Summary Report

HSIS

HIGHWAY SAFETY INFORMATION SYSTEM

The Highway Safety Information System (HSIS) is a multi-State safety data base that contains crash, roadway inventory, and traffic volume data for a select group of States. The participating States—Illinois, Maine, Michigan, Minnesota, and Utah—were selected based on the quality of their data, the range of data available, and their ability to merge data from the various files. The HSIS is used by FHWA staff, contractors, university researchers , and others to study current highway safety issues, direct research efforts, and evaluate the effectiveness of crash countermeasures.

Research and Development
Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

SAFETY EFFECTS OF CROSS-SECTION DESIGN ON RURAL MULTILANE HIGHWAYS

National statistics indicate that fatality rates on rural Federal-aid primary highways have been significantly higher compared to those for urban and rural Interstate highways and urban primary highways. Although this group of highways includes two-lane rural roads, an important component of the rural Federal-aid primary highways are multilane rural highways. More than 56 000 km of arterial highways in the United States are multilane, non-Interstate roads in rural areas.

Many previous studies have been conducted regarding the safety effects of various traffic and geometric roadway features. The majority of these studies were concentrated on rural two-lane roads. There have also been a few notable studies that investigated roadway cross-section design elements for suburban highways and urban streets. However, there has been limited research on the safety effects of geometric design features on rural, multilane, non-freeway highways.

This study examined the effects of various cross-section-related design elements on accident frequency and developed an accident prediction model for rural, multilane, non-freeway highways.

State Data Bases Used

The Highway Safety Information System (HSIS) data base was used for this study. In examining the existing data for the five States in the system, which has since been expanded to eight States, it was determined that supplemental information on roadway access points and roadside condition would be needed. An efficient way to collect this type of data is through the use of videodisc photologs. Videodisc photologs contain images of the roadway taken at 16-m intervals. These images can be randomly accessed in seconds under the control of a microcomputer. At the time that this study was conducted, videodisc photologs were only available for Minnesota. Consequently, only data from Minnesota were used for statistical modeling analysis. Data for accidents reported from 1985 through 1990 were used for the study.

Analysis Methods

The analysis was restricted to rural, multilane, non-freeway sections. One-way, multilane, rural streets were eliminated from the analysis. Based on consideration of the reliability of reported accident location and variance related to the accident rate estimates, a section length of 0.48 km was chosen as the minimum section length. Sections on local road systems were also eliminated due to somewhat suspect reliability of roadway data and accuracy of the location reporting of accidents on local roads.

For each multilane, non-freeway, rural roadway section, accident data that were reported over the 6-year period of 1985 through 1990 were obtained from the HSIS data base. A review of these data indicated that there were very few pedestrian and bicycle accidents reported on multilane rural roads (i.e., less than 2 percent of all reported accidents). As a result, these accidents were excluded in an attempt to restrict accidents to those that are more highly correlated to cross-section design of multilane rural road segments. In a similar manner, vehicle-animal crashes were also eliminated from the accident data base, which was subsequently employed in the modeling analysis.

Previous highway safety studies have shown that roadside conditions are important factors as both control and independent variables in the sense that they affect accident rates. While the HSIS contains a wealth of information on both accidents and roadways, data on roadside conditions are not included in the existing roadway files. As noted earlier, an efficient way to collect data for selected roadside variables is to use State roadway photologs. The HSIS is equipped with a Photolog Laser Videodisc (PLV) system that can be used to collect data for selected variables that do not exist in the HSIS data base. A specialized software application was developed to collect and integrate the supplemental data semi-automatically while using the PLV system.

A roadside hazard rating was collected from the PLV images to characterize roadside conditions. The roadside hazard rating is a subjective measure of the hazard associated with the roadside environment. The rating values indicate the accident damage likely to be sustained by errant vehicles on a scale from 1 (low likelihood of an off-roadway collision or overturn) to 7 (high likelihood of an accident resulting in a fatality or severe injury). The ratings are determined from a seven-point pictorial scale.

Preliminary data analysis and previous studies all indicate that intersections and driveways are factors that appear to be associated with roadway accident occurrence. Therefore, it was decided that data on access points (driveways, intersections, etc.) should be collected from the PLV system for the roadway sections included in the modeling analysis. In addition, the PLV system was also used in verifying other data elements for correctness. One such application for this study was to obtain supplemental estimates of median width based on the PLV images because a large number of roadway segments had an unknown median width value.

Statistical modeling analysis was performed to establish mathematical relationships between accidents and various cross-section-related roadway and traffic variables. A Poisson regression model was used in the model development. This model assumes that for a given roadway segment, the number of accidents

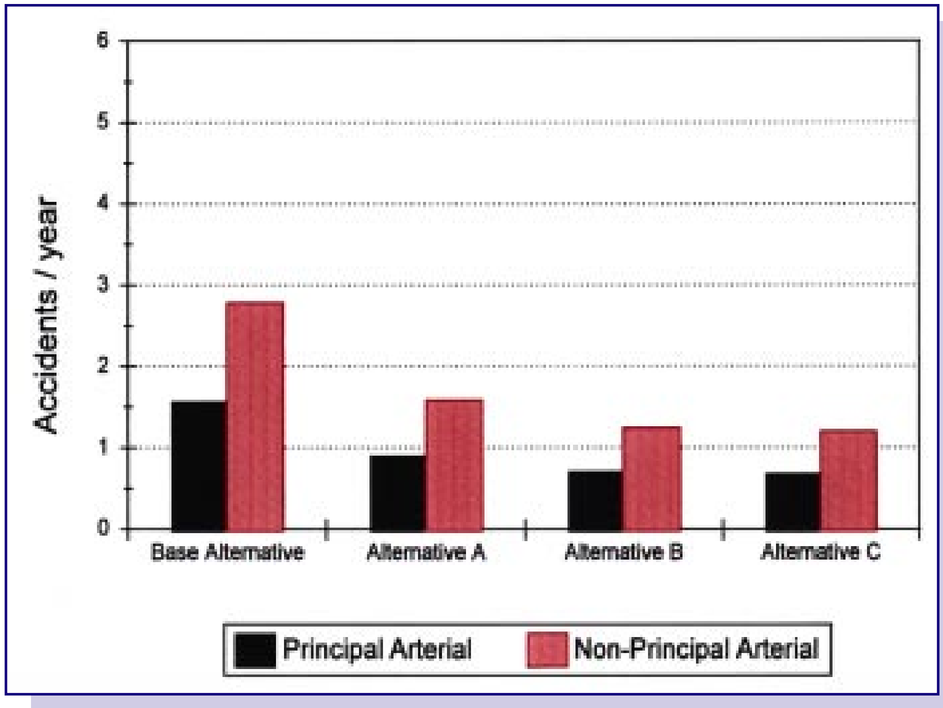

Figure 1. Predicted annual accidents by four cross-section alternatives using the model for DVKT = 6440 (DMVT = 4,000).

that occur over a specified time period is distributed as a Poisson random variable. Based on available variables in the analysis file and prior data analysis results, the independent variables considered in the modeling analysis were:

X_1 = Average roadside hazard rating.

X_2 = Access control (partial control = 1, no control = 0).

X_3 = Driveways/mile.

X_4 = Intersections with turn lanes/mile.

X_5 = Intersections without turn lanes/mile.

X_6 = Functional class (rural principal arterial = 1, rural minor arterial/collector = 0).

X_7 = Shoulder width (ft).

X_8 = Median width (ft).

X_9 = Area location type (rural municipal = 1, rural non-municipal = 0).

X_{10} = Road surface width.

X_{11} = Median type.

X_{12} = Percent commercial vehicles.

During the model development process, the last three variables were not found to greatly influence accident occurrence. Although X_3, X_4, X_5, and X_2 may appear to be correlated, the initial statistical analysis did not reveal that they were.

Results

The model development process yielded the following predictive equation:

$$Y = 0.0002(DVMT)^{1.073} e^{(0.131X_1 - 0.151X_2 + 0.034X_3 + 0.163X_4 + 0.052X_5 - 0.572X_6 - 0.094X_7 - 0.003X_8 + 0.429X_9)}$$

where: Y = Predicted annual accidents.

DVMT = Daily vehicle-miles of travel.

e = .

The above equation appears to have reasonable coefficients for a model with total accidents as a function of the 10 variables listed. That is, predicted accidents increase as a result of worsening roadside conditions, increasing exposure measures (i.e., daily vehicle-miles of travel), increasing numbers of driveways per mile, and increasing intersections (with and without turn lanes) per mile. Predicted accidents decrease as a result of increasing outside shoulder widths and increasing median widths. The model coefficients also show lower accident

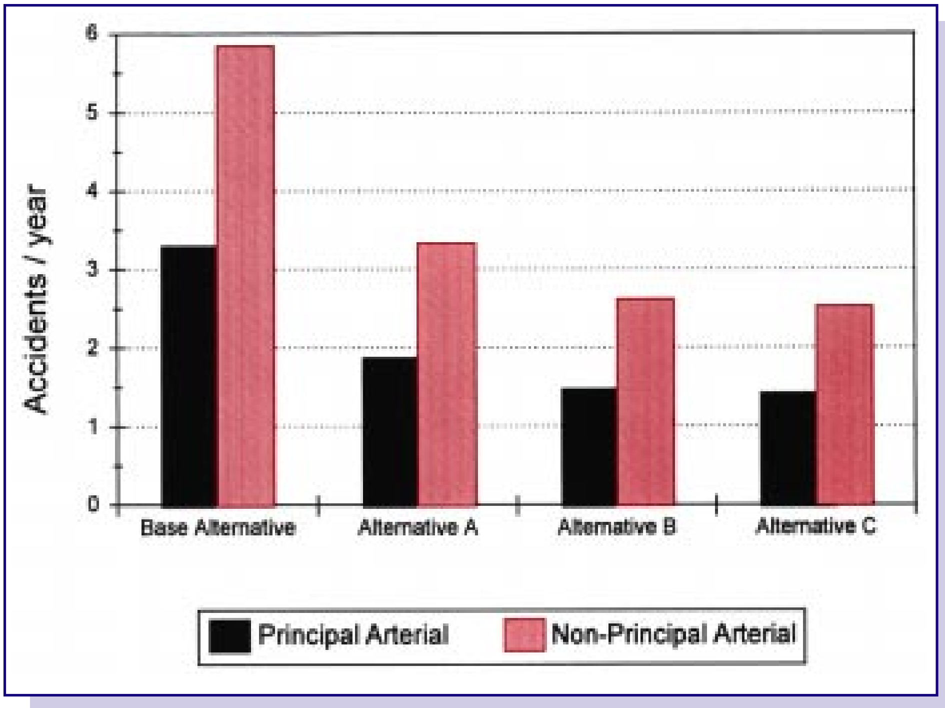

Figure 2. Predicted annual accidents by four cross-section alternatives using the model for DVKT = 12 880 (DMVT = 8,000).

frequencies on multilane roads with partial access control compared to roads with no access control, on rural principal arterials as opposed to rural minor arterials and collectors, and on rural roads outside municipal areas compared to roads in rural municipal areas. In fact, the χ^2 statistics show functional class and area location type to be among the more significant variables in the model. Guidelines for classifying roadways according to the variables of "functional class" and "area location type" were obtained from discussions with Minnesota traffic engineers. The discussions revealed that the rural municipal area is simply defined as an incorporated area in rural locations; thus, the boundaries of a municipality would be the incorporated limits. Functional classifications such as rural principal arterial highways, rural minor arterial roads, and rural collector roads are based on the definitions within the AASHTO Green Book.

This model can be used for a variety of applications, such as: (1) developing accident predictions for different rural, multilane highway design alternatives; (2) estimating the accident reductions attributed to changes in the cross section of rural multilane highways; and (3) assessing the potential safety impact of alternative cross sections when upgrading a two-lane rural road to a multilane rural highway. To illustrate these applications, figure 1 and figure 2 present predicted annual accidents for four illustrative rural multilane cross-section design alternatives under two traffic conditions, respectively. In this example, the model was applied to multilane roadway design alternatives for both principal arterial and nonprincipal arterial highways in nonmunicipal areas. The two exposure conditions being considered are 6440 DVKT (daily vehicle-kilometers of travel) (4,000 DVMT) and 12 880 DVKT (8,000 DVMT). Other roadway conditions considered in this example are 2.8 average roadside hazard rating, no access control, 0.3 driveways per kilometer, 0.18 intersections with turn lanes per kilometer, and 0.6 intersections without turn lanes per kilometer. For these specific conditions of rural multilane highways, the safety effects of the four alternatives of different cross-section designs can be quantitatively assessed. The alternatives included:

- *"Base" alternative:* An undivided highway with no shoulders (median width = 0 and shoulder width = 0).
- *Alternative A:* An undivided highway with a 1.83-m shoulder width.
- *Alternative B:* A divided highway with a 5.5-m median width and a 2.4-m shoulder width.
- *Alternative C:* A divided highway with a 9.2-m median width and a 2.4-m shoulder width.

Figure 3 depicts incremental accident reduction factors (percent of accidents that would be reduced) for alternatives A, B, and C compared to the "base" alternative under the same exposure condition, functional class, and area location type between the alternatives. In a similar fashion, the safety impact of upgrading a rural highway from a two-lane road to a four-lane highway can be derived by comparing a given accident frequency on a two-lane road to a model-predicted accident frequency for a four-lane highway, controlling for the independent variables.

Study Implications

This study benefited from the use of a more comprehensive data base and advanced data collection means through a PLV system. The data used are also more current than those in older studies. The study employed the method of Poisson regression, which represents a more appropriate model for accident count data than those used in many earlier studies.

This study represents a preliminary effort to establish a quantitative relationship between accident frequency and cross-section design elements for rural multilane non-Interstate highways. While the basic data set used for the statistical modeling analysis was relatively small and the range of variation in many of the variables of interest was quite limited, the study should be viewed as an initial step toward development of improved safety relationships linking geometric design characteristics and accident occurrence. With improved knowledge of the safety relationships, highway and traffic engineers can make more informed design decisions. As illustrated in the results section of this report, models such as this could be applied to assess the incremental safety effects among various cross-section alternatives. Additional research involving these types of models and other methodologies will result in greater understanding

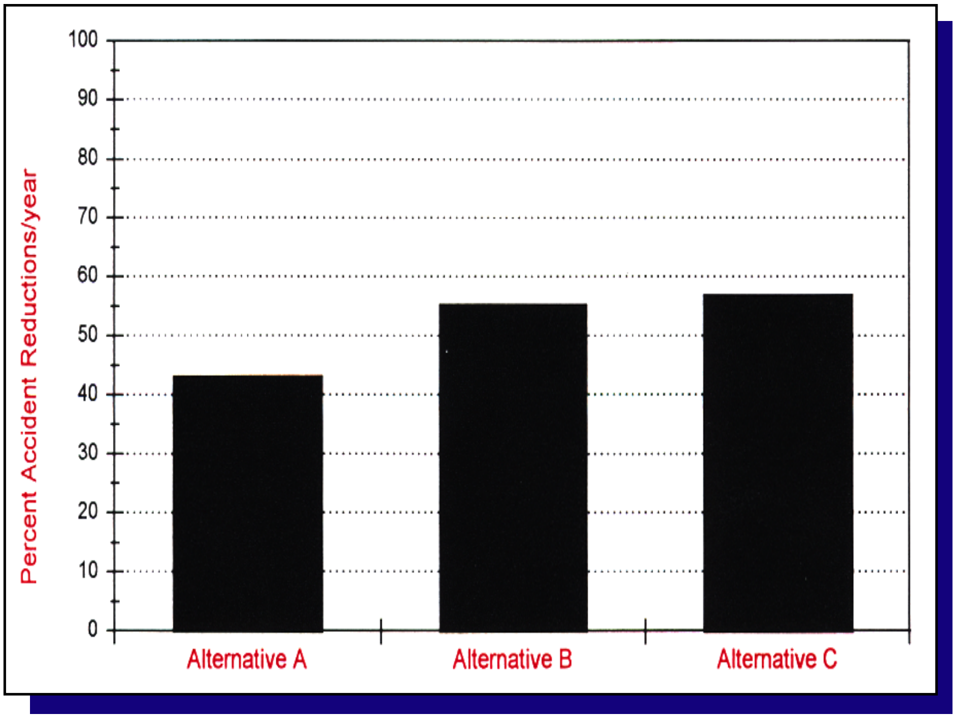

Figure 3. Accident reduction factors of three alternatives compared to base alternative using the model.

of the safety consequences of designs. This, in turn, could result in improved highway designs and, ultimately, enhanced highway safety.

For More Information

This study was conducted by Jun Wang (LENDIS Corp.), Warren E. Hughes (Bellomo-McGee, Inc.), and Richard Stewart (Highway Safety Research Center of the University of North Carolina) as part of the HSIS support contract. The final report will be published by the Transportation Research Board as part of an upcoming *Transportation Research Record*. For more information, contact Jeffrey F. Paniati, Chief of FHWA's Safety Design Division of the Office of Safety and Traffic Operations R&D, HSR-20, (703) 285-2057.