EFFECT OF CERTAIN ROADWAY CHARACTERISTICS ON ACCIDENT RATES FOR TWO-LANE, TWO-WAY ROADS IN CONNECTICUT

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ABRIDGMENT

This study identified and defined which roadway elements are statistically correlated with accident occurrence and evaluated the relative merit of each element as an index of accident prediction. Of the three principal factors associated with accidents, the vehicle, the driver, and the roadway, this paper considers contribution of the roadway. Four selected geometric elements, roadway width, horizontal curvature, vertical clearance, and restricted sight distance were rated for adequacy, and these ratings were then correlated with accident rates. Multiple linear regression analyses were performed to examine these relationships. The resulting correlation coefficients were quite small. Of the four geometric characteristics considered, restricted sight distance and horizontal curvature appear to have some effect on accident rates and vertical clearance appears to have no effect.

•MOTOR vehicle accidents have increased as automobile registration and population have increased. There were 3,100 fatalities on roads in 1912 and 55,800 in 1973. Though the total number of fatalities has increased from 1925 to 1973 (1), the fatality rate has decreased from 17.9 to 4.3 per 100 million vehicle miles (160 million vehicle km). Of the total 1,060 accident deaths in Connecticut in 1973, about 50 percent or 516 were fatalities resulting from motor vehicles (1). In 1973, the annual economic waste attributable to highway accidents totaled $13.9 billion for the nation. These figures indicate the enormous magnitude of the highway safety problem.

Our national goal in highway safety is to provide for a substantial reduction in the number of lives lost, in the number of crippling injuries, and in the staggering cost of property damage. The nation must take an aggressive step in support of the technological innovations and actions required to reduce this drain on the country's resources. Because of this problem, much effort has been expended in increasing overall knowledge of the factors affecting highway safety to provide information for making sound decisions about programs designed to improve safety performance.

The principal elements related to accident causation are the driver, the vehicle, and the environment, including roadway. Of these factors, roadway geometric characteristics are among the most important determinants. Roadway characteristics, therefore, may provide an effective means for predicting accident experience on a given section of roadway.

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STUDY OBJECTIVE

This research identified and defined roadway elements that are statistically correlated with accident occurrence and evaluated the relative merit of each element as an index of accident prediction. Mathematical models were developed to depict the effect of four geometric characteristics: roadway width, horizontal curvature, vertical clearance, and restricted sight distance on accident rates. Such information is useful both in the design of safe, new facilities and in improvement of existing high-accident locations for safer operation.

DATA ACQUISITION AND REDUCTION

Accident data for the 5-year period from July 1964 to June 1969 on two-lane, two-way rural state highways were obtained from the Accident Analysis Unit of the Connecticut Department of Transportation. In this study 31,211 motor vehicle accidents on Connecticut rural roads were considered. The available accident data were not stratified into fatal, injury, or property damage because of sample size requirements. For the analysis, 1,548 sections of roadway varying in length from 0.30 to 8.87 miles (0.48 to 14.20 km) were used. Each roadway section had uniform characteristics with regard to the variables considered. Highway geometric characteristics considered in the analysis were

1. Pavement width,
2. Shoulder width,
3. Horizontal curvature,
4. Vertical clearance, and
5. Sight distance restrictions.

Pavement and shoulder width were combined and rated as roadway width. Adequacy ratings for these four variables were obtained from the Connecticut Department of Transportation (2). For the calculation of ratings, actual dimension of the worst feature (i.e., least width, worst curvature) in a section was compared with the desirable geometric standard. Each individual element was evaluated empirically with a rectilinear scale of 0 to 100 points on which 50 is the threshold of adequacy. Threshold of adequacy is based on the tolerable design standards for various geometric design elements. A condition equal to standard or better was rated 100. All highway sections were rated for lowest overhead obstruction, whether or not such obstructions existed. Thus, for the sections without restrictions, the vertical clearance rating was considered to be 100 points. Restricted sight distance is defined as the shortest distance of roadway surface that can be seen by an operator of an automobile from a given point on the roadway when the view is limited by a fixed obstruction. This design characteristic was evaluated by measuring the reduction of the maximum safe speed below an assumed criterion at the location of the most restricted sight distance within a highway section under study.

These elemental ratings were then adjusted in accordance with the amount of traffic use. Adjustments for volume involved the use of a base volume (average daily traffic = 5,000) above which the ratings were reduced and below which the ratings were increased. These adjusted elemental ratings were combined into a geometric characteristic index (GCI) on a 100-point log scale. A GCI of 77 points, based on the department's previous work, was considered to be the threshold of adequacy in relation to the combined effect of all four elements rated.

For each section considered, the total number of all accidents that occurred during the 5-year period was tabulated, and total accident rate per 100 million vehicle miles (160 million vehicle km) was computed. Accident rate was used as a dependent variable. A multiple linear regression program for use on the IBM 360-65 was used with minor modifications. The computer program provided correlations between accident rates and the individual variables considered and gave regression coefficients for the model.

The computer analysis resulted in the development of four regression models given below. For equations 1 through 4, the variable definitions are

Y = accident rate,
X_1 = adequacy rating for roadway width,
X_2 = adequacy rating for horizontal curvature,
X_3 = adequacy rating for vertical clearance,
X_4 = adequacy rating for restricted sight distance,
X_5 = GCI, and
X_6 = section length in miles.

$$Y = 141.023 + 0.775X_1 - 0.527X_2 + 1.074X_3 - 0.518X_4 \quad (1)$$

where $R^2 = 0.051$. Equation 1 relates accident rate to the four geometric variables.

$$Y = 181.345 - 0.304X_5 \quad (2)$$

where $R^2 = 0.003$. Equation 2 relates accident rate to GCI.

$$Y = 180.160 + 0.794X_1 - 0.586X_2 + 0.88X_3 - 0.631X_4 \quad (3)$$

where $R^2 = 0.073$. Equation 3 relates accident rate to roadway sections with GCI = 77.

$$Y = 261.620 - 21.254X_6 \quad (4)$$

where $R^2 = 0.017$. Equation 4 relates accident rate to section length.

In addition to the above analyses, the data were classified into five ADT groups (0 to 1,400; 1,500 to 3,900; 4,000 to 6,900; 7,000 to 9,900; and 10,000 to 24,900), and a multiple linear regression model was developed for each ADT group.

DISCUSSION OF RESULTS

In this study, ratings were used, instead of actual values for various geometric variables, to indicate a comparison with the desirable standards for each geometric element. Thus, a roadway section that has adequate geometric standards can be checked for safety by this analysis.

Of the four independent variables considered in this research, accident rate was better correlated with the restricted sight distance rating than the others. As restricted sight distance rating increases, accident rate decreases. That is, accident rate is higher on roadway sections that are inadequate from the standpoint of sight distance requirements. If safety is to be built into highways, the design must provide sight distances of sufficient length to give drivers enough time and distance to make the speed and distance judgments required for vehicle control.

The next best correlation with accident rate was obtained for the horizontal curvature rating. The lower the degree of curvature of a curve was, the higher the rating was, and hence, the lower the accident rate was. This conclusion agrees with the results of studies by Raff (3), who concluded that accident rates vary with the degree of curvature and that sharp curves have higher accident rates than flat curves. Kihlberg and Tharp (4) found that 19 percent more multivehicle accidents occurred on curved segments than on straight segments (curvature and gradient under 4 degrees and 4 percent respectively).

Of the four geometric variables studied, the vertical clearance rating had no correlation with the accident rate. Most of the sections considered have unlimited vertical clearance. Low correlation was also found between roadway width rating and the accident rate. This finding agrees with that of Sparks (5) who found no significant relation between accident rate and surface width. Our study, however, indicated that, as the roadway width rating increased, accident rate also increased.

The R^2 value in equation 1 of 0.051 indicates that only 5.1 percent of the variation in the accident rate is accounted for. Similarly, equation 3 explains only 7.3 percent of the variation. R^2 for equation 2 is quite low (0.003) and indicates no relation between accident rate and GCI. This is contrary to the expected results. The correlation of accident rate with section length is also quite low ($R^2 = 0.017$). Regression equations relating accident rate to GCI, for all five ADT groups, had low R^2 values. The models are therefore not useful in making accurate or meaningful prediction of accident rates.

It was expected in the beginning of the study that the selected variables would be able to explain a larger portion of the variation in accident rate; however, results did not support this. Following are some of the possible reasons for the low correlations obtained.

1. The accident rates include intersection accidents that cluster in a short length of the section and distort the accident rate for the study section. Elimination of intersection accidents from the data may improve the results.
2. Although most of the study sections had adequacy ratings based on geometric features existing at the time of accident occurrence, the geometric features on some study sections were changed between the time of accident occurrence and rating determination.
3. Part of the reason for lack of correlation between accident rate and GCI seems to be related to the method of calculation of GCI. GCI apparently should not be a simple summation of element ratings for the variables considered, as used in this analysis; it should probably be an empirically computed value from the ratings.
4. Vehicle and driver, the other two components of the system, were not considered in this study.
5. Other geometric variables, such as grade surface type, surface texture, and control of access, were not included in this study.
6. Influence of environment and weather, such as high winds and atmospheric electricity, on accidents was also excluded.
7. Further stratification of accident data into fatal, injury, and property damage accidents and into single- and multiple-vehicle accidents may improve the correlation between the variables to a great extent.

CONCLUSIONS

Based on the analysis of available data for two-lane, two-way rural highways in Connecticut, the following conclusions seem valid.

1. No significant effect of the geometric variables on total accident rate could be found.
2. Of the four geometric variables investigated, vertical clearance had no significant effect on the accident rate.
3. Statistically, the regression equations obtained are not significant. Only 5 percent of the variation in accident rate is explained by the geometric characteristics included in this study. However, the sections with 0 to 1,400 ADT accounted for 9.75 percent of the variation in accident rate. In sections below the threshold of adequacy (GCI < 77), the variation explained is 7.3 percent. This indicates that the remaining variation may be caused by other geometric features not considered in this study and by other environmental variables and variables associated with the driver and the

vehicle. Therefore, sections with poor sight distance and sharp horizontal curvature should be given top priority in highway safety improvement programs.

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