Automated Statewide Highway Intersection Safety Data Collection and Evaluation Strategy

Fan Yang, Ph.D. Candidate
Department of Civil and Environmental Engineering,
University of Wisconsin-Madison,
Madison, WI 53706
Phone: (608)609-3386
Email: fyang29@wisc.edu

Steven T. Parker, Ph.D.
IT Program Manager, TOPS Lab
Department of Civil and Environmental Engineering,
University of Wisconsin-Madison
Madison, WI 53706
Phone: (608) 262-2591 Fax: (608) 262-5199
Email: sparker@engr.wisc.edu

Bin Ran, Ph.D., Professor
Department of Civil & Environmental Engineering,
University of Wisconsin-Madison,
Madison, WI 53706
Phone: (608)262-0052 Fax: (608) 262-5199
Email: bran@wisc.edu
and
School of Transportation, Southeast University
No.2 Si Pai Lou, Nanjing 210096, China

David A. Noyce, Ph.D., P.E., Professor
Director, TOPS Lab
Department of Civil and Environmental Engineering
University of Wisconsin-Madison
Madison, WI 53706
Phone: (608) 265-1882 Fax: (608) 262-5199
Email: noyce@engr.wisc.edu

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ABSTRACT

Effective evaluation of intersection safety requires the ability to develop meaningful benchmarks to help assess the relative safety risk for a given intersection. This paper introduces an automated intersection safety data collection and evaluation method, including an algorithm to update intersection crash rates and geometric features from existing sources. The automation algorithm involves the integration of five separate Wisconsin Department of Transportation (WisDOT) databases through association with a common Linear Referencing System (LRS). The result of the QA/QC suggests the methodology is feasible and can improve the quality of intersection safety data collection. This paper also presents results of a comparative intersection safety analysis for different intersection types based on the automated algorithm. Although the methodology introduced is specific to Wisconsin data, the results can also be applied to other state DOTs that manage traffic data with respect to a LRS.

KEYWORDS: Linear Referencing System, Intersection Safety, Data Management

1 INTRODUCTION

Highway intersection safety is a major concern for transportation safety engineers worldwide. A significantly large proportion of crashes occur at intersections because turning and crossing activities have the potential for conflicts. According to the National Highway Traffic Safety Administration (NHTSA), about 2,210,000 crashes occurred at intersections in the United States in 2009, which accounts for 40 percent of the total 5,505,000 crashes that occurred across the country*(1)*. Highway intersections can expose drivers to higher risk since the speed of the traffic is higher on highway segments than on local roads.

Federal and State DOTS have expended considerable effort to reduce crashes at intersections. The limited budget should be allocated to improve intersections with higher risk. Identifying sites deserving safety improvement requires effective intersection safety evaluation strategy. Comprehensive analysis of intersection safety not only require crash data and traffic volume data, the intersection geometric data such as area type, number of approaches and number of lanes are also needed since most of the evaluation models are based on the relation between road geometry and accident occurrence. Collecting high quality data requires huge financial resource and human efforts, while updating the crash data annually makes these procedures even more time consuming. Most state DOTs*(2, 3)* rely on sampling techniques to determine the statewide standard safety measures, however the sampling process may induce bias and errors in the safety evaluation. Therefore, it's critical to find an automatic way to update the crash information for intersections and collect the intersection related features. This paper proposed a method to fully leverage LRS roadway network information to collect intersection geometric data such as number of approaches and area type based on existing datasets. The objective of this research was to develop an intersection database, automatically calculate intersection crash rates for various types of intersections and identify intersections with higher crash rates for Wisconsin DOT. The proposed methodology can be transferred to other DOTs that maintain crash, volume, and roadway attribute data with respect to a Linear Referencing System (LRS). This automation method can also be extended to automatically calculate safety evaluation measures other than crash rates.

The rest of the paper is organized as: Section 2 reviews the related work, Section 3 presents the automated highway intersection safety information collection methodology. Section 4 studies the crash pattern in different types of intersections. Section 5 concludes the paper.

2 RELATED WORK

The key components of this research include a GIS data integration process and subsequent intersection safety ranking method. This section first introduces the Linear Reference System concept which is applied in most state DOTs for recording transportation related data and serves as the underlying framework for the GIS data integration step. In addition, the Wisconsin transportation source data that are used for the integration are discussed. Finally, the Intersection Safety Evaluation Tool (ISET) project, which drives the intersection safety ranking approach, is presented.

2.1 Linear Referencing System

A Linear Reference System (LRS) is the method of storing geographic locations by using relative positions along a linear element, for example a milepost along a roadway. LRS is widely used in the field of transportation data management. The Highway Performance Monitoring System (HPMS) now requires state DOTs to use an LRS network for spatial referencing purposes *(4)*. The LRS will be integrated into the National Highway Planning Network (NHPN), which serves as a national framework for information exchange and will be provided to the U.S. Geological Survey, the Bureau of Census, the Intelligent Transportation System (ITS) community, and the Bureau of Transportation Statistics (BTS) to represent the higher order highways *(5)*.

The Wisconsin Department of Transportation (WisDOT) developed and currently maintains two geographic information systems based on two separate linear referencing systems (LRSs). The State Trunk Network (STN) covers all state, U.S., and interstate highways, while the Wisconsin Information System for Local Roads (WISLR) covers county highway and local roads. For purposes of intersection safety evaluation, the LRS facilitates the process of generating intersection crash rates by combing LRS assigned crash locations and traffic counts, and integrating those crash rates with other LRS network attributes and business data, such as highway functional class. . All STN and WISLR business data are located to the underlying LRS network in terms of link and link-offset attributes. For the case of crash data, whether a crash is intersection related can be determined by the distance along a link from a given intersection. If traditional geo-referencing system is used, additional process to calculate the distance between crashes and intersections by the geo-coordinates will be needed, which requires more computing time and manual review for quality control.

2.2 The Wisconsin Roadway Databases

The highway intersection safety database developed for this research was constructed by integrating the following information sources: the GIS roadway network and inventory, the crash history, and traffic volumes. In Wisconsin, these data are maintained in five primary databases: the MV4000 Traffic Accident Database, the Wisconsin Information System for Local Roads

(WISLR), the State Trunk Network (STN), the WISLR Crash Geographic Information System (GIS) database, and the WisDOT Traffic Data System (TRADAS) database. The integration framework of the databases is shown in Figure 1.This section introduces the basic information of these databases. Detailed information about specific tables and fields relevant to the automation methodology will be described in subsequent sections.

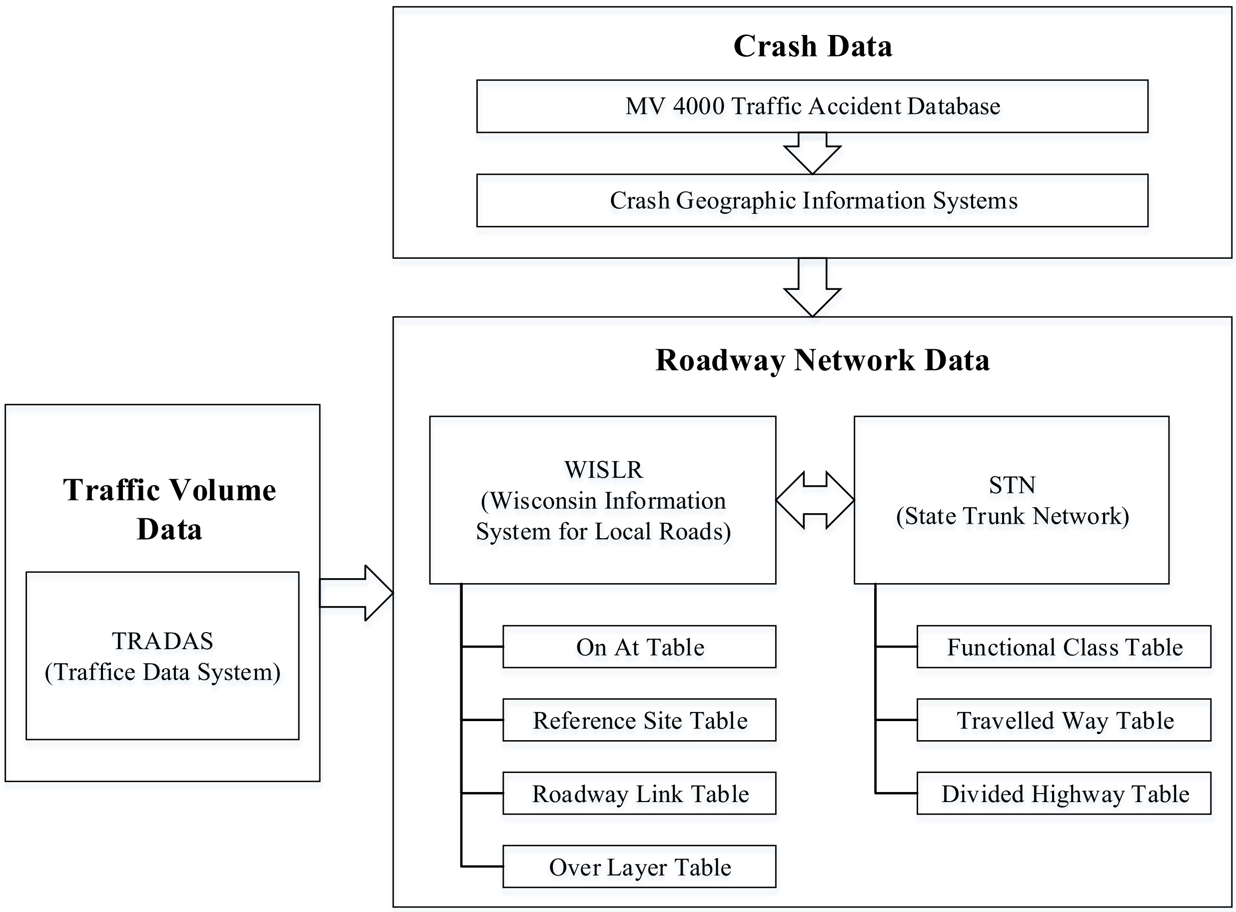


Figure 1 Framework of Wisconsin Transportation Databases

2.2.1 Wisconsin Information System for Local Roads (WISLR)

The Wisconsin Information System for Local Roads (WISLR) is a GIS-based system of local road inventory data developed and maintained by WisDOT. Within the WISLR LRS roadway network, intersections and terminals are represented as nodes and roadways segments are identified by links. The roadway attribute data used in this paper are maintained in three tables: the On-At table, the Roadway Link table and the Overlay table. Every intersection node is stored as a "reference site" in the On-At table, and the roadway segments are identified by the start reference site and the end reference site in the Roadway Link table. The Overlay table collects detailed business data including median characteristics, roadway category, access control, urban/rural location, federal urban area, and functional classification. WISLR includes a complete cartographic network representation of the highway system, however, since it is primarily oriented towards local roads, highway inventory information is generally missing and is maintained instead in the State Trunk Network LRS.

2.2.2 State Trunk Network (STN)

The State Trunk Network (STN) is a GIS-based inventory system for the state highway (STH) system, containing attribute data about State, Interstate, and National Highways that support the national roadway infrastructure within the State of Wisconsin. WisDOT is responsible for maintaining, analyzing, inventorying, and reporting on the STN.

The STN uses a separate, independent LRS network from WISLR. The STN links and WISLR links are transferable through a table which contains the start and end point of the STN link segment and the WISLR link segment that represent the same roadway part. The STN database manages the geometric information of the state highways, including the functional class, the number of lanes, the median feature, etc.

2.2.3 MV4000 Traffic Accident Database

The TOPS Lab WisTransPortal system*(6)* contains a complete database of Wisconsin MV4000 Traffic Accident Extract data from 1994 through the current year. This database contains information on all police reported crashes in Wisconsin, including the location of each crash, vehicles involved, and general crash attributes. This database is updated on a monthly basis through coordination with WisDOT Division of Motor Vehicles.

Crash information in this database is reported by a police officer via the Wisconsin MV4000 police form and is eventually archived in the WisDOT DMV crash database. Crash locations are reported in terms of relative offset from an intersection, based on on- and at-street name information, which identifies the intersection, and direction and distance information, which identifies the offset. The police officer also reports many other important pieces of information such as the area type, the severity, the roadway condition, the weather, the reason for the crash, and the driver's information, which can be utilized for a variety of comprehensive safety studies.

2.2.4 WISLR Crash Geographic Information Systems (GIS) database

The WISLR Crash GIS database is the integration of the two separate databases mentioned above - the WISLR LRS and the Wisconsin Crash Database. This database is generated through an automated process that locates crash records to the WISLR network in terms of roadway link and link-offset values. The WISLR Crash GIS database also provides a pinpoint map of all the intersection and segment crashes that occurred on local roads in Wisconsin, along with the complete crash information associated with each mapped crash. Preliminary quality evaluation on six years of statewide crash data indicates that 93% of all crashes are located to the WISLR network with 98% accuracy on the state trunk highway and 96% accuracy on local roads*(7)*. The integration of WISLR and crash reports provides invaluable access to more comprehensive safety analysis.

2.2.5 WisDOT TRAffic DAta System (TRADAS)

TRADAS processes and validates all continuous and short duration volume, speed, classification, and Weight in Motion (WIM) traffic data. The data files are processed through a series of quality checks based on AASHTO, ASTM, FHWA and user defined standards. Principal Arterials, Highway Performance Monitoring System (HPMS) Sections, National Highway System (NHS), and minor arterials with an Annual Average Daily Traffic (AADT) greater than 5,000 have counts taken on a three year cycle. Minor arterials with an AADT less than 5,000 and collectors with an AADT greater than 5,000 are on a six-year cycle and low volume collectors have counts taken on a ten-year cycle*(8)*. All TRADAS count sites are located to WISLR links and are available as an ESRI point shapefile.

2.3 Intersection Safety Evaluation Tool (ISET)

The Intersection Safety Evaluation Tool (ISET) *(6)* is a web application and intersection crash rate database supported by the Traffic Operations and Safety (TOPS) Laboratory to assist WisDOT regional offices and local government in identifying high risk intersections with respect to a variety of safety thresholds and analysis levels. The user interface of ISET is shown in Figure 1. Users can query and compare specific intersections to a representative "library" of the state average crash rates for any combinations of intersection features through the ISET tool.

ISET classifies intersections by seven different features, which are listed as:

- Area Type: Rural, Urban
- Number of Legs: 3 Legs, 4 Legs
- Number of Lanes: 1 Lane, 2 Lanes, 3 Lanes
- Left Turn Lane: Left Turn Lane Exists, No Left Turn Lane
- Traffic Control: Signalized, Two Way Stop Control, All Way Stop Control, Interchange
- Median Type: Divided, Undivided
- Volume Group: <5000, 5000~10000, 10000~20000, >20000

The original ISET database included 2,000 intersection crash rates from 2001-2003. It was updated in 2010 to incorporate 2003-2007 crash data and traffic counts*(6)*. In both cases, the database was populated through a manual procedure of locating crashes to intersections and compiling volume and attribute information for those intersections. The automated highway intersection safety information collection method proposed in the paper can be used to automatically collect intersection feature information and update the crash rate for ISET to incorporate the most up-to-date crash data.

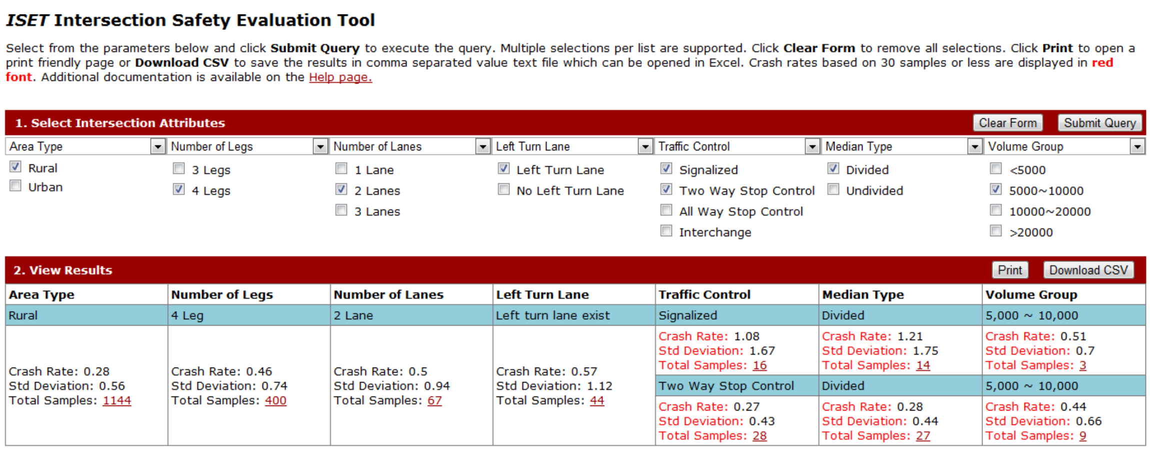


Figure 2 ISET User Interface

3 AUTOMATED HIGHWAY INTERSECTION SAFETY DATA COLLECTION METHODOLOGY

This section introduces the methodology to automatically collect intersection safety data. The framework of the method is illustrated as Figure 3. The objective of this methodology is to automatically collect the intersection features such as number of legs, area type, number of lanes and median type, as well as calculate and update crash rates for each intersection when new crash information and traffic volume data is available. The important tables and fields of the tables will be described in detail.

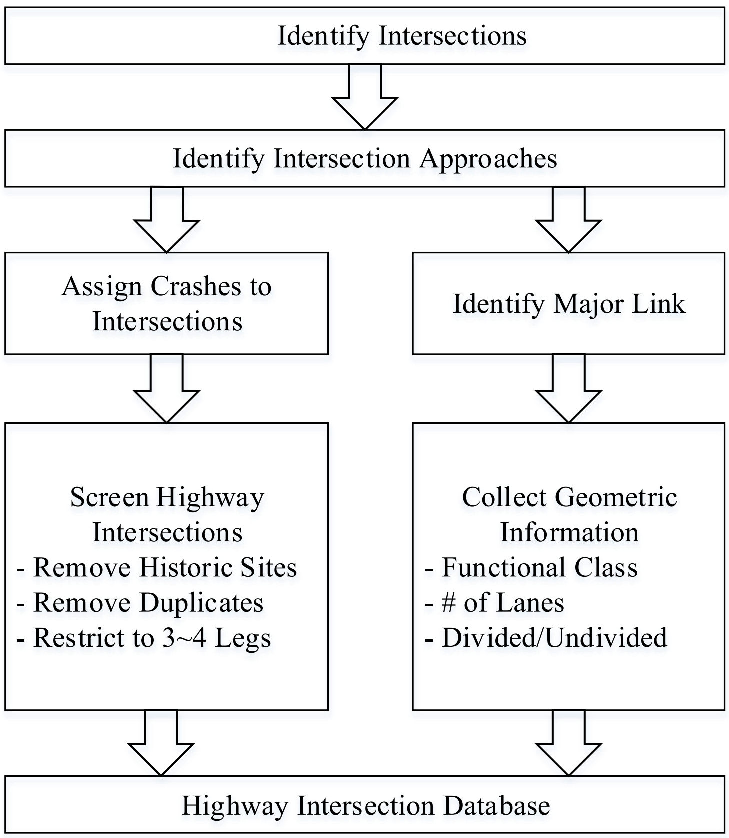


Figure 3 Framework of the Highway Intersection Safety Data Collection Methodology

3.1 Identify Intersections

The first step in this process is to develop a database of all roadway intersections in Wisconsin. In the WISLR database, intersections are identified as nodes in the On-At table. The fields used in the algorithm are listed in Table 1.

TABLE 1 Fields in On-At Table

Field	Description
ON_AT_ID	The primary key of the table
LCM_STUS_TYCD	The status of the record. Values include: C="Current" H="Historic"
REF_SITE_ID	Each node is associated with one REF_SITE_ID
ON_AT_TYCD	The function of the node. A node may have multiple functions. Values include: I="Intersection", N="Name Change", M="Muni change", T="Termini", X="Invalid", L="Loop Termini"
LCM_CURR_DT	The time when the node is effective

Each node is identified with a unique Reference-Site-ID (REF_SITE_ID). The intersections can be identified in the On-At table as REF_SITE_IDs associated with On-At type (ON_AT_TYCD) “Intersection”.

3.2 Identify Intersection Approaches

The number of intersection approaches can be obtained by using the LRS-based GIS roadway network. The roadway segments connected to the intersection can be identified from the Roadway Link table in the WISLR database, which is described in Table 2. The two directions of a roadway segment are stored as two separate links, identified by the start reference point (REF_SITE_FROM_ID) and the end reference point (REF_SITE_TO_ID).

TABLE 2 Fields in Roadway Link Table

Field	Description
RDWY_LINK_ID	The primary key of the table
LCM_STUS_TYCD	The status of the record. Values include: C="Current" H="Historic"
REF_SITE_FROM_ID	The start reference point of a link
REF_SITE_TO_ID	The end reference point of a link
LCM_FROM_TO_DIS	The length of a roadway link

The ISET intersection types include three-leg (T- intersections) and four-leg (cross-intersections) with some five-way intersections. The number of legs for each intersection can be derived by counting the number of WISLR links connected to an intersection reference site. Considering an intersection approach may be a one-way roadway segment, the number of approaches was determined by taking the maximum of the from-links and the to-links.

3.3 Assign Crashes to Intersections

The crashes located to the roadway segments of an intersection are screened based on the distance to the intersection, as described below.

In the WISLR Crash GIS Database, each crash record is associated with a WISLR_LINK, by which the Crash GIS table can be connected with the roadway link table. The locations of crashes are represented as a distance along the roadway link.

Based on previous study*(9)*, crashes within 0.02 mile (106 feet) of an intersection are considered to be intersection related for this investigation. It should be noted that the threshold might be different in other DOTs, for example, the Kentucky DOT uses 0.02 miles radius for urban intersections and 0.05 miles radius for rural intersections*(10)*. The number of intersection crashes is aggregated from the total number of crashes on each of the approaches.

Figure 4 illustrates the two sample intersections in the WISLR Crash Map*(6)*. Each crash is marked as a dot in the Crash Map and the color indicates the severity of the crash. As shown in Figure 4, four crashes are assigned to the intersections on the left and three crashes are assigned to the intersection on the right by the algorithm. The two intersections are 0.26 miles apart and the circles around each intersection represent the 0.02 threshold radius.

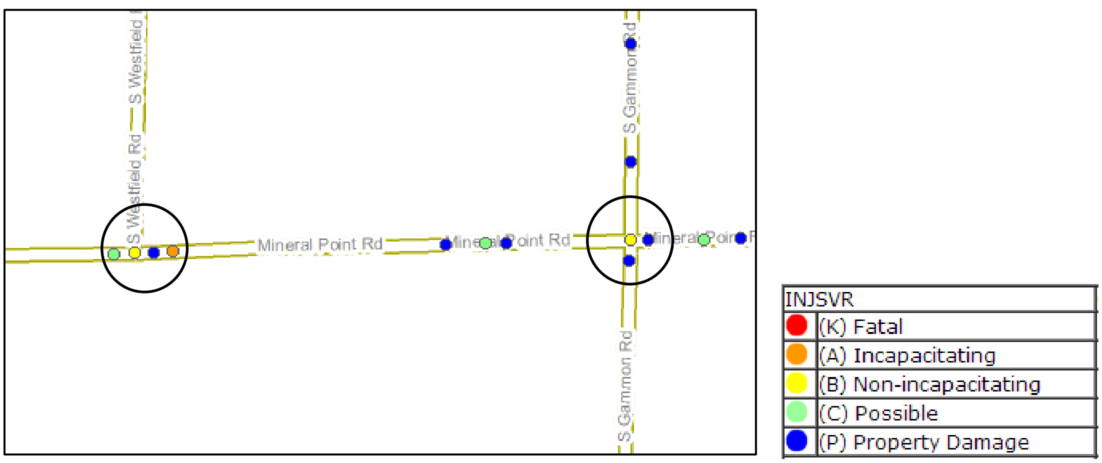


FIGURE 4 Sample Intersections in WISLR Crash Map

3.4 Highway Intersection Screening

An intersection database containing 216403 intersections was created following the aforementioned steps. The intersections need to be screened to keep only current active highway intersections during study period (2007-2011) following the process below. In order to avoid bias in removing intersections, the number of intersections per crash count distribution should be reserved in each screening step, which are illustrated in Figure 5.

Step 1: Find highway intersections

This paper defines the highway intersection as any intersection in WISLR with at least one highway link, determined through association with the STN link network. Intersections without any links in the STN database will be removed. 29873 highway intersections are identified in this step, which constitutes 13.8% of the 216403 total WISLR intersections statewide.

Step 2: Remove historic intersections and duplicated intersections

When an intersection is relocated or removed, the WISLR database will identify the changed intersection as historic. Historic intersections should be removed since their status changed prior to or during the 2007-2011 crash rate study period. Additionally, the WISLR crash mapping algorithm occasionally locates crashes to multiple intersections. These cases arise when two intersections within the same municipality share the same ON/AT roadway location descriptions. Some examples will be presented and discussed in Section 3.6. Such intersections should be removed to ensure the accuracy of the safety information collection method. 7722 intersections (25.8% of 29873) are removed in this step.

Step 3: Restrict to 3~4 legged intersections

The ISET methodology is currently limited to 3 and 4 legged intersections. Ramps and more complex configurations are excluded. A typical highway ramp will be identified as a 2 legged intersection in the proposed methodology, since on-ramps have two in-links and one out-link and off-ramps have two out-links and one in-link. Hence they are excluded by the filtering process. Although a small number of 5 legged intersections exist in Wisconsin, they are accurately identified and excluded by the process. The number of remaining intersections is 21729 after this step.

As shown in Figure 5, the crash count distribution in each step generally matches the crash count distribution of all intersections, except that the 0-crash intersections are underrepresented. The reason may be that the highway intersection expose to more traffic, therefore highway intersections are less likely to have no crash history than the general (local road) intersections.

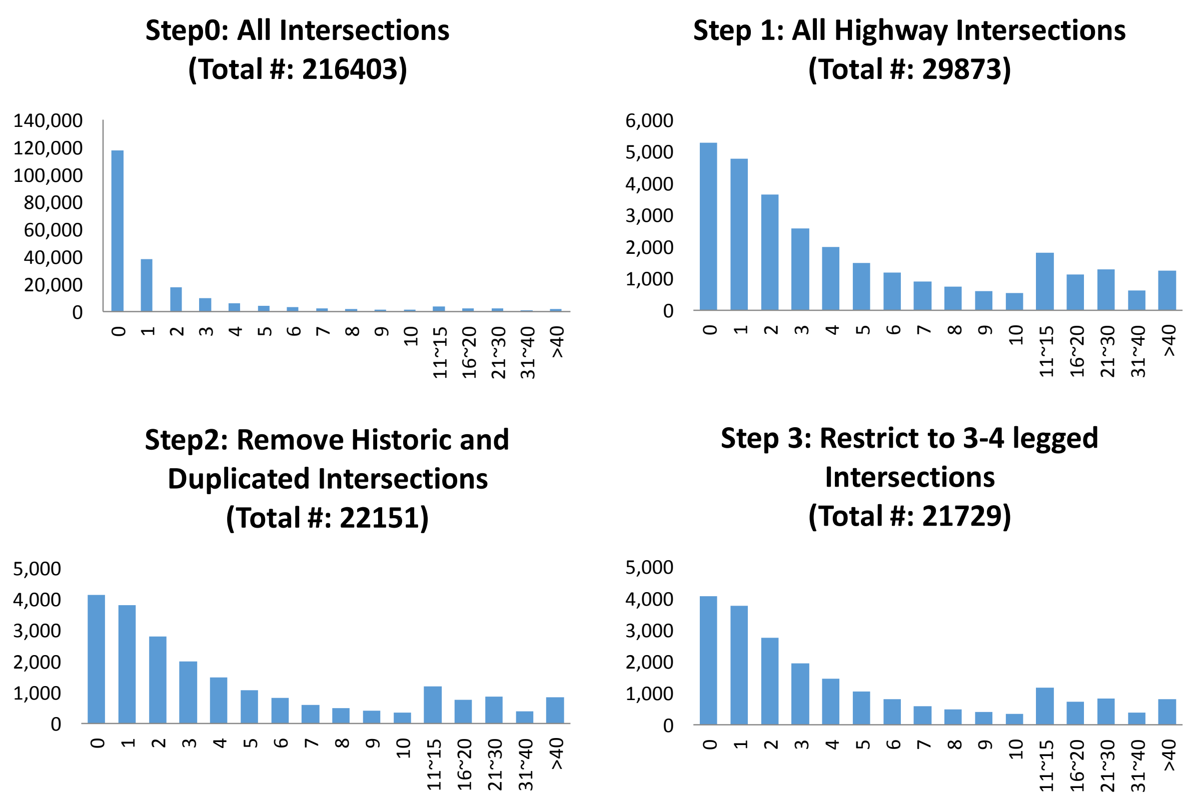


Figure 5 Change of Crash Distributions in the Highway Intersection Screening Process

3.5 Intersection Geometric Information Collection

The intersection geometric features are determined by the geometric feature of the major entering road. In general, minor roadway volumes are not available, hence ISET intersection crash rates are based on the major entering roadway volume at a given intersection. The entering link with the maximum Average Annual Daily Traffic (AADT) is regarded as the major road. The most up-to-date AADT data for most links are available from the TRADAS database and associated WISLR GIS files. However TRADAS volume data is not available for every major roadway link in WISLR. Only 10602 (48.8%) of the highway intersections have TRADAS record.

STN contains geometric features of highway roads such as the number of lanes, functional class, and the median type. The area type of an intersection can be deduced from the functional class. The median types include two categories: divided and undivided.

3.6 Quality Assurance/Quality Control

A Quality Assurance/Quality Control (QA/QC) procedure was implemented in this study to evaluate the effectiveness of the automated highway intersection safety information collection method. 10 random highway routes were selected and approximately 20 intersections on each route were inspected manually to identify mismatched highway intersections. About 97% of the intersections are correctly matched by the automated algorithm. However, there are some cases where the algorithm would fail to work, which are shown in Figure 6.

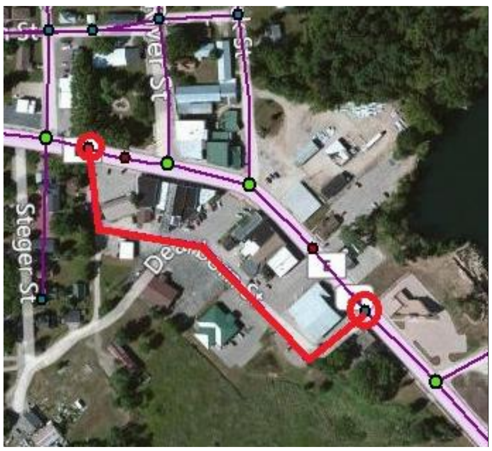
Artifact in the GIS Network: Figure 6(A) illustrates an artifact in the database - a divided highway segment where excessive REF_SITES are used, which will cause error in calculating number of approaches for these intersections.

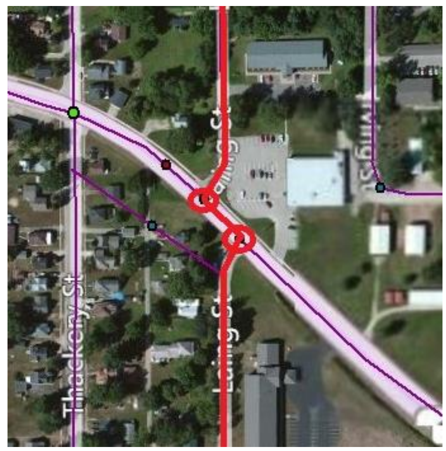
Ambiguous Intersection: Figure 6(B) shows how ambiguous intersection names which will cause the duplicate intersection problem in the crash mapping process.

Irregular Shape: Figure 6(c) presents a condition where two opposite approaches are not in the same line. The algorithm will identify Figure 6(c) as two 3-legged intersections, however some people will regard it as a 4-legged intersection.

Private Roadway: In addition, the WISLR database only contains public roadway information, since private roadways (such as the trailer park communities) are not maintained by the state DOT. The automated algorithm may miss the private approaches in calculating number of approaches.

(A) Artifact in the Database





(B) Ambiguous Intersection (C) Irregular Shape

Figure 6 Special Conditions in Highway Intersection Screening

4 STATEWIDE HIGHWAY INTERSECTION CRASH STATISTICS

The ISET library provides an opportunity to perform systematic intersection safety analysis against a representative sample set of crash rates and intersection types. This section analyzes the systematic crash patterns by different intersection geometric features. The intersection safety measures used in this section include: percentage of intersections per crash count distribution, crash frequency, crash rate and KA Ratio.

An intersection crash frequency is defined as the average number of crashes per year. An intersection crash rate is defined as the average number of crashes per year divided by the average yearly traffic volume at that intersection. The intersection crash rate is calculated in per million vehicles, the equation is defined as:

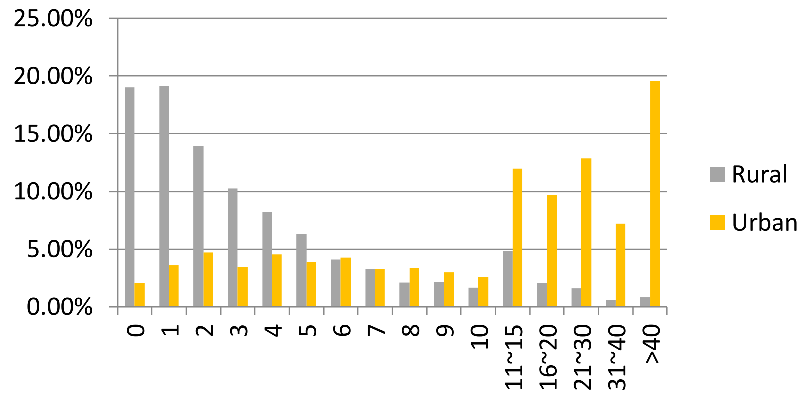
$$\text{crash rate} = \frac{\#\ of\ crashes\ per\ year}{Annual\ Average\ Daily\ Traffic\ \times 365 \div 1000000}$$

The KA Ratio indicates the risk level of an intersection, which is defined as the percentage of crashes with severity level ‘K’(fatal crash) or ‘A’(incapacitating crash) in all crashes.

The geometric information is not available for every intersection, since the databases could not cover every aspect of all roadways. This analysis only uses data when it’s available.

4.1 Crash Analysis by Area Type

Figure 7 suggests that the percentage of urban intersections with larger number of crashes is higher than the rural intersections. The rural crash rate is 1.44 times larger than the urban crash rate, the rural KA ratio is 2.46 times greater than urban, but the urban crash frequency is 4.83 times higher than rural. The reason may be that the volume are higher in the rural area, therefore the number of crashes are higher, however the speed in rural area is higher therefore the crashes tend to be more dangerous than the urban area.

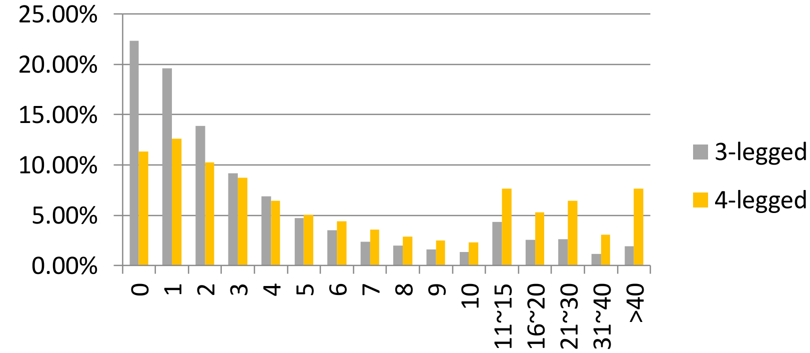


Area Type	Number	Crash Rate	Crash Frequency	KA Ratio
Rural	3214	1.50	0.89	0.32
Urban	2514	1.04	4.30	0.13

Figure 7 Crash Analyses by Area Type

4.2 Crash Analysis by Number of Approaches

Figure 8 shows that 4-legged intersections have a larger concentration at the higher crash frequency ranges compared to 3-legged intersections. Moreover, both of the crash measurements- crash frequency and crash rate - confirm that 4-legged intersections expose to a higher risk. The result is consistent with the empirical knowledge that 4-legged intersections have more conflicting points than the 3-legged intersections.

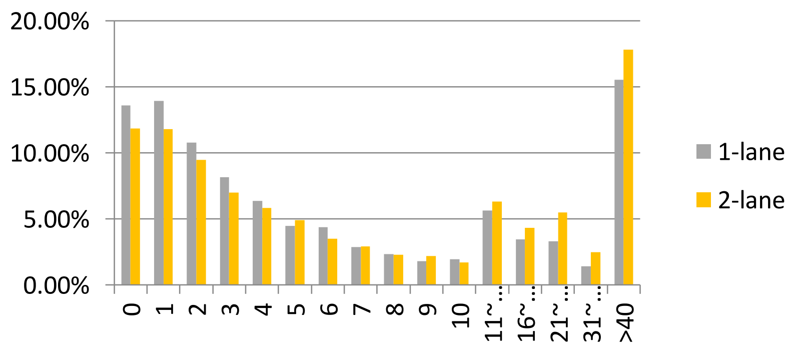


# of Legs	# of Intersections	Crash Rate	Crash Frequency	KA Ratio
3	6303	0.99	1.83	0.21
4	4189	1.44	3.49	0.13

Figure 8 Crash Analyses by Number of Approaches

4.3 Crash Analysis by Number of Lanes

As shown in Figure 9, the percentages of intersections per crash count distribution are very close between the 1-lane intersection and the 2-lane intersection. The crash rate is lower in 2-lane intersections however the crash frequency is higher, which may associate with the higher traffic volume in 2-lane intersections.

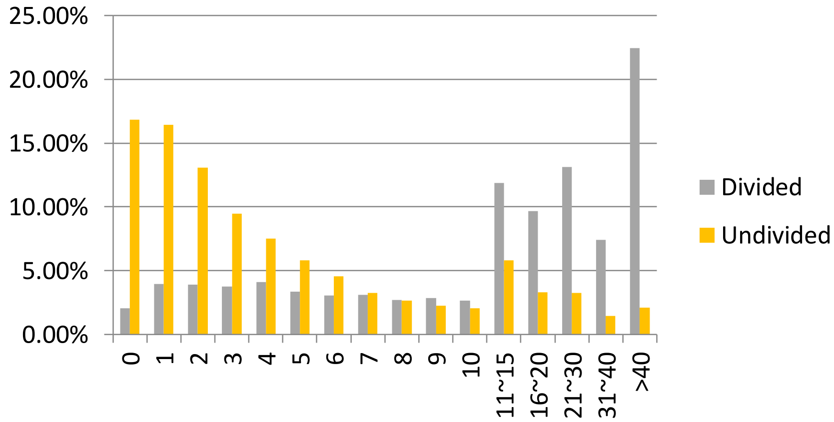


# of Lanes	# of Intersections	Crash Rate	Crash Frequency	KA Ratio
1	3953	1.09	1.83	0.19
2	4832	0.75	2.58	0.16

Figure 9 Crash Analyses by Number of Lanes

4.4 Crash Analysis by Median Type

Figure 10 shows that divided highways have a larger concentration at the higher crash frequency ranges compared to undivided highways. Most of the highways are undivided in Wisconsin. The crash frequency is significantly higher in divided highways but the crash rate is comparably not so high. The crash severity in the divided intersections is significantly lower than in the undivided intersections, which indicates separating conflicting traffic flows can help to improve the safety level.



Median Type	# of Intersections	Crash Rate	Crash Frequency	KA Ratio
Divided	1893	0.84	5.64	0.08
Undivided	7239	0.73	1.52	0.23

Figure 10 Crash Analyses by Median Type

4.5 Comprehensive Analysis

Table 3 calculates the intersection crash rates, crash frequencies and KA Ratio by area type, number of approaches, number of lanes, and median type, which provide a statewide average crash information statistics by geometric features. For a certain intersection with a crash rate significantly higher than the statewide average, counter measures are suggested to be taken to improve the safety condition.

Table 3 only contains intersection categories with more than 30 intersections, since the statistical reliability is questionable for categories with less than 30 samples.

TABLE 3 Comprehensive Analysis

Area Type	# of Legs	# of Lanes	Median Type	# of Intersections	Crash Rate	Crash Rate Rank	Crash Freq.	Crash Freq. Rank	KA Ratio	KA Rank
Rural	3	2	Undivided	1761	0.62	11	0.73	14	0.32	1
Rural	3	1	Undivided	81	0.61	12	1.67	9	0.27	2
Rural	4	2	Undivided	895	0.73	5	1.04	13	0.24	3
Rural	3	2	Divided	156	0.43	13	1.55	11	0.23	4
Rural	4	1	Undivided	61	0.80	4	2.66	5	0.19	5
Rural	3	1	Divided	35	0.70	7	1.51	12	0.17	6
Urban	3	2	Undivided	363	0.63	10	2.00	7	0.16	7
Rural	4	2	Divided	166	0.66	9	2.40	6	0.16	8
Rural	4	1	Divided	36	0.71	6	1.99	8	0.12	9
Urban	4	2	Undivided	257	1.07	2	3.41	4	0.10	10
Urban	3	1	Divided	44	0.41	14	1.66	10	0.10	11
Urban	4	1	Divided	49	1.06	3	3.56	3	0.09	12
Urban	3	2	Divided	629	0.67	8	4.44	2	0.07	13
Urban	4	2	Divided	528	1.15	1	7.47	1	0.05	14

As indicated in Table 3, although urban 4-legged intersection with divided 2-lane major road has the highest statewide average crash rate, the average crash severity is lowest among all types of intersections. Rural 3- legged intersections with undivided 2-lane major road exposed to the most dangerous crash possibility, about 1/3 of the crashes are fatal or incapacitating. The urban intersections with divided major road have the highest crash rates but relatively low KA ratios. In conclusion, intersections with different geometric features vary in the statewide crash statistics. The specific rankings are highly sensitive to the ranking methodology (e.g., injury severity vs. overall crash rate).

5 CONCLUSION

In this study, a new intersection safety information evaluation method is proposed to automate the process of generating highway intersection crash rates and integrating those crash rates with roadway features such as the area type, the number of lanes, the median type and the number of approaches. In the proposed methodology, five databases - the Wisconsin crash database of police traffic accident reports, the Wisconsin Information System of Local Roads (WISLR), State Trunk Network (STN), Crash Geographic Information Systems (GIS) database, and the TRAffic DAta System (TRADAS) - are combined to produce a database of intersection crashes, which can provide a significant approach for more comprehensive intersection safety analysis. The QA/QC result suggests that this methodology is reliable in collecting the intersection data. This paper also presented the statewide average crash statistics by different combinations of intersection features, which provides a bench mark for Wisconsin safety engineers to identify intersections that need safety improvement. This study has implied the advantages of using LRS to manage transportation data, since crashes can be directly related to roadways and intersections. In addition, the study can be applied to other state DOTs that uses

LRS to manage traffic data. Future studies would explore adding more intersection features such as the left turn lane and the traffic control type.

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