HSIS

HIGHWAY SAFETY INFORMATION SYSTEM

SUMMARY REPORT

Association of Selected Intersection Factors With Red-Light-Running Crashes

RED-LIGHT-RUNNING (RLR) CRASHES HAVE BECOME AN INCREASING CONCERN FOR the traffic safety community. According to Retting et al.,[1] there are approximately 750 fatalities and 260,000 crashes annually in the United States. A second study (Retting et al.[2]) found that occupant injuries occurred in 45 percent of the RLR crashes, compared to 30 percent for other urban crash types. Review of crash data for four States in the Federal Highway Administration's Highway Safety Information System (HSIS) showed that RLR crashes account for 16 percent to 20 percent of the total crashes at urban signalized intersections. Thus, based on both previous research and HSIS data, RLR crashes represent a significant safety problem that warrants attention.

It can be hypothesized that the majority of these crashes result from inadvertent driver error or intentional violation. However, very little is known about the possible contribution of the geometric and traffic characteristics of intersections to RLR crash risk. The purpose of this study was to examine selected geometric characteristics of intersections and their impact on RLR crash rates and to establish a relationship between them.

The major questions addressed in this report concerning RLR crashes are:

- Does the width of the cross-street have any effect on RLR crash risk?
- What is the relationship of other select intersection characteristics to RLR crashes?
- Using this information, how can one better target urban intersections for traffic law enforcement techniques such as RLR cameras or heightened intersection enforcement coupled with publicity?

State Databases Used

The key criterion in developing a statistical model showing the relationship of geometric variables to RLR crashes is the identification of both the RLR crash and the specific vehicle that ran the red light. In addition, the RLR vehicle needs to be linked to a given street at an intersection and a "street record" must be present that contains information on both streets (the street from which the vehicle entered the intersection and the street it was crossing). Initial review of the data files from eight States in the HSIS database showed that three States—California, Michigan, and Minnesota—have separate inter-

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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section files. Of those three, Michigan and Minnesota do not have adequate information concerning traffic volume on the cross-street of the intersection—information that is essential for this study. Thus, in the final analysis, data from California were used. The crash files for a 4-year period (from 1993 through 1996) and the intersection characteristics data for 1996 were used in model development.

Crash records from California were filtered using a combination of two variables—Violation and Fault—which indicate whether or not the crash was an RLR crash and which vehicle was at fault in a two-vehicle crash, respectively. To properly model the relationship between the RLR crashes and the geometric features of the intersection, it became clear that the RLR vehicle had to be assigned to a given street approach. This required that the analysis file be a street-based file, with each street (major and cross-streets) being a record. Each record was then developed to contain information on the street in question, information on the number of RLR crashes assigned to that street approach, and information on the cross-street. Linkage of the RLR vehicle to a specific street (i.e., the entering street) was done through a street-assignment procedure that was based on a combination of "side of the highway" where the crash occurred and the "compass direction" of the vehicle in the crash. About one-third of the crashes were eliminated from the final analysis due to coding errors in the two variables. The final analysis file contained 1,756 four-legged signalized urban intersections (3,512 "street" records), and 4,709 two-vehicle RLR crashes for a 4-year period.

Analysis Methods and Model Development

Two types of analyses were conducted. First, limited contingency table analysis was done to examine the similarities and differences between RLR crashes and all crashes at urban signalized intersections (USI). Second, regression-type models were developed to examine the effects of intersection characteristics on RLR crash frequencies.

The contingency table analysis allowed the comparison of a number of variables, including year, month, day, and hour of the crash; weather conditions at the time of the crash; road surface conditions at the time of the crash; and severity of the crash. All variables, with the exception of severity of the crash, did not show much difference between the USI and RLR crashes. The RLR crashes were characterized by a higher percentage of total injuries than the USI crashes (54 percent vs. 44 percent, respectively).

The designation of streets (i.e., "mainline" vs. "cross-street" and "entering street" vs. "crossing street") is somewhat complex due to the fact that separate models were developed for two types of entering streets, both of which are associated with a crossing street. That is, separate models were developed to predict RLR crashes for streets defined in the raw intersection file as "mainline" (i.e., primarily higher volume streets) and for streets defined as "cross-streets" (i.e., primarily lower volume streets). Thus, there is a model for the "mainline as entering street" and a model for the "cross-street as entering street." In each case, the RLR vehicles, and thus the count of RLR crashes, are associated with the entering street. And, in both cases, the entering street model will contain variables related to the crossing street. For example, for the model related to the "cross-street as entering street," the designated crossing street would be one of the original high-volume mainlines. While somewhat confusing, we hope that the use of "entering street" (to which the RLR vehicles are attached) and "crossing street" will help the reader.

The variables examined in the regression models are:

- Number of lanes on both streets (a surrogate for street width).
- Left-turn lanes.
- Right-turn lanes.
- Entering/Crossing traffic flows.
- Traffic control type.

Traffic control type was limited to multi-phase vs. two-phase, fully actuated vs. pre-timed, and semi-actuated vs. pre-timed.

A Poisson regression with an over-dispersion correction based on annual, 2-year, and 4-year data was used to explore the relationship between RLR crashes and the geometric characteristics. Based on these results, negative binomial regression coefficients were used to quantify the relationship. Negative binomial models were developed for "mainline as entering street" and "cross-street as entering street" for the same time frames, and goodness of fit, predicted values, coefficients, and p-values were studied for each. The modeling process showed that predictors for mainline models as entering street were more consistent within the annual data set than cross-street models as entering street. Left-turn channelization variables (left turn onto the mainline, left turn onto the cross-street, and the interaction of the two) as predictors were left in the model for cross-street as entering street as covariates or background information because these variables showed consistency within 2-year and 4-year data sets. They were also retained since the primary intent of the study was to examine the effects of total number of cross-street lanes and average daily traffic (ADT) of the cross-streets at the intersections.

Results

The Effect of Cross-Street Lanes

The primary variable of interest was the width of the cross-street. **Figure 1** shows the effect of the number of cross-street lanes on RLR crashes. The Negative-Binomial (N-B) model for the cross-street as entering street shows that there is a 7-percent increase in cross-street RLR crashes for each one-lane increase on the mainline when one controls for signal operation type, opposite street ADT, and left-turn channelization. However, the number of cross-street lanes (as a measure of cross-street width) did not have a significant effect on mainline RLR crashes (i.e., on RLR crashes associated with vehicles entering from the mainline approaches). The lack of effect of number of lanes on the cross-street for the mainline entering RLR crashes can possibly be attributed to an increase in the number of safe gaps on the lower volume cross-street. Perhaps the effect is really a combination of the intersection width of the cross-street and cross-street volume.

The Effect of ADT

It was hypothesized that ADT would affect RLR crashes in two ways. First, if there is an increase in the number of vehicles approaching the red light, there would be more RLR vehicles. Second, the higher the ADT on the cross-street, the fewer the number of gaps available and the higher the chance of a vehicle running a red light and colliding with another vehicle. This study analyzed ADT on the entering street and ADT per lane of the cross-street. **Figure 2**, based on the N-B regressions, indicates that RLR crashes on the mainline seemed to increase with higher entering street ADT as well as with the increase in cross-street ADT per lane. Similar to the mainline (figure not shown), RLR crashes involving vehicles entering from the cross-street tended to increase with higher entering street ADT. However, in contrast to the mainline finding, RLR crashes for vehicles entering from the cross-street did not increase with the opposite street (i.e., mainline) ADT per lane.

The Effect of Traffic Control

Poorly timed signals are one example of traffic control that could cause inadvertent RLR crashes by forcing vehicles progressing at a given speed to stop unexpectedly. Long red phases, coupled with low crossing volumes, may cause RLR crashes for fixed-time signals. This study examined the effects of traffic controls by analyzing three types (fully actuated, semi-actuated, and pre-timed) rather than individual signal phasing. **Figure 3** (on the back spread) shows that fully actuated signals tend to have more crashes per approaching street than approaches with semi-actuated and pre-timed signals when other factors are held constant. Overall, the number of expected RLR crashes for fully actuated signals was approximately 35 percent to 39 percent higher than those for pre-timed signals.

Discussion

The results of this study show that ADT, width of the intersection, and traffic signal actuation are important non-driver

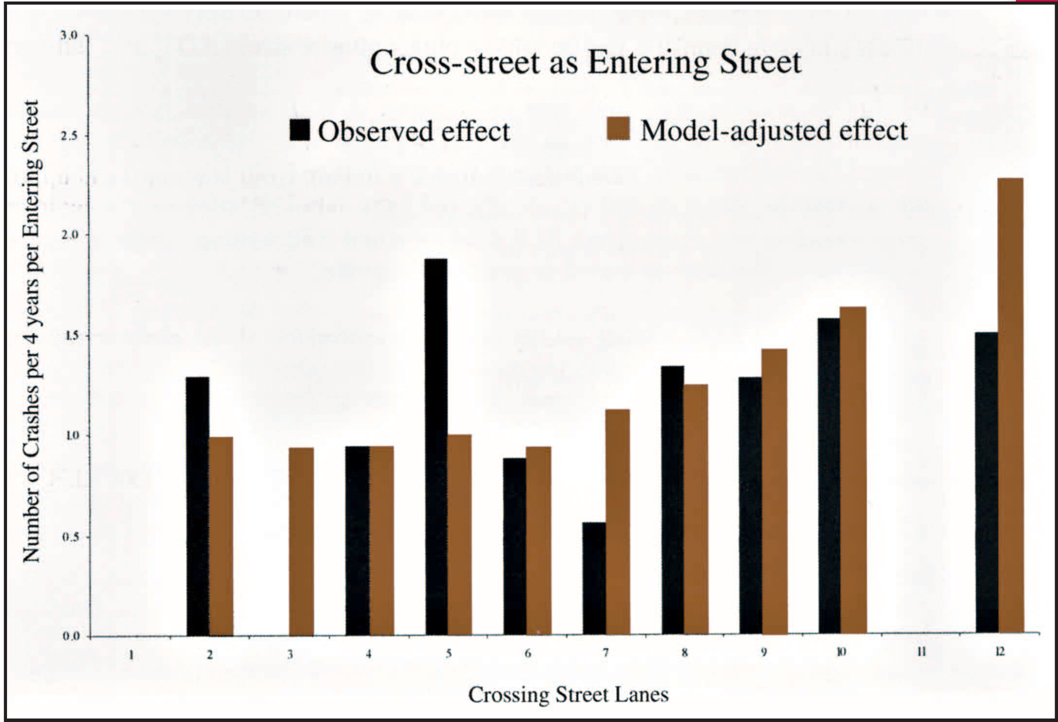

Figure 1. Effects of the Number of Crossing Street Lanes on Crashes.

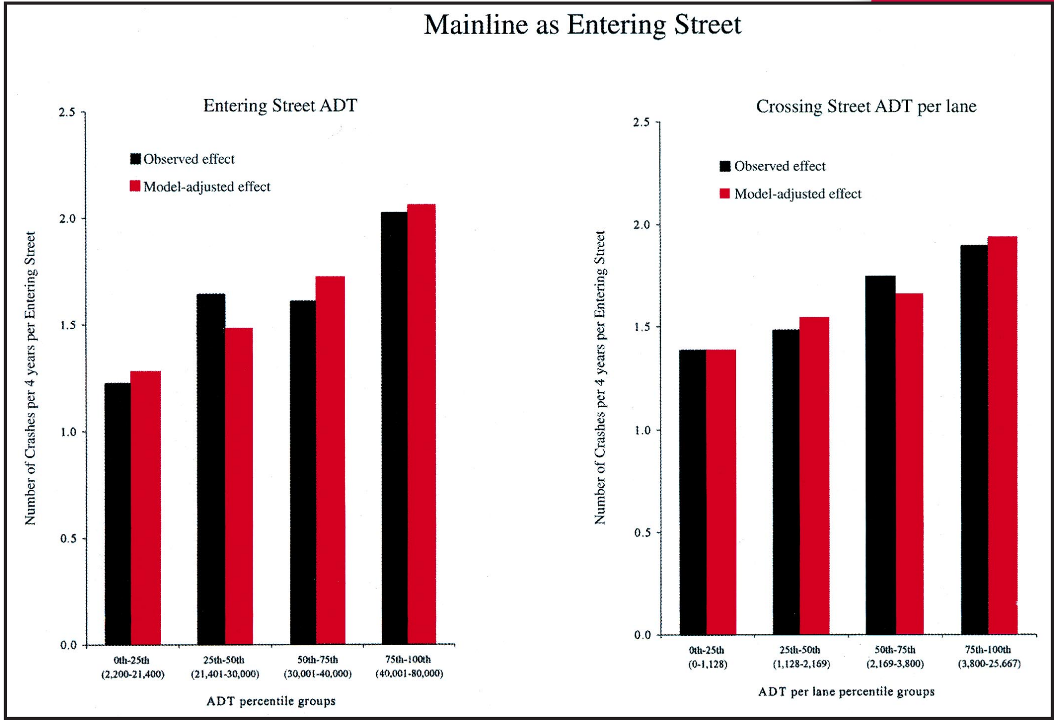

Figure 2. The Effects of ADT on Crashes.

factors for RLR crashes. These results differ slightly when the RLR vehicle is entering from the higher volume mainline vs. the lower volume cross-street.

The models showed that there was an increase in RLR crashes for both mainlines and cross-streets, with an increase in the ADT on the street from which the RLR vehicle entered the intersection. This suggests that the higher volume provides more chances for the vehicles to arrive at, and violate, the red light. Another similarity was the increase in both mainline and cross-street RLR crashes when fully actuated signals were present as compared to the semi-actuated or pre-timed signals.

However, the RLR crashes on the mainlines and cross-streets differed with respect to the width of the intersection (as measured by the number of cross-street lanes) and the traffic volume on the cross-street. The number of lanes on the cross-street does not significantly affect the mainline RLR crashes. In contrast, the cross-street RLR crashes increase with an increase in the number of lanes (width) of the mainline. Also, an increase in traffic volume on the cross-street increases the chances of a mainline RLR crash, whereas the traffic volume on the mainline does not seem to impact the RLR crashes on the cross-street.

The lack of effect of the mainline volume on the cross-street RLR crashes can perhaps be attributed to fewer safe gaps on the mainline through the full distribution of volumes, i.e., even the lower mainline volumes may afford few safe gaps.

The increase in crashes where traffic control is fully actuated is more perplexing. These signals tend to be located in suburban areas with high speeds and are non-networked. The high speeds, combined with the non-networked nature of the

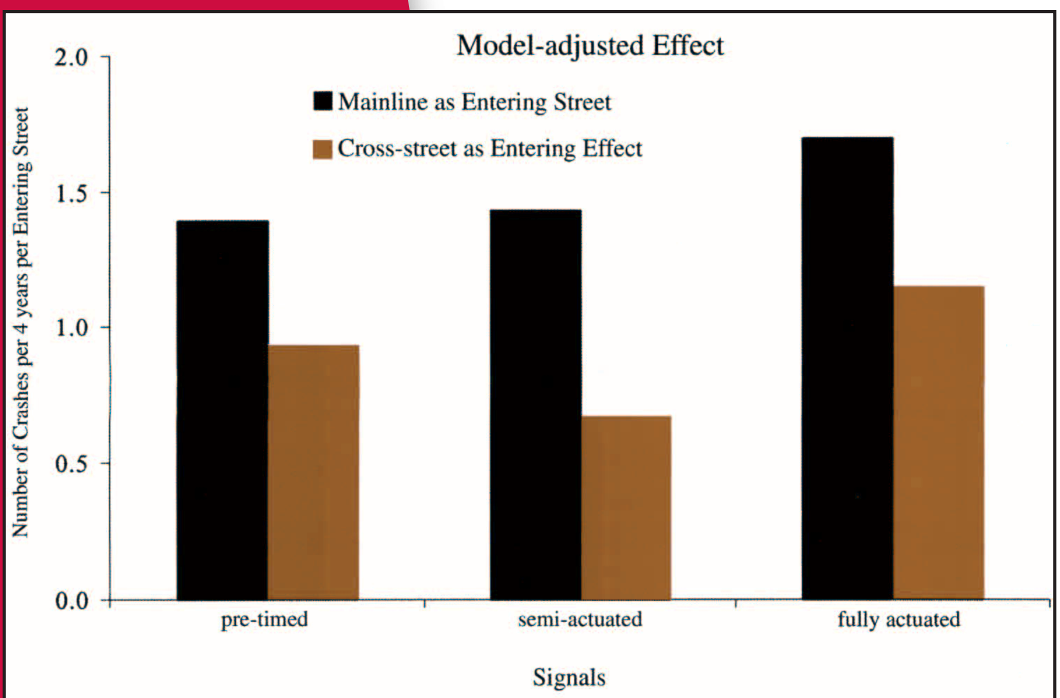

Figure 3. The Effects of Traffic Control Type

signals, might cause fewer safe gaps and some unexpected red signals, creating more opportunity for vehicles to run the red light. Also, due to longer cycle lengths, more intentional RLR may occur for the side-street vehicles that are delayed by the longer red signals.

The speed limit may be a potential variable correlated with the signal type and would be a significant factor affecting the RLR crashes. Unfortunately, this variable was not present in either the geometric file or the crash file available for modeling.

Conclusions and Recommendations

The results obtained from the model show that the traffic volume on both the entering and crossing streets, the type of signal in operation at the intersection, and the width of the cross-street at the intersection are the major variables affecting RLR crashes. In most of the intersection designs, it would be difficult or impossible to control these design/flow variables to reduce the RLR crashes. However, the results can be used to target specific intersections for traffic law enforcement measures, such as installing cameras that detect red-light running, or heightened spot enforcement coupled with publicity, or other techniques. The intersections with higher entering volumes on the mainline and cross-streets, especially intersections with high volumes on cross-streets (minor road); intersections where the volume on a minor road is relatively high, coupled with a wide mainline street; and locations with fully actuated signals should be considered as high-priority intersections for such treatments.

REFERENCES

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FOR MORE INFORMATION

This research was conducted by Yusuf M. Mohamedshah and Dr. Li Wan Chen of LENDIS Corporation and Dr. Forrest M. Council of the University of North Carolina Highway Research Center. The full report, *Association of Selected Intersection Factors With Red-Light-Running Crashes*, has been accepted for presentation by the Institute of Transportation Engineers (August 2000). For more information regarding the research, contact Forrest Council at (919) 962-0454. For more information about HSIS, contact Michael S. Griffith, HSIS Program Manager, HRDS, at (202) 493-3336, *mike.griffith@fhwa.dot.gov*.

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FHWA-RD-00-112

May 2000