HSIS

HIGHWAY SAFETY INFORMATION SYSTEM

SUMMARY REPORT

Safety Effects of the Conversion of Rural Two-Lane Roadways to Four-Lane Roadways

AS TRAFFIC INCREASES ON A TWO-LANE RURAL ROADWAY TO THE POINT OF congested or near-congested conditions, a highway agency is faced with several options:

- The road can be left with two lanes, ever-increasing congestion, and ever-increasing dissatisfaction among road users.
- The agency can add short sections of passing lanes to reduce traffic queues.
- The two-lane road can be converted to either a four-lane undivided or a four-lane divided facility. The converted roadway will usually follow the same right-of-way and sometimes the same alignment. While a conversion is usually based on the need to more efficiently move increased traffic volumes, it has been assumed that the conversion to the higher order roadway also produces safety benefits.

Given the lack of funds for new highway construction and the ever-increasing traffic flows that must be handled in existing roadway corridors, the issue of conversion from two lanes to four lanes is of increasing importance to the State and local transportation departments, the Federal Highway Administration (FHWA), and the public. There is also increasing interest in better defining the safety effects of such conversions, since quite often the conversion becomes highly politicized.

The best way to assess these safety effects would be to develop a model that would take a set of pre-existing ("before") two-lane conditions, no matter how extreme, and predict the benefit of conversion to a second set of "after" four-lane conditions. This would require a database of geometric and crash information for a massive number of conversions in which many different sets of "before" conditions were converted to many different sets of "after" conditions. Since no such dataset is available anywhere, judgment of the safety effects of conversion of rural two-lane roads to a greater number of lanes must be based on other sources of information.

An alternative source of such information is predictive cross-sectional models for different before/after conditions. Unlike the stronger before/after methodology, where an actual change has occurred, the alternative

The Highway Safety Information Systems (HSIS) is a multi-State safety data base that contains accident, roadway inventory, and traffic volume data for a select group of States. The participating States, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Utah, and Washington, 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 accident countermeasures.

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cross-sectional analysis bases its results not on actual changes, but on differences between two sets of data—undivided roadways. This cross-sectional analysis approach was used in this study to develop an initial estimate of the safety effects of conversion of typical sections of two- to four-lane roads, and to determine whether such effects would be similar across multiple States.

State Databases Used

Differences in crash rates for these typical sections of two- and four-lane roadways were examined in four States—California, Michigan, North Carolina, and Washington. The crash, roadway inventory, and traffic data used in this study were extracted from the Highway Safety Information System (HSIS). While individual models were developed for two-lane and four-lane divided roads in all four States, only California had a sufficient sample of four-lane undivided roadways for analysis. Crash data for California, North Carolina, and Washington represent counts of crashes over the 3-year period 1993-1995, while Minnesota models include 1991-1993 data. The full description of this research effort can be found in ref. 1.

Analysis Methods

The basic methodology involved the development of cross-sectional models. For each State, individual models predicting crash rate per kilometer for typical sections of two-lane, four-lane undivided, and four-lane divided (non-freeway) roadways were developed. Over-dispersed Poisson models were fitted to the data. The general form of the underlying model predicting crash frequency (A) on two-lane roads is:

$$A = (\text{segment length}) * e^{b_0} * (ADT)^{b_1} * e^{b_2(\text{shoulder width})} * e^{b_3(\text{surface width})}$$

Crash rate per kilometer differences between pairs of road classes were then calculated as a measure of safety effect.

Because the models developed to estimate the safety effect of conversion are for typical sections of each of the three roadway configurations, we are working under the assumption that the two-lane roadways will resemble typical two-lane sections. After conversion, we assume that engineers will have designed typical four-lane divided or four-lane undivided sections. One can clearly argue with this assumption in that two-lane roadways that are converted to four lanes may indeed be atypical in terms of both traffic and/or geometrics. Since we could not cover all possibilities, and since we feel that most of the "after conversion" layouts will resemble these American Association of State Highway and Transportation Officials (AASHTO)-based typical sections, we chose to work under this assumption.

Typical sections were defined by a careful review of guidelines in AASHTO's *A Policy on Geometric Design of Highways and Streets* (the "Greenbook"), a review of State highway design standards from two different States, and cross-tabulations of surface width, shoulder width, and median width for State system mileage in four HSIS States. A decision was also made to include in the analysis database only those homogeneous sections of roadway that were 0.16 km (0.10 mi) in length or longer. This restriction was based on an earlier unpublished work by Ezra Hauer, where analysis of sections shorter than 0.16 km indicated that crash frequencies did not increase with section length—an illogical finding. In addition to the above restrictions, the analysis database was restricted to annual average daily traffic (AADTs) between the 5^{th} and 95^{th} percentile within each roadway class. This was done to ensure that the predictive models developed were based on adequate samples of locations on a given AADT level.

Because intersections produce a significant number of crashes in a section of roadway, differences in the number (and type) of intersections within the three samples could severely bias the comparative analysis being conducted. Since we could not account for this potential bias in the models, a decision was made to omit intersection and intersection-related crashes from the analysis databases.

In addition to intersection crashes, the number and type of driveways per kilometer could differ between our roadway classes and could bias the comparative results. Because we do not have data on driveways per kilometer in three of our States, we retained driveway crashes in the final models developed. We also developed separate models without driveway crashes for three States in order to examine potential differences. As discussed in the full paper, the driveway effect would be a function of both driveway frequency and a possible difference in effect per driveway for two- and four-lane roads due to different conflict patterns. Unfortunately, we were not able to determine from our limited analyses the actual effect of possible differences in driveway frequencies between the two road classes.

The final step in the analysis was to utilize the models to estimate the safety effects of two- to four-lane conversions within each State, and then to compare these results across States. Here, the output for the two-lane model was compared to the output for the four-lane model at the same AADT level, and the safety effect was measured as the percentage of reduction in crashes per kilometer, with the two-lane scenario as the base. The "safety effect" was then calculated *at the same* AADT for both road classes.

This use of the same traffic flow might be questioned by some who would hypothesize that conversion to a four-lane facility might generate additional traffic growth over and above the expected growth on the two-lane facility. This generated growth would result in increased crashes on the four-lane facility relative to the two-lane road. While the increased traffic will indeed generate crashes on the four-lane facility, the crash risk per trip (or per kilometer) for this subset of diverted traffic has decreased. In this case, the true comparison should not be between the original two-lane roadway and the new four-lane facility with, say, 10 percent more traffic. Instead, it should be a before and after "system" comparison, comparing all streets in the system affected before and after the upgrade occurs. Since we have no way of modeling such a system effect, our comparisons are at the same AADT level.

The results from predictive equations developed for the two- and four-lane roads could be compared for a wide range of AADTs, surface widths, and shoulder widths. For demonstration purposes, we chose to produce results for the set of "most typical sections" for each road class, as shown in **figure 1**. Here, "most typical" two-lane plots are calculated for surface widths of 7.32-m (24-ft) and 1.83-m (6-ft) shoulder widths, and the "most typical" four-lane plots are for lane widths of 3.66 m (12 ft) and shoulder widths of 3.05 m (10 ft). Predicted crashes as functions of AADT as plotted in figure 1 were then used to generate functions representing predicted two-lane to four-lane crash reductions as a percentage of predicted two-lane crashes for these "most typical sections." Plots of these predicted reductions for two-lane to four-lane divided "conversions" are shown in **figure 2**. Note again that for a given State, crash reductions were only calculated for AADT values that are common to both the two-lane and four-lane divided roads.

For these "most typical sections," the figures indicate that conversion from a two-lane to a four-lane divided road would result in a crash per kilometer reduction of between 40 percent to 60 percent. The reduction appears to be decreasing very slightly as AADT increases for both California and North Carolina. For Minnesota and Washington, the reduction increases with increases in AADT. Why the general shapes of these curves differ across States is difficult to specify, but probably reflects unmeasured differences in the roadway classes between the States.

While not shown in the figures, the models for each State were also exercised for the two "extreme conditions" within the typical section ranges. For average daily traffic (ADTs) between 8,000 vehicles/day and 15,000 vehicles/day (where most conversions would occur), the "best" two-lane typical section (widest lanes and shoulders) was compared to the most restricted four-lane divided typical section (narrowest shoulders), and the "worst" two-lane section was then compared to the "best" typical four-lane divided section. Percent decreases in crashes per kilometer then ranged from approximately 10 percent to approximately 70 percent, a much wider range.

For the conversion from two-lane to four-lane undivided roadways, the single-state (California) estimate indicates a much smaller reduction in crash rates per kilometer on these "most typical sections." The difference between two- and four-lane undivided rates varies from a 20-percent reduction in crash rate to a slight increase in rate. These results are similar to crash rate decreases shown in an earlier work by Rogness et al.[2] for ADTs between 3,000 and 5,000 vehicles/day. However, the lower effect for higher ADTs and the decreasing effect as AADT increases as shown here differ from the Rogness results that showed an increasing effect with increasing AADT. Clearly, the two studies do not produce similar patterns of effect, and the effects of conversion to a four-lane undivided configuration are still open to debate.

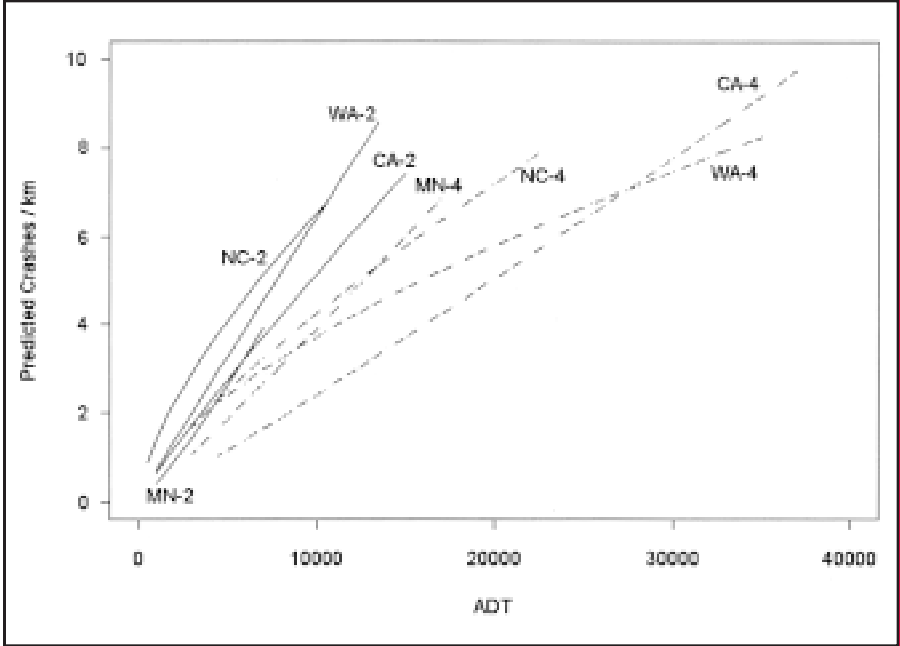

Figure 1. Predicted crashes per kilometer on two-lane and four-lane divided roads with "most typical sections" (i.e., two-lane sections with 7.32-m (24-ft) surface widths and 1.83-m (6-ft) shoulder widths and four-lane divided sections with 3.66-m (12-ft) lane widths and 3.05-m (10-ft) shoulder widths).

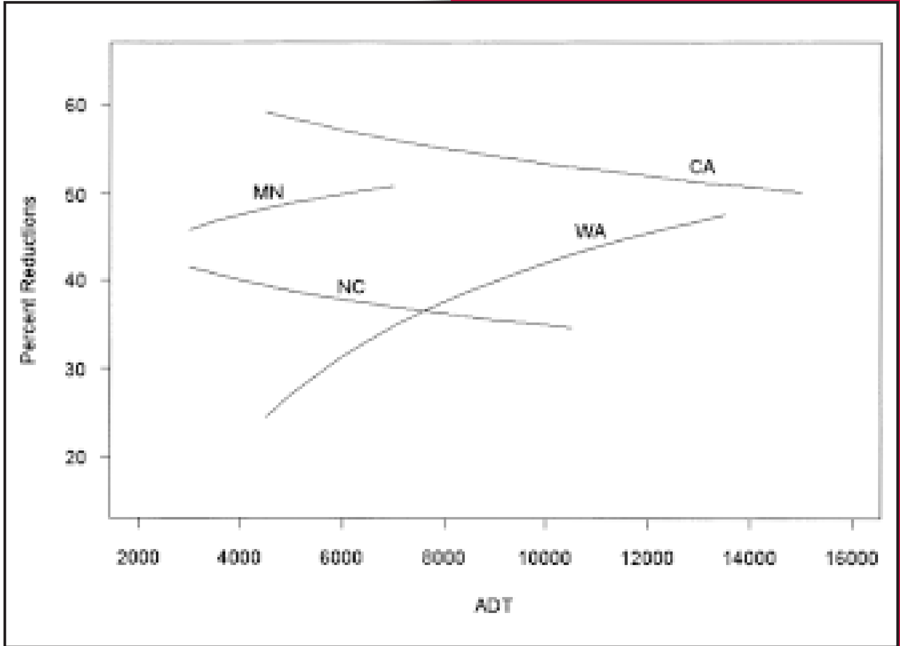

Figure 2. Predicted two-lane to four-lane divided crash reductions for "most typical sections."

REFERENCES

1. Council, F.M. and J.R. Stewart. "Safety Effects of the Conversion of Rural Two-Lane to Four-Lane Roadways Based on Cross-Sectional Models." To appear in Transportation Research Record, TRB, National Research Council, Washington, D.C. (In press).

2. Rogness, R.O.; D.B. Fambro; and D.S. Turner. "Before-After Accident Analysis for Two Shoulder Upgrading Alternatives." In Transportation Research Record 855, TRB, National Research Council, Washington, D.C., 1982, pp. 41-46.

FOR MORE INFORMATION

This research was conducted by Forrest M. Council and J. Richard Stewart of the University of North Carolina Highway Safety Research Center. The full report, Safety Effects of the Conversion of Rural Two-Lane to Four-Lane Roadways Based on Cross-Sectional Models, is being published in an upcoming Transportation Research Board Record. For more information about HSIS, contact Michael S. Griffith, HSIS Program Manager, HRDS, at (202) 493-3316, *mike.griffith@fhwa.dot.gov.*

Study Implications

As indicated above, the results of this cross-sectional analysis are not as strong as would be the results of before/after analyses of a large sample of locations where two- to four-lane conversions had actually occurred. However, since such a database is not currently available, these cross-sectional results do provide useful information for the safety engineer. These analyses indicated that conversion from "most typical" two-lane sections to "most typical" four-lane *divided* sections appears to result in a crash per kilometer reduction of between 40 percent to 60 percent. For conversions of more extreme configurations (e.g., best typical two-lane to worst typical four-lane or vice versa), crash reductions appear to vary from 10 percent to 70 percent. Thus, conversion to four-lane divided sections appears to result in significant safety benefits.

However, the effects of conversion from two-lane to four-lane *undivided* roadway are clearly still open to debate. Our single-state estimate ranged from a 20-percent reduction to a slight increase in crash rate, depending on AADT. This did not completely agree with the results of an earlier similar study, again emphasizing the need for additional study of a larger sample of current data from multiple States.

Future research needs include: (1) verification of the *undivided* four-lane results with additional States and data; (2) additional information on the effects of driveways on two- and four-lane crash rates; (3) new estimates for higher two-lane AADT levels, perhaps in suburban locations where more conversions may be occurring; (4) expansion of the outcome variable to include crash severity, since the true outcome variable of interest is total crash costs, which may vary with changes in crash types (e.g., less head-ons on divided roads, but perhaps more run-off-road crashes due to increased speeds); and (5) verification of all results through before/after studies of actual conversions.

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