

Intersection Crash Summary Statistics for Wisconsin

June 2005



**TRAFFIC OPERATIONS AND SAFETY LABORATORY
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16. Abstract Intersection safety is a concern throughout the United States and Wisconsin. The efficient and effective application of intersection safety improvements requires the identification of locations in need. One method of identifying these locations of concern is to compare their individual crash experience to similar summary statistics. One objective of the project described in this report was to summarize the past and current methods used by state DOTs to identify and rank intersection locations with potential safety concerns. Another objective was to calculate intersection crash summary statistics for Wisconsin. The database summarized in this report consisted of information about more than 33,000 crashes at more than 1,700 locations along the Wisconsin state highway system. Crash frequencies and rates, including their average, minimum, maximum, standard deviation, and 85 th percentile, were calculated for all the intersections in the database. Similar measures were also calculated for rural and urban intersections separately, and these types of intersections are further grouped by traffic control and average annual entering volume. The overall percentage of crash type, injury levels, and crash road conditions are also summarized for all three groups. This project also defined 18 general intersection geometric designs or layouts, and approximately 67 percent of the intersections in the database were assigned one of these categories. The primary geometric differences in the design layouts were their number of intersection approach legs, number of through lanes on the major roadway, existence of a median, and existence of a left-turn lane. Crash summary statistics are provided for the 18 geometric designs grouped by these four primary characteristics. The average percentages of crash types and characteristics for these geometric design groups and for each individual geometric category are also presented in Appendix C. For quick reference, Appendix A contains all the tables/figures within Chapter 3, and Appendix B includes detailed volume-based crash statistics.			
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Intersection Crash Summary Statistics for Wisconsin

by

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Study Title: Systematic Evaluation of Intersection and Run-off-the-Road Crash Locations

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EXECUTIVE SUMMARY

Intersection safety is a concern throughout the United States. Nationally, about one in five crash fatalities are intersection related. In Wisconsin, about 35 percent of the crashes in 2003 were at or near intersections. The proper and systematic identification, evaluation, and improvement of intersections for safety purposes require a good knowledge of what the existing safety situation is within a jurisdiction. Similar intersection facilities should be expected to have similar crash experiences. A comparison of the crash patterns at a particular intersection to typical crash measures can be used to identify locations of concern (i.e., those intersections that may need closer consideration) and assist with the selection of proper safety improvement(s). This report presents and describes intersection crash summary measures for a range of intersection characteristics within Wisconsin. It should be used as a tool for intersection safety evaluation and improvement.

Chapter 2 of this report includes a discussion of the current state-of-the-knowledge with respect to the systematic identification and/or ranking of “high” crash locations. A review of the literature revealed that many states systematically rank locations of concern with a composite of crash frequency, rate, and severity measures is often used. A rate-quality-control or critical measure approach is also used frequently. The efficient implementation of intersection safety improvements also requires the calculation of their expected crash reduction impacts. Currently, no national crash reduction factors are used throughout the United States, and states have either created their own factors, used those from other state departments of transportation (DOTs), or some combination of the two. The approaches used by 34 state DOTs are presented in Chapter 2 along with a series of intersection improvement (e.g., geometry, traffic signal, and signing changes) crash reduction factors. These factors can be used for improvement comparison purposes, but should be applied with caution because the process used in their development has not been critically evaluated. Only the crash reduction percentages discussed in more detail for intersection turn-lane additions were well-documented and known to be statistically robust.

One of the primary objectives of this project was to provide useful crash summary statistics for the evaluation of intersection safety in Wisconsin. Chapter 3 and the appendices of this report provide a series of tables that can be used to accomplish this activity. The database used to create the crash statistics in these tables included information about more than 33,000 crashes and 1,700 intersections. Only those rural intersections with three or more crashes in any one year from 2001 to 2003 (the three years considered) were included in the database, and urban intersections were required to have five or more crashes. About 62 to 70 percent of the intersections and crashes were from Wisconsin DOT Districts 1 and 2. Approximately one-third of the intersections were in rural or unincorporated areas and about 82 percent of the crashes were within urban or incorporated areas.

Several crash statistics were calculated for all the intersections in the database, and also for those designated as rural and urban. First, percentages of crash types, injury levels, and road conditions were calculated and are presented. In general, a greater percentage of injury and fatalities collisions was found in rural areas, and the percentage of rear-end collisions was higher in urban areas. Crash frequency and rate averages, minimums, maximums, standard deviations, and 85th percentiles were also calculated. These measures were determined for urban and rural intersections with different traffic control, entering volumes, and geometric features. For most combinations of these factors the urban crash frequencies and rates were generally greater than their rural counterparts. Overall, the average annual crash frequencies for rural and urban intersections were 3.58 and 7.87 crashes per year, respectively. The average rural and urban intersection crash rates, on the other hand, were determined to be 0.94 and 0.96 crashes per million entering vehicles, respectively. Signalized intersections had the highest crash frequency of the three traffic controls considered, and the highest urban intersection crash rate calculated (ignoring the urban four-way stop-controlled rate which was based on only five intersections). The highest average crash rate calculated in rural areas occurred at through-stop-controlled intersections. Average crash frequencies increased with entering volumes and rates generally decreased. However, the average crash rate at rural intersections with moderate entering volumes was slightly lower (i.e.,

0.03 crashes per million entering vehicles) than the average crash rate calculated for rural intersections with high entering volumes. For quick reference, Appendix A of this report contains all the crash and intersection summary tables and figures from Chapter 3. Appendix B provides similar statistics, by volume level, for intersections with different traffic controls and geometric features.

In the early stages of the project described in this report it was recognized that very few crash report inputs describe the geometric design of an intersection. This project defined 18 intersection geometric categories and these were assigned to about 67 percent of the intersections in the database. For summary purposes, the crash data for the intersections assigned a geometric category were combined into groups determined by four characteristics: number of approach legs, number of major roadway lanes, existence of a median, and existence of left-turn lane(s). Crash statistics (as defined previously) for these geometric category groups are presented in Chapter 3 and the appendices of this report. In general, it was found that average annual crash frequencies increased with the number of approach legs, number of major roadway lanes, the addition of a median, and the addition of left-turn lane. All of these characteristics, however, are related to increases in volume and the increased potential for vehicle conflicts/crashes. The average crash rates, on the other hand, generally increased with the number of approach legs and were higher along two-lane (versus four-lane) roadways. The average crash rate decreased when the major roadway was divided and the intersection had left-turn lane(s). Average percentages for different crash types (e.g., angle collision) and characteristics (e.g., wet roadway conditions) were also calculated for each geometric category and category group. This information is provided in Appendix C.

It is recommended that the crash reduction factors and summary crash statistics in this report be used for intersection safety evaluation and improvement activities in Wisconsin. It is suggested, however, that comparisons to the data in this report be completed only after the intersection of interest has been designated as either rural or urban. In addition, the geometric category and category group crash measures and percentages presented in this report can further assist in the identification of intersection

safety problems and the determination of intersection design impacts. Several improvements are also recommended to the database created in this project. These recommendations include collecting more intersection crash data from throughout Wisconsin, assigning a geometric category to all the intersections in the database, and a consistent annual update of the database. It is also recommended that in the near-term an automated analysis tool be developed that can calculate the relevant crash characteristics of a particular intersection and automatically compare them to the measures presented in this report. In the long-term, the development of a geographically-referenced crash data management system is recommended.

CHAPTER 1 INTRODUCTION

In 2003 there were about 43,640 fatalities along the roadways of the United States (1). More than 20 percent of these fatalities were intersection related (1). In that same year more than 800 fatalities occurred along Wisconsin roadways and about 35 percent of all the crashes that occurred were at intersections (2).

Both the American Association of State Highway Transportation Officials (AASHTO) and the Wisconsin Department of Transportation (WisDOT) are working to improve intersection safety. This report, for example, includes statewide intersection safety summary statistics for Wisconsin. This information was developed to assist Wisconsin transportation professionals with the identification of intersections that may require a more detailed safety investigation. The effective and efficient improvement of roadway segments and intersections for safety purposes requires the proper identification of these types of locations. The information in this report can also help determine the potential cause(s) and significance of a potential safety concern at an intersection.

Project Background

In 1997 AASHTO developed a Strategic Highway Safety plan that contained a series of safety improvement goals and suggested strategies (3). Guideline documents for the implementation of these strategies have been created and can be found at the following website: <http://safety.transportation.org/guides.aspx>. Two of these documents focus on safety improvement measures that can be applied at signalized and unsignalized intersections (4, 5). Wisconsin has been chosen as a lead state in the effective and appropriate application of the measures contained in the unsignalized intersection guidance document (5). The content of this report will assist WisDOT with this activity.

WisDOT also has its own Highway Safety Plan that includes 24 safety action items (6). Seven crash types were also initially suggested as emphasis areas for safety improvement. Two of the crash type emphasis areas were intersection and run-off-the-

road crashes. This report presents and discusses a statewide summary of crash data for intersections in Wisconsin from 2001 to 2003.

Project Purpose and Need

The annual economic loss in 2003 due to roadway crashes in Wisconsin was estimated at greater than \$2.6 billion (2). Intersections crashes throughout the United States are a costly problem, both economically and in the injuries and fatalities that they produce. Limited public funds, however, require that the application of intersection safety improvements be efficient and effective.

The general objective of any statewide safety management system is to implement appropriate safety improvements that produce the most benefit (e.g., reduction in intersection crashes, injuries, and fatalities). The number of improvements that can be implemented is limited, however, by the funding available. An effective and efficient reduction in intersection crashes also requires a systematic understanding of the safety problem within a jurisdiction. The content of this report is the first such safety summary for Wisconsin intersections. It should assist WisDOT staff and other transportation professionals in their safety decision-making process. The information should help identify intersection locations of concern (e.g., locations with greater than average crash experience), assist in the investigation of what might be the problem, and also point the user toward potential countermeasures. The crash reduction benefits of several intersection safety improvements are discussed in Chapter 2.

Project Objectives

The project described in this document had a number of objectives. The first objective was to investigate the current state-of-the-knowledge. A literature review was completed and several Departments of Transportation (DOTs) surveyed to investigate how others have filtered all their intersection crash locations to focus on those with the greatest potential problems. In addition, the methods used to rank intersection crash locations were investigated, and the factors that contribute to a reduction in the number and severity of intersection crashes identified. The second objective of this project was to

produce and document a summary of intersection safety data in Wisconsin. State highway intersection and intersection-related crash statistics were calculated and summarized by area type (i.e., urban and rural), traffic control, and volume. In addition, crash types, injury levels, and road conditions were considered, and crash statistics calculated for intersections with different geometric characteristics (e.g., number of approach legs).

The crash statistics described above are provided in Chapter 3 and the appendices of this report. The basis for these statistics is three years (i.e., 2001 to 2003) of intersection and intersection-related crash data extracted by project team and WisDOT personnel from the WisDOT database. Only locations along the WisDOT state or connecting highway (i.e., those sections of the state or United States highway system that are maintained by a local jurisdiction) system were considered. In addition, only those rural intersection locations with at least three crashes in any one year from 2001 to 2003 were summarized. Urban intersections had to have at least five crashes in any one year. Similar crash location filters are used in other states (See Chapter 2). The crash patterns at the intersection locations that met these minimum crash requirements are summarized in this report.

Report Organization

This report includes four chapters. Chapter 1 contains an introduction to the national and state intersection problem, and describes the project and project objectives. Chapter 2 includes a discussion of how intersections with potential safety problems have been identified and ranked. It contains the results of the literature review and a survey of several state DOTs. Chapter 3 consists of a series of tables that describe and summarize statewide intersection crash patterns. Urban and rural statewide intersection crash frequency and rate statistics are reported for a range of traffic control, traffic volumes, and geometric designs. For quick reference, Appendix A contains all the tables and figures in Chapter 3. Chapter 4 summarizes the project conclusions and recommendations for the future. Appendices B and C, respectively, include volume-

based crash statistics and the average percentages for crash types and characteristics at intersections with different geometric designs.

The content of this report should be used by WisDOT and other transportation professionals for the identification and safety analysis of individual intersections. However, the statewide crash magnitudes and patterns in this report should be used for comparison purposes only. If similar reliable safety summary data is available for the local area it should be used.

CHAPTER 2 LITERATURE REVIEW AND SURVEY RESULTS

One objective of the project documented in this report was to assist transportation professionals in the identification and improvement of intersections with potential safety concerns. In this chapter, a sample of some of the information already available on these activities is summarized. First, some safety measures and methods that have been used to identify and/or rank potentially hazardous intersection locations are discussed. Then, the results of a literature review and DOT survey about their identification and ranking activities are presented. Finally, the results from a national survey about crash reduction factors (CRFs) are described, and the approaches used by DOTs to determine crash reduction factors identified. A sample of CRFs for different intersection safety improvements is provided for reference purposes. This chapter concludes with a discussion of turn lane addition crash reduction impacts.

“High” Crash Location Identification and/or Ranking Measures and Methods

Several approaches have been used to create lists of roadway locations that, due to their safety records, may need further evaluation and analysis. Some of these methodologies are straightforward. For example, intersections in a particular jurisdiction might be listed by their annual crash frequency (i.e., number of crashes per year). An additional level of sophistication, however, can and often is added to this activity by combining more than one safety measure and/or listing only those locations that exceed a critical or expected level of safety. The following paragraphs discuss some of the approaches that have been used to identify and rank “high” crash intersection locations. The approaches used by several state DOTs are summarized later in this chapter.

Crash Frequency

Many smaller agencies use crash frequency during a defined period of time to identify and/or rank potentially hazardous locations. Typically, average crash frequencies from a time period of two to five years are used, however, in an attempt to compensate for and reduce the impact of safety data fluctuations that are known to occur from year to year at any one location. Larger agencies that use crash frequency also often set a minimum

“crash filter” that must be met for a location to be listed/ranked at all. This minimum number of crashes is used to limit the evaluation to those intersections that might need improvement rather than all the intersections that experience a crash.

The use of crash frequency for intersection identification and/or ranking has a number of disadvantages and advantages. The advantages of this approach are that it is simple, easy to understand, and only requires frequency data. One disadvantage of the method is that high volume intersections typically have more crashes and may always be highly ranked, but lower volume locations with more crashes per vehicle may be missed. For this reason crash frequency identification and/or rankings are often used in combination with the following measures.

Crash Rate

A crash rate is used by a number of jurisdictions to identify and rank intersections that may need safety improvements. These rates can be calculated on a per capita basis, but are more typically based on vehicle exposure (e.g., million-entering vehicles). Population-based rates are intended to measure, to some extent, the crash risk of individuals in a jurisdiction. Some common characteristics used to calculate a population-based crash rate include total population, the number of registered vehicles, and the number of licensed drivers. Vehicle exposure crash rates are determined by calculating a ratio of crashes to a measure of vehicle travel. The most commonly used vehicle exposure crash rate for intersections is crashes per million entering vehicles. The calculation for crashes per million entering vehicles can be found in a number of references (7, 8).

A rate-quality-control method can also be used to identify and rank only those intersections that have experienced what is considered to be an abnormally high crash rate. This methodology compares the crash rate at a particular location to a predefined critical crash rate (e.g., an expected crash rate plus some statistical measure of variability) for similar sites. The critical crash rate for a particular type of intersection can be calculated with the following equation:

$$R_c = \lambda + \kappa \sqrt{\frac{\lambda}{m}} + \frac{1}{2m} \quad (1)$$

where R_c = Critical rate (crash per million entering vehicles),

λ = Average crash rate for group of similar intersections (crashes per million entering vehicles),

m = Number of vehicles (entering vehicles in millions), and

κ = Probability factor determined by the level of statistical significance desired.

This equation assumes a Poisson distribution of crashes, and only applies to crash rates. Intersections can be ranked by the ratio of their actual and critical crash rates. New methods, such as an Empirical Bayes approach, have been recommended as more appropriate to the calculation of the expected crash experience at an intersection. A general description of this new approach is provided later in this chapter.

Using crash rate to identify and rank intersections has a number of advantages and disadvantages. An advantage to the approach is that it attempts to take some type of vehicle exposure into account in the identification, comparison, and/or modeling of the crash measures at a site. The inclusion of volume can eliminate some of the disadvantages of using just crash frequency. Low volume intersections with only few crashes, however, may have large crash rates that are not considered to be representative of a safety problem at these locations. It has also been shown that the number of crashes at rural intersections is closely related to daily entering volume, and the impact of this relationship needs to at least be recognized when evaluating the value of crash rate comparisons (9). Many jurisdictions combine crash frequency and rate in some manner to take advantage of the strengths of each approach.

Crash Severity

Crash severity is used by some agencies to rank the safety experience of intersections. It is often used in combination with one or both of the previously described measures.

Typically, crash severity is measured by the number and level of injuries sustained in each crash at a location. These data are summed for a particular period of time and then used to rank the intersection. The typical severity levels that can be recorded for a crash include property-damage-only (PDO) (i.e., no injuries), injury, and fatality. Crash severity results are often summarized by the most severe level of injury for each crash, but can also be calculated based on the injuries experienced by each person in a vehicle within a crash.

For comparison and ranking purposes, the severity of individual crashes at an intersection can be expressed and summed in terms of equivalent property-damage only (EPDO) crashes. This approach assigns a weight to crash injuries and fatalities that is intended to represent their equivalent as a PDO crash. For example, the Missouri Department of Transportation assigns a weight of 6.5 EPDO crashes for every fatal crash and three EPDO crashes for every injury crash (10). Each PDO crash is weighted as one EPDO (10). The total crash EPDO value for each intersection is calculated and the locations ranked (10). Several EPDO weighting schemes are used throughout the country.

A second approach that is used to quantify and rank the crash severity of an intersection is to weight the different crash injury severities by a cost or dollar value. Estimating the costs of crashes is not an easy task, and a wide range of values can be found. The Federal Highway Administration (FHWA) suggests that the following 1994 cost estimates be properly adjusted for the current year as a basis for quantifying crash severity:

- Fatality = \$2,600,000
- Incapacitating injury = \$180,000
- Non-incapacitating injury = \$36,000
- Possible injury = \$19,000
- PDO = \$2,000

The National Safety Council also estimates the cost of motor vehicle injuries (See <http://secure.nsc.org/lrs/statinfo/estcost.htm>), and for a number of reasons some states also use cost estimates that they think are more appropriate (11, 12). For example, the Minnesota DOT uses the cost estimates listed below (12):

- Fatality crash = \$3,400,00
- Incapacitating injury crash = \$270,000
- Non-incapacitating injury crash = \$58,000
- Possible injury crash = \$29,000
- PDO crash = \$4,200

The level of injuries considered can also be further refined. These injury refinements are an input to typical crash reports and they are defined in Sections 2.3.4 to 2.3.6 of the *Manual on Classification of Motor Vehicle Traffic Accidents* (Sixth Edition) (13). The Idaho DOT has also calculated average crash costs by injury severity for particular crash types within certain speed limit ranges (14). They believe that severity costs grouped in this manner help identify and rank locations that experience crash types more likely to cause severe injuries and fatalities (14).

One advantage or disadvantage, depending on the point of view, of crash severity ranking approaches can be that the application of the typical PDO, injury, and fatality costs results in intersections with one fatality being more highly ranked than intersections with a much larger sum of crashes with lower level injuries. This outcome is caused by the large relative difference in the costs assigned to fatalities and injuries. The value of the resultant ranking depends on whether or not the cause of fatality (once determined) can be reasonably mitigated or not. In many cases, crash severity measures and rankings are combined with rankings based on the other two measures already discussed (e.g., crash frequency and rate).

Empirical Bayes Method

The Empirical Bayes (EB) method to identify “sites of promise” has been suggested by Hauer, et al., and is the newly emerging standard in the evaluation of safety (15). This approach is generally accepted as more statistically rigorous than the basic methods previously discussed. However, it’s application does have it’s own set of assumptions and data requirements. A general discussion of the EB approach to safety analysis is explained below. In addition, the FHWA and thirteen state DOTs (including Wisconsin) are working together to develop the SafetyAnalyst. This software package will use the EB methodology (combining observed and expected crash frequencies) to assist transportation professionals in their screening and safety diagnostics of transportation facilities. Information and updates about the SafetyAnalyst project can be found at www.safetyanalyst.org.

The general approach followed by the EB methodology is not entirely different than the modeling methods used in the past, but the results are of a higher statistical quality. In general, the methodology creates a crash prediction model for a set of defined locations. This model development takes into account many of the factors that can and have confounded safety analysis and modeling results in the past. For example, it accounts for regression to the mean (i.e., the assumption that from year to year the crash data at a location will naturally normalize without intervention). The creation of an Empirical Bayes model, or safety performance function, allows the actual crash experience of a location to be compared to its expected crash experience. The model output is often expected crash frequency (i.e., crashes per year) that, if possible, is segmented or adjusted by crash severity. A location of concern or “site of promise” is identified if the actual crash experience is higher than what was expected or modeled. Locations (e.g., intersections) can be ranked by the model results and/or how far their actual crash experience deviates from what is expected.

State DOT “High Crash” Location Identification and Ranking Approaches

As part of this project, the literature was reviewed to determine which methods were used by several state DOTs to identify and/or rank intersection within their jurisdiction. A

number of state DOTs were also contacted by telephone to discuss their methods. The following is a short summary of the results from these activities.

Connecticut

The Connecticut DOT creates a Suggested List of Surveillance Study Sites (SLOSSS) from their state highway and freeway systems (16, 17). The locations that appear in the SLOSSS have a crash rate that exceeds a DOT critical crash rate and have at least fifteen crashes in the last three years. A list of spots (i.e., intersections and roadway segments less than or equal to 0.1 mile long) and segments (greater than 0.1 miles long) are created. A rate-quality-control approach is used to calculate the critical crash rate for various roadway classifications (e.g., urban/rural, number of lanes, divided/undivided, and freeway). An assumption is also made about signalized intersection minor roadway entering volumes if they are not available (either 2,500 vehicles per day or 35 percent of the major street average daily traffic is used). The locations are ranked by their actual to critical crash rate ratio. About 1,500 locations are identified and those that have not been recently improved, or planned for improvements, are considered more closely.

Delaware

As part of its Hazard Elimination Program, the Delaware DOT identifies locations at which there may be safety concerns. The locations (i.e., 0.3 mile segments) must have at least 15 crashes during the past three years. The Delaware DOT then compares the crash rate at each location to an appropriate critical rate and typically identifies 200 to 300 that exceed their critical rate. The Delaware DOT selects 30 intersections from this list for further analysis (18).

Florida

The Florida DOT defines a potentially hazardous location as any roadway site that experiences an abnormal number of crashes during a one year time period. For a location to be considered in the Florida “high crash” identification procedure, however, it typically needs to have at least 8 crashes in one year and a crash rate greater than or equal to the average crash rate for similar locations. Other potential improvement locations are

also identified by district safety engineers through citizen complaints, the Florida Highway Patrol, incident reports, fatal crash reports, and district personnel.

Florida DOT uses a rate-quality-control approach to find locations that have experienced an abnormal number of crashes (11, 18, 19). Locations that meet a predefined filter are grouped by the number of roadway lanes they have, median type, urban/rural/suburban classification, and the general of roadway type (e.g., one-way road, ramp, interstate, and turnpike). Other geometric design characteristics are also considered. Critical crash rates are calculated for each group, and the locations that meet the initial crash filter are then ranked by the ratio of their actual to critical crash rate (19).

Georgia

The Georgia DOT annually ranks intersections and roadway segments by their crash frequency, crash rate, and crash severity. The ranks are based on one year of crash data. The three ranks are combined and re-ranked for each location and a composite score is then compared to an average composite score for similar locations (11, 20).

Idaho

The Idaho DOT utilizes a high accident location (HAL) program to extract and analyze high crash locations. The objectives of the HAL program are to identify locations on the state highway system with potential safety deficiencies and to systematically compare problem locations on a statewide basis. A three-year analysis period is used, and locations must have had at least 4 crashes to be considered in the system.

The final list of “high crash” locations is determined from a composite score that combines crash frequency, crash severity, and crash rate (11, 14). The locations are first ranked by a total three-year crash frequency, and then by a ratio of the actual crash rate at the location and an average crash rate calculated for the appropriate traffic volume range. For intersections in Idaho crash rates are calculated for 10 volume ranges. A crash severity ranking is then produced. Idaho DOT severity rankings are based on average injury costs that they calculate from five years of vehicle crash data defined by one of 64

“most harmful events” and three posted speed limit ranges. These cost estimates are applied to each vehicle involved in a crash at a particular location during the most recent three years, and their sum at each location is then used to create a severity ranking. This approach attempts to limit the typical bias the cost of a fatality can have on individual intersection crash severity rankings.

A final intersection composite safety score for crash frequency, rate, and severity is calculated with the following equation: Frequency Rank (0.25) + Crash Rank (0.25) + Severity Rank (0.50). The results of this calculation are then re-ranked for a final “high crash” location list.

Illinois

The Illinois DOT uses an automated computer system named the High Accident Location System (HALIS) to identify locations of concern. HALIS organizes data, creates statewide statistics, finds possible candidate locations, identifies and ranks “high crash” locations, and also provides crash diagrams for each “high crash” location. Three years of crash data are categorized by roadway segments, signalized and non-signalized intersections, bridges, railroad crossings, and ramps. These categories are also segmented by their urban/rural classification, type of street, type of location, and number of lanes.

The final location ranking completed by the Illinois DOT is based on a composite Priority Index Value (PIV). First, however, critical values of crash frequency, rate, and EPDO are calculated for each of these categories, and their ratio of actual to critical values checked. The signalized intersection critical value for crash frequency is the calculated average plus two standard deviations, and the average critical crash rate and EPDO are their average plus one standard deviation. The non-signalized intersection critical values are twice those of signalized intersections. Any intersection with an actual to critical ratio greater than one then has a PIV calculated for it, and the PIV is the sum of weighted crash frequency, rate, and EPDO ratios, plus a weighted delta change (i.e., the overall three year rate of change in quarterly crash frequency). The weights used in the

PIV equation are chosen by an Illinois DOT task force. The locations remaining in each of the geometric categories described previously are ranked by their PIV values (11).

Indiana

The Indiana DOT uses a Vehicle Crash Records System to identify intersections of concern. This system was first implemented in 2003 and uses electronic mapping techniques to pinpoint crash locations by latitude and longitude using reference point data provided by officers on the crash reports. Intersections with the highest crash frequencies are identified and examined (21).

Iowa

Iowa's Safety Improvement Candidate List Process is used to identify locations with potential safety concerns. For a location to be considered it must have had at least one fatal crash, four personal injury crashes, or eight total crashes over the five-year analysis period. Links (i.e., road segments) and nodes (e.g., intersections, ramp terminals, bridges, and railroad crossings) are listed separately, and ranked using an equally weighted composite of crash frequency, rate, and severity. The top 200 intersections and top 150 segments are identified (11, 18).

Minnesota

The Minnesota DOT uses several ranking methods to identify locations of concern. In addition, all 12,000 miles of Minnesota state highway system are considered in its rankings, but it is divided into intersections and roadway segments. Each segment is defined by its posted speed limit, urban/rural area type, freeway/expressway/conventional classification, number of lanes, and type of median.

Three years of data in the Minnesota DOT ranking methodology, and locations are ranked by total crashes, crash rate, severity rate, crash cost, and also a composite score. The crash costs that are used in the methodology are based on average costs from the four largest insurance carriers in Minnesota. However, to reduce the bias fatalities can have on rankings based on crash cost, the first and second fatal crashes at a particular

location are assumed to have a cost of \$540,000 (which is twice the cost of the highest level of severe injury) instead of the \$3,400,000 used for any additional fatalities at the location. A composite score is calculated for each location by summing the four individual crash frequency, rate, severity, and cost rankings. A total of 200 intersection and 150 roadway segments are ranked.

Missouri

The Missouri DOT completes annual analyses of city crash locations using one to three years of data. For a location to be considered for potential improvements it must have a three-year crash frequency of at least 40 crashes. However, while the initial candidate location lists are based on crash frequency, factors such as crash rate, EPDO values, EPDO rate, and site evaluations are considered in the prioritization of potential improvements (10, 11). Missouri DOT also produces a list identifying potential wet crash problem locations. A list is produced of locations that experience 10 or more wet crashes in 3 years or have a wet to dry crash ratio greater than or equal to 1/3 (10).

North Dakota

North Dakota DOT uses a combination of crash frequency, rate, and severity to identify its hazardous locations. Each year, for the 13 major cities (population > 5,000) in the state, a ranking of roadway locations is completed with one year of crash data. Three years of crash data, however, are used for ranking the non-city locations in North Dakota. Overall, a location with an EPDO severity score greater than or equal to 15 is considered for further analysis and these locations are ranked by crash frequency, rate, and severity. These rankings are then summed into a composite score and re-ranked (11).

State Practice Summary

A number of methods are used to identify and/or rank “high crash” locations within the states considered. The majority of the methods appear to some type of combination or composite of crash frequency, rate, and sometimes severity. A series of states also use some version of the rate-quality-control approach. In addition, some type of filter is used by most states to limit the number of intersections and roadway segments that need to be

considered in their “high crash” evaluation. These filters are either minimum crash magnitudes (sometimes differentiated by crash severity) or some type of calculated critical crash rate. The factors that seem to impact how “high” crash location ranking activities are completed in each state appear to be primarily related to the data and resources (e.g., human, financial, and computer software) needed and what is available. It also appears that most DOTs would like to do more in this area, but they are often limited in their resources or capabilities.

Intersection-Related Crash Reduction Factors (CRFs)

There has been a significant amount of research recently completed that has focused on transportation safety. Several of these projects have focused specifically on intersection-related CRFs. The results from two projects are summarized here. First, some of the output from a DOT crash reduction factor survey is described. This information, when used appropriately, could be helpful to a transportation professional. Second, the total crash reduction results from one of most statistically valid and generally accepted studies of left- and right-turn lane additions are provided. The results of this study are currently being used in the FHWA Interactive Highway Safety Design Model (IHSDM) software package.

Additional information about the magnitude and development of intersection-related CRFs is also forthcoming. In July 2005 a National Cooperative Highway Research Program (NCHRP) project will be completed. NCHRP Project 17-25 is attempting to develop national CRFs for traffic engineering, operations, and intelligent transportation system improvements. In addition, a safety evaluation software package called SafetyAnalyst is currently being developed and is expected to be of great assistance in the evaluation of transportation safety improvements (See www.safetyanalyst.org).

Current CRF Practice

CRFs are the estimated or expected percent reduction in crashes (total or for a particular severity level) due to the implementation of a safety improvement. Currently, CRFs are

typically based on the results of before-and-after crash studies or cross sectional analyses. More advanced and statistically valid analysis procedures do currently exist, but their application requirements have primarily limited their use to researchers rather than DOTs. The inverse of a CRF is the accident modification factor (AMF). AMFs are used in the FHWA IHSDM methodology, and are expected to be used in the forthcoming Transportation Research Board Highway Safety Manual.

National measures of CRFs or AMFs do not currently exist, but state DOTs still need to compare and/or evaluate the potential safety improvement benefits of intersection mitigation measures. Individual DOTs have taken different approaches to address this need. A survey of CRF use and practice in the United States was completed in 2002 and the results are shown in Table 1 (22). Forty-two states responded to the survey, and 34 indicated they use CRFs in some manner. Nineteen of the states also developed all or part of their CRFs, and five completely adopted CRFs from other states (See Table 1). New York and Missouri have calculated the most CRFs. Other states most often use CRFs directly from three states: Kentucky, Florida, and New York.

Summary of Sample CRFs

A summary of the DOT CRF survey results was also used to create a sample of intersection-related CRFs. Some of these CRFs are shown in Tables 2 to 6 (22). The CRFs in the tables are categorized by geometric, traffic control and signal, traffic signing, and general miscellaneous intersection improvements. The reader is referred to the document referenced in the tables for additional intersection, non-intersection, and crash severity CRFs (22). The CRFs in Tables 2 to 6 came from 16 of the 19 state DOTs that indicated they created all or part of their own CRFs (See Table 1) (22).

It is recommended that the CRFs in Table 2 to 6 (and the indicated reference) be used with an appropriate level of caution (22). The robustness and statistical validity of their creation has not been documented, and the common use of simple before-and-after typically will lead to exaggerated crash reduction results. The methodologies used in the creation of these CRFs were not critically evaluated or compared. However, the results

TABLE 1. Crash Reduction Factor Approaches (22)

Crash Reduction Factor (CRF) Approaches	State
Developed All or Part of Own CRFs	Alaska, Arizona, California, Florida, Idaho, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Montana, New York, Ohio, Oklahoma, Oregon, Texas, Vermont, Virginia
Updating/Developing CRFs	Connecticut, Florida, Kentucky, New York, Ohio, Oregon, Virginia
Use CRFs from Literature and Other States	Alabama, Colorado, Connecticut, Indiana, Kentucky, Louisiana, Michigan, Montana, Nebraska, North Carolina, Pennsylvania, South Carolina, South Dakota, Virginia
Adopted CRFs from Other States	Delaware, Maine, Maryland, Nevada, West Virginia

are useful as a reference and they also sometimes show similar CRFs from multiple locations. The general range of crash reductions that have been found is of interest and is useful for overall comparison purposes. In addition, relative crash reduction comparisons could be done if it is assumed the different CRFs are created in a similar manner.

Left- and Right-Turn Lane Total Crash Reduction Impacts

As previously mentioned, there has been some significant and helpful intersection-related research completed in recent years. One of the most recent generally accepted and statistically robust intersection safety projects focused on the crash reduction effectiveness of left- and right-turn lane additions. In 2002, Harwood, et al. used an Empirical Bayes approach to determine most of the crash reduction percentages shown in Tables 7 to 9 (23). These results are considered much more statistically valid and exact than CRFs based on the simple before-and-after studies used by most states (i.e., those that appear in Tables 2 to 6). Other crash reduction percentages shown in Tables 7 to 9 were determined from a comparison-group analysis approach and/or an expert assessment of the literature (these percentages are noted in the tables).

TABLE 2. Intersection Geometric Improvement Crash Reduction Factors (22)^{1,2}

Improvement	Crash Reduction Factor (Percent)						
	All Crashes	Head-On	Rear-End	Right-Angle	Sideswipe	Left-Turn	Right-Turn
Increase Turning Radii	15 (KY) 15 (MO) 10 (MT)		15 (MI)		15 (MI)		
Increase Turn Lane Length	15 (KY) 15 (MO) 40 (MT) ³ 15 (OK)						
Provide Right-Turn Lane	61 (FL) 25 (KY) 25 (MO) 25 (MT) 25 (OK)		66 (FL) 65 (MI)	90 (FL) 50 (OK)	100 (FL) 20 (MI)		50 (KY) 56 (MI) 50 (MO)
Add Left-Turn Lane w/ Painted Separation	50 (ny)		39 (NY) 54 (ny)	49 (NY) 62 (ny)		35 (NY) 57 (ny)	
Add Left-Turn Lane w/ Phys. Separation	19 (NY) 51 (ny)		28 (NY) 50 (ny)	55 (NY) 68 (ny)		24 (NY) 24 (ny)	
Add Left- and Right-Turn Lanes w/ Signal	14 (NY) 41 (ny)		38 (NY) 64 (ny)	42 (NY) 70 (ny)	38 (NY) 64 (ny)		
Provide Left-Turn Lane (w/ Signal)	25 (KY) 25 (MO) 28 (MT) 30 (OK)					45 (KY) 50 (MO) 24 (NY) 45 (OK)	
Provide Left-Turn Lane (without Signal)	35 (CA) 19 (FL) 35 (KY) 35 (MO) 25 (MT) ⁴ 40 (OK)				41 (FL)	51 (FL) 50 (KY) 55 (OK)	73 (FL)
Channelization w/ no left-turn phase	15 (CA) 15 (MO)					57 (FL)	
Channelization w/ Existing Left-Turn Phase	35 (CA) 35 (MO)						
Modify Channelization at Existing Signal	36 (FL)		28 (FL)		27 (FL)	67 (FL)	50 (FL)
Modify Channelization and add Signal	27 (FL)					58 (FL)	
Add Dual Left-Turn Lanes	36 (FL)	75 (MN) ⁵	45 (FL) 29 (MN) ⁵ 32 (MN) ⁵	20 (MN) ⁵ 8 (MN) ⁵	50 (MN) ⁵	47 (MN) ⁵ 71 (MN) ⁵	
Add Turn and Bypass Lane at T-Intersection		13 (MN) ⁵	18 (MN) ⁵ 21 (MN) ⁵	24 (MN) ⁵ 53 (MN) ⁵	31 (FL) 30 (MN) ⁵	43 (FL) 36 (MN) ⁵ 28 (MN) ⁵	69 (FL)

TABLE 2. Continued

Replace Signal or Stop-Controlled 3-Leg Intersection with Single-Lane Roundabout	50 (AK)						
Replace Signal or Stop-Controlled 4-Leg Intersection with Single-Lane Roundabout	75 (AK)						

¹(XX) = state abbreviations.

²(ny) = factors for average annual daily traffic < 5,000 vehicles/lane, (NY) = factors for average annual daily traffic > 5,000 vehicles/lane.

³MT = factor for average daily traffic from 400 to 3,000 vehicles.

⁴MT = factor for average daily traffic less than 400 vehicles.

⁵MN = factors in bold are for fatal and injury crashes. Those not in bold text are property damage factors.

TABLE 3. Intersection Traffic Control Improvement Crash Reduction Factors (22)^{1,2}

Improvement	Crash Reduction Factor (Percent)						
	All Crashes	Head-On	Rear-End	Right-Angle	Sideswipe	Left-Turn	Right-Turn
Install Two-Way Stop Sign	35 (MO) 35 (KY)						
Change from Two-Way to Stop to All-Way Stop	50 (CA) 55 (KY) 55 (MO) 53 (MT)		13 (MO)	72 (MO)		20 (MO)	39 (MO)
Install Signal (General)	15 (CA) 20 (IA) 13 (IN) 25 (KY) 25 (MO) 20 (OK) 20 (NY) 38 (ny)		20 (NY) 22 (ny)	60 (AK) 42 (AZ) 65 (KY) 65 (MO) 65 (OK) 43 (NY) 74 (ny)			
Install Signal at Channelized Intersection	42 (FL)			88 (FL)		45 (FL)	65(FL)
Install Signal Non-Channelized Intersection	20 (FL)		25 (FL)			34 (FL)	
Install Signal and Channelization	25 (FL)	27 (MN) ³		51 (FL) 67 (MN)³ 63 (MN) ³	54 (MN)³	40 (FL) 24 (MN) ³	40 (FL)
Install Signal at Two-Way Stop-Controlled Intersection	28 (MO)			74 (MO)			

TABLE 3. Continued

Install Signal at Two-Way Stop-Controlled Intersection and Add Left-Turn Lane	36 (MO)		8 (MO)	74 (MO)			
Install Flashing Red/Yellow Signal	26 (NY) 25 (ny)	50 (VA)		36 (NY) 35 (ny)			
Remove Unwarranted Signal	100 (AZ) 50 (KY) 50 (MO) 75 (OK)		100 (AZ) 90 (MO)	48 (FL)		33 (FL)	

¹(XX) = state abbreviations.

²(ny) = factors for average annual daily traffic < 5,000 vehicles/lane, (NY) = factors for average annual daily traffic > 5,000 vehicles/lane.

³MN = factors in bold are for fatal and injury crashes. Those not in bold text are property damage factors.

TABLE 4. Intersection Traffic Signal Improvement Crash Reduction Factors (22)^{1,2}

Improvement	Crash Reduction Factor (Percent)						
	All Crashes	Head-On	Rear-End	Right-Angle	Sideswipe	Left-Turn	Right-Turn
Upgrade Signal (General)	15 (CA)						
	15 (IA)						
	11 (IN)						
	20 (KY)	47 (MN)³	22 (MN)³	29 (MN)³	50 (MN)³	27 (MN)³	
	20 (MO)	61 (MN) ³	32 (MN)	32 (MN)	28 (MN)	21 (MN)	
	22 (MT)	52 (NY)	26 (NY)	37 (NY)	52 (NY)	26 (NY)	
	19 (NY)	32 (ny)	41 (ny)	47 (ny)	32 (ny)	38 (ny)	
	37 (ny)						
	20 (OK)						
62 (VT)							
Upgrade Signal and Add Ped. Feature	56 (FL)					81 (FL)	
Upgrade Signal-Optical Program	15 (OK)						
Install Opt. Prog. Signal Lenses	15 (KY)	20 (MO)	10 (MO)	10 (MO)		10 (MO)	
	15 (MO)						
Improve Signal Phasing	25 (KY)	75 (MN)³	17 (MN) ³	30 (MN)³		55 (MN)³	
	25 (MO)			46 (MN) ³		63 (MN) ³ 75 (OK)	
Signal Upgrade w/ No Left-Turn Lane	51 (MO)		24 (MO)	69 (MO)		28 (MO)	
Signal Upgrade w/ Existing Left-Turn Lane	44 (MO)		35 (MO)	74 (MO)		2 (MO)	
Signal Upgrade and Added Left-Turn Lane	84 (MO)		72 (MO)	83 (MO)		87 (MO)	

TABLE 4. Continued

Add Protected Left-Turn Phase	15 (AZ) 25 (KY) 25 (MO) 30 (MT) 36 (NY) 30 (ny)		35 (NY) 27 (ny)	80 (AK) 56 (NY) 54 (ny)		35 (AZ) 70 (KY) 70 (MO) 46 (NY) 41 (ny)	
Add Prot./Perm. Left-Turn Phase	10 (KY) 10 (MO)					40 (MO) 40 (OK)	
Improve Timing	10 (KY) 10 (MO)						
Change from Pre-Timed to Actuated	28 (NY) 39 (ny)	60 (NY) 81 (ny)	26 (NY) 53 (ny)	32 (NY) 41 (ny)	26 (NY) 53 (ny)	30 (NY)	
Install Actuated Signal				10 (MO)	20 (MO)	80 (MO)	
Install/Improve Pedestrian Signal	56 (FL) 25 (KY) 25 (MO) 15 (MT)					81 (FL)	
Improve Yellow Change Interval	15 (KY) 15 (MO)			30 (KY) 30 (MO)			
Add All-Red Interval	15 (MO)			30 (MO)			
Interconnect Signals	15 (KY) 15 (MO) 15 (OK) 10 (TX)	34 (MN) ³	15 (MN) ³ 20 (MN) ³ 20 (MO)	21 (MN) ³ 40 (MN) ³ 10 (MO)	51 (MN) ³ 31 (MN) ³	38 (FL) 24 (MN) ³ 15 (MN) ³ 38 (MO)	36 (FL) 36 (MO)
Install 12-Inch Lenses	10 (KY) 10 (MO)						
Install Visor or Backplates				20 (KY) 20 (MO)			

¹(XX) = state abbreviations.

²(ny) = factors for average annual daily traffic < 5,000 vehicles/lane, (NY) = factors for average annual daily traffic > 5,000 vehicles/lane.

³MN = factors in bold are for fatal and injury crashes. Those not in bold text are property damage factors.

Overall, Harwood, et al. considered turn lane additions or extensions at 280 intersections. These intersections were signalized and unsignalized (and sometimes turn lanes were added along with a signal). The intersections were located in eight different states, and 9 to 13 years of crash data were used at each intersection. No reliable crash reduction measures for the extension of turn lanes were found, but the total crash reduction from the addition of left-turn lanes ranged from 27 to 48 percent and 7 to 33 percent at signalized and unsignalized intersections, respectively, within urban and rural areas (See Tables 7 and 8). Not unexpectedly, the total crash reduction that can be

TABLE 5. Intersection Signing and Beacon Improvement Crash Reduction Factors (22)^{1, 2, 3, 4, 5}

Improvement	Crash Reduction Factor (Percent)						
	All Crashes	Head-On	Rear-End	Right-Angle	Sideswipe	Left-Turn	Right-Turn
Install or Upgrade Traffic Signs	100 (AZ) 5 (CA) 15 (IN) 13 (NY) 28 (ny) 20 (OK)					34 (NY) 34 (ny)	
Install Advance Warning Signs	30 (KY)						
Install Advance Warning Signs (Urban)	30 (MO)						
Install Advance Warning Signs (Rural)	40 (MO)						
Install Stop Ahead Sign	15 (NY)						
Replace Standard Size Stop Sign with Larger Stop Sign	19 (NY)						
Install Flashing Beacon (General)	25 (IA) 7 (IN) 30 (KY) 30 (MO) 25 (OK)	100 (MN)⁶ 29 (MN) ⁶	47 (MN)⁶	25 (MN)⁶			
Upgrade Flashing Beacon (General)	9 (IN) 10 (TX)						
Install Flashing Beacon at Intersection	30 (KY) 30 (MO) 4 (MT) ³ 39 (MT) ⁴ 70 (MT) ⁵ 30 (OK)						
Install Intersection Advance Warning Flashers	25 (KY) 25 (MO) 27 (MT) ³ 25 (OK)						
Install General Advance Warning Flashers	35 (KY) 35 (MO) 35 (OK)	67 (MN)⁶	16 (MN) ⁶	73 (MN)⁶ 62 (MN) ⁶	33 (MN)⁶ 83 (MN) ⁶	100 (FL) 67 (MN)⁶ 79 (MN) ³	

¹(XX) = state abbreviations.

²(ny) = factors for average annual daily traffic < 5,000 vehicles/lane, (NY) = factors for average annual daily traffic > 5,000 vehicles/lane.

³Includes curves.

⁴4-leg intersections red-yellow beacons.

⁵3-leg intersections red-yellow beacons.

⁶MN = factors in bold are for fatal and injury crashes. Those not in bold text are property damage factors.

TABLE 6. Miscellaneous Intersection Improvement Crash Reduction Factors (22)¹

Improvement	Crash Reduction Factor (Percent)						
	All Crashes	Head-On	Night Time	Rear-End	Right-Angle	Sideswipe	Left-Turn
Improve Intersection Sight Distance	75 (AK) 7 (AZ) 20 (CA) 35 (IA) 30 (KY) 30 (MO)	75(AK) 100² (MN) 10 (MO)		10 (AZ)	21 (AZ) 21 (MO) 70 (MN)	75 (AK) 10 (MO)	13 (AZ) 13 (MO)
Install/Improve Lighting	36 (CA) 30 (KY) 30 (MO)		50 (AK) 67 (CA) 50 (KY) 50 (MO) 64 (MT) 50 (OK)				
Install Stop-Controlled Approach Rumble Strips	28 (MT)						
Change Two-Way Roadway to One-Way (Intersection Crashes Only)	30 (KY) 26 (MO)						
Construct a Grade Separation	80 (TX)						
Prohibit Left Turns	45 (KY) 45 (MO)			30 (MO)			90 (MO)
Prohibit Right-Turn-On-Red at Signal				20 (MO)	30 (MO)	20 (MO)	

¹(XX) = state abbreviations.

²MN = factors in bold are for fatal and injury crashes. Those not in bold text are property damage factors.

expected from the addition of a right-lane was smaller, but still ranged from 4 to 26 percent (See Table 9). These crash reduction percentages could be used in benefit-cost evaluations for turn-lane additions if no reliable local information is available.

Summary

This chapter summarized the current state-of-the-knowledge related to several intersection safety management subjects. The measures and methods used to identify and/or rank “high” crash intersection locations were described, and the approaches used by a number of state DOTs presented. Most states appear to use some type of composite

TABLE 7. Expected Percentage Reduction in Total Crashes from Installation of Left-Turn Lanes on the Major-Road Approaches to Rural Intersections (23)

Intersection Type	Intersection Traffic Control	Number of Major-Road Approaches on which Left-turn Lanes are Installed	
		One Approach	Both Approaches
Three-Leg Intersection	Stop sign (Minor Approach)	44	
	Traffic Signal	15 ¹	
Four-Leg Intersection	Stop sign (Minor Approaches)	28	48
	Traffic Signal	18 ¹	33 ¹

¹Based on expert assessment of the literature (9).

TABLE 8. Expected Percentage Reduction in Total Crashes from Installation of Left-Turn Lanes on the Major-Road Approaches to Urban Intersections (23)

Intersection Type	Intersection Traffic Control	Number of Major-Road Approaches on which Left-turn Lanes are Installed	
		One Approach	Both Approaches
Three-Leg Intersection	Stop sign (Minor Approach)	33	
	Traffic Signal	7 ¹	
Four-Leg Intersection	Stop sign (Minor Approaches)	27 ²	47
	Traffic Signal	10	19

¹Based on an Empirical Bayes evaluation and expert assessment of the literature (9).

²Based on a Comparison-Group evaluation (23).

TABLE 9. Expected Percentage Reduction in Total Crashes from Installation of Right-Turn Lanes on the Major-Road Approaches to Rural and Urban Intersections (23)

Intersection Traffic Control	Number of Major-Road Approaches on which Right-Turn Lanes are Installed	
	One Approach	Both Approaches
Stop Sign	14	26
Traffic signal	4	8

crash measure or rate-quality-control approach to identify, rank, and/or evaluate “high” crash locations.

The expected reduction in crashes due to safety improvements is needed to evaluate their effectiveness at “high” crash intersection locations. The CRF approaches used by 34 state DOTs to acquire these CRFs are presented in this chapter. In addition, a summary of sample CRFs for intersection improvements is provided. Caution is suggested in the use of these factors, however, because their development has not been critically evaluated. The reader is also referred to the summary reference document for additional CRFs and the identification of the 20 documents from which these CRFs were originally obtained (22). Finally, the crash reduction results from a statistically robust safety impact evaluation of intersection turn-lane additions were presented. It is suggested that the results from this study, which are currently used in the FWHA IHSDM, be used if equivalent local data is not available.

CHAPTER 3 INTERSECTION CRASH STATISTICS

This chapter contains a series of statewide intersection crash statistics that can be used by transportation professionals to identify intersections that may require more detailed safety evaluations. First, the development and content of the overall crash database created in this project is generally summarized. The appropriate application of the crash statistics provided in this chapter requires an understanding of both. A series of tables is then provided which summarize the crash data for all the intersections included in the database. Average crash frequency and rate summary statistics are presented for the entire database and groups of rural and urban intersections with different traffic control and annual average daily entering volumes. Finally, many of the intersections in the database were also assigned one of 18 geometric codes. These codes are defined and summary crash statistics for appropriate combinations of these categories are provided.

Database Development

A crash database for 3,215 intersection locations was initially acquired from the WisDOT. This database contained information about the 38,573 crashes that were reported at or within approximately 0.02 miles (106 feet) of the 3,215 intersections from 2001 to 2003. The intersections in the database were all located along the Wisconsin state and connecting highway systems.

For evaluative purposes, a crash filter was then applied to the crash database initially acquired from WisDOT. This type of filter is used by DOTs throughout the United States and is typically applied to focus systematic crash summaries and analyses only on those locations with some minimum number of crashes. The project team, in consultation with WisDOT, decided that only those urban (i.e., locations reported within an incorporated village or city) intersections with five or more crashes in any one of the three years should be summarized further. Similarly, only those rural (i.e., locations reported outside of an incorporated village or city) intersections with three or more crashes in one of the three years would be included in the statewide summary statistics presented in this report. The application of this filter, and a series of quality control

activities (e.g., missing crash data), reduced the number of intersections in the database to 1,704, and the number of crashes summarized in this report to 33,090. These reductions represented a decrease of approximately 47 percent in the number of intersection locations within the database, and 14 percent reduction in the crashes. The percentage of intersections and crashes in the database from each WisDOT district is shown in Table 10.

TABLE 10. Database Intersections and Crashes by WisDOT District

District	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
1	320	18.8	6,514	19.7
2	739	43.3	16,479	49.8
3	136	8.0	2,205	6.7
4	182	10.7	2,684	8.1
5	92	5.4	1,548	4.7
6	114	6.7	2,214	6.7
7	63	3.7	620	1.8
8	58	3.4	826	2.5
Total	1,704	100.0	33,090	100.0

Table 10 shows that the majority of the intersection and crash data used in the calculation of the summary statistics shown in this report are from Districts 1 and 2. Approximately 62 percent of the intersection and 70 percent of the crash information comes from these two districts. These database characteristics are most likely an outcome of the project focus on intersections with a minimum numbers of crashes (see previous discussion), and the general distribution of Wisconsin population and traffic flow.

Database Summary Statistics

Basic summary crash statistics have been calculated and are presented in this report for three intersection groups. First, summary statistics were calculated for *all* the intersections in the database. The intersection and crash characteristics for the entire database are defined, and the overall average intersection crash frequency and rate, for the three years considered, presented. In addition, crash frequency and rate minimums,

maximums, standard deviations, and 85th percentiles are provided. Similar information, with the addition of crash statistics grouped by intersection traffic control and volumes, are also calculated and presented for intersections designated as either rural or urban. Finally, this project also defined 18 general intersection geometric layouts, and a number of the intersections in the database were categorized geometrically by WisDOT district personnel. This information was used to complete a preliminary evaluation of some crash statistics for groups of intersection geometrics in Wisconsin. The results of this evaluation are presented in this chapter.

The database used to calculate the summary statistics in this chapter included information about more than 33,000 crashes at over 1,700 Wisconsin intersections. The number and percentage of intersections and crashes at rural and urban locations are shown in Table 11 along with similar information segmented by traffic control and annual average daily entering volume.

TABLE 11. Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Area Type				
Urban	1,148	67.4	27,113	81.9
Rural	556	32.6	5,977	18.1
Traffic Control				
Signal	826	48.5	22,772	68.8
Through-Stop	847	49.7	10,011	30.3
Four-Way Stop	31	1.8	307	0.9
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	692	40.6	7,572	22.9
15,000 to 25,000	534	31.3	9,537	28.8
> 25,000	478	28.1	15,981	48.3

Table 11 summarizes all the intersections within the database used for this project. Approximately two-thirds of the intersections in the database were from crash reports that indicated they were within incorporated or urban areas. These intersections

experienced about 82 percent of the crashes in the database. Approximately 69 percent of the crashes in the database occurred at intersections that were signalized, and about 48 percent occurred at intersections with annual average daily entering traffic of more than 25,000 vehicles per day (vpd). Almost 23 percent of the crashes in the database occurred at intersections with entering daily volumes less than 15,000 vpd. The distribution of the volumes entering the intersections within the database is shown in the Figure 1. Signalized and through-stop (i.e., minor roadway stop-controlled) intersections represented about 99 percent of the locations. Similar summaries are completed later in this report for the rural and urban locations in the database.

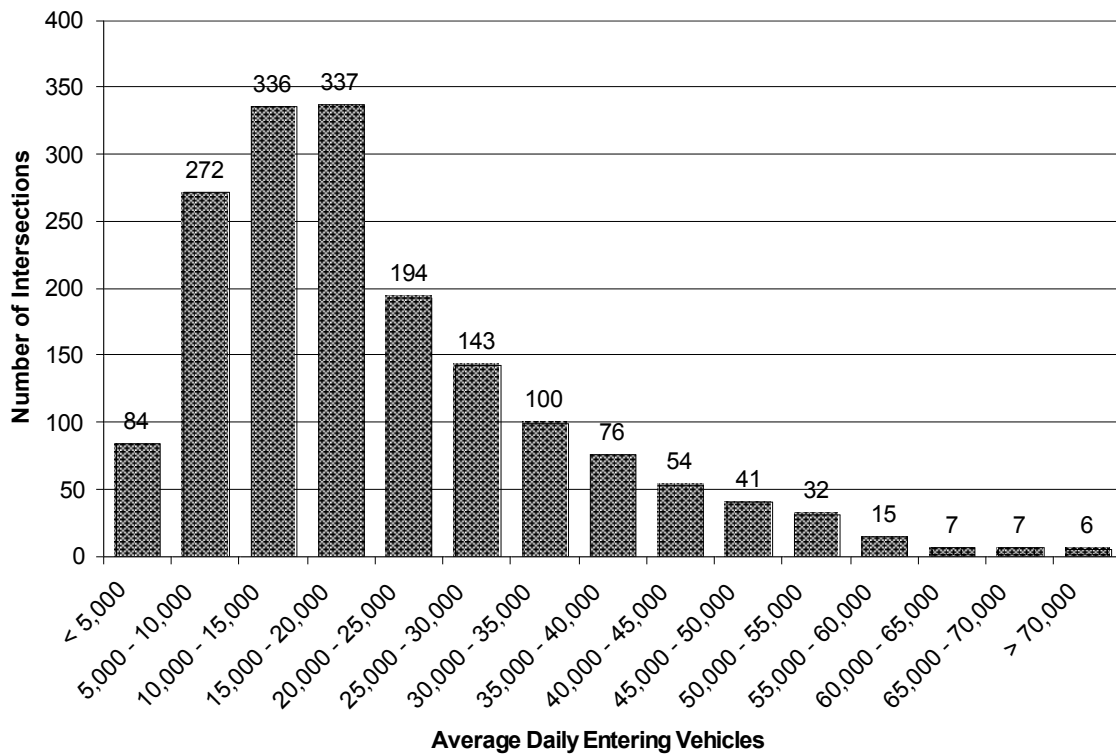


FIGURE 1. Annual Average Daily Entering Volume Distribution of All Intersections

The crash types, injury severity, and roadway conditions that occurred at the 1,704 locations in the database are summarized in Table 12. Approximately 42 percent of the collisions summarized in this project were angle crashes, and about 34 percent

TABLE 12. All Database Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	13,872	41.9
Head-On	659	2.0
No Collision/Fixed Object	3,508	10.6
Rear-End	11,223	33.9
Sideswipe – Opposite Direction	631	1.9
Sideswipe – Same Direction	2,755	8.3
Unknown	442	1.4
Maximum Injury		
Fatality	117	0.4
Injury	13,073	39.5
None	19,900	60.1
Road Condition		
Dry	24,612	74.4
Wet	5,797	17.5
Snow	1,398	4.2
Ice	449	1.4
Mud	27	0.1
Unknown or Other	807	2.4

rear-end crashes. Another 10.6 and 8.3 percent of the crashes, respectively, were no collision (e.g., run-off-the-road)/fixed object and sideswipe-same direction collisions. The remaining crash types in the database were head-on, sideswipe-opposite direction, or unknown. About 60 percent of the crashes in the database did not result in injuries and only 0.4 percent (n = 117) resulted in fatalities. Approximately 74 percent of the crashes occurred with dry roadway conditions, and about 18 percent during wet conditions. Approximately 5.6 percent of the crashes occurred with snow or icy roadway conditions.

The average annual intersection crash frequency at all the intersections in the database was 6.41 crashes per year, and this safety measure had a standard deviation of 5.32 (See Table 13). Not surprisingly, there was a large amount of variability in this data. The minimum annual average frequency was 1.0 crash (i.e., only three crashes occurred

TABLE 13. All Database Intersection Crash Frequencies and Rates

Descriptive Statistic	Annual Crash Frequency (Crashes per Year)	Crash Rate (per Million Entering Vehicles)
Average	6.41	0.95
Minimum	1.00	0.15
Maximum	44.67	8.22
Standard Deviation	5.32	0.62
85 th Percentile (Approx.) ¹	11.0	1.4

¹85 percent of the database intersections have a safety measure at or below this level.

in all three years – the minimum for a rural intersection to be included in the database) and the maximum was 44.67 (i.e., a total of 134 crashes in three years). In addition, the 85th percentile average annual crash frequency for the entire database was approximately 11.0. In other words, 85 percent of the intersections in the database had an average annual crash frequency at or below this number.

The overall intersection crash rates (for the three years considered) in the database ranged from 0.15 crashes per million entering vehicles (MEV) to 8.22 crashes per MEV, and this safety measure had a standard deviation of 0.62 crashes per MEV (See Table 13). The average three-year crash rate (i.e., the overall crash rate per intersection divided by the number of intersections) was 0.95 crashes per MEV, and the 85th percentile rate was about 1.4 crashes per MEV.

For comparison or evaluation purposes, the values in Table 13 should be used with caution. The different crash filters that were applied to the rural and urban intersections in the database (e.g., three or five crashes in any one year, respectively) limit the usefulness of these generally defined descriptive statistics. Table 13 is provided for informational purposes only, and it is recommended that individual intersections be identified as either rural or urban first. Then, the crash statistics provided in the next three sections of this report can be used for comparison purposes. Crash statistics similar to those shown in Table 13 are calculated and presented for both rural and urban intersections.

Rural Intersection Crash Statistics

The intersections included in the crash database summarized in this report were identified as either rural or urban. Those locations that were reported as being in rural areas (i.e., unincorporated locations) were included in the database if they experienced three or more crashes in any one year from 2001 to 2003. The information provided in the next several paragraphs should be used for comparative purposes when the safety experience of rural intersections is being evaluated.

The following data summary discussions are based on the characteristics of 5,977 crashes at or near 556 rural intersection locations. These totals represent about 33 percent of the intersection locations in the database and about 18 percent of the crashes (See Tables 11 and 14). Approximately 68 percent of the rural intersection locations are in WisDOT Districts 1, 2, and 3 (with District 2 having about 35.6 percent of the locations). WisDOT Districts 4 to 7, on the other hand, each contained 5.2 to 10.3 percent of the intersections in the database, and District 8 about 2.5 percent of locations. A similar pattern of percentages was also true for the location of the rural crashes in the database (e.g., District 2 has 41.2 percent of the crashes). This statewide pattern of rural intersections and crashes in the database is not entirely surprising given the minimum crash requirement necessary for inclusion of a location. The data percentages by WisDOT district for the entire database are shown in Table 10.

TABLE 14. Rural Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Traffic Control				
Signal	106	19.0	2,046	34.2
Through-Stop	424	76.3	3,690	61.8
Four-Way Stop	26	4.7	241	4.0
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	428	77.0	3,590	60.1
15,000 to 25,000	96	17.3	1,449	24.2
> 25,000	32	5.7	938	15.7
Rural Total	556	32.6	5,977	18.1

Table 14 summarizes the type of traffic control and annual average daily entering volume levels of the rural intersections evaluated in this project. Approximately 76 percent of the rural intersections were through-stop-controlled (i.e., minor roadway stop-controlled), and another 4.7 percent were four-way stop-controlled. The crashes, however, were more heavily distributed toward the signalized locations. Signalized rural intersections represented only about 19 percent of the sites, but experienced about 34 percent of the crashes. Not surprisingly, about 77 percent of the intersections also had annual average entering daily traffic of less than 15,000 vpd, and around 17 percent had entering volumes between 15,000 and 25,000 vpd. In this case, the rural crashes were distributed toward the moderate and higher volume locations (i.e., they represented 23.0 percent of the locations, but 39.9 percent of the crashes). The distribution of the entering volumes at the rural intersections in the database is shown in Figure 2.

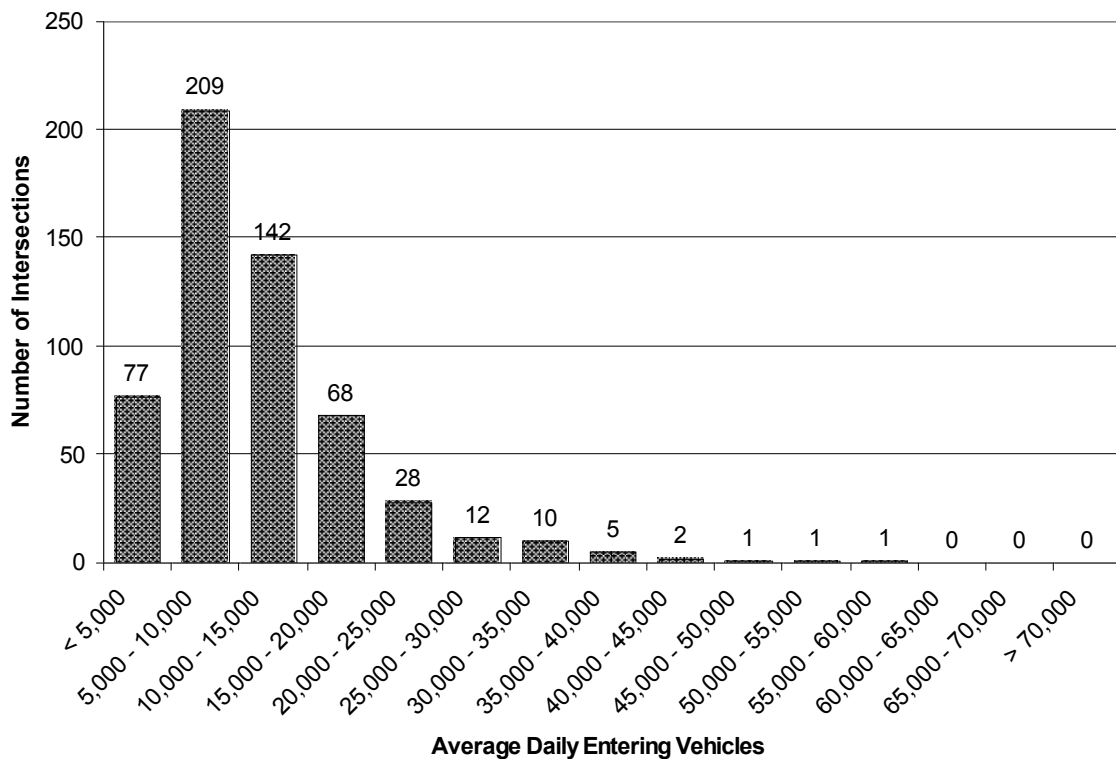


FIGURE 2. Annual Average Daily Entering Volume Distribution of Rural Intersections

The crash types, injury severity, and roadway conditions that occurred at the 556 rural locations in the database are summarized in Table 15. Approximately 45 percent of the rural collisions summarized in this project were angle crashes, and about 29 percent rear-end crashes. Another 13.7 and 6.4 percent of the crashes, respectively, were no collision (e.g., run-off-the-road)/fixed object and sideswipe-same direction collisions. The remaining crash types in the database were head-on, sideswipe-opposite direction, or unknown. About 56 percent of the rural crashes in the database did not result in injuries, but approximately 43 percent were injury collisions and 1.1 percent resulted in fatalities (n = 66). These three percentages, respectively, represent a decrease from the “all intersection” crash severity injury distribution (See Table 12) of about seven percent for non-injury crashes, and an increase of about 9 and 175 percent for injury and fatality crashes. In fact, although only about 18 percent of the crashes in the database were defined as rural (See Table 14), approximately 61 percent of the fatal crashes in the entire database were at rural locations. The other crash severities, on the other hand, occurred in approximately the same proportions as that of the entire database (i.e., closer to what might be expected). Similar to the percentages shown for the entire database (See Table 12), approximately 74 percent of the rural crashes also occurred with dry roadway conditions, and about 16 percent during wet conditions. Approximately 7 percent of the crashes occurred with snow or icy roadway conditions.

The average annual intersection crash frequency at the rural intersections in the database was 3.58 crashes per year, and this safety measure had a standard deviation of 2.92 (See Table 16). This average rural crash frequency was about 56 percent of the frequency calculated for the entire database (which included urban intersections). Not surprisingly, there is large amount of variability in this data. The minimum average annual frequency was 1.0 crash (i.e., only three crashes occurred in all three years – the minimum for a rural intersection to be included in the database) and maximum 30.33 (i.e., a total of 91 crashes in three years). In addition, the 85th percentile average annual crash frequency for the rural intersections was approximately 5.7 (about 52 percent of this statistic for the entire database). The average annual crash frequency was largest for the signalized rural intersections and the smallest for the through-stop-controlled (i.e.,

TABLE 15. Rural Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	2,678	44.8
Head-On	120	2.0
No Collision/Fixed Object	818	13.7
Rear-End	1,740	29.1
Sideswipe – Opposite Direction	147	2.5
Sideswipe – Same Direction	383	6.4
Unknown	91	1.5
Maximum Injury		
Fatality	66	1.1
Injury	2,574	43.1
None	3,337	55.8
Road Condition		
Dry	4,440	74.3
Wet	956	16.0
Snow	286	4.8
Ice	122	2.0
Mud	7	0.1
Unknown or Other	166	2.8

TABLE 16. Rural Intersection Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				85th Percentile (Approx.)¹
			Avg.	Min.	Max.	Std Dev.	
All Rural Intersections	556	5,977	3.58	1.00	30.33	2.92	5.7
Rural Intersections by Traffic Control							
Signal	106	2,046	6.43	1.33	30.33	4.60	10.0
Through-Stop	424	3,690	2.90	1.00	10.67	1.82	4.0
Four-Way Stop	26	241	3.09	1.00	7.67	1.54	4.8
Rural Intersections by Annual Average Daily Entering Volume (Vehicles)							
< 15,000	428	3,590	2.80	1.00	9.00	1.56	4.0
15,000 to 25,000	96	1,449	5.03	1.33	14.33	3.14	8.6
> 25,000	32	938	9.77	2.67	30.33	5.87	12.5

¹85 percent of the database rural intersections have a safety measure at or below this level.

minor roadway stop-controlled) intersections (See Table 16). Average annual crash frequency also increased with intersection entering volumes (See Table 16).

The rural intersection crash rates (for the three years considered) in the database ranged from 0.19 crashes per MEV to 4.71 crashes per MEV, and this safety measure had a standard deviation of 0.56 crashes per MEV (See Table 17). The overall maximum and minimum crash rates in the entire database (See Table 13) did not occur at rural intersections, and the rural intersection crash rate standard deviation was somewhat smaller than that calculated from the entire database (See Table 13). The average three-year crash rate (i.e., the overall crash rate per intersection divided by the number of intersections) calculated for rural intersections was 0.94 crashes per MEV, and the 85th percentile rate was about 1.4 crashes per MEV. The difference between the rural intersection 85th percentile crash rate and the same measure for *all* the intersections was negligible (See Table 13).

TABLE 17. Rural Intersection Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				
			Avg.	Min.	Max.	Std Dev.	85 th Percentile (Approx.) ¹
All Rural Intersections	556	5,977	0.94	0.19	4.71	0.56	1.4
Rural Intersections by Traffic Control							
Signal	106	2,046	0.88	0.28	1.95	0.38	1.3
Through-Stop	424	3,690	0.96	0.19	4.71	0.60	1.5
Four-Way Stop	26	241	0.88	0.45	2.26	0.45	1.2
Rural Intersections by Annual Average Daily Entering Volume (Vehicles)							
< 15,000	428	3,590	1.00	0.19	4.71	0.59	1.5
15,000 to 25,000	96	1,449	0.74	0.20	1.95	0.42	1.2
> 25,000	32	938	0.77	0.28	1.55	0.33	1.1

¹85 percent of the database rural intersections have a safety measure at or below this level.

Table 17 also provides summary crash information for rural intersections with different traffic control and annual average daily entering volumes. The table content

shows that the average crash rate was highest for through-stop-controlled rural intersections, and the average crash rate calculated for signalized and four-way stop-controlled rural intersections were the same at 0.88 crashes per MEV. The crash rates calculated were also the highest for the low volume (i.e., < 15,000 vpd) rural intersections, and approximately equal although slightly increasing between moderate (i.e., 15,000 to 25,000 vpd) and high (i.e., > 25,000 vpd) volume intersections. These crash rate outcomes are most likely the result of the crash filter used and the distribution of crashes and volumes at WisDOT rural state highway intersections. Low volume intersections with a moderate to large number of crashes can produce high crash rates, and signalized intersections with a low number of crashes but higher volumes can produce low crash rates.

Tables 16 and 17 should be used to evaluate rural intersection safety in Wisconsin. For quick referencing, Appendix A of this report includes all the tables in this chapter. In addition, Appendix B includes tables that provide similar crash statistics (all but the 85th percentile) for rural signalized, through-stop-controlled, and four-way stop-controlled rural intersections with the three categories of annual average daily entering volume in Table 17. Appendix B also includes crash frequency and rate summary statistics for rural intersections with different geometric characteristics.

Urban Intersection Crash Statistics

The intersections included in the crash database summarized in this report were identified as either rural or urban. Those locations that were reported as being in urban areas (i.e., incorporated locations) were included in the database if they experienced five or more crashes in any one year from 2001 to 2003. The information provided in the next several paragraphs should be used for comparative purposes when the safety experience of urban intersections is being evaluated.

The following data summary discussions are based on the characteristics of 27,113 crashes at or near 1,148 urban intersection locations. These totals represent about 67 percent of the intersection locations in the database and about 82 percent of the

crashes (See Tables 11 and 18). Approximately 66 percent of the urban intersection locations were in WisDOT Districts 1 and 2 (with District 2 having about 47 percent of the locations). WisDOT District 4, on the other hand, contained about 11 percent of the urban intersections in the database, and Districts 3, 5, and 6 included 5.2 to 6.5 percent of the locations. Districts 7 and 8 contained only 2.0 and 3.8 percent of locations, respectively. A similar pattern of percentages was also true for the location of the urban crashes in the database, although District 1 and 2 intersections experienced a slightly larger percentage of the crashes than expected and most of the other districts (particularly Districts 4, 5, 7, and 8) intersections a smaller percentage. This statewide pattern of urban intersections and crashes in the database is not entirely surprising given the minimum crash requirement necessary for inclusion of a location. The data percentages by WisDOT district for the entire database are shown in Table 10.

Table 18 summarizes the type of traffic control and annual average daily entering volume levels of the urban intersections evaluated in this project. Approximately 63 percent of the urban intersections were signalized (only 19 percent were signalized in the rural database), and another 36.8 percent were through-stop-controlled (i.e., minor roadway stop-controlled). Similar to the rural intersections, however, the crashes are more distributed toward the signalized locations. Signalized urban intersections represented about 63 percent of the sites, but experienced about 77 percent of the crashes. Not surprisingly, about 77 percent of the urban intersections had annual average entering daily traffic of more than 15,000 vpd, but the percentage of intersections with entering volumes above 25,000 vpd was about the same as that between 15,000 and 25,000 vpd. In this case, the crashes were distributed more heavily toward the highest volume locations (i.e., they represented 38.8 percent of the locations, but 55.5 percent of the crashes). The distribution of the entering volumes at the urban intersections in the database is shown in the Figure 3.

The crash types, injury severity, and roadway conditions that occurred at the 1,148 urban locations in the database are summarized in Table 19. Approximately 41 percent of the urban collisions summarized in this project were angle crashes, and about

TABLE 18. Urban Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Traffic Control				
Signal	720	62.7	20,726	76.5
Through-Stop	423	36.8	6,321	23.3
Four-Way Stop	5	0.5	66	0.2
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	264	23.0	3,982	14.7
15,000 to 25,000	438	38.2	8,088	29.8
> 25,000	446	38.8	15,043	55.5
Urban Total	1,148	67.4	27,113	81.9

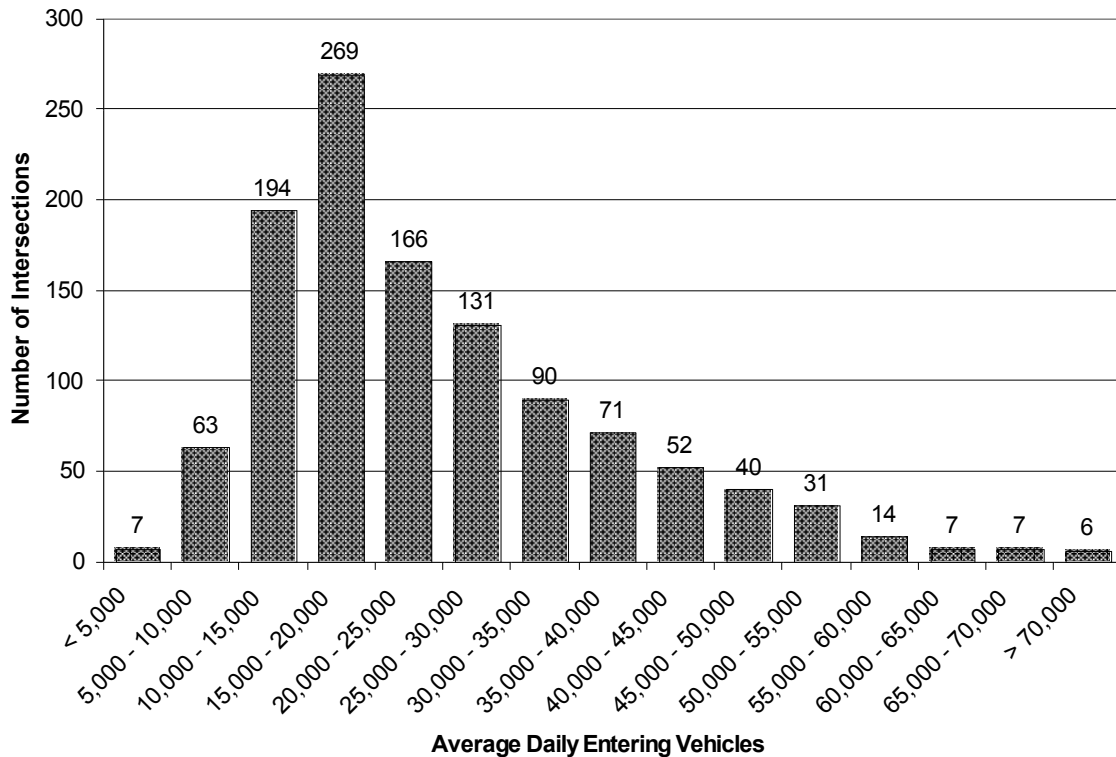


FIGURE 3. Annual Average Daily Entering Volume Distribution of Urban Intersections

TABLE 19. Urban Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	11,194	41.3
Head-On	539	2.0
No Collision/Fixed Object	2,690	9.9
Rear-End	9,483	35.0
Sideswipe – Opposite Direction	484	1.8
Sideswipe – Same Direction	2,372	8.7
Unknown	351	1.3
Maximum Injury		
Fatality	51	0.2
Injury	10,499	38.7
None	16,563	61.1
Road Condition		
Dry	20,172	74.4
Wet	4,841	17.8
Snow	1,112	4.1
Ice	327	1.2
Mud	20	0.1
Unknown or Other	641	2.4

35 percent rear-end crashes. This percentage of rear-end collisions is about 20 percent greater than that found for the rural intersections in the database (See Table 15). Another 9.9 and 8.7 percent of the crashes, respectively, are no collision (e.g., run-off-the-road)/fixed object and sideswipe-same direction collisions. The remaining crash types in the database were head-on, sideswipe-opposite direction, or unknown. About 61 percent of the urban crashes in the database did not result in injuries, but approximately 39 percent were injury collisions and 0.2 percent resulted in fatalities (n = 51). The proportion of non-injury crashes at the urban locations is greater than the rural locations, and the proportion of injury crashes less (See Table 15). The proportion of fatalities at urban locations is also much smaller than that occurring at rural locations. In fact, although approximately 82 percent of the crashes in the database were defined as urban (See Table 18), only about 44 percent of the fatal crashes occurred in urban areas. Road

conditions during the crashes were similar to that shown for the entire database (See Table 12) and rural locations (See Table 15). Approximately 74 percent of the urban crashes occurred with dry roadway conditions, and about 18 percent during wet conditions. Approximately five percent of the crashes occurred with snow or icy roadway conditions.

The average annual intersection crash frequency at the urban intersections in the database was 7.87 crashes per year, and this safety measure had a standard deviation of 5.65 (See Table 20). This average urban crash frequency was about 123 percent of the frequency calculated for the entire database (which included rural intersections). Not surprisingly, there was also a large amount of variability in this data. The minimum average annual crash frequency was 1.67 crashes (e.g., only five crashes occurred in all three years – the minimum for a urban intersection to be included in the urban database) and the maximum 44.67 (i.e., a total of 134 crashes in three years). In addition, the 85th percentile average annual crash frequency for the urban intersections was approximately 13.0 (about 118 percent of this statistic for the entire database). The average annual crash frequency was largest for the signalized urban intersections and smaller for through-stop-controlled (i.e., minor roadway stop-controlled) intersections. The five four-way stop-controlled urban intersections in the database had the lowest calculated average annual crash frequency, but due to the small dataset size the statistics for this type of control should be used with caution. Similar to the patterns shown for rural intersections, the average annual crash frequency at urban intersections also increased with entering volumes.

The urban intersection crash rates (for the three years considered) ranged from 0.15 crashes per MEV to 8.22 crashes per MEV, and this safety measure had a standard deviation of 0.65 crashes per MEV (See Table 21). All three of these variability measures are similar to those calculated for the entire database (See Table 13). The average three-year crash rate (i.e., the overall crash rate per intersection divided by the number of intersections) was 0.96 crashes per MEV, and the 85th percentile rate was about 1.4 crashes per MEV. The difference between the urban intersection 85th percentile

TABLE 20. Urban Intersection Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Urban Intersections	1,148	27,113	7.87	1.67	44.67	5.65	13.0	
Urban Intersections by Traffic Control								
Signal	720	20,726	9.60	2.00	44.67	6.27	15.3	
Through-Stop	423	6,321	4.98	1.67	17.33	2.46	7.0	
Four-Way Stop ²	5	66	4.40	2.67	6.33	1.55	--	
Urban Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	264	3,982	5.03	1.67	17.67	2.60	7.0	
15,000 to 25,000	438	8,088	6.16	1.67	25.33	3.30	9.3	
> 25,000	446	15,043	11.24	1.67	44.67	6.96	17.8	

¹85 percent of the database urban intersections have a safety measure at or below this level.

²Use with caution due to small sample size.

TABLE 21. Urban Intersection Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Urban Intersections	1,148	27,113	0.96	0.15	8.22	0.65	1.4	
Urban Intersections by Traffic Control								
Signal	720	20,726	1.00	0.17	5.60	0.55	1.5	
Through-Stop	423	6,321	0.88	0.15	8.22	0.78	1.2	
Four-Way Stop ²	5	66	1.02	0.74	1.47	0.29	--	
Urban Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	264	3,982	1.33	0.31	8.22	0.99	1.9	
15,000 to 25,000	438	8,088	0.87	0.22	3.00	0.45	1.3	
> 25,000	446	15,043	0.82	0.15	3.12	0.44	1.2	

¹85 percent of the database urban intersections have a safety measure at or below this level.

²Use with caution due to small sample size.

crash rate and the same measure for *all* the intersections and the *rural* intersections was negligible (See Tables 13 and 17).

Table 21 also provides summary crash information for urban intersection with different traffic control and average annual daily entering volumes. The table content shows that the average crash rate for signalized urban intersections was higher than that for the through-stop-controlled (i.e., minor roadway stop-controlled) intersections. The crash rate for urban four-way stop-controlled intersections was the highest of the three, but it should be noted that the crash statistics calculated for this type of intersection are based on data from only five intersections and should be used with caution. The crash rates calculated were also the highest for the low volume (i.e., < 15,000 vpd), but similar for the moderate (i.e., 15,000 to 25,000 vpd) and high (> 25,000 vpd) volume intersections. These crash rate outcomes are the result of the distribution of crashes and volumes at the urban intersections. Low volume intersections with a moderate number of crashes can produce high rates, and high volume intersections with only a few crashes can result in very low average crash rates. The low crash rate average shown in Table 21 for urban through-stop-controlled intersections is believed to be the result of the latter situation.

Tables 20 and 21 should be used to evaluate urban intersection safety in Wisconsin. For quicker reference, Appendix A of this report includes all the tables in this chapter. In addition, Appendix B includes tables that provide similar crash statistics (all but the 85th percentile) for urban signalized, through-stop-controlled, and four-way stop-controlled intersections with the three categories of annual average daily entering volume in Table 21. Appendix B also includes crash frequency and rate summary statistics for urban intersections with different geometric characteristics.

Rural-Urban Intersection Crash Comparison

As previously noted, the rural and urban intersection locations included in the crash database summarized in this report were identified with two minimum crash requirements. Rural intersections were included in the summary database if they

experienced three or more crashes in any one year from 2001 to 2003, and urban intersections had to have five or more crashes. These were the minimum number of crashes for rural and urban intersection, respectively, at which it was thought intersection safety should be more closely considered and summarized. Table 22 shows the average annual crash frequencies and crash rates for the intersections in the database designated as rural and urban. The frequencies and rates presented in Table 22 are also grouped by intersection traffic control and volumes. Comparisons of these crash statistics, however, should account for the different minimum crash requirements used to identify the rural and urban intersections in the database.

TABLE 22. Rural and Urban Intersection Average Crash Frequencies and Rates

	Average Annual Crash Frequency (Crashes per Year)		Crash Rate (per Million Entering Vehicles)	
	Rural	Urban	Rural	Urban
All Intersections	3.58	7.87	0.94	0.96
Intersections by Traffic Control				
Signal	6.43	9.60	0.88	1.00
Through-Stop	2.90	4.98	0.96	0.88
Four-Way Stop ¹	3.09	4.40	0.88	1.02
Intersections by Annual Average Daily Entering Volume (Vehicles)				
< 15,000	2.80	5.03	1.00	1.33
15,000 to 25,000	5.03	6.16	0.74	0.87
> 25,000	9.77	11.24	0.77	0.82

¹Use urban values with caution due to small sample size.

There are a few interesting data patterns and/or trends shown in Table 22. Not surprisingly, the average annual crash frequencies at the urban intersections were always larger than those that occurred at the rural intersections. In addition, the trends in the crash frequencies for different traffic control and annual average daily entering volumes are similar for both rural and urban locations. The through-stop-controlled intersections always had the lowest frequency of crashes and the signalized intersections the highest. Of course, the crash frequencies also increased with volume in both rural and urban areas.

The patterns shown in Table 22 for average crash rates are less consistent than those described for the crash frequencies. These differences are due to the introduction of entering volumes into the calculation, and the wide range of crash-volume combinations that can and do occur in the database. As expected, urban crash rates are almost always higher than their comparable rural crash rates. However, the urban crash rate calculated for through-stop-controlled intersections was smaller than that calculated for similar rural intersections. This outcome appears to be due to the fact that the database contains data for a number of urban through-stop-controlled intersections with very large entering volumes but relatively few crashes. In some cases a crash rate produced for this type of situation may not be a true measure of its safety. The high volumes may simply be restricting its use by minor roadway vehicles and subsequently reducing the potential for crashes. The urban four-way stop-controlled crash rate in Table 22 should also be used with caution due to the small sample used in its calculation (only five intersections with these characteristics are in the database). Not surprisingly, the crash rates at both rural and urban intersections also generally decrease with volume (i.e., the volume using the intersections generally increases more quickly than the number of crashes at the intersections), although a very small increase was observed as entering volumes increase from moderate to high in rural areas. In rural areas it can be generally concluded that the average crash rates at intersections with moderate and high volume levels are approximately equal.

Intersection Geometrics

In the early stages of this study the project team and WisDOT recognized that there were few crash report inputs specifically related to the geometrics of an intersection. Therefore, a series of 18 geometric categories or general intersection layouts were defined, and WisDOT district staff were asked to assign, if possible, one of these categories to each of the intersections in the previously described crash database. A total of 363 rural and 809 urban intersections were assigned a geometric category. These totals represent about 69 percent of the locations in the crash database (See Table 23).

TABLE 23. Geometric Category Data

Geometric Category	Number of Intersections	Percentage of Intersections	Number of Crashes	Percentage of Crashes
Three-Leg Intersections				
A: Two-Lane Major Roadway with No Left-Turn Lane	34	2.0	313	0.9
B: Two-Lane Major Roadway with Left-Turn Lane	38	2.2	346	1.0
C: Four-Lane Major Undivided Roadway with No Left-Turn Lane	31	1.8	535	1.6
D: Four-Lane Major Divided Roadway with No Left-Turn Lane	5	0.3	64	0.2
E: Four-Lane Major Divided 55+ mph Roadway with Signal or Dual Left-Turn Lane ¹	4	0.23	31	0.1
F: Four-Lane Major Divided Roadway with Left-Turn Lane	43	2.5	908	2.8
G: Four-Lane Major Divided Roadway with Dual Left-Turn Lane	4	0.23	72	0.2
Four-Leg Intersections				
H: Two-Lane Major Roadway with No Left-Turn Lane	140	8.2	1,743	5.3
I: Two-Lane Major Roadway with Left-Turn Lane (One or Both Approaches)	143	8.4	2,249	6.8
J: Four-Lane Major Undivided Roadway with No Left-Turn Lane	92	5.4	1,795	5.4
K: Four-Lane Major Divided Roadway with No Left-Turn Lane	24	1.4	432	1.3
L: Four-Lane Major Divided 55+ mph Roadway with Signal or Dual Left-Turn Lane (One or Both Approaches) ¹	36	2.1	531	1.6
M: Four-Lane Major Divided Roadway with Left-Turn Lane (One or Both Approaches)	457	26.8	13,313	40.2
N: Four-Lane Major Divided Roadway with Dual Left-Turn Lane (One or Both Approaches)	39	2.3	2,166	6.6
Special Intersections				
O: Five or More Intersection Approaches	4	0.24	133	0.4
P: Roundabout	0	0.0	0	0.0
Q: Four-Lane Major Undivided Roadway with Left-Turn Lane (One or Both Approaches)	48	2.8	1,172	3.5
R: Four-Lane Major Undivided Roadway with Dual Left-Turn Lane (One or Both Approaches)	0	0.0	0	0.0
Other or Unknown Intersections				
S: Other	30	1.8	562	1.7
Unknown	532	31.3	6,725	20.4

¹Posted Speed on at least one major roadway approach.

The geometric categories defined in this project are listed in Table 23 along with the number and percentage of intersections and crashes in the entire database assigned to each. Overall, about 55 and 67 percent of the intersections and crashes, respectively, were identified as four-legged. However, only about 9 percent and 7 percent of the intersections and crashes, respectively, were three-legged. About three to four percent of the intersections and crashes were assigned special intersection status (i.e., Categories O to R – See Table 23). Almost two percent of the intersections were included in the Category S or “Other” category. This category contains intersection locations for which the geometry was known but was not included in Categories A to R. About 27 percent of the intersections in the overall database are four-legged with left-turn lanes and along four-lane divided roadways (i.e., Category M). Another 16.6 percent are four-legged intersections along two-lane roadways (i.e., Categories H and I). None of the intersections in the database were categorized as roundabouts (i.e., Category P) or assigned an undivided four-lane major roadway dual left-lane layout (i.e., Category R). The remaining geometric categories include about 67 and 78 percent of all the intersections and crashes, respectively, contained in the database initially described in this chapter.

Four primary geometrics were used to differentiate the geometric categories listed in Table 23. These geometrics included the number of intersection approach legs, number of major roadway lanes, whether the major roadway had a median or not, and the existence of left-turn lane(s). The categories in Table 23 were grouped by these four geometrics for both rural and urban intersections. The crash frequency and rate summary statistics for these groups were then calculated and these are presented in the following paragraphs. Only the special intersection Categories Q and R were used in these calculations. The special intersection Categories O and P – See Table 23) and Category S – “Other” were excluded.

Rural Intersection Geometry and Crash Statistics

The average annual crash frequency and crash rate per MEV were calculated for the rural intersections assigned a geometric category. For summary purposes, these intersections

were grouped by their number of approach legs, number of major roadway through lanes, whether the major roadway had a median or not, and the existence of left-turn lane(s). The average crash frequency statistics calculated for these groups are shown in Table 24. They follow expected patterns. Average annual crash frequencies increase with the number of intersection legs and major roadway lanes. In addition, crash frequency also appears to increase with the addition of a median and left-turn lanes. This increase, however, is likely due to the fact that these types of facilities are only added as intersection entering volumes increase. For example, approximately 70 percent of the rural undivided major roadway intersection crashes in the database of interest occurred at locations with a low number of entering vehicles (i.e., < 15,000 vpd), but this was true for only 27.1 percent of the rural intersection crashes along divided major roadways. In addition, approximately 76 percent of the crashes in the geometric category database occurred at low volume (i.e., < 15,000 vpd) intersections without left-turn lane(s), but this was true for only about 42 percent of this type of intersection with left-turn lanes. The distribution of volume and crashes for the four geometric groups considered can be found in a series of tables within Appendix B.

TABLE 24. Rural Intersection Geometry and Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.	Std Dev.	
Rural Intersections by Number of Approach Legs							
Three-Leg	69	588	2.84	1.00	9.00	1.45	3.9
Four-Leg	281	3,858	4.58	1.00	30.33	3.50	7.7
Rural Intersections by Number of Major Roadway Lanes							
Two-Lane	221	2,310	3.48	1.00	14.00	2.15	5.7
Four-Lane	136	2,272	5.57	1.33	30.33	4.28	8.8
Rural Intersections by Median Existence							
Undivided	247	2,683	3.62	1.00	14.33	2.35	5.7
Divided	110	1,899	5.75	1.67	30.33	4.44	8.8
Rural Intersections by Left-Turn Lane Existence							
Left-Turn Lane	222	3,195	4.80	1.33	30.33	3.69	7.7
No Left-Turn Lane	135	1,387	3.42	1.00	14.33	2.28	5.3

¹85 percent of the database rural intersections have a safety measure at or below this level.

Table 25 shows crash rate statistics for rural intersections grouped by the four geometrics of interest (i.e., number of approach legs and major roadway lanes, existence of a median, and the existence of a left-turn lane(s)). The average crash rate calculated for four-legged intersections was higher than that calculated for three-legged intersections. This result is not unexpected because the number of potential vehicle conflicts at four-legged intersections is more than three times that of one three-legged intersection. The average intersection crash rate at rural intersections along two-lane roadways was higher than that along four-lane roadways, and a similar relationship was found for intersection crash rates along undivided and divided roadways. These results are most likely due to changes in volume that occur with these roadway and intersection characteristics, and the correlation between these characteristics and additional safety-related geometrics that are included in projects when the cross section of roadways and intersections are upgraded (e.g., better roadside design). These crash patterns are not unlike those found for roadway segment collisions in the past. Finally, the overall average crash rate of rural intersections with no left-turn lane(s) was greater than those

TABLE 25. Rural Intersection Geometry and Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				
			Avg.	Min.	Max.	Std Dev.	85 th Percentile (Approx.) ¹
Rural Intersections by Number of Approach Legs							
Three-Leg	69	588	0.86	0.22	4.10	0.55	1.4
Four-Leg	281	3,858	0.99	0.28	3.46	0.54	1.2
Rural Intersections by Number of Major Roadway Lanes							
Two-Lane	221	2,310	1.02	0.29	4.10	0.56	1.5
Four-Lane	136	2,272	0.86	0.22	3.26	0.47	1.3
Rural Intersections by Median Existence							
Undivided	247	2,683	1.00	0.22	4.10	0.56	1.5
Divided	110	1,899	0.87	0.28	3.26	0.47	1.2
Rural Intersections by Left-Turn Lane Existence							
Left-Turn Lane	222	3,195	0.91	0.28	3.26	0.45	1.4
No Left-Turn Lane	135	1,387	1.05	0.22	4.10	0.64	1.5

¹85 percent of the database rural intersections have a safety measure at or below this level.

with left-turn lanes. The addition of a left-turn lane reduces potential vehicle conflicts and also occurs when volumes increase to a level that warrants their use. The average percentage of left-turn collisions at intersections with different geometries is shown in Appendix C.

Urban Intersection Geometry and Crash Statistics

The average annual crash frequency and crash rate per MEV were calculated for the urban intersections assigned a geometric category. For summary purposes, these intersections were grouped by their number of approach legs, number of major roadway through lanes, whether the major roadway had a median or not, and the existence of left-turn lane(s). The average crash frequency statistics calculated for these groups are shown in Table 26. The magnitude of the urban crash frequencies is greater than that calculated for the rural intersections (See Table 24), but they follow the same patterns (See Table 26). Average annual crash frequencies increase with the number of urban intersection legs and major roadway lanes. In addition, crash frequency appears to increase with the

TABLE 26. Urban Intersection Geometry and Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.	Std Dev.	
Urban Intersections by Number of Approach Legs							
Three-Leg	90	1,681	6.23	1.67	20.67	3.51	8.7
Four-Leg	650	18,371	9.42	1.67	44.67	6.33	15.3
Urban Intersections by Number of Major Roadway Lanes							
Two-Lane	134	2,341	5.82	1.67	18.00	3.10	8.7
Four-Lane	647	18,747	9.66	1.67	44.67	6.36	15.3
Urban Intersections by Median Existence							
Undivided	279	5,470	6.54	1.67	29.67	3.53	9.3
Divided	502	15,618	10.37	1.67	44.67	6.76	16.7
Urban Intersections by Left-Turn Lane Existence							
Left-Turn Lane	590	17,593	9.94	1.67	44.67	6.57	16.0
No Left-Turn Lane	191	3,495	6.10	1.67	17.33	2.77	8.7

¹85 percent of the database urban intersections have a safety measure at or below this level.

addition of a median and left-turn lanes. This increase, however, is likely due to the fact that these types of facilities are only added as intersection entering volumes increase. For example, only 18.4 percent of the urban undivided major roadway intersection crashes in the database of interest occurred at locations with a high number of entering vehicles (i.e., > 25,000 vpd), but this was true for approximately 81 percent of the urban intersections crashes along divided major roadways. In addition, only about 15 percent of the crashes in the geometric category database occurred at high volume (i.e., > 25,000 vpd) intersections without left-turn lane(s), but this was true for about 74 percent of this type of intersection with left-turn lanes. The distribution of volume and crashes for the four geometric groups considered can be found in a series of tables within Appendix B.

Table 27 shows crash rate statistics for urban intersections grouped by the four geometrics of interest (i.e., number of approach legs and major roadway lanes, existence of a median, and the existence of a left-turn lane(s)). Again, the patterns followed by the average crash rates at the urban intersections are similar to that produced for the rural

TABLE 27. Urban Intersection Geometry and Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)					85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.	Std Dev.		
Urban Intersections by Number of Approach Legs								
Three-Leg	90	1,681	0.80	0.23	3.46	0.50	1.1	
Four-Leg	650	18,371	0.98	0.17	6.85	0.55	1.4	
Urban Intersections by Number of Major Roadway Lanes								
Two-Lane	134	2,341	1.07	0.30	6.85	0.74	1.5	
Four-Lane	647	18,747	0.94	0.17	4.15	0.50	1.4	
Urban Intersections by Median Existence								
Undivided	279	5,470	1.07	0.30	6.85	0.65	1.5	
Divided	502	15,618	0.90	0.17	4.15	0.48	1.4	
Urban Intersections by Left-Turn Lane Existence								
Left-Turn Lane	590	17,593	0.93	0.17	6.85	0.55	1.4	
No Left-Turn Lane	191	3,495	1.04	0.29	3.52	0.55	1.5	

¹85 percent of the database urban intersections have a safety measure at or below this level.

intersections (See Table 25). The average crash rate calculated for four-legged urban intersections was higher than that calculated for three-legged urban intersections, but the potential for vehicle conflicts is also much greater at four-legged intersections. The average intersection crash rates along two-lane roadways and undivided roadways were also higher than those calculated along four-lane and divided roadways, respectively. These results are most likely due to changes in volume with these roadway and intersection characteristics, and the correlations between these characteristics and additional safety-related design components that are included in projects when the cross section of roadways and intersections are upgraded. Finally, the overall average crash rate for urban intersections with no left-turn lane was greater than those with left-turn lanes (See Table 27).

Geometrics and Crash Characteristics

Additional summary statistics were also calculated that more closely describe the crashes of the 18 geometric categories and four geometric groups (e.g., number of major roadway lanes) previously described. These statistics can be used to evaluate whether crashes with certain characteristics (e.g., wet roadway conditions) are an issue at a particular location, and this knowledge can be applied to choose a more appropriate intersection safety improvement. Average percentages for the following crash types are provided in Appendix C.

- Injury Crashes,
- Left-Turn Crashes,
- Angle Crashes,
- Rear-End Crashes,
- Sideswipe – Same Direction Crashes,
- Dry Roadway Condition Crashes,
- Wet Roadway Condition Crashes,
- Snow/Ice Crashes, and
- Night Crashes.

Six tables are provided in Appendix C. The first three tables include average percentages of the crash types listed above for the intersections in the four geometric groups previously defined (e.g., number of approach legs). This information is provided for *all* the intersections assigned a geometric category and those designated as rural or urban. Some interesting patterns in these data include an increase in angle collisions and a decrease in rear-end crashes when the number of approach legs is increased. These differences are especially obvious in the rural data. There is also an increase in the average percentage of rear-end collisions when the number of lanes on the major roadway are increased. The percentage of left-turn collisions also increased slightly with the addition of a left-turn lane.

The other three tables in Appendix C include average percentages for the crash types listed for each of the 18 geometric categories previously defined (See Table 23). Tables are provided for *all* the intersections assigned a geometric category and those designated as rural or urban. Of note in these tables is that the percentages are relatively similar throughout. The other data pattern of interest includes the fact that injury crashes represent a higher percentage of the collisions at rural rather than urban locations. In fact the percentage of injury crashes at rural locations (with an assigned geometric category) was about 21 percent greater than the same measure of injury crashes at urban locations. However, the average percentage of rear-end collisions at urban locations is about 32 percent greater than the average percentage of rear-end collisions at the rural intersections.

Summary

A statewide intersection crash database was created as part of this project. Its development and content is summarized and discussed in this chapter. First, the methodology and crash filter applied to create the database was described. At least three crashes in any one year from 2001 to 2003 were necessary for rural locations to be included the database and at least five crashes at urban locations.

The original database used to calculate the summary information in this chapter included information about 1,704 intersections and 33,090 crashes along the state highway (and connecting highway) system in Wisconsin. Approximately 62 and 70 percent of the intersections and crashes in the database, respectively, were located within WisDOT Districts 1 and 2. In this chapter the intersections and crashes were summarized by area (i.e., urban and rural), traffic control, and three levels of entering volume. In addition, the characteristics of the crashes (e.g., crash type, maximum injury, and road condition) are discussed, and the average, minimum, maximum, standard deviation and 85th percentile of the crash frequencies and rates at the intersections in the database are presented and described. Finally, the crash patterns at intersections with different geometric designs are documented.

This chapter provided summary intersection crash statistics for those locations designated as rural and urban. Approximately two-thirds of the intersections and 82 percent of the crashes in the database were urban. The crash statistics calculated for the rural and urban intersections were also grouped by three intersection traffic controls and three categories of average annual daily entering volume. The rural and urban intersection crash frequencies and rates, segmented by traffic control and volume, are also compared. Not surprisingly the average annual crash frequencies for the urban intersections in the database were always greater than those for similar rural locations. In addition, in all but one case, the crash rates for the urban intersections were greater than the crash rates for rural intersections. The one exception to this pattern was the urban crash rate at through-stop-controlled (i.e., minor roadway stop-controlled) intersections. The database used in this project includes a number of high volume urban through-stop-controlled intersections that had a minimal number of crashes, and this resulted in a lower than expected crash rate. The low crash experiences at this type of intersection may be the result of few minor roadway movements. In addition, the database used only contained five *urban* four-way stop-controlled intersections, and this limits the usefulness of the crash statistic calculated for this type of intersection. These two database characteristics limit some of its usefulness.

A series of 18 geometric categories were also defined as part of this project. A total of 1,142 intersections were assigned one of these categories by WisDOT district personnel. Overall, approximately 67 percent of the intersections in the database were assigned a geometric category and about 78 percent of the crashes in the database occurred at these intersections. About 27 percent of the intersections in the original database were assigned a four-legged geometry with left-turn lane(s) along a four-lane divided roadway, and approximately 17 percent were assigned a four-legged geometry (with and without left-turn lane(s)) along a two-lane undivided roadway. The crash data for these intersections were combined into groups with three and four approach legs and two and four major roadway lanes. Additional groups considered intersections along major roadways with and without a median and with and without left-turn lane(s). Summary crash frequency and rate statistics (i.e., average, minimum, maximum, standard deviation, and 85th percentile) were calculated for these groups in both rural and urban locations. In general, average crash frequencies increased with the number of legs and major roadway lanes, and the addition of a median or left-turn lane(s). All of these characteristics are generally added as volumes increase. Intersections with four legs had average crash rates higher than those with three legs, and intersections along roadways with two lanes had higher crash rates than those along roadways with four-lanes. Not surprisingly, the crash rate at intersections along undivided roadways was also higher than those on divided roadways, and the crash rate at intersections with left-turn lanes was greater than those without them.

Three appendices to this report include additional intersection crash summary data. For quick reference, Appendix A includes all the tables/figures contained in Chapter 3. Appendix B includes crash statistics for rural and urban intersections with different traffic controls and average annual daily entering volumes. The tables in Appendix B provide more detailed information than could be contained in this chapter. Appendix C includes the average percentages of several crash types and characteristics. These percentages are provided for each of the 18 geometric categories defined in this chapter, and for the four groups used within this study to summarize crash patterns and intersection geometrics.

CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS

A significant amount of information and data was gathered and summarized as part of this intersection safety project. The following conclusions are based on the results of the literature review, DOT survey, and intersection crash calculations completed.

Recommendations are also provided about the use of the crash statistics included in this report and appendices, and suggestions are made related to additional intersection safety crash calculations and analysis that might be completed in the future.

Conclusions

- Limited public resources require the efficient and effective application of intersection safety improvements. Intersection locations that may need a more detailed safety analysis and/or potential improvements must be identified. An understanding of the typical or expected intersection crash patterns within a jurisdiction can assist transportation professionals with this identification. This project produced summary measures of intersection crash safety for the WisDOT.

- A number of measures and methods are used throughout the United States to identify and/or rank intersections with potential safety problems. The typical crash measures used in these activities include crash frequency, rate, and severity. The application of these measures each has its own advantages and disadvantages. Combinations of these measures are often used to reduce the impact of their individual disadvantages. “Critical” measures of safety and/or models that predict expected crashes are also sometimes developed and then compared to what has occurred at a particular intersection. Currently, the most statistically valid approach to crash prediction modeling includes some type of Bayesian methodology.

- Crash reduction factors (CRFs) are used to determine what type of crash impacts might be expected if an intersection improvement is implemented. CRFs can also be used to calculate and compare the benefit-cost statistics of alternative intersection safety improvements. There are currently no national CRFs used throughout the

United States, and most individual states have either created their own set of CRFs, used those from other states, or some combination of the two. A series of intersection related CRFs are provided in Chapter 2 of this report. However, no critical evaluation of how these CRFs were calculated was completed.

- The database created for this project included three years of crash information from those intersections that met a predefined minimum crash requirement. The application of this type of “filter” is typical, and normally applied to limit the scope of a safety evaluation to those facilities expected to be of interest. The database summarized in this report considered urban intersections if they had five or more crashes in any one year from 2001 to 2003. Rural intersections were included in the database if they had 3 or more crashes in any one year from 2001 to 2003. All the locations in the database were along the state highway or connecting highway system. The database included information about more than 33,000 crashes at more than 1,700 locations. About 62 to 70 percent of the locations and crashes were from WisDOT Districts 1 and 2 (Madison and Waukesha, respectively).
- A series of crash statistics for *all* the intersections in the database are presented in Chapter 3. Percentages of crash types, injury levels, and road conditions are presented, and crash frequency and rate provided. In addition, crash frequency and rate averages, minimums, maximums, and standard deviations are provided and discussed. Unfortunately, the usefulness of the crash statistics based on *all* the intersections in the database is limited because the rural and urban locations included in the database were defined differently (See the conclusion above). They should be used appropriately and are for informational purposes only.

The crash statistics described in the previous paragraph were also calculated for the rural and urban intersections in the database. The average annual crash frequencies for the rural and urban intersections, respectively, were 3.58 and 7.87 crashes per year. The average rural and urban intersection crash rates, on the other hand, were determined to be 0.94 and 0.96 crashes per MEV, respectively. For more detailed

safety evaluations, similar statistics are also provided in Chapter 3 for rural and urban intersections with different traffic control and annual average daily entering volume.

- The patterns and trends found for the crash frequencies and rates at rural and urban intersections were generally as expected. Not surprisingly, the crash frequencies increased and the rates generally decreased with volume at both rural and urban locations. The one exception was that the crash rate calculated for high volume rural intersections was slightly greater (only 0.03 crashes per MEV) than that calculated for moderate volume rural intersections. The average annual crash frequency at signalized intersections was also greater than this measure at four-way stop-controlled intersections. Rural through-stop-controlled (i.e., minor-roadway stop-controlled) intersections had the smallest average annual crash frequency.

The crash rate patterns found for rural and urban intersections with different traffic control varied more than the previously described crash frequency patterns. Rural signalized and four-way stop-controlled intersections had the same calculated average crash rates, and the rural through-stop-controlled intersections had the lowest crash rate of the three. At the urban intersections the lowest average crash rate was calculated for through-stop-controlled locations, but this outcome was believed to be the result of a series of very high volume intersections with very few crashes. In fact, the average crash rate calculated for urban through-stop-controlled intersections was unexpectedly smaller than the same measure for rural intersections. This characteristic of the database is believed to be one of its potential weaknesses. The crash rate calculated for signalized and four-way stop-controlled urban intersections was greater than those for the rural intersections, and the four-way stop-controlled rate was the largest average urban crash rate calculated. Unfortunately, this crash rates was also only based on data from five intersections and it should be used with cautions. This lack of data is the second recognized weakness in the database created as part of this project.

- There are few crash report inputs related to the geometrics of an intersection. This project defined 18 intersection geometric categories. About 67 percent of the intersections in the initial database were assigned a useable geometric category. The geometric categories defined are described in this report, and summary crash statistics are provided for the geometric categories grouped by the following intersection characteristics: number of approach legs, number of major roadway lanes, existence of a median, and existence of left-turn lane(s). The average percentage of several different crash types and characteristics for each geometric category and category group was calculated. This information is provided in Appendix C.

Recommendations

- It is recommended that the information provided in Chapter 2 of this report be used to compare current practice in Wisconsin to what is occurring throughout the United States. It is believed that the content of this report and the database created as part of this project are a good first step toward a more detailed understanding and evaluation of intersection safety in Wisconsin.
- It is recommended that the CRFs provided in Chapter 2 of this report be used to evaluate the potential benefits of intersection safety improvements, but only if more appropriate WisDOT or locally generated CRFs do not exist. The CRFs provided in this report should be used with caution because the methodologies used in their creation have not been critically evaluated. Relative comparisons of the impacts of multiple safety improvements can be completed if it is assumed that the CRFs are created in a similar manner. The creation of a comprehensive WisDOT CRF catalog for intersection improvements is recommended.
- It is recommended that the summary crash statistics from this project be used to evaluate the existing safety of WisDOT intersections. Actual crash measures at existing intersections can be compared to the statewide averages, minimums, maximums, and 85th percentiles presented in this report. If desired, the standard deviations provided for these statewide crash measures could also be used to

determine “critical” values for comparison purposes (but only if certain data distribution assumptions are confirmed or assumed). It is recommended that these types of comparisons be completed only after the intersection of interest has been designated as either rural or urban. In addition, the intersection being evaluated could be further defined by its traffic control, entering volumes, and certain geometric features. Statewide crash statistics for all combinations of these characteristics are provided in this report. The crash frequency and rate statistics provided for *all* the intersections in the database, on the other hand, should only be used for informational purposes. The average percentages provided for intersection crash types, injuries, and roadway conditions can also be used to determine whether a particular location is experiencing a greater than typical number of collisions with particular characteristics (e.g., wet roadway conditions).

- It is recommended that the crash summary information provided for intersections with different geometric characteristics also be used for safety comparisons. Typical crash statistics for intersections with a different number of approach legs and major roadway through lanes can be compared to the experiences at similar intersections. The same type of comparison can also be completed for intersections with or without a median or left-turn lane. Average percentages for rural and urban types and characteristics (e.g., wet roadway conditions) are also provided in Appendix C for the 18 geometric categories and four category groups defined in this project. These statistics can be very helpful in the identification of specific safety problems at intersections.
- Several improvements to the crash database created in this project are recommended. First, it is recommended that more data from throughout Wisconsin be incorporated into the database. The majority of locations and crashes in the database are currently in WisDOT Districts 1 and 2. The inclusion of more data may begin to address the two potential database weaknesses discussed in the conclusions section of this chapter. All the intersections in the database should also be assigned a geometric category. Second, it is recommended that WisDOT continue to pursue the

development of an automated and geographically-based safety data management system. In the short term, a quality-controlled and consistent annual updating of the intersection crash database created as part of this project is recommended. In addition, an automated analysis tool for end users could also be created to calculate relevant crash characteristics for particular intersections and compare them to the measures determined in this project. In the long-term, Wisconsin crash information needs to become geographically-referenced for more efficient and effective safety summarization and evaluation at the operational decision-making level. Complete compatibility between a geographically-based crash information system and other relevant WisDOT databases (e.g., signing) is necessary.

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Appendix A
Chapter 3 Tables and Figures

Database Intersections and Crashes by WisDOT District

District	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
1	320	18.8	6,514	19.7
2	739	43.3	16,479	49.8
3	136	8.0	2,205	6.7
4	182	10.7	2,684	8.1
5	92	5.4	1,548	4.7
6	114	6.7	2,214	6.7
7	63	3.7	620	1.8
8	58	3.4	826	2.5
Total	1,704	100.0	33,090	100.0

Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Area Type				
Urban	1,148	67.4	27,113	81.9
Rural	556	32.6	5,977	18.1
Traffic Control				
Signal	826	48.5	22,772	68.8
Through-Stop	847	49.7	10,011	30.3
Four-Way Stop	31	1.8	307	0.9
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	692	40.6	7,572	22.9
15,000 to 25,000	534	31.3	9,537	28.8
> 25,000	478	28.1	15,981	48.3

All Database Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	13,872	41.9
Head-On	659	2.0
No Collision/Fixed Object	3,508	10.6
Rear-End	11,223	33.9
Sideswipe – Opposite Direction	631	1.9
Sideswipe – Same Direction	2,755	8.3
Unknown	442	1.4
Maximum Injury		
Fatality	117	0.4
Injury	13,073	39.5
None	19,900	60.1
Road Condition		
Dry	24,612	74.4
Wet	5,797	17.5
Snow	1,398	4.2
Ice	449	1.4
Mud	27	0.1
Unknown or Other	807	2.4

All Database Intersection Crash Frequencies and Rates

Descriptive Statistic	Annual Crash Frequency (Crashes per Year)	Crash Rate (per Million Entering Vehicles)
Average	6.41	0.95
Minimum	1.00	0.15
Maximum	44.67	8.22
Standard Deviation	5.32	0.62
85 th Percentile (Approx.) ¹	11.0	1.4

¹85 percent of the database intersections have a safety measure at or below this level.

Rural Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Traffic Control				
Signal	106	19.0	2,046	34.2
Through-Stop	424	76.3	3,690	61.8
Four-Way Stop	26	4.7	241	4.0
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	428	77.0	3,590	60.1
15,000 to 25,000	96	17.3	1,449	24.2
> 25,000	32	5.7	938	15.7
Rural Total	556	32.6	5,977	18.1

Rural Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	2,678	44.8
Head-On	120	2.0
No Collision/Fixed Object	818	13.7
Rear-End	1,740	29.1
Sideswipe – Opposite Direction	147	2.5
Sideswipe – Same Direction	383	6.4
Unknown	91	1.5
Maximum Injury		
Fatality	66	1.1
Injury	2,574	43.1
None	3,337	55.8
Road Condition		
Dry	4,440	74.3
Wet	956	16.0
Snow	286	4.8
Ice	122	2.0
Mud	7	0.1
Unknown or Other	166	2.8

Rural Intersection Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Rural Intersections	556	5,977	3.58	1.00	30.33	2.92	5.7	
Rural Intersections by Traffic Control								
Signal	106	2,046	6.43	1.33	30.33	4.60	10.0	
Through-Stop	424	3,690	2.90	1.00	10.67	1.82	4.0	
Four-Way Stop	26	241	3.09	1.00	7.67	1.54	4.8	
Rural Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	428	3,590	2.80	1.00	9.00	1.56	4.0	
15,000 to 25,000	96	1,449	5.03	1.33	14.33	3.14	8.6	
> 25,000	32	938	9.77	2.67	30.33	5.87	12.5	

¹85 percent of the database rural intersections have a safety measure at or below this level

Rural Intersection Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Rural Intersections	556	5,977	0.94	0.19	4.71	0.56	1.4	
Rural Intersections by Traffic Control								
Signal	106	2,046	0.88	0.28	1.95	0.38	1.3	
Through-Stop	424	3,690	0.96	0.19	4.71	0.60	1.5	
Four-Way Stop	26	241	0.88	0.45	2.26	0.45	1.2	
Rural Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	428	3,590	1.00	0.19	4.71	0.59	1.5	
15,000 to 25,000	96	1,449	0.74	0.20	1.95	0.42	1.2	
> 25,000	32	938	0.77	0.28	1.55	0.33	1.1	

¹85 percent of the database rural intersections have a safety measure at or below this level.

Urban Intersection Characteristics

Intersection Characteristic	Number of Intersections	Percent of Total Intersections	Number of Crashes	Percent of Total Crashes
Traffic Control				
Signal	720	62.7	20,726	76.5
Through-Stop	423	36.8	6,321	23.3
Four-Way Stop	5	0.5	66	0.2
Annual Average Daily Entering Volume (Vehicles)				
< 15,000	264	23.0	3,982	14.7
15,000 to 25,000	438	38.2	8,088	29.8
> 25,000	446	38.8	15,043	55.5
Urban Total	1,148	67.4	27,113	81.9

Urban Intersection Crash Characteristics

Crash Characteristic	Number of Crashes	Percent of Total Crashes
Type		
Angle	11,194	41.3
Head-On	539	2.0
No Collision/Fixed Object	2,690	9.9
Rear-End	9,483	35.0
Sideswipe – Opposite Direction	484	1.8
Sideswipe – Same Direction	2,372	8.7
Unknown	351	1.3
Maximum Injury		
Fatality	51	0.2
Injury	10,499	38.7
None	16,563	60.1
Road Condition		
Dry	20,172	74.4
Wet	4,841	17.8
Snow	1,112	4.1
Ice	327	1.2
Mud	20	0.1
Unknown or Other	641	2.4

Urban Intersection Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Urban Intersections	1,148	27,113	7.87	1.67	44.67	5.65	13.0	
Urban Intersections by Traffic Control								
Signal	720	20,726	9.60	2.00	44.67	6.27	15.3	
Through-Stop	423	6,321	4.98	1.67	17.33	2.46	7.0	
Four-Way Stop ²	5	66	4.40	2.67	6.33	1.55	--	
Urban Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	264	3,982	5.03	1.67	17.67	2.60	7.0	
15,000 to 25,000	438	8,088	6.16	1.67	25.33	3.30	9.3	
> 25,000	446	15,043	11.24	1.67	44.67	6.96	17.8	

¹85 percent of the database urban intersections have a safety measure at or below this level.

²Use with caution due to small sample size.

Urban Intersection Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
All Urban Intersections	1,148	27,113	0.96	0.15	8.22	0.65	1.4	
Urban Intersections by Traffic Control								
Signal	720	20,726	1.00	0.17	5.60	0.55	1.5	
Through-Stop	423	6,321	0.88	0.15	8.22	0.78	1.2	
Four-Way Stop ²	5	66	1.02	0.74	1.47	0.29	--	
Urban Intersections by Annual Average Daily Entering Volume (Vehicles)								
< 15,000	264	3,982	1.33	0.31	8.22	0.99	1.9	
15,000 to 25,000	438	8,088	0.87	0.22	3.00	0.45	1.3	
> 25,000	446	15,043	0.82	0.15	3.12	0.44	1.2	

¹85 percent of the database urban intersections have a safety measure at or below this level.

²Use with caution due to small sample size.

Rural and Urban Intersection Average Crash Frequencies and Rates

	Average Annual Crash Frequency (Crashes per Year)		Crash Rate (per Million Entering Vehicles)	
	Rural	Urban	Rural	Urban
All Intersections	3.58	7.87	0.94	0.96
Intersections by Traffic Control				
Signal	6.43	9.60	0.88	1.00
Through-Stop	2.90	4.98	0.96	0.88
Four-Way Stop ¹	3.09	4.40	0.88	1.02
Intersections by Annual Average Daily Entering Volume (Vehicles)				
< 15,000	2.80	5.03	1.00	1.33
15,000 to 25,000	5.03	6.16	0.74	0.87
> 25,000	9.77	11.24	0.77	0.82

¹Use urban values with caution due to small sample size.

Geometric Category Data

Geometric Category	Number of Intersections	Percentage of Intersections	Number of Crashes	Percentage of Crashes
Three-Leg Intersections				
A: Two-Lane Major Roadway with No Left-Turn Lane	34	2.0	313	0.9
B: Two-Lane Major Roadway with Left-Turn Lane	38	2.2	346	1.0
C: Four-Lane Major Undivided Roadway with No Left-Turn Lane	31	1.8	535	1.6
D: Four-Lane Major Divided Roadway with No Left-Turn Lane	5	0.3	64	0.2
E: Four-Lane Major Divided 55+ mph Roadway with Signal or Dual Left-Turn Lane ¹	4	0.23	31	0.1
F: Four-Lane Major Divided Roadway with Left-Turn Lane	43	2.5	908	2.8
G: Four-Lane Major Divided Roadway with Dual Left-Turn Lane	4	0.23	72	0.2
Four-Leg Intersections				
H: Two-Lane Major Roadway with No Left-Turn Lane	140	8.2	1,743	5.3
I: Two-Lane Major Roadway with Left-Turn Lane (One or Both Approaches)	143	8.4	2,249	6.8
J: Four-Lane Major Undivided Roadway with No Left-Turn Lane	92	5.4	1,795	5.4
K: Four-Lane Major Divided Roadway with No Left-Turn Lane	24	1.4	432	1.3
L: Four-Lane Major Divided 55+ mph Roadway with Signal or Dual Left-Turn Lane (One or Both Approaches) ¹	36	2.1	531	1.6
M: Four-Lane Major Divided Roadway with Left-Turn Lane (One or Both Approaches)	457	26.8	13,313	40.2
N: Four-Lane Major Divided Roadway with Dual Left-Turn Lane (One or Both Approaches)	39	2.3	2,166	6.6
Special Intersections				
O: Five or More Intersection Approaches	4	0.24	133	0.4
P: Roundabout	0	0.0	0	0.0
Q: Four-Lane Major Undivided Roadway with Left-Turn Lane (One or Both Approaches)	48	2.8	1,172	3.5
R: Four-Lane Major Undivided Roadway with Dual Left-Turn Lane (One or Both Approaches)	0	0.0	0	0.0
Other or Unknown Intersections				
S: Other	30	1.8	562	1.7
Unknown	532	31.3	6,725	20.4

¹Posted Speed on at least one major roadway approach.

Rural Intersection Geometry and Crash Frequencies

Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)					85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.	Std Dev.		
Rural Intersections by Number of Approach Legs								
Three-Leg	69	588	2.84	1.00	9.00	1.45	3.9	
Four-Leg	281	3,858	4.58	1.00	30.33	3.50	7.7	
Rural Intersections by Number of Major Roadway Lanes								
Two-Lane	221	2,310	3.48	1.00	14.00	2.15	5.7	
Four-Lane	136	2,272	5.57	1.33	30.33	4.28	8.8	
Rural Intersections by Median Existence								
Undivided	247	2,683	3.62	1.00	14.33	2.35	5.7	
Divided	110	1,899	5.75	1.67	30.33	4.44	8.8	
Rural Intersections by Left-Turn Lane Existence								
Left-Turn Lane	222	3,195	4.80	1.33	30.33	3.69	7.7	
No Left-Turn Lane	135	1,387	3.42	1.00	14.33	2.28	5.3	

¹85 percent of the database rural intersections have a safety measure at or below this level.

Rural Intersection Geometry and Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)					85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.	Std Dev.		
Rural Intersections by Number of Approach Legs								
Three-Leg	69	588	0.86	0.22	4.10	0.55	1.4	
Four-Leg	281	3,858	0.99	0.28	3.46	0.54	1.2	
Rural Intersections by Number of Major Roadway Lanes								
Two-Lane	221	2,310	1.02	0.29	4.10	0.56	1.5	
Four-Lane	136	2,272	0.86	0.22	3.26	0.47	1.3	
Rural Intersections by Median Existence								
Undivided	247	2,683	1.00	0.22	4.10	0.56	1.5	
Divided	110	1,899	0.87	0.28	3.26	0.47	1.2	
Rural Intersections by Left-Turn Lane Existence								
Left-Turn Lane	222	3,195	0.91	0.28	3.26	0.45	1.4	
No Left-Turn Lane	135	1,387	1.05	0.22	4.10	0.64	1.5	

¹85 percent of the database rural intersections have a safety measure at or below this level.

Urban Intersection Geometry and Crash Frequencies

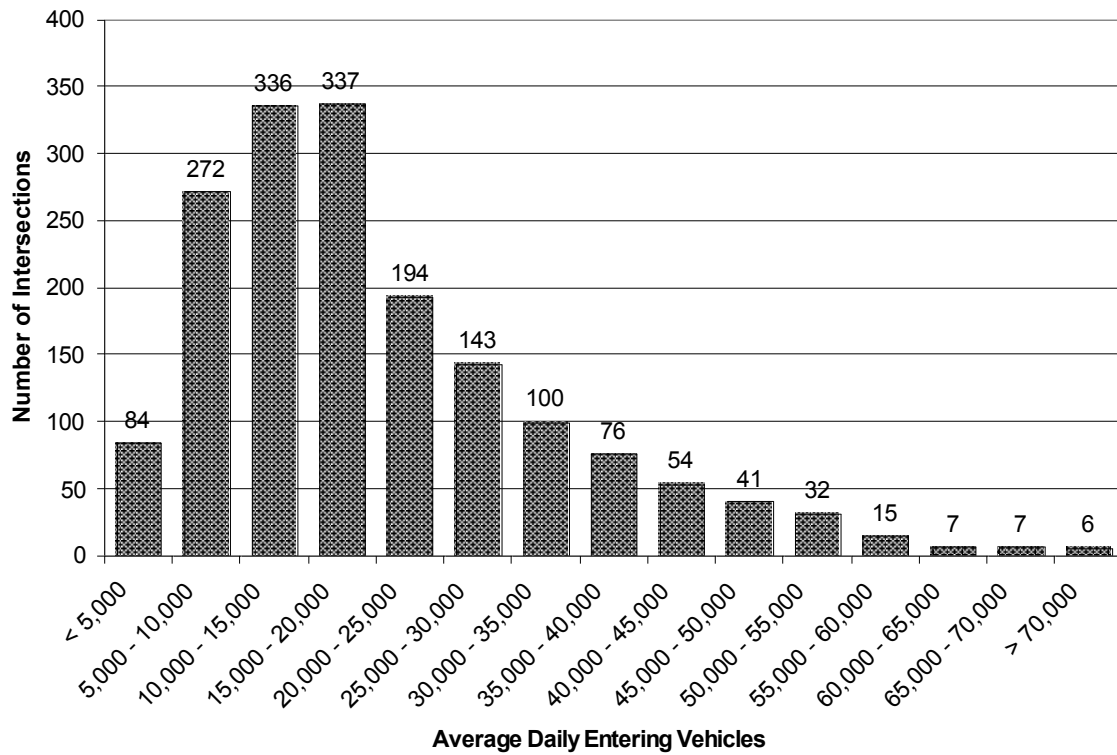
Category	Number of Intersections	Number of Crashes	Average Annual Crash Frequency (Crashes per Year)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
Urban Intersections by Number of Approach Legs								
Three-Leg	90	1,681	6.23	1.67	20.67	3.51	8.7	
Four-Leg	650	18,371	9.42	1.67	44.67	6.33	15.3	
Urban Intersections by Number of Major Roadway Lanes								
Two-Lane	134	2,341	5.82	1.67	18.00	3.10	8.7	
Four-Lane	647	18,747	9.66	1.67	44.67	6.36	15.3	
Urban Intersections by Median Existence								
Undivided	279	5,470	6.54	1.67	29.67	3.53	9.3	
Divided	502	15,618	10.37	1.67	44.67	6.76	16.7	
Urban Intersections by Left-Turn Lane Existence								
Left-Turn Lane	590	17,593	9.94	1.67	44.67	6.57	16.0	
No Left-Turn Lane	191	3,495	6.10	1.67	17.33	2.77	8.7	

¹85 percent of the database urban intersections have a safety measure at or below this level.

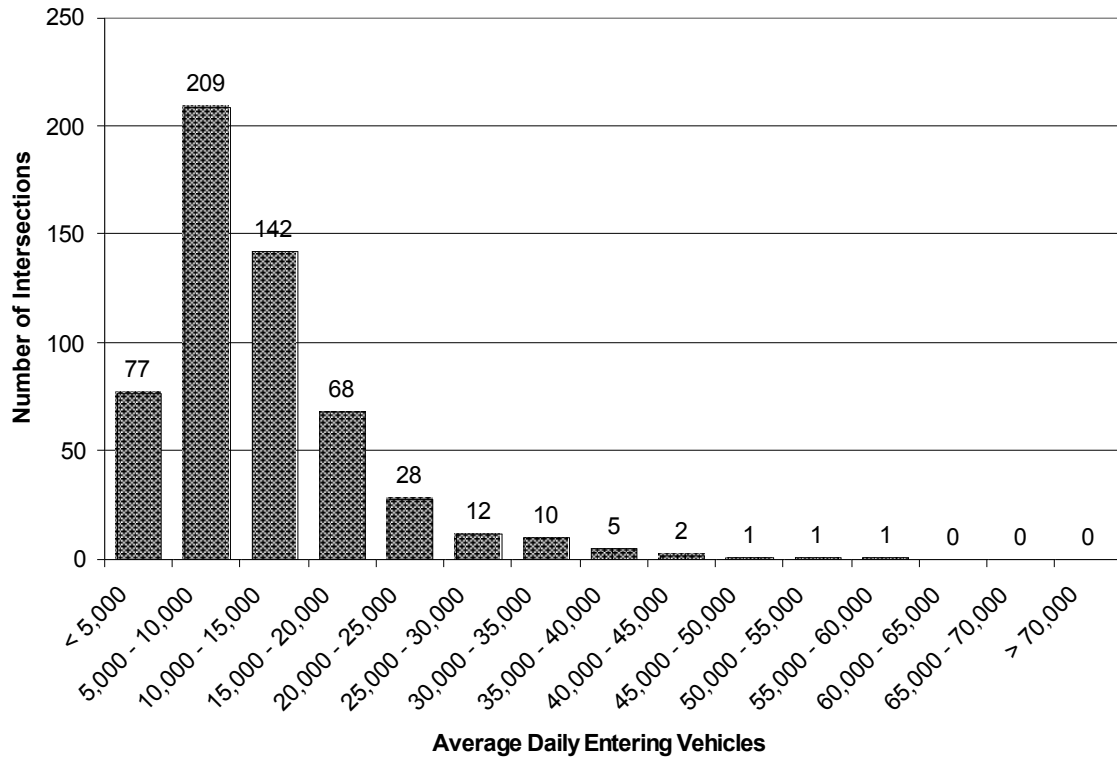
Urban Intersection Geometry and Crash Rates

Category	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)				Std Dev.	85 th Percentile (Approx.) ¹
			Avg.	Min.	Max.			
Urban Intersections by Number of Approach Legs								
Three-Leg	90	1,681	0.80	0.23	3.46	0.50	1.1	
Four-Leg	650	18,371	0.98	0.17	6.85	0.55	1.4	
Urban Intersections by Number of Major Roadway Lanes								
Two-Lane	134	2,341	1.07	0.30	6.85	0.74	1.5	
Four-Lane	647	18,747	0.94	0.17	4.15	0.50	1.4	
Urban Intersections by Median Existence								
Undivided	279	5,470	1.07	0.30	6.85	0.65	1.5	
Divided	502	15,618	0.90	0.17	4.15	0.48	1.4	
Urban Intersections by Left-Turn Lane Existence								
Left-Turn Lane	590	17,593	0.93	0.17	6.85	0.55	1.4	
No Left-Turn Lane	191	3,495	1.04	0.29	3.52	0.55	1.5	

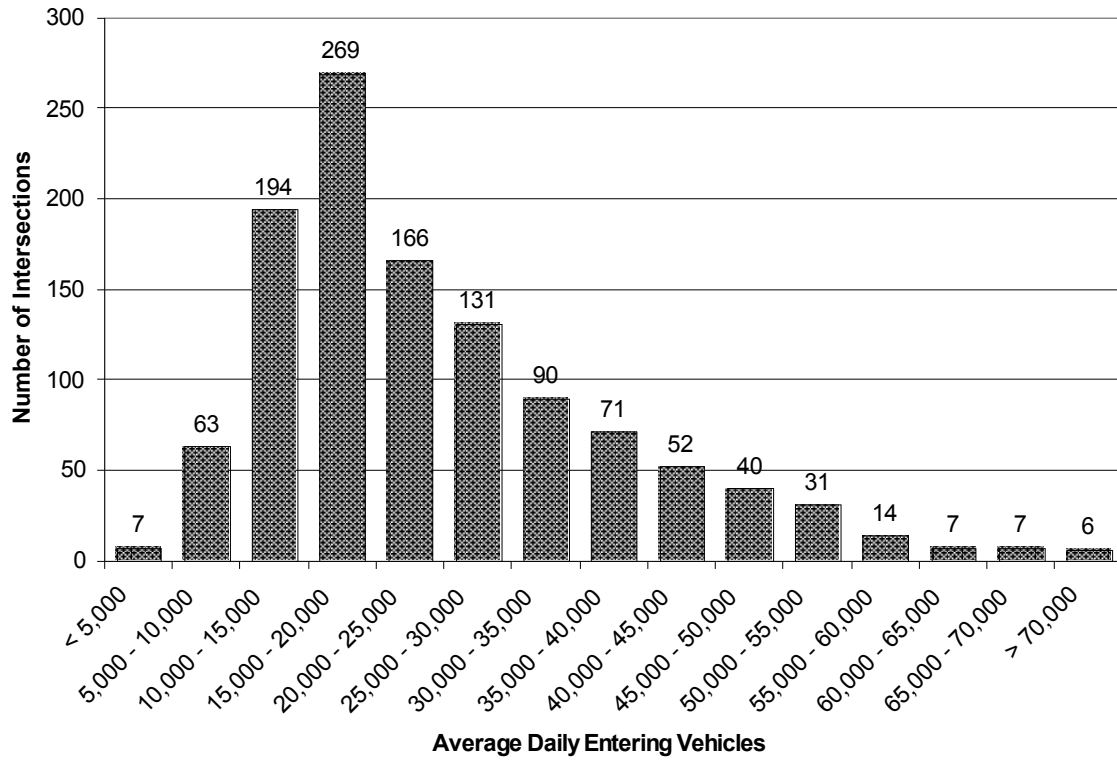
¹85 percent of the database urban intersections have a safety measure at or below this level.



Annual Average Daily Entering Volume Distribution of All Intersections



Annual Average Daily Entering Volume Distribution of Rural Intersections



Annual Average Daily Entering Volume Distribution of Urban Intersections

Appendix B
Crash Statistics by Intersections Characteristics and Volume
(Average, Minimum, Maximum, and Standard Deviation)

Rural Intersection Crash Frequencies by Traffic Control and Volume

Traffic Control and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Signal	106	2,046	6.43	1.33	30.33	4.60
Low Volume (< 15,000 vpd)	37	415	3.74	1.33	8.00	1.58
Moderate Volume (15,000 - 25,000 vpd)	45	860	6.37	2.00	14.33	3.34
High Volume (> 25,000 vpd)	24	771	10.71	2.67	30.33	6.37
Through-Stop	424	3,690	2.90	1.00	10.67	1.82
Low Volume (< 15,000 vpd)	367	2,957	2.69	1.00	9.00	1.53
Moderate Volume (15,000 - 25,000 vpd)	49	566	3.85	1.33	10.67	2.48
High Volume (> 25,000 vpd)	8	167	6.96	3.67	10.33	2.62
Four-Way Stop	26	241	3.09	1.00	7.67	1.54
Low Volume (< 15,000 vpd)	24	218	3.03	1.00	7.67	1.55
Moderate Volume (15,000 - 25,000 vpd)	2	23	3.83	2.67	5.00	1.65
High Volume (> 25,000 vpd) ²	--	--	--	--	--	--
Total	556	5,977	3.58	1.00	30.33	2.92

¹ Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

²--" = No locations in this category.

Rural Intersection Crash Frequencies by Number of Approach Legs and Volume

Number of Legs and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Three-Leg	69	588	2.84	1.00	9.00	1.45
Low Volume (< 15,000 vpd)	52	402	2.58	1.00	9.00	1.25
Moderate Volume (15,000 - 25,000 vpd)	15	157	3.49	1.33	8.00	1.79
High Volume (> 25,000 vpd)	2	29	4.83	4.00	5.67	1.18
Four-Leg	281	3,858	4.58	1.00	30.33	3.50
Low Volume (< 15,000 vpd)	193	1,980	3.42	1.00	8.67	1.75
Moderate Volume (15,000 - 25,000 vpd)	61	1,035	5.66	1.67	14.33	3.29
High Volume (> 25,000 vpd)	27	843	10.41	2.67	30.33	6.04
Total	350	4,446	4.23	1.00	30.33	3.28

¹ Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Rural Intersection Crash Frequencies by Median Existence and Volume

Median Existence and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Undivided Major Road	247	2,683	3.62	1.00	14.33	2.35
Low Volume (< 15,000 vpd)	203	1,886	3.10	1.00	9.00	1.64
Moderate Volume (15,000 - 25,000 vpd)	36	612	5.67	1.33	14.33	3.39
High Volume (> 25,000 vpd)	8	185	7.71	4.00	12.33	3.12
Divided Major Road	110	1,899	5.75	1.67	30.33	4.44
Low Volume (< 15,000 vpd)	44	515	3.90	1.67	8.33	1.74
Moderate Volume (15,000 - 25,000 vpd)	43	644	4.99	1.67	14.33	2.94
High Volume (> 25,000 vpd)	23	740	10.72	2.67	30.33	6.44
Total	357	4,582	4.28	1.00	30.33	3.29

¹ Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Rural Intersection Crash Frequencies by Left-Turn Lane Existence and Volume

Left-Turn Lane Existence and Average Annual Entering Volume ²	Average Annual Crash Frequency ¹					Standard Deviation
	Number of Intersections	Number of Crashes	Average	Minimum	Maximum	
Left-Turn Lane	222	3,195	4.80	1.33	30.33	3.69
Low Volume (< 15,000 vpd)	133	1,343	3.37	1.33	8.33	1.57
Moderate Volume (15,000 - 25,000 vpd)	60	964	5.36	1.67	14.33	3.03
High Volume (> 25,000 vpd)	29	888	10.21	2.67	30.33	5.96
No Left-Turn Lane	135	1,387	3.42	1.00	14.33	2.28
Low Volume (< 15,000 vpd)	114	1,058	3.09	1.00	9.00	1.81
Moderate Volume (15,000 - 25,000 vpd)	19	292	5.12	1.33	14.33	3.59
High Volume (> 25,000 vpd)	2	37	6.17	4.00	8.33	3.06
Total	357	4,582	4.28	1.00	30.33	3.29

¹ Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

² One or more left-turn lanes located on major roadway.

Rural Intersection Crash Frequencies by Number of Through Lanes and Volume

Major Road Through Lanes and Average Annual Entering Volume	Average Annual Crash Frequency ¹					Standard Deviation
	Number of Intersections	Number of Crashes	Average	Minimum	Maximum	
Two-Lane	221	2,310	3.48	1.00	14.00	2.15
Low Volume (< 15,000 vpd)	192	1,797	3.12	1.00	9.00	1.67
Moderate Volume (15,000 - 25,000 vpd)	24	393	5.46	1.67	14.00	3.18
High Volume (> 25,000 vpd)	5	120	8.00	5.33	11.67	2.60
Four-Lane	136	2,272	5.57	1.33	30.33	4.28
Low Volume (< 15,000 vpd)	55	604	3.66	1.67	8.33	1.69
Moderate Volume (15,000 - 25,000 vpd)	55	863	5.23	1.33	14.33	3.16
High Volume (> 25,000 vpd)	26	805	10.32	2.67	30.33	6.28
Total	357	4,582	4.28	1.00	30.33	3.29

¹ Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Rural Intersection Crash Rates by Traffic Control and Volume

Traffic Control and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)			
			Average ¹	Minimum	Maximum	Standard Deviation
Signal	106	2,046	0.88	0.28	1.95	0.38
Low Volume (< 15,000 vpd)	37	415	0.88	0.29	1.78	0.35
Moderate Volume (15,000 - 25,000 vpd)	45	860	0.91	0.31	1.95	0.43
High Volume (> 25,000 vpd)	24	771	0.82	0.28	1.55	0.35
Through-Stop	424	3,690	0.96	0.19	4.71	0.60
Low Volume (< 15,000 vpd)	367	2,957	1.01	0.19	4.71	0.61
Moderate Volume (15,000 - 25,000 vpd)	49	566	0.59	0.20	1.57	0.35
High Volume (> 25,000 vpd)	8	167	0.62	0.38	0.87	0.21
Four-Way Stop	26	241	0.88	0.45	2.26	0.45
Low Volume (< 15,000 vpd)	24	218	0.90	0.45	2.26	0.46
Moderate Volume (15,000 - 25,000 vpd)	2	23	0.67	0.48	0.86	0.27
High Volume (> 25,000 vpd) ²	--	--	--	--	--	--
Total	556	5,977	0.94	0.19	4.71	0.56

¹Average crash rate of intersection rate calculated using three years of data.

²--" = No locations in this category.

Rural Intersection Crash Rates by Number of Approach Legs and Volume

Crash Rate (per Million Entering Vehicles)						
Number of Legs and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Three-Leg	69	588	0.86	0.22	4.10	0.55
Low Volume (< 15,000 vpd)	52	402	0.95	0.37	4.10	0.58
Moderate Volume (15,000 - 25,000 vpd)	15	157	0.58	0.22	1.43	0.32
High Volume (> 25,000 vpd)	2	29	0.47	0.43	0.51	0.06
Four-Leg	281	3,858	0.99	0.28	3.46	0.54
Low Volume (< 15,000 vpd)	193	1,980	1.07	0.32	3.46	0.57
Moderate Volume (15,000 - 25,000 vpd)	61	1,035	0.81	0.28	1.95	0.42
High Volume (> 25,000 vpd)	27	843	0.81	0.28	1.55	0.33
Total	350	4,446	0.96	0.22	4.10	0.54

¹Average crash rate of intersection rate calculated using three years of data.

Rural Intersection Crash Rates by Median Existence and Volume

Crash Rate (per Million Entering Vehicles)						
Median Existence and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Undivided Major Road	247	2,683	1.00	0.22	4.10	0.56
Low Volume (< 15,000 vpd)	203	1,886	3.10	1.00	9.00	1.64
Moderate Volume (15,000 - 25,000 vpd)	36	612	5.67	1.33	14.33	3.39
High Volume (> 25,000 vpd)	8	185	7.71	4.00	12.33	3.12
Divided Major Road	110	1,899	0.87	0.28	3.26	0.47
Low Volume (< 15,000 vpd)	44	515	1.05	0.42	3.26	0.56
Moderate Volume (15,000 - 25,000 vpd)	43	644	0.72	0.28	1.82	0.37
High Volume (> 25,000 vpd)	23	740	0.80	0.28	1.55	0.34
Total	357	4,582	0.96	0.22	4.10	0.54

¹Average crash rate of intersection rate calculated using three years of data.

Rural Intersection Crash Rates by Left-Turn Lane Existence and Volume

Left-Turn Lane Existence and Average Annual Entering Volume ²	Crash Rate (per Million Entering Vehicles)					
	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Left-Turn Lane	222	3,195	0.91	0.28	3.26	0.45
Low Volume (< 15,000 vpd)	133	1,343	0.99	0.32	3.26	0.48
Moderate Volume (15,000 - 25,000 vpd)	60	964	0.78	0.28	1.88	0.40
High Volume (> 25,000 vpd)	29	888	0.79	0.28	1.55	0.33
No Left-Turn Lane	135	1,387	1.05	0.22	4.10	0.64
Low Volume (< 15,000 vpd)	114	1,058	3.09	1.00	9.00	1.81
Moderate Volume (15,000 - 25,000 vpd)	19	292	5.12	1.33	14.33	3.59
High Volume (> 25,000 vpd)	2	37	6.17	4.00	8.33	3.06
Total	357	4,582	0.96	0.22	4.10	0.54

¹Average crash rate of intersection rate calculated using three years of data.

²One or more left-turn lanes located on major roadway.

Rural Intersection Crash Rates by Number of Through Lanes and Volume

Major Road Through Lanes and Average Annual Entering Volume	Crash Rate (per Million Entering Vehicles)					
	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Two-Lane	221	2,310	1.02	0.29	4.10	0.56
Low Volume (< 15,000 vpd)	192	1,797	3.12	1.00	9.00	1.67
Moderate Volume (15,000 - 25,000 vpd)	24	393	5.46	1.67	14.00	3.18
High Volume (> 25,000 vpd)	5	120	8.00	5.33	11.67	2.60
Four-Lane	136	2,272	0.86	0.22	3.26	0.47
Low Volume (< 15,000 vpd)	55	604	1.00	0.42	3.26	0.55
Moderate Volume (15,000 - 25,000 vpd)	55	863	0.76	0.22	1.95	0.41
High Volume (> 25,000 vpd)	26	805	0.78	0.28	1.55	0.34
Total	357	4,582	0.96	0.22	4.10	0.54

¹Average crash rate of intersection rate calculated using three years of data.

Urban Intersection Crash Frequencies by Traffic Control and Volume

Traffic Control and Average Annual Entering Volume ²	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Signal	720	20,726	9.60	2.00	44.67	6.27
Low Volume (< 15,000 vpd)	93	1,643	5.89	2.33	17.67	3.02
Moderate Volume (15,000 - 25,000 vpd)	274	5,655	6.88	2.00	25.33	3.53
High Volume (> 25,000 vpd)	353	13,428	12.68	2.33	44.67	7.03
Through-Stop	423	6,321	4.98	1.67	17.33	2.46
Low Volume (< 15,000 vpd)	166	2,273	4.56	1.67	14.00	2.24
Moderate Volume (15,000 - 25,000 vpd)	164	2,433	4.95	1.67	17.33	2.43
High Volume (> 25,000 vpd)	93	1,615	5.79	1.67	15.00	2.70
Total	1,148	27,113	7.87	1.67	44.67	5.65

¹Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

²Too few four-way stop-controlled urban intersections to report (n = 5), but they are included in the total.

Urban Intersection Crash Frequencies by Number of Approach Legs and Volume

Number of Legs and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Three-Leg	90	1,681	6.23	1.67	20.67	3.51
Low Volume (< 15,000 vpd)	16	243	5.06	2.33	13.00	2.61
Moderate Volume (15,000 - 25,000 vpd)	43	693	5.37	1.67	14.33	2.75
High Volume (> 25,000 vpd)	31	745	8.01	3.33	20.67	4.20
Four-Leg	650	18,371	9.42	1.67	44.67	6.33
Low Volume (< 15,000 vpd)	104	1,675	5.37	1.67	17.67	2.77
Moderate Volume (15,000 - 25,000 vpd)	211	4,320	6.82	2.00	18.33	3.23
High Volume (> 25,000 vpd)	335	12,376	12.31	2.33	44.67	7.16
Total	740	20,052	9.03	1.67	44.67	6.15

¹Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Urban Intersection Crash Frequencies by Median Existence and Volume

Median Existence and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Undivided Major Road	279	5,470	6.54	1.67	29.67	3.53
Low Volume (< 15,000 vpd)	91	1,487	5.45	1.67	16.33	2.89
Moderate Volume (15,000 - 25,000 vpd)	156	2,977	6.36	2.33	17.33	2.90
High Volume (> 25,000 vpd)	32	1,006	10.48	4.00	29.67	5.10
Divided Major Road	502	15,618	10.37	1.67	44.67	6.76
Low Volume (< 15,000 vpd)	32	510	5.31	2.00	17.67	2.93
Moderate Volume (15,000 - 25,000 vpd)	123	2,514	6.81	1.67	18.33	3.43
High Volume (> 25,000 vpd)	347	12,594	12.10	2.33	44.67	7.17
Total	781	21,088	9.00	1.67	44.67	6.10

¹Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Urban Intersection Crash Frequencies by Left-Turn Lane Existence and Volume

Left-Turn Lane Existence and Average Annual Entering Volume ²	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Left-Turn Lane	590	17,593	9.94	1.67	44.67	6.57
Low Volume (< 15,000 vpd)	51	834	5.45	2.00	17.67	3.17
Moderate Volume (15,000 - 25,000 vpd)	183	3,681	6.70	1.67	18.33	3.31
High Volume (> 25,000 vpd)	356	13,078	12.25	2.33	44.67	7.14
No Left-Turn Lane	191	3,495	6.10	1.67	17.33	2.77
Low Volume (< 15,000 vpd)	72	1,163	5.38	1.67	16.00	2.69
Moderate Volume (15,000 - 25,000 vpd)	96	1,810	6.28	2.33	17.33	2.81
High Volume (> 25,000 vpd)	23	522	7.57	3.33	12.00	2.25
Total	781	21,088	9.00	1.67	44.67	6.10

¹Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

²One or more left-turn lanes located on major roadway.

Urban Intersection Crash Frequencies by Number of Through Lanes and Volume

Major Road Through Lanes and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Average Annual Crash Frequency ¹			Standard Deviation
			Average	Minimum	Maximum	
Two-Lane	134	2,341	5.82	1.67	18.00	3.10
Low Volume (< 15,000 vpd)	54	807	4.98	1.67	14.00	2.29
Moderate Volume (15,000 - 25,000 vpd)	73	1,318	6.02	2.33	15.67	2.94
High Volume (> 25,000 vpd)	7	216	10.29	4.00	18.00	5.73
Four-Lane	647	18,747	9.66	1.67	44.67	6.36
Low Volume (< 15,000 vpd)	69	1,190	5.75	2.00	17.67	3.26
Moderate Volume (15,000 - 25,000 vpd)	206	4,173	6.75	1.67	18.33	3.20
High Volume (> 25,000 vpd)	372	13,384	11.99	2.33	44.67	7.05
Total	781	21,088	9.00	1.67	44.67	6.10

¹Three-year (2001 to 2003) crash frequency total at an intersection divided by three.

Urban Intersection Crash Rates by Traffic Control and Volume

Traffic Control and Average Annual Entering Volume ²	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)			Standard Deviation
			Average ¹	Minimum	Maximum	
Signal	720	20,726	1.00	0.17	5.60	0.55
Low Volume (< 15,000 vpd)	93	1,643	1.47	0.47	5.60	0.85
Moderate Volume (15,000 - 25,000 vpd)	274	5,655	0.96	0.30	3.00	0.47
High Volume (> 25,000 vpd)	353	13,428	0.91	0.17	3.12	0.43
Through-Stop	423	6,321	0.88	0.15	8.22	0.78
Low Volume (< 15,000 vpd)	166	2,273	1.26	0.31	8.22	1.06
Moderate Volume (15,000 - 25,000 vpd)	164	2,433	0.72	0.22	2.34	0.35
High Volume (> 25,000 vpd)	93	1,615	0.46	0.15	1.26	0.22
Total	1,148	27,113	0.96	0.15	8.22	0.65

¹Average crash rate of intersection rate calculated using three years of data.

²Too few four-way stop-controlled urban intersections to report (n = 5), but they are included in the total.

Urban Intersection Crash Rates by Number of Approach Legs and Volume

Number of Legs and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)			Standard Deviation
			Average ¹	Minimum	Maximum	
Three-Leg	90	1,681	0.80	0.23	3.46	0.50
Low Volume (< 15,000 vpd)	16	243	1.36	0.64	3.46	0.76
Moderate Volume (15,000 - 25,000 vpd)	43	693	0.76	0.29	1.79	0.35
High Volume (> 25,000 vpd)	31	745	0.56	0.23	0.91	0.21
Four-Leg	650	18,371	0.98	0.17	6.85	0.55
Low Volume (< 15,000 vpd)	104	1,675	1.33	0.42	6.85	0.89
Moderate Volume (15,000 - 25,000 vpd)	211	4,320	0.97	0.30	2.64	0.43
High Volume (> 25,000 vpd)	335	12,376	0.87	0.17	3.12	0.43
Total	740	20,052	0.95	0.17	6.85	0.55

¹Average crash rate of intersection rate calculated using three years of data.

Urban Intersection Crash Rates by Median Existence and Volume

Median Existence and Average Annual Entering Volume	Number of Intersections	Number of Crashes	Crash Rate (per Million Entering Vehicles)			Standard Deviation
			Average ¹	Minimum	Maximum	
Undivided Major Road	279	5,470	1.07	0.30	6.85	0.65
Low Volume (< 15,000 vpd)	91	1,487	1.36	0.49	6.85	0.91
Moderate Volume (15,000 - 25,000 vpd)	156	2,977	0.93	0.30	2.64	0.41
High Volume (> 25,000 vpd)	32	1,006	0.94	0.44	2.46	0.42
Divided Major Road	502	15,618	0.90	0.17	4.15	0.48
Low Volume (< 15,000 vpd)	32	510	1.32	0.42	4.15	0.83
Moderate Volume (15,000 - 25,000 vpd)	123	2,514	0.93	0.29	2.21	0.44
High Volume (> 25,000 vpd)	347	12,594	0.85	0.17	3.12	0.43
Total	781	21,088	0.96	0.17	6.85	0.55

¹Average crash rate of intersection rate calculated using three years of data.

Urban Intersection Crash Rates by Left-Turn Lane Existence and Volume

Left-Turn Lane Existence and Average Annual Entering Volume ²	Crash Rate (per Million Entering Vehicles)					
	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Left-Turn Lane	590	17,593	0.93	0.17	6.85	0.55
Low Volume (< 15,000 vpd)	51	834	1.41	0.42	6.85	1.13
Moderate Volume (15,000 - 25,000 vpd)	183	3,681	0.93	0.29	2.21	0.43
High Volume (> 25,000 vpd)	356	13,078	0.87	0.17	3.12	0.44
No Left-Turn Lane	191	3,495	1.04	0.29	3.52	0.55
Low Volume (< 15,000 vpd)	72	1,163	1.31	0.49	3.52	0.66
Moderate Volume (15,000 - 25,000 vpd)	96	1,810	0.93	0.30	2.64	0.41
High Volume (> 25,000 vpd)	23	522	0.66	0.29	1.00	0.21
Total	781	21,088	0.96	0.17	6.85	0.55

¹Average crash rate of intersection rate calculated using three years of data.

²One or more left-turn lanes located on major roadway.

Urban Intersection Crash Rates by Number of Through Lanes and Volume

Major Road Through Lanes and Average Annual Entering Volume	Crash Rate (per Million Entering Vehicles)					
	Number of Intersections	Number of Crashes	Average ¹	Minimum	Maximum	Standard Deviation
Two-Lane	134	2,341	1.07	0.30	6.85	0.74
Low Volume (< 15,000 vpd)	54	807	1.34	0.52	6.85	1.01
Moderate Volume (15,000 - 25,000 vpd)	73	1,318	0.90	0.30	2.08	0.40
High Volume (> 25,000 vpd)	7	216	0.87	0.44	1.56	0.41
Four-Lane	647	18,747	0.94	0.17	4.15	0.50
Low Volume (< 15,000 vpd)	69	1,190	1.36	0.42	4.15	0.79
Moderate Volume (15,000 - 25,000 vpd)	206	4,173	0.94	0.29	2.64	0.43
High Volume (> 25,000 vpd)	372	13,384	0.86	0.17	3.12	0.43
Total	781	21,088	0.96	0.17	6.85	0.55

¹Average crash rate of intersection rate calculated using three years of data.

Appendix C
Average Crash Type Percentages and Geometrics

Average Crash Type Percentages and Four Intersection Geometries - All Inclusive

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Intersections by Number of Approach Legs											
Three-Leg	159	2,269	39	41	37	33	10	75	18	7	24
Four-Leg	931	22,229	42	33	45	31	8	77	17	6	21
Intersections by Number of Major Roadway Lanes											
Two-Lane	355	4,651	42	34	43	27	8	77	17	6	21
Four-Lane	783	21,019	41	34	44	33	8	76	18	6	22
Intersections by Median Existence											
Undivided	526	8,153	41	34	43	28	9	77	16	6	20
Divided	612	17,517	42	35	45	33	8	76	18	6	22
Intersections by Left-Turn Lane Existence											
Left-Turn Lane	812	20,788	41	35	44	32	8	76	18	6	22
No Left-Turn Lane	326	4,882	42	32	45	27	10	78	16	6	20

Rural Average Crash Type Percentages and Four Intersection Geometrics

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Intersections by Number of Approach Legs											
Three-Leg	69	588	45	43	32	32	9	72	19	8	28
Four-Leg	281	3,858	48	31	51	25	6	77	16	7	20
Intersections by Number of Major Roadway Lanes											
Two-Lane	221	2,310	46	34	46	25	7	75	17	7	21
Four-Lane	136	2,272	47	33	48	29	6	77	16	7	22
Intersections by Median Existence											
Undivided	247	2,683	47	34	45	26	7	75	17	7	21
Divided	110	1,899	47	32	51	28	6	77	16	6	23
Intersections by Left-Turn Lane Existence											
Left-Turn Lane	222	3,195	45	34	47	28	6	76	16	7	22
No Left-Turn Lane	135	1,387	50	32	47	24	8	75	17	7	21

Urban Average Crash Type Percentages and Four Intersection Geometries

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Intersections by Number of Approach Legs											
Three-Leg	90	1,681	34	39	41	34	10	77	18	5	21
Four-Leg	650	18,371	40	34	43	33	8	77	17	5	21
Intersections by Number of Major Roadway Lanes											
Two-Lane	134	2,341	34	34	39	30	10	79	16	5	20
Four-Lane	647	18,747	40	35	43	34	8	76	18	6	22
Intersections by Median Existence											
Undivided	279	5,470	36	33	42	30	10	78	16	5	20
Divided	502	15,618	41	35	43	35	8	76	18	6	22
Intersections by Left-Turn Lane Existence											
Left-Turn Lane	590	17,593	40	35	43	34	8	76	18	6	22
No Left-Turn Lane	191	3,495	36	32	43	30	10	79	15	5	19

Average Crash Type Percentages by Intersection Geometric Code - All Inclusive (See Table 23 in Report Text for Definition of Codes)

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Three-Leg Intersections											
A	34	313	39	40	33	34	9	67	24	8	23
B	38	346	39	45	37	26	11	78	15	6	28
C	31	535	40	37	33	42	11	76	19	5	21
D	5	64	42	44	46	28	8	90	8	2	29
E	4	31	52	39	46	19	2	82	10	8	38
F	43	908	35	40	41	33	10	74	19	7	24
G	4	72	38	31	40	36	6	71	16	13	16
Four-Leg Intersections											
H	140	1,743	44	28	47	24	10	79	14	6	20
I	143	2,249	41	34	44	29	6	76	17	7	20
J	92	1,795	39	33	48	26	9	79	15	6	18
K	24	432	42	33	50	27	9	77	18	5	18
L	36	531	52	26	60	22	5	79	15	6	21
M	457	13,313	42	35	45	34	8	76	18	6	22
N	39	2,166	38	30	29	49	9	77	18	5	23
Special Intersections											
O	4	133	29	31	31	36	23	81	13	6	21
P	--	--	--	--	--	--	--	--	--	--	--
Q	48	1,172	38	32	41	32	9	75	17	7	23
R	--	--	--	--	--	--	--	--	--	--	--
Other or Unknown Intersections											
S: Other	30	562	35	27	46	21	18	74	19	7	22
Unknown	532	6,725	40	35	41	29	9	77	15	8	21
Total	1,704	33,090	41	34	43	30	8	76	16	7	21

-- = No intersections in this geometric code.

Rural Average Crash Type Percentages by Intersection Geometric Code (See Table 23 in Report Text for Definition of Codes)

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Three-Leg Intersections											
A	21	163	44	41	27	34	9	59	28	12	27
B	31	251	41	46	35	27	9	78	15	7	29
C	9	94	54	37	23	44	13	75	18	6	25
D	--	--	--	--	--	--	--	--	--	--	--
E	4	31	52	39	46	19	2	82	10	8	38
F	4	49	44	53	49	36	6	72	18	10	22
G	--	--	--	--	--	--	--	--	--	--	--
Four-Leg Intersections											
H	91	931	50	30	52	20	8	78	15	6	20
I	78	965	45	32	48	28	5	75	17	8	19
J	10	143	49	34	52	25	5	76	14	7	16
K	4	56	61	28	58	17	5	81	15	4	23
L	29	429	54	26	61	21	4	80	15	5	20
M	67	1,242	44	34	47	31	7	76	17	7	23
N	2	92	29	28	27	51	4	79	14	4	28
Special Intersections											
O	--	--	--	--	--	--	--	--	--	--	--
P	--	--	--	--	--	--	--	--	--	--	--
Q	7	136	34	40	36	38	8	74	14	9	18
R	--	--	--	--	--	--	--	--	--	--	--
Other or Unknown Intersections											
S: Other	6	44	42	28	38	16	23	65	22	13	34
Unknown	193	1,351	45	41	41	23	7	78	12	10	24
Total	556	5,977	46	36	45	25	7	76	15	8	23

-- = No intersections in this geometric code.

Urban Average Crash Type Percentages by Intersection Geometric Code (See Table 23 in Report Text for Definition of Codes)

Category	Number of Intersections	Number of Crashes	Injury Crashes	Left-Turn Crashes	Angle Crashes	Rear-End Crashes	Sideswipe Same Direction Crashes	Dry Road Condition Crashes	Wet Road Condition Crashes	Snow/Ice Road Condition Crashes	Night Crashes
Three-Leg Intersections											
A	13	150	29	40	43	33	9	79	17	3	18
B	7	95	29	44	46	19	16	80	17	3	19
C	22	441	35	37	37	41	10	77	19	4	19
D	5	64	42	44	46	28	8	90	8	2	29
E	--	--	--	--	--	--	--	--	--	--	--
F	39	859	34	39	40	32	11	74	19	7	24
G	4	72	38	31	40	36	6	71	16	13	16
Four-Leg Intersections											
H	49	812	34	26	36	30	14	82	13	5	20
I	65	1,284	35	38	40	31	7	77	17	5	21
J	82	1,652	38	32	47	26	9	79	15	6	18
K	20	376	38	33	49	28	10	76	18	5	17
L	7	102	47	28	57	24	6	76	14	10	23
M	390	12,071	42	35	44	34	8	76	18	5	22
N	37	2,074	38	31	29	49	9	77	18	5	23
Special Intersections											
O	4	133	29	31	31	36	23	81	13	6	21
P	--	--	--	--	--	--	--	--	--	--	--
Q	41	1,036	39	31	42	31	9	76	18	6	24
R	--	--	--	--	--	--	--	--	--	--	--
Other or Unknown Intersections											
S: Other	24	518	33	27	47	22	17	77	18	5	19
Unknown	339	5,374	36	32	41	32	10	76	17	7	20
Total	1,148	27,113	38	34	42	33	9	77	17	6	21

-- = No intersections in this geometric code.