT per lane, shoulder width, horizontal curvature, and vertical gradient. The results suggest that truck involvement rate increases with AADT and truck AADT, degree of curvature and gradient. Hadi et al. (1993), using data from the Florida Department of Transportation's Roadway Characteristics Inventory (RCI) system, estimated negative binomial (NB) regression for accident rates on various types of rural and urban highways with different traffic levels. Their results suggest that higher AADT levels and the presence of intersections are associated with higher crash frequency, while wider lanes and shoulders are effective in reducing crash rates. In that paper, the authors also provide an extensive review of earlier findings relating accident rates and geometric characteristics. More recently, Ivan and O'Mara (1997), using NB regression on 1991–1993 data from the Traffic Accident Surveillance Report of Connecticut found that annual average daily traffic was a critical accident prediction variable, while geometric design variables and speed differential measures were not found to be effective predictors of accident rates. Karlaftis and Tarko (1998), based on a county accident data set from Indiana, estimated macroscopic accident models that attempt to explicitly control for cross-section heterogeneity in NB regression that may otherwise seriously bias the resulting estimates and invalidate statistical tests. Data collected from the States of Minnesota and Washington on rural two-lane highways, estimated accident models for segments and three-legged and fourlegged intersections stop- controlled on the minor legs. Independent variables for their models included traffic, horizontal and vertical alignments, lane and shoulder widths, roadside hazard rating, channelization, and number of driveways. Results imply that segment accidents depend significantly on most of the roadway variables collected, while intersection accidents depend primarily on traffic. This brief review of some of the existing literature suggests that a variety of traffic and design elements such as AADT, cross-section design, horizontal alignment, roadside features, access control, pavement conditions, speed limit, lane width (LW), and median width, affect accident rates. And, most of these results have been based on multiple linear or Poisson and NB regression models. Much of the early work in the empirical analysis of accident data was done with the use of multiple linear regression models. As the literature has repeatedly pointed out, these models suffer from several methodological limitations and practical inconsistencies in the case of accident modelling (Lerman and Gonzales, 1980). To overcome these limitations, several authors used Poisson regression models that are a reasonable alternative for events that occur randomly and independently over time. Despite its advantages, Poisson regression assumes equality of the variance and mean of the dependent variable. This restriction (which, when violated, leads to invalid t-tests of the parameter estimates), can be overcome with the use of NB regression which allows the variance of the dependent variable to be larger than the mean. As a result, most of the recent literature has used NB regression models to evaluate accident data. But, while NB regression has been instrumental in overcoming most of the problems associated with models involving count data, it still remains a parametric procedure requiring the functional form of the model to be specified in advance, it is not invariant with respect to monotone transformation of the variables, it is easily and significantly influenced by outliers, it does not handle well discrete independent variables with more than two levels, and it is adversely affected by multcollinearity among independent variables (Hadi et al., 1993; Mohamedshah et al., 1993; Tarko et al., 1996; Karlaftis and Tarko, 1998). It is likely, for example, that while the accident models have been correctly specified, multicollinearity has inflated the variance of some of the independent variables coefficient estimates, leading to lower t-statistic values and to coefficients that are not significant and/or are counter-intuitive. In this paper a methodology which attempts to recognize the existence of the above mentioned problems and develop a framework to account for them is introduced. This methodology, known as HTBR or as Binary Recursive Partitioning (BRT) (Breiman et al., 1984), can be of assistance in overcoming some of the problems associated with multiple linear and NB regression. It should be noted that besides overcoming the above, rather theoretical problems, the proposed methodology has three additional strengths. First, it allows for straightforward and quantitative assessment of the effect of various rural road geometric characteristics on accident rates; second, it allows for the quick estimation of predicted accident rates for a given rural road section; and, third, it is easily amenable to 'if-then' statements for incorporation in expert systems which have become increasingly popular and useful in safety management. The strengths and weaknesses of the proposed methodology are demonstrated using Indiana State Police Accident Information records and Indiana Department of Transportation's Road Inventory database. The combined database includes five years (1991– 1995) of crashes on Indiana rural roads, along with the geometric and traffic characteristics for these roads.

3. Data and methodology

3.1. The data

The data used in this paper concern rural roads and come from two sources: the Road Inventory database, from the Indiana Department of Transportation (INDOT), and the Accident Information Record form the Indiana State Police. The first database contains a list of road sections and various traffic and geometric characteristics for those sections. The second database contains a description of the location and type of accidents that occurred on Indiana's roads. Combining these two yields a database that contains five years (1991–1995) of accident data for Indiana along with the traffic and geometric characteristics for the location of each accident. The availability of such data allows for inferences to be drawn on the effects of traffic and geometric characteristics on highway accidents. Further, to avoid the possibility of heterogeneity among roads with different number of lanes and based on previous findings in the literature (Hadi et al., 1993; Mohamedshah et al., 1993; Karlaftis and Tarko, 1998), road sections were grouped into two main categories: rural two-lane and rural multilane.

3.2. The methodology As previously mentioned, NB regression has accounted for most of the theoretical issues in count data research. Nevertheless, there still remain a number of issues that have not been addressed (Hadi et al., 1993; Mohamedshah et al., 1993; Tarko et al., 1996; Karlaftis and Tarko, 1998). First, NB regression, much like multiple linear and Poisson regression, is a parametric procedure requiring for the functional form of the model to be known in advance. Second, it is easily and significantly affected by outliers. Third, it cannot handle missing data well. Fourth, it does not treat satisfactorily discrete variables with more than two levels. Fifth, it does not deal well with multicollinear independent variables. HTBR is a tree-structured non-parametric data analysis methodology that was first used in the 1960s in the medical and the social sciences (Morgan and Sonquist, 1963). An extensive review of the methods used to estimate the regression trees and their applications can be found in Breiman et al. (1984). HTBR is technically binary, because parent nodes are always split into exactly two child nodes, and is recursive because the process can be repeated by treating each child node as a parent. In essence, the HTBR algorithm proceeds by iteratively asking the following two questions: (i) which of the independent variables available should be selected for the model to obtain the maximum reduction in the variability of the response (dependent variable); and (ii) which value of the selected independent variable (discrete or continuous) results in the maximum reduction in the variability of the response. These two steps are repeated using a numerical search procedure until a desirable end-condition is met.

4.Literature Review The study is an effective traffic accident modelling in minimizing the accident rates depending on road factors and finding the impact of highway geometric elements. Hence, a literature survey was carried out in the field of accident causative factors and accident prediction and optimisation modelling and presented as below.

4.1 Accident Causative Factors Overview Feng-Bor 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. As their curvatures increase, horizontal curves tend to have higher accident rates. He suggests that the differences between the 85th percentile speeds and the safe speeds have no statistically significant relationships with the accident rates. In contrast, the magnitudes of speed reduction, when vehicle moves from a tangent section to a curve, have a significant impact on traffic safety. Such speed reductions on horizontal curve with gentle grades are strongly correlated with the curvatures of the curves. Therefore, curvatures can be used as a safety indicator of the curves. Y. Hassan et al. (2003) studied on effect of vertical alignment on driver perception of horizontal curves and found that perception of the driver of the road features ahead is an important human factor and should be addressed in road design. An erroneous perception of the road can lead to actions that may compromise traffic safety and poor coordination of horizontal and vertical alignments is believed to cause such wrong perceptions. Through statistical analysis, they suggested that the horizontal curvature looked consistently sharper when it overlapped with a crest curve and consistently flatter when it overlaps with a sag curve. Zhang Yingxue (2009) analysed the relation between highway horizontal curve and traffic safety and found that curve radius, super-elevation, widening, transition curve and sight distance have the important effect on traffic accidents, Ali Aram (2010) studied on effective safety factors on horizontal curves of two-lane highway and observed that several traffic volumes and mix, geometric features of the curve, cross section, roadside hazards, stopping sight distance, curve coordination, pavement friction and traffic control devices affect the safety performance of horizontal curve. He found that degree of horizontal curve, length of curve, superelevation, transition length, shoulder width and ADT responses are the important independent effective variables. He also suggested that horizontal curves have higher crash rates than straight section of similar length and traffic composition.

4.2.Accident Prediction Model Eric T. Donnell et al. (2009) studied on appraisal of the interactive highway safety design model's crash prediction and design consistency modules and evaluated the safety and operational effects of geometric on two lane rural highways through interactive highway safety design model (IHSDM). The design consistency module can evaluate the alignment complexity and thus predict the accident. Jaisung Choi et al. (2011) studied on the safety effects of highway terrain types in a crash model and suggested that when the design speed is changed, the terrain types will have some safety effects using regression analysis. The statistical analysis was performed with an ordinal logistic regression model in order to relate several independent variables of highway geometric elements such as terrain type, tangent length, curve length, radius of curvature and vertical grade to actual crash occurrences. Through this investigation, terrain type was found to be a significant independent variable that explains crash occurrences for rural arterial roads in South Korea.

Discussion and conclusions

Much interest exists in the area of accident rate estimation, and the identification of the various factors affecting this rate. Much of the literature in this area has concentrated in identifying the factors affecting accident occurrence (accident rates), and secondarily in predicting them. The ability to predict accident rates is very important to transportation planners and engineers, because it can help in identifying hazardous locations, sites which require treatment, as well as spots where deviations (either higher or lower rates) from expected (predicted) levels warrants further examination. The aim of this paper was twofold. First, it developed a methodology that quantitatively assesses the effects of various highway characteristics on accident rates. Second, it provided a straightforward, yet fundamentally and mathematically sound way of predicting accident rates. The methodology used in this paper, known as HTBR, has a number of both theoretical and applied advantages over multiple linear and NB regression that have been commonly used in accident rate research. It allows for the quantitative assessment of the effect of various geometric characteristics on accident rates. It allows for the quick estimation of predicted accident rates for a given highway section. Finally, it is easily amenable to 'if-then' statements for incorporation in expert systems, which have become increasingly popular and useful in safety management. The methodology was demonstrated using data from the Indiana State Police Accident Information records and the INDOT's Road Inventory database

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