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Final Report

Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support (IDS)

Report #1 in the Series: Developing Intersection Decision Support Solutions

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16. Abstract (Limit: 200 words)

Minnesota's rural crash records were analyzed in order to develop a better understanding of crashes at rural intersections and their cause. The objective in studying the causes of crashes at rural intersections is to support development of technology based strategies to mitigate high crash rates. Since previous research found that 80 percent of intersection crashes at thru-STOP intersections may be related to selection of insufficient gaps, the development and validation of Intersection Decision Support (IDS) technology that assists in proper gap selection was identified as a primary goal.

A database of over 3,700 intersections was examined. Using the critical crash rate as an indicator, 23 rural expressway intersections and 104 rural two-lane intersections were identified as unusually "dangerous" locations. Right angle crashes (which are most often related to gap selection) were observed to account for approximately 50 percent of all crashes at the "dangerous" intersections, up from 28 percent for all rural thru-STOP intersections.

A specific intersection identified, evaluated and then was selected for testing IDS technologies that can track vehicles approaching on the major roadway, compute the gap and communicate the information to drivers stopped on the minor street waiting to enter the intersection. The data acquisition system to be installed will allow analysis of driver decision making behavior and study the effects of introducing an IDS under development at the University of Minnesota.

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Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support (IDS)

Report #1 in the Series: Developing Intersection Decision Support Solutions

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Table of Contents

List of Tables

List of Figures

Executive Summary

Minnesota's rural crash records were analyzed in order to develop a better understanding of crashes at rural intersections and their cause. The study's objective was to investigate the causes of crashes at rural intersections and to support the development of technology based strategies to mitigate the high crash rate. Since previous research found that up to 80 percent of intersection crashes at thru-STOP intersections may be related to selection of insufficient gaps, the development and validation of Intersection Decision Support (IDS) technology that assists in proper gap selection was identified as a primary goal.

The investigation addressed questions such as: how many unsafe rural intersections are there in Minnesota, where are they, and what are the characteristics of crashes at these intersections. Without a comprehensive understanding of Minnesota's rural intersection crashes, effective deployment of IDS technology would be difficult, especially if the hypothesis that drivers have difficulties selecting adequate gaps is invalid.

A database of over 3,700 intersections was examined. Using the critical crash rate as an indicator, 23 rural expressway intersections and 104 rural two-lane intersections were identified as unusually "dangerous" locations. Of these 127 intersections, further investigation focused on the rural expressway intersections since expressways tend to carry higher volumes at higher speeds when compared to two-lane roadways. Also, past studies found that the percentage of intersection crashes on rural expressways increases with increasing mainline volumes, and there are several high-volume rural expressway corridors in Minnesota.

As a group, crashes at rural expressway thru-STOP intersections have similar crash and severity rate as all rural thru-STOP intersections. However, right angle crashes (which are most often related to gap selection) were observed to account for 36 percent of all crashes at the rural expressway intersections and approximately 50 percent of all crashes at the "dangerous" expressway intersections (as opposed to 28 percent for all rural thru-STOP intersections). Further investigation also found that drivers' inability to recognize the intersection, which led them to run the STOP sign, was cause for only a small fraction of right angle crashes; instead, gap selection was the predominant problem.

A specific intersection was selected for testing IDS technologies that can track the gaps between vehicles and communicate that information to drivers who are stopped and waiting to enter the intersection. The data acquisition system to be installed will allow in-situ analysis of driver decision making behavior and the effects of introducing an IDS system under development at the University of Minnesota.

If the IDS technology proves to be effective at reducing gap-related intersection crashes, a system-wide deployment to all rural thru-STOP intersections is not feasible due to the large number of rural intersections in Minnesota. If the goal was to specifically target fatal crashes, only seven rural thru-STOP intersections in Minnesota had two fatal crashes during the analysis period (3 years) and no intersections had three or more fatal crashes. Further, of the 590 fatal crashes that occurred in 2002, only 8 percent occurred at rural thru-STOP intersections on the state highway system. This information lends support to the need for a systematic deployment of the technology since a crash frequency based deployment would be ineffective and a system-wide deployment is not financially feasible. One approach to a systematic deployment would be to deploy the IDS system at the 127 "dangerous" locations identified earlier. This approach could potentially eliminate 270 crashes per year with an annual crash cost of almost $26 million.

Chapter 1
Introduction

Intersections make up only a small portion of the nation's highways, but past research has found that intersection crashes constitute more than 30 percent of all crashes (*1*). As a result, the American Association of State Highway and Transportation Officials (AASHTO) identified design and operational improvements of highway intersections as one of the 22 key emphasis areas in their Strategic Highway Safety Plan (SHSP) (*2*). Development and use of new technologies at high-priority intersections was identified in the SHSP as one initiative to address intersection crashes.

In response to AASHTO's SHSP, the *National Cooperative Highway Research Program* (NCHRP) *Report 500 (Volume 5)* was written to provide state and local agencies with tools to address crashes at unsignalized intersections (*3*). *NCHRP Report 500* recognizes that providing gap selection assistance to drivers is critical to improving unsignalized intersection safety. Using automated real-time information systems to inform drivers when a safe gap exists is one strategy highlighted in *NCHRP Report 500*.

In accordance with these Federal initiatives, this study posed the questions: how many unsafe intersections are there in Minnesota, where are they, what are the characteristics of crashes at these intersections, and which intersections are most likely to benefit from new technology to address the gap selection problem.

1.1 Research Study

The State of Minnesota has partnered with California and Virginia in an effort to improve intersection safety. The Minnesota focus is to address rural unsignalized intersection crashes. The Minnesota team's objective is to "develop a better understanding of the causes of crashes at rural intersections that support development of technology based strategies to mitigate the high crash rate." In previous research, intersection crashes at thru-STOP intersections have been categorized as either based on a sign violation (i.e., did not stop) or a selection of an insufficient gap (i.e., stopped, but was hit, or hit car when entering the intersection).

One such study by Najm et al. classified approximately 80 percent of thru-STOP crashes as related to the selection of insufficient gaps (*4*). Other studies have further broken out the types of driver error at thru-STOP intersections. In a 1994 study of over one hundred straight crossing path crashes at thru-STOP intersections selected from the 1992 Crashworthiness Data System, Chovan et al. (5) found that the primary causal factors for drivers who stopped before entering the intersection was:

1. The driver looked but did not see the other vehicle (62.1 percent)
2. The driver misjudged the gap size or velocity of the approaching vehicle (19.6 percent),
3. The driver had an obstructed view (14.0 percent), or
4. The roads were ice-covered (4.4 percent).

Of these four driver errors, the first three can be described as either problems with gap detection or gap selection. The crash data that was used for this analysis are part of the National Accident Sampling System (NASS), which is designed to support the development, implementation, and assessment of highway safety programs.

Intersection Decision Support (IDS) technology is meant to provide driver decision aids that reduce driver error. For rural unsignalized intersections, providing drivers with assistance in selecting and identifying an appropriate gap is clearly warranted.

Minnesota's rural crash records were reviewed in detail in order to develop a better understanding of the causes of crashes at rural intersections and also to identify any rural intersections with a crash problem that would benefit from IDS. A second objective was to identify key contributing factors to high crash frequencies. Without a comprehensive understanding of Minnesota's rural intersection crashes, effective deployment of IDS technology would be difficult, especially if the hypothesis that drivers have difficulty selecting adequate gaps is invalid. The final objective was to recommend an intersection to be used as the model for further data collection and research and for possible deployment in a follow up field operational test.

This report provides a review of Minnesota's rural crash information, describes the criteria and process that were used to identify high crash intersections, and summarizes rural intersection crash patterns. The report concludes with a specific recommendation for an intersection to be used for testing IDS technologies that can track vehicles approaching on the major roadway, compute the gaps between vehicles and communicate that information to drivers who are stopped and on the minor street waiting to enter the intersection. The data acquisition system to be installed at the selected intersection will allow driver decision making behavior to be analyzed in-situ and will facilitate an analysis of the effects of introducing IDS technology presently under development at the University of Minnesota.

Chapter 2
Review of Rural Crash Information

Given the extensive amount of crash information available through the Minnesota Department of Transportation's (Mn/DOT) crash records system, the following criteria were used to reduce the amount of data to a manageable level:

- Only intersections along the State's highway system were included in the database,
- Only rural expressways and rural two-lane roadways were considered, and
- Only crash records from 2000 to 2002 were analyzed.

It was expected that the majority of the high-crash intersections in Minnesota would be located on the state highway system because it accounts for a majority of the high-volume, high-speed rural roadways. Of the state highway system, the crash review was focused on expressways and two-lane roadways that account for nearly 98 percent Minnesota's rural roadways (excluding rural freeways). [NOTE: Minnesota's rural expressways have many similarities to interstate highways while at the same time having stark differences. In Minnesota, rural expressways are four-lane, divided facilities with interchanges at junctions with major, high volume highways (interstate highways and other expressways). However, the majority of the intersections are at-grade and are STOP controlled for the crossing roadway only, while some intersections near the edges of urbanized areas are controlled by traffic signals. Posted speed limits are typically between 55 and 65 miles per hour, but may be lower in and near urbanized areas. If right-of-way is available, access is combined using frontage roads connected to roadways that cross the expressway. Where frontage roads are not used, direct access may be limited to right-in / right-out design.] In addition, crashes along rural county and local roads where excluded because there is no database of roadway and intersection control characteristics for these facilities.

Limiting the analysis to three years of crash records is a typical Mn/DOT practice when performing safety analyses. Using three years of crash records reduces the chance that a major change was made to either the roadway or intersection during the selected years while generally providing a sufficient sample of crash records. Between 2000 and 2002, there were 23,179 reported crashes on rural two-lane roadways and 10,996 on rural expressways.

2.1 Minnesota's Crash Records Compared to the General Estimates System Crash Database

The General Estimates System (GES) crash database is a national sample of police-reported crashes used in many safety studies. However, because Mn/DOT has an extensive and more detailed crash database available, the GES was not used to summarize Minnesota's rural intersection crashes. David Ragland and Aleksandr Zabyshny had previously used the GES database to summarize crossing path crashes – or crashes which are most likely related to poor gap selection (6). As a starting point, the Minnesota crash records were compared to the major findings from this previous work based on the GES database.

Comparison of the Minnesota and GES crash databases was somewhat limited by differences in crash type reporting. The GES summarizes crossing path crashes into the following five categories (see **Figure 2-1**):

- Left Turn Across Path – Opposite Direction (LTAP/OD)
- Left Turn Across Path – Lateral Direction (LTAP/LD)
- Left Turn Into Path – Merge (LTIP)
- Right Turn Into Path – Merge (RTIP)
- Straight Crossing Path (SCP)

While the GES crash database uses five categories to define crossing path crashes, the Minnesota system has only three categories. The crossing path crash types used by Mn/DOT and the corresponding GES categories are summarized in **Table 2-1**.

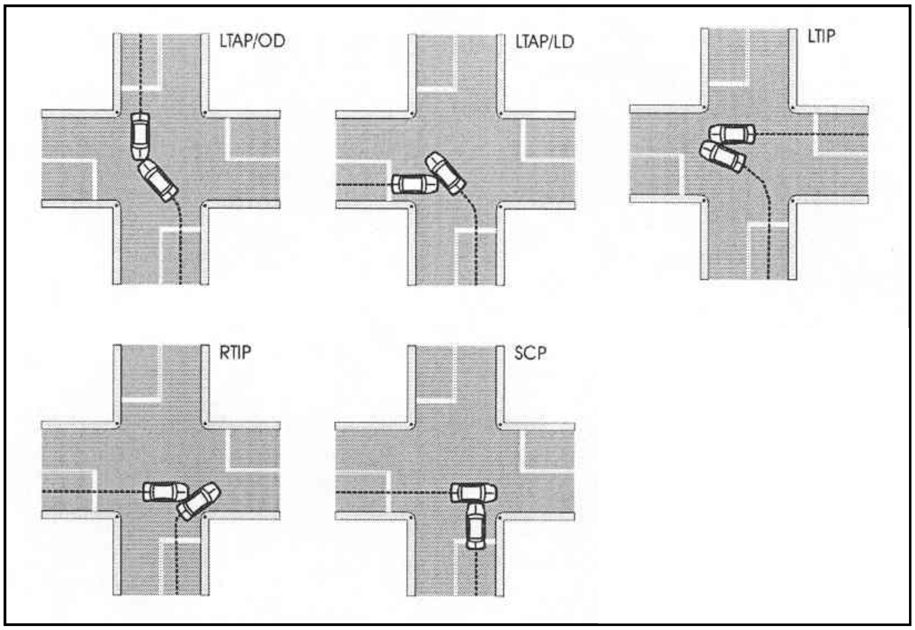


Figure 2-1: GES Crossing Path Crash Designations

Table 2-1: Crash Type Reporting Differences

Mn/DOT Crash Type	GES Crash Type
Right Angle	Left Turn Across Path – Lateral Direction (LTAP/LD)
	Left Turn Into Path – Merge (LTIP)
	Straight Crossing Path (SCP)
Left Turn into Oncoming Traffic	Left Turn Across Path – Opposite Direction (LTAP/OD)
Right Turn into Cross-Street, Traffic from Left	Right Turn Into Path – Merge (RTIP)

Table 2-2 shows the major findings from the Ragland et al. analysis as well as the analysis from Mn/DOT's crash records. The notable differences between the findings from the GES and the Mn/DOT crash record analysis can be partially explained by the differences in what data were analyzed. The GES summary includes information for all types of intersections, while the

Minnesota data was sorted to focus on only rural two-lane roadways and rural expressways. Notable differences between the GES crash database and Mn/DOT's crash records are summarized as follows.

- In Minnesota, rural two-lane roadways and rural expressways have a lower percentage of crashes occurring at either all junctions or at intersections.
- Rural Minnesota roadways have a lower percentage of LTAP-OD and RTIP crashes compared to the GES crash records while Minnesota roadways have a slightly higher percentage of right angle crashes.
- Rural two-lane roadways in Minnesota have a lower percentage of crashes occurring at controlled intersections, including signalized intersections, when compared to Minnesota's rural expressways and the GES crash records. The percentage of intersection crashes occurring at two-way STOPs of rural two-lane roadways is much greater than that of rural expressways or the GES crash records.
- The percentage of rear end crashes is similar between the GES crash records and Minnesota's rural roadways. The percentage of pedestrians and bikes involved in intersection crashes of rural expressways is higher than those from rural two-lane roadways or the GES crash records.

2.2 Observations from Minnesota Crash Records

During the review of Minnesota's crash records on rural two-lane roadways and expressways, several observations were made other than those for comparison to the GES. The general highlights of Minnesota's rural crash data analysis are summarized in the following.

- For both classifications of rural roadways, approximately one-third of all crashes occurred at intersections (29.5% for two-lane roadways and 38.5% for expressways).
- The percentage of rural expressway crashes occurring at traffic signals (18.6%) is nearly five times larger than the percentage for rural two-lane roadways (3.8%).
- The percentage of crashes occurring at thru-STOP intersections was 13.6% for two-lane roadways and 8.6% for expressways. Most at-grade intersections on rural expressways have YIELD signs placed in the median crossover. If crashes that were coded as occurring at a YIELD sign are assumed to have happened at the median cross-over of a thru-STOP intersection, then the percentage of crashes at thru-STOP intersections increases to 14.2%. [NOTE: Crashes coded with a traffic control device of "STOP Sign – Other" were assumed to represent thru-STOP intersections.]
- Crossing path type crashes account for 18.7% of all crashes on two-lane roadways (Right Angle = 15.8%, Left Turn = 2.6%, & Right Turn = 0.3%). For rural expressways, crossing path crashes represent 21.1% of all crashes (Right Angle = 18.4%, Left Turn = 2.3%, & Right Turn = 0.4%).
- Rural expressways and rural two-lane roadways were found to have near identical distributions in intersection crash severity. For both facility types, thru-STOP intersection crashes have only a slightly higher percentage of fatalities when compared to all rural crashes, but the percentage of injury crashes at thru-STOP intersections is approximately 5 percentage points higher than all rural crashes (see **Table 2-3**).

Table 2-2: Comparison of GES Crash Database to Mn/DOT Crash Records

Of...		GES Crash Records*	Mn/DOT Crash Records**		Description
			Rural Two-Lane	Rural Expressways	
All Crashes	Crashes at Junctions	60%	37%	45%	Includes: Interchange Area, Intersection, Alley / Driveway, School Crossing
	Intersections	44%	30%	39%	
All Crashes	Crossing Path	25%	19%	21%	
	Straight Crossing Path (SCP)	8.6%	16%	18%	Includes: Right Angle
	Left Turn Across Path, Lateral Direction Crashes (LTAP-LD)	4.8%			
	Left Turn into Path Crashes (LTIP)	1.5%			
	Left-Turn Across Path, Opposite Direction Crashes (LTAP-OD)	6.7%	3%	2%	Includes: Left Turn into Oncoming Traffic
	Right Turn into Path Crashes (RTIP)	1.5%	0%	0%	Includes: Right Turn into Cross-Street Traffic From Left
	Other Types of Crossing Path Crashes	2.0%	-- NA --		
Intersection Crashes	Controlled Intersections	74%	54%	73%	
	Signalized Intersections	46%	10%	40%	Includes: Traffic signal
	Two-Way STOP	16%	42%	20%	Includes: STOP Sign - Other
	Four-Way STOP	6%	2%	0%	Includes: STOP Sign - All Approaches
	Other	5%	1%	12%	Includes: YIELD Sign
	Uncontrolled Intersections	26%	-- NA --	-- NA --	
Intersection Crashes	Signalized Intersections of Type LTAP-OD, SCP and Rear End	73%	69%	76%	Includes: Left Turn into Oncoming Traffic, Right Angle, Rear End
	Two-Way STOP Intersections of Type SCP and LTAP-LD	71%	56%	67%	Includes: Right Angle
	Four-Way STOP Intersections of Type SCP and Rear End	59%	62%	48%	Includes: Right Angle, Rear End
Intersection Crashes	Non Crossing Path				
	Rear End	32%	27%	36%	Includes: Rear End
	Pedestrians and Bikes	3%	4%	10%	Includes: Collision with Bicyclist and Collision with Pedestrian

*Source: *Taxonomy of Crossing Path Crashes at Intersections Using GES 2000 Data* (*6*)

**Source: 2000-2002 Mn/DOT Crash Data

Table 2-3: Crash Severity Distribution by Facility Type and Crash Description

	Rural Two-Lane Roadways			Rural Expressways		
Injury Severity [a]	**All Crashes** [b]	**Thru-STOP Crashes**	**Percentage Change**	**All Crashes** [c]	**Thru-STOP Crashes**	**Percentage Change**
Fatal	1.7%	1.8%	+ 0.1%	1.2%	1.4%	+ 0.2%
All Injuries	33.7%	38.3%	+ 4.6%	33.1%	38.2%	+ 5.1%
Serious Injury	2.9%	3.2%	+ 0.3%	2.2%	3.9%	+ 1.7%
Moderate Injury	14.0%	15.8%	+ 1.8%	12.7%	16.3%	+ 3.6%
Minor Injury	16.8%	19.3%	+ 2.5%	18.2%	18.0%	- 0.2%
Property Damage Only	64.6%	59.9%	- 4.7%	65.7%	60.4%	- 5.3%
TOTAL	**100.0%**	**100.0%**	**-----**	**100.0%**	**100.0%**	**-----**

Source: 2000-2002 Mn/DOT Crash Data

[a] Crashes that result in an injury to a person but not in their death are divided into three categories. A serious injury is defined as an "injury that prevents the injured person from walking, driving or normally continuing the activities he or she was capable of performing before the injury occurred. Includes severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconsciousness, etc. Hospitalization is usually required." The definition of a moderate injury is an "injury that is evident to the officer at the scene of the crash. Includes abrasions, minor lacerations, bleeding, etc. May require medical treatment, but hospitalization is usually not required." The least severe injury, moderate injury, is an "injury that is reported by a person involved in the crash. Includes complaint of physical pain when no cause is evident, momentary unconsciousness, limping, nausea, hysteria, etc." (*7*)

[b] Includes all intersection and non-intersection crashes that occurred on rural two-lane roadways in Minnesota's state highway system.

[c] Includes all intersection and non-intersection crashes that occurred on rural expressways in Minnesota's state highway system.

2.2.1 Rural Roadway Segments

Past research has found that several factors can affect the crash frequency of a roadway. The first factor to consider is the roadway type. Differences in the number of lanes, presence of median, and access control can have a positive or negative impact on crash frequency. The impact of roadway type on the crash and fatality rate is evident from Mn/DOT's crash records (see **Figure 2-2**).

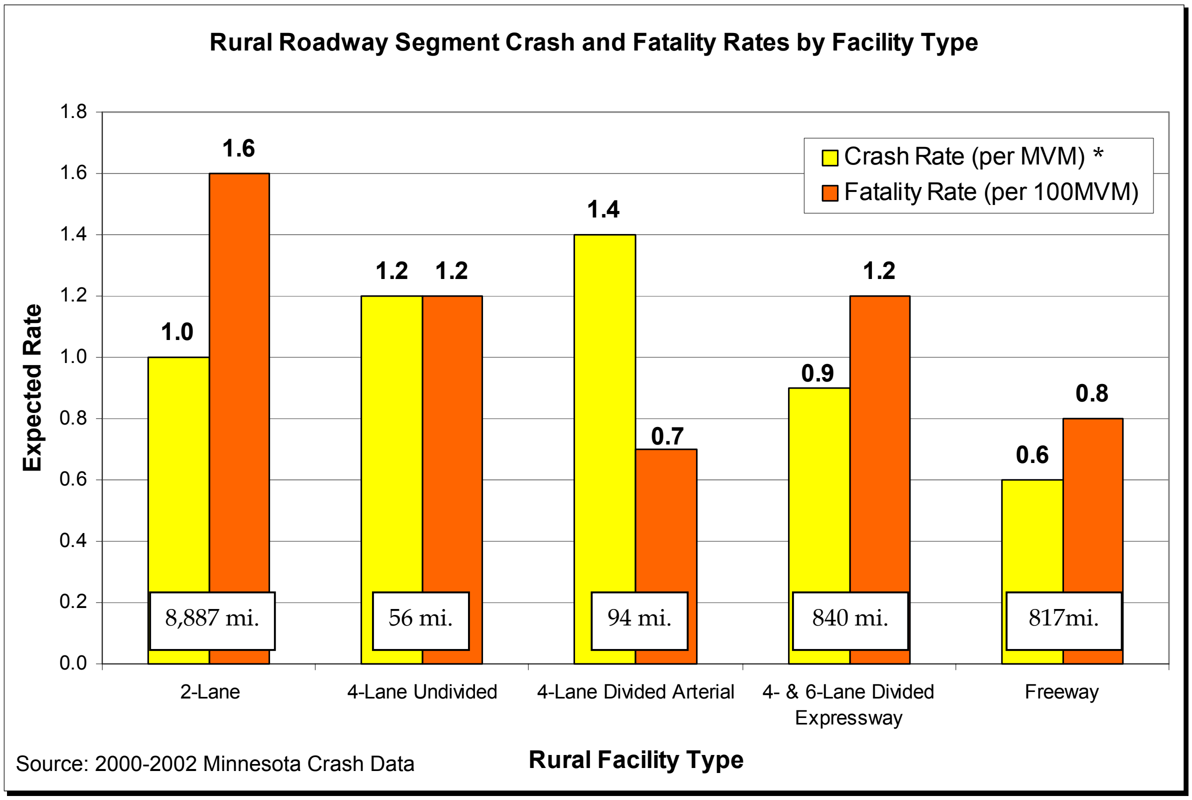


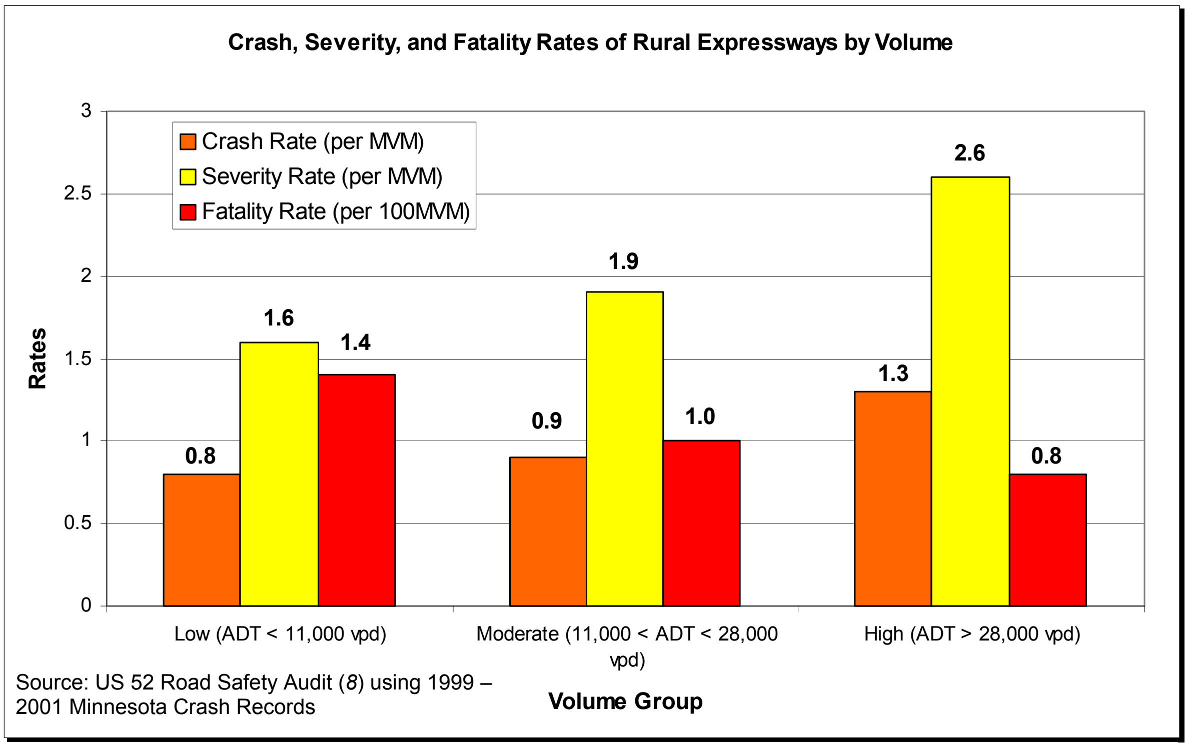
Figure 2-2: Effect of Roadway Type
*NOTE: MVM = Million Vehicle Miles.

As seen in **Figure 2-2**, freeways have the lowest crash rate and the second lowest fatality rate, making them the safest type of rural roadway. While two-lane roadways have a crash rate in the middle of all of the categories, the expected fatality rate is the highest. The expected crash rate for rural expressways is only slightly lower than that for two-lane roadways, while the fatality rate is reduced by 25%. [NOTE: A 4-lane divided arterial is similar to expressways in that it has a median to divide the road and some restrictions on access. However, the design of the divided arterial is generally older, meaning that it may have a narrower median, no turn lanes at intersections, and greater access density. These factors generally result in lower posted speed limits.]

When looking specifically at rural expressways, two other factors have been observed to influence crash frequency, average daily traffic (ADT) volumes and access density. With increasing ADTs, the crash rate and severity rate (a rate weighted by severity of each crash) of rural expressways increased while the fatality rate was observed to decrease (see **Figure 2-3**) (*8*).

It is not known for sure what causes the downward trend in the fatality rate, but it has been speculated that the higher volume expressway segments are generally closer to urban areas, where documented emergency response times are lower, possibly resulting in the saving of more lives.

The other factor shown to influence expressway crash rates is access density (*9*). As the number of access points increase, so does the crash rate (see **Figure 2-4**). The effect of access is greater on multi-vehicle crashes (and subsequently total crashes) because the majority of intersection



crashes include two or more vehicles.

Figure 2-3: Effect of ADT on Rural Expressways

2.2.2 Rural Thru-STOP Intersections

In looking at intersection crashes, the decision was made to focuse on thru-STOP controlled intersections since they make up a majority of the rural interstections on the Minnesota state highway system. Further, all drivers stopped on the cross-street have to make a decision regarding available gap size, creating the potential for a gap related crash.

Similar to roadway segments, several factors may influence intersection related crashes. In the US 52 Road Safety Audit, it was found that the percentage of intersection-related crashes increased as the expressway's traffic volumes increased (see **Table 2-4**). Further, roadway type influenced the crash type distribution at rural thru-STOP intersections (see **Figure 2-5**). Since rural expressways tend to have higher volumes and higher speeds than two-lane roadways, the increase in right angle crashes is likely related to a decrease in the number of safe gaps in the mainline traffic stream. This supports the major hypothesis that crossing path crashes are the most frequent crash type and are caused by a driver's selection of insufficient gaps.

Because right angle crashes represent the largest portion of crossing path crashes and are the most frequent of Minnesota's rural intersection crash types, several additional aspects were reviewed, including crash severity, contributing factors, and effect of volume. For all rural thru-STOP intersections, a higher percentage of right angle crashes resulted in a fatality or injury crash than was seen in all crashes (see **Figure 2-6**). Since right angle crashes are overrepresented in severe crashes, preventing right angle crashes could have an added bonus of significantly reducing severity rates.

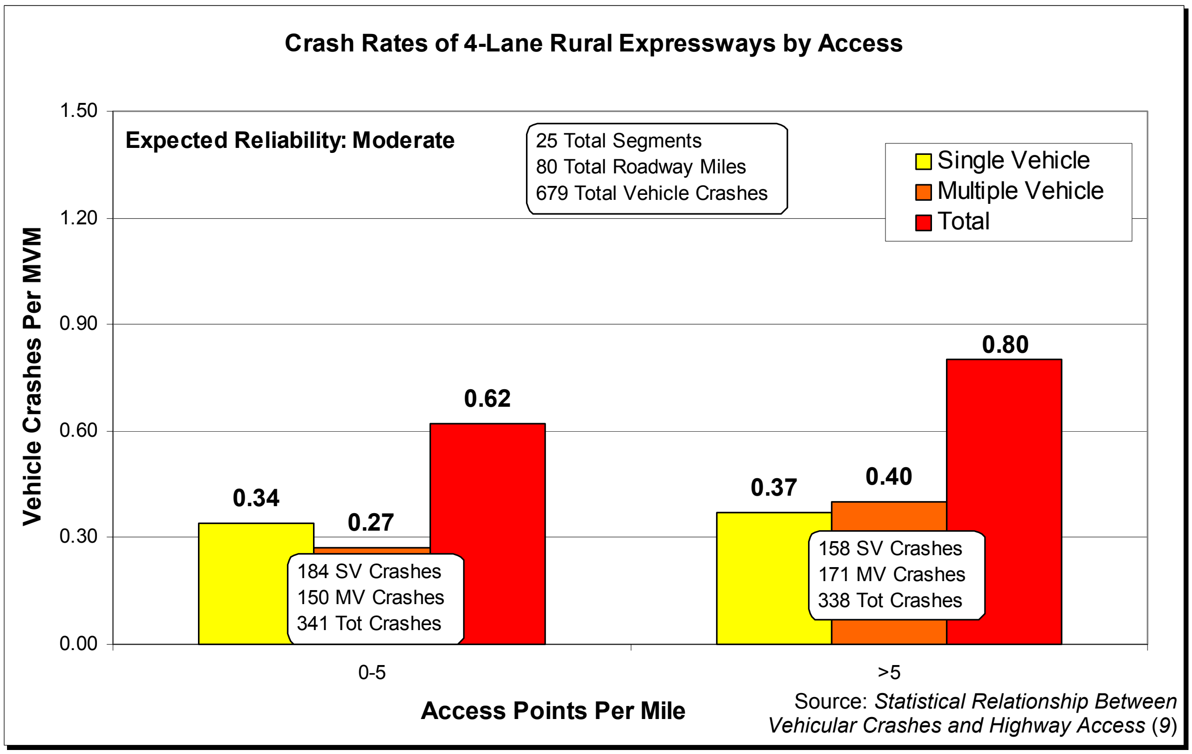


Figure 2-4: Effect of Access on Rural Expressways

Regarding causes of right angle crashes, a study of rural thru-STOP intersections for two-lane roadways found that the at-fault driver was unable to detect oncoming traffic or selected an unsafe gap in 56 percent of all right angle crashes (*10*). Only one-quarter of right angle crashes were caused by the driver failing to stop because they did not recognize they were approaching an intersection (see **Figure 2-7**). Therefore, providing the driver with information on whether it is safe to proceed would have a greater benefit than technology that increases driver awareness of intersection conspicuity.

Finally, when the most dangerous intersections were reviewed (those intersections with crash rates statistically significantly higher than the average for similar intersections), it was found that the likelihood of a right angle crash increased as mainline volumes increased (see **Figure 2-8)**.

Table 2-4: Effect of ADT on Intersection Crashes

Volume Group	Major Street Average Daily Traffic (ADT)	Percent Intersection Related Crashes
Low	ADT < 11,000 vpd	27%
Moderate	11,000 vpd ≤ ADT < 28,000 vpd	43%
High	ADT ≥ 28,000 vpd	59%

Source: US 52 Road Safety Audit (*8*)

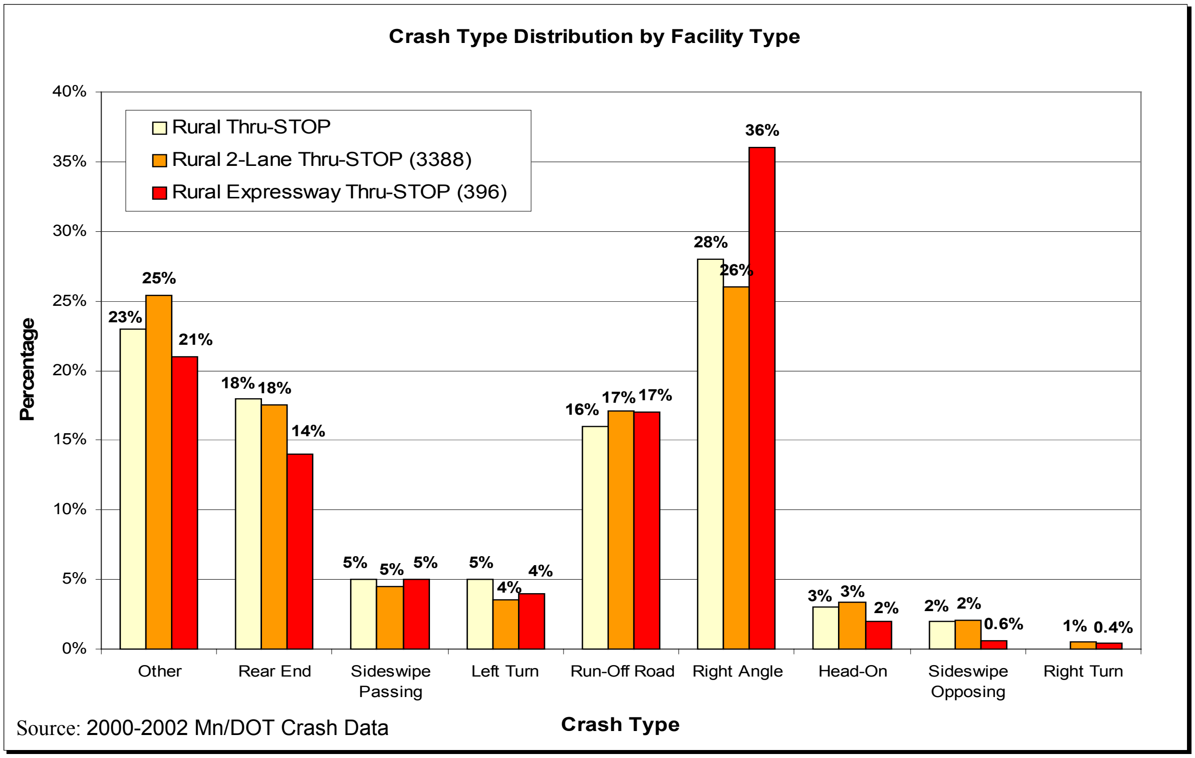


Figure 2-5: Differences in Crash Type Distribution

NOTE: The numbers in legend enclosed in parenthesis represent the number of intersections in each category.

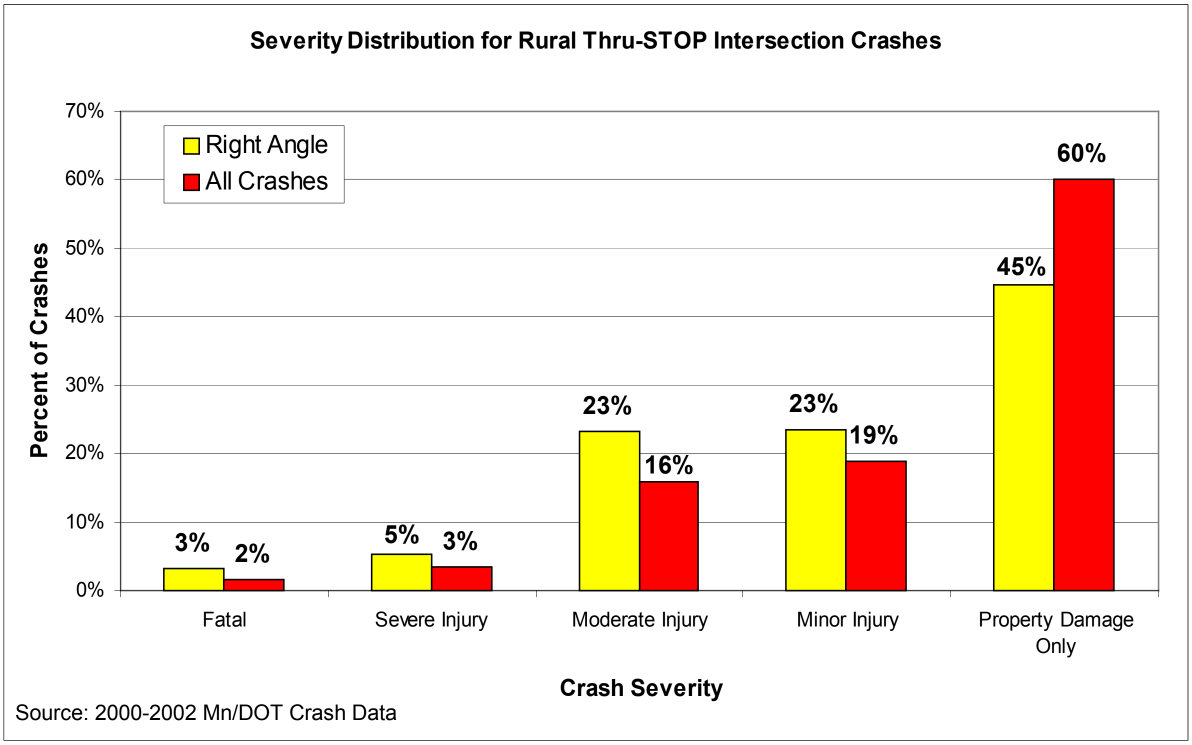


Figure 2-6: Right Angle Crash Severity

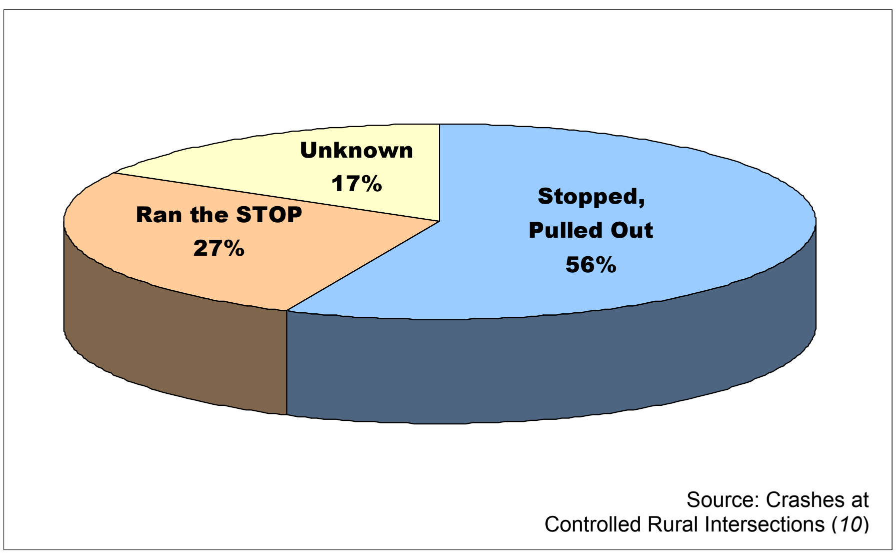


Figure 2-7: Contributing Factors for Right Angle Crashes at Rural Two-Lane Roadway, Thru-STOP Intersections

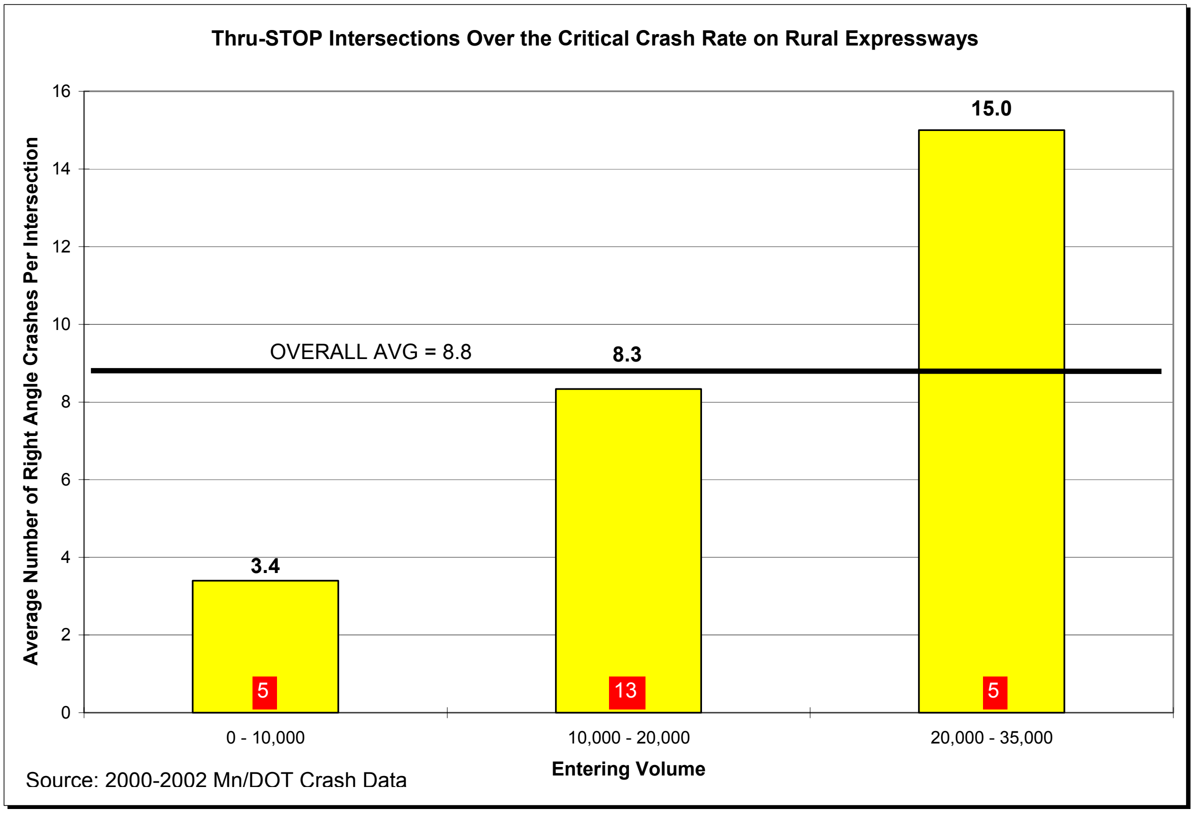


Figure 2-8: Effect of Volume on Right Angle Crashes

NOTE: The number at the bottom of each bar represents the number of intersections in each category.

Chapter 3.
Identification of High Crash Locations (Rural Thru-STOP Intersections)

The location of an acceptable test intersection is important in allowing researchers to observe the impacts of the IDS technology. From a crash history perspective, identification of a "dangerous" intersection will allow researchers to collect useful data for determining the safety benefit (if any) in a shorter period of time. Since there are 396 rural, thru-STOP intersections on expressways and 3,388 rural, thru-STOP intersections on two-lane roadways in Minnesota's state highway system, additional criteria were needed to identify intersections suitable for a field test. To ensure the test intersection had all types of crossing path crashes, intersections were further screened by eliminating all "T" intersections and intersections with five or more legs, reducing the number of intersections to 198 for expressways and 1,774 for two-lane roadways.

Intersections where the crash rate was higher than the critical crash rate were considered dangerous locations, which were then considered for further analysis. [NOTE: The critical crash rate is a statistically determined crash rate significantly above the average crash rate (*11*). Therefore, locations with a crash rate above the critical crash rate are known to have conditions that result in an unusually unsafe condition because a large increase in the number of crashes can not be sufficiently explained by their random nature.] Of the 198 expressway intersections, 23 have a crash rate above the critical crash rate while the number of two-lane intersections above the critical crash rate is 104. Of the intersections over the critical crash rate, the detailed review of the crash data focused on the expressway intersections for the following reasons:

- Mn/DOT was seeking a solution for intersections with a gap related crash problem that previously would have been considered a candidate for a new traffic signal. Because expressways tend to carry higher volumes, an expressway intersection is more likely to be a candidate for a traffic signal.
- Higher posted speeds on expressways require larger gaps for vehicles to safely cross or merge into traffic.
- Of the seven rural thru-STOP intersections on Minnesota's state highway system that have more than one fatal crash over the most recent three-year reporting period, five are located on expressways.
- Crossing path crashes (i.e., left turn, right angle, and right turn) at all rural, thru-STOP expressway intersections account for approximately 40 percent of all crashes, while crossing path crashes at all similar two-lane intersections account for only 31 percent (see **Figure 2-5**).

A detailed review of the expressway intersections shows that the intersections over the critical crash rate not only have a crash rate twice the expected crash rate, the severity rate is approximately three times the expected (see **Figure 3-1**). Further, a summary of the crash type distribution for the expressway intersections that exceed the critical crash rate reveals a significant increase in the percentage of right angle crashes, which are the primary target for correction by any IDS solution (see **Figure 3-2**). [NOTE: The same trends in crash rate, severity rate, and crash type distribution hold true for critical intersections identified in the US 52 Road Safety Audit. (*8*) Given Because US 52, a major rural expressway, has been associated with many intersection crashes, the US 52 Road Safety Audit was used to provide additional validation to the findings of this study.]

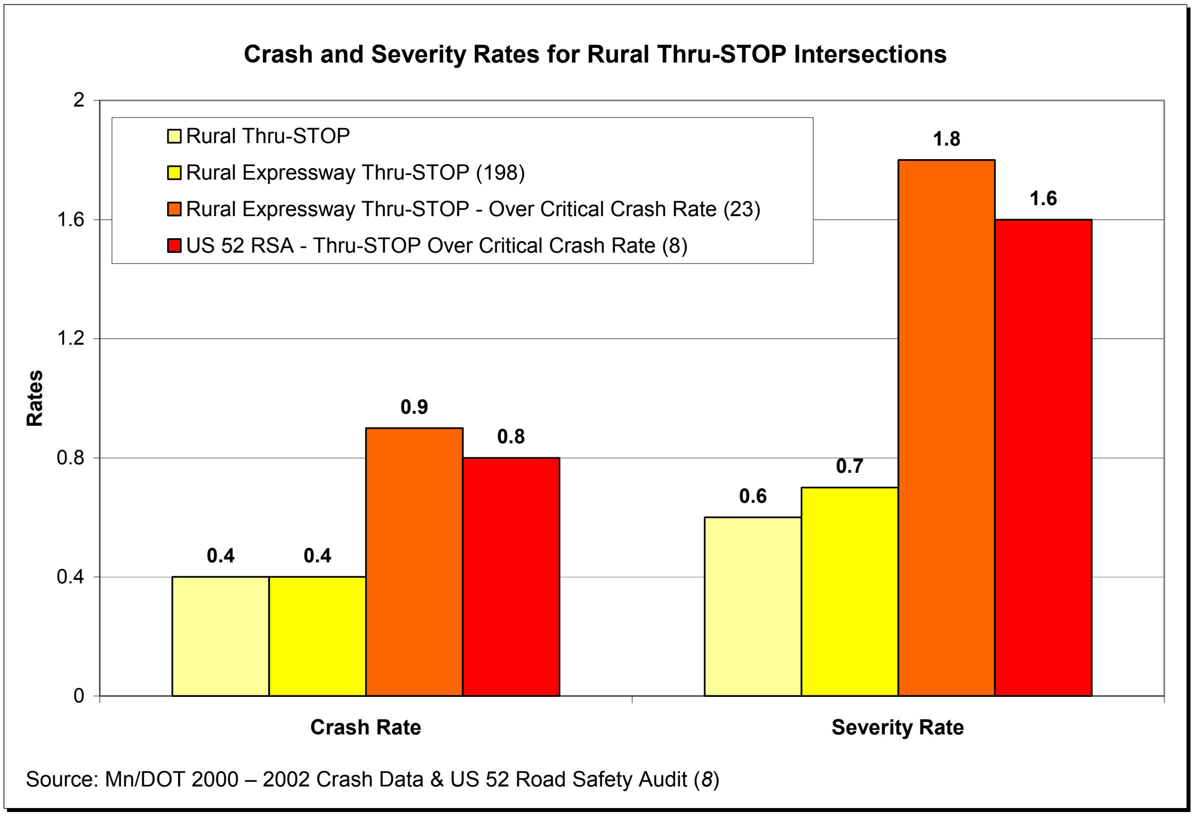


Figure 3-1: Crash and Severity Rates for Intersections Over the Critical Crash Rate

A summary is provided in **Table 3-1** of the 23 intersections considered for further analysis. From this group, three intersections were selected from the 23 by the research team for more detailed review. Priority was given to selecting intersections with a high crash rate, a high frequency of crashes, and a high percentage of right angle crashes (**Figure 3-3**). The three intersections selected for further review were:

- US 52 and CSAH 9 (Goodhue County)
- US 10 and CR 43 (Big Lake, MN)
- MN 65 and 177th Avenue (Ham Lake, MN).

Several intersections were not considered for review because major upgrades planned or already underway precluded their use in field observational tests. Additionally, intersections with low volumes but high crash rates were eliminated from further consideration because of the need to quickly observe changes in the number of crashes during the experimental testing. With lower volumes and crash frequency, quantifying the impacts of deployed technology would take longer and/or have a lower reliability. Finally, it was discovered that some intersections classified as rural are on the fringes of growing urban areas and surrounding land uses are beginning to change to suburban or urban. Therefore, these intersections could not fill the needs of this study.

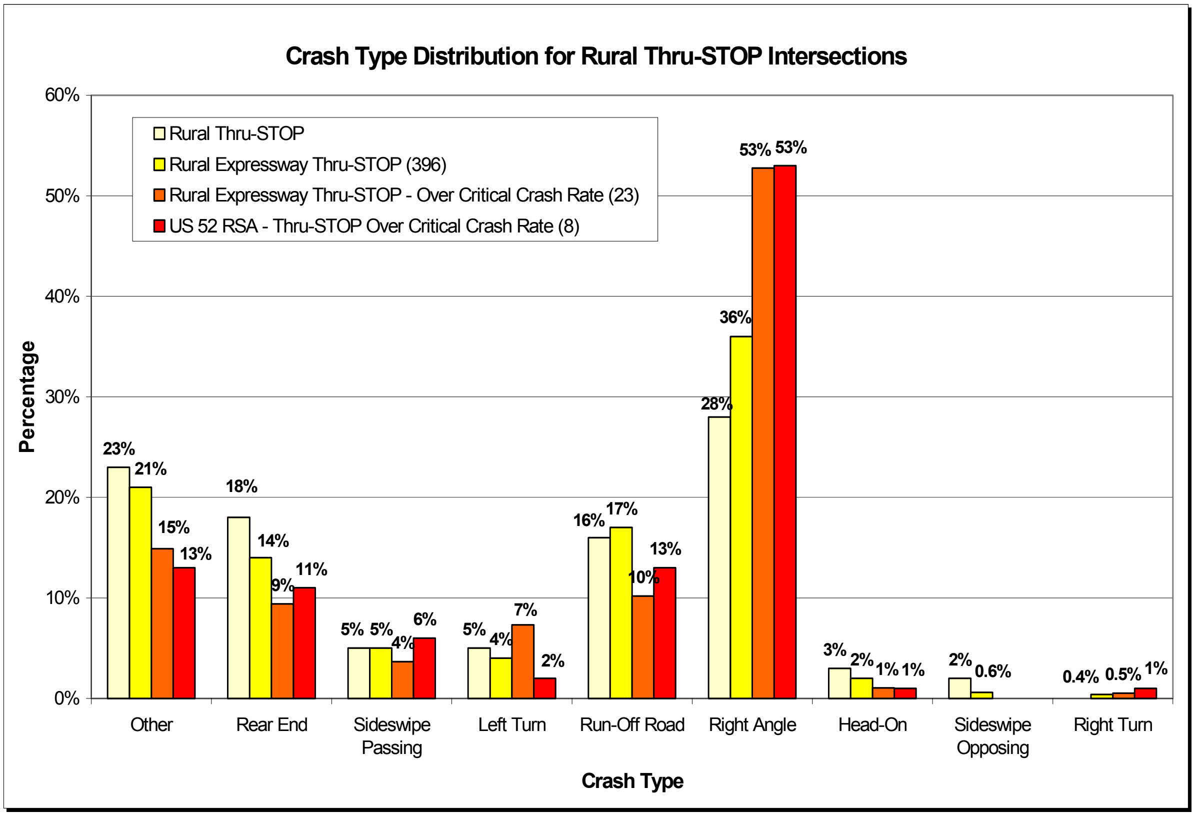


Figure 3-2: Crash Type Distribution for Intersections Over the Critical Crash Rate

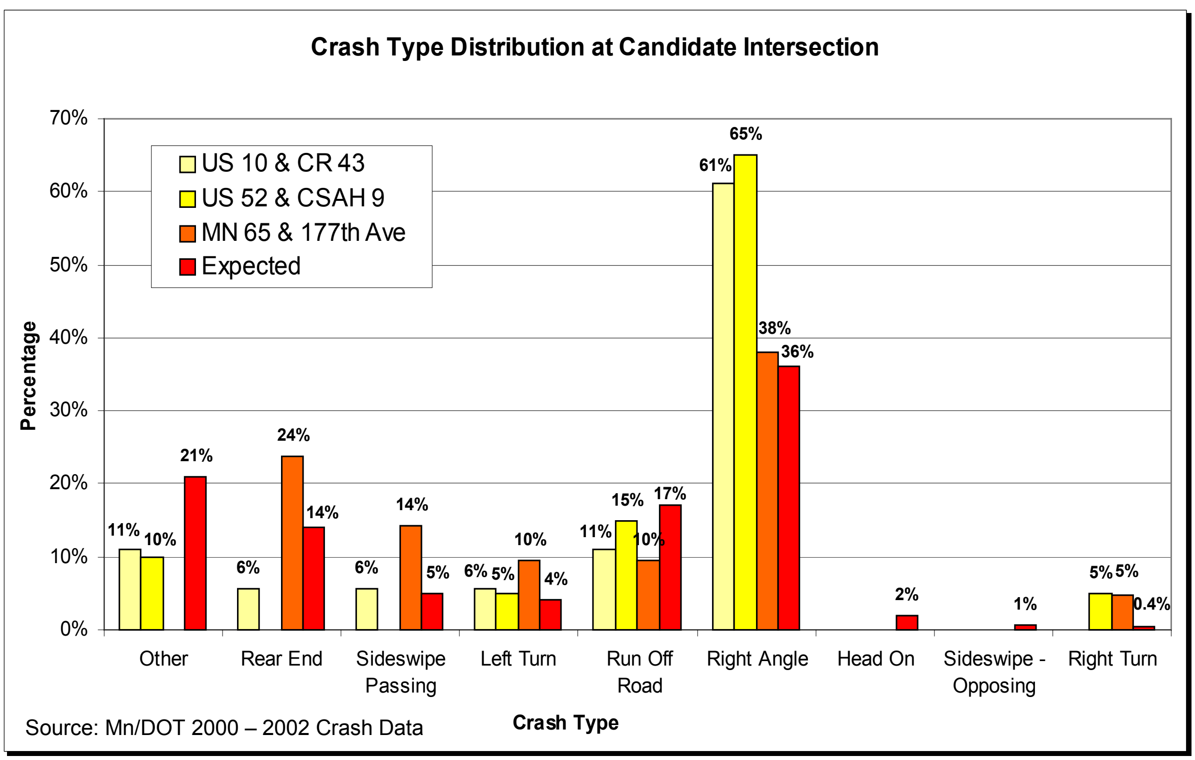


Figure 3-3: Crash Type Distribution at Candidate Intersections

Table 3-1: Rural Expressway Thru-STOP Intersections with Crash Rates Greater than the Critical Crash Rate

Intersection of:		Entering ADT	Number of Crashes	Fatal + "A" Injury Crashes	Crash Rate	Critical Crash Rate	Severity Rate	Right Angle Crashes
US 2	CSAH 41	4,190	6	0	1.3	0.8	2.4	5 (83%)
US 2	CSAH 9	14,610	12	1	0.7	0.6	1.1	3 (25%)
US 2	CSAH 11	16,710	16	2	0.9	0.6	1.5	5 (31%)
US 10	CSAH 8	15,690	15	2	0.9	0.6	1.7	6 (40%)
US 10	***CR 43***	***18,450***	***18***	***1***	***0.9***	***0.6***	***1.9***	***11 (61%)***
US 52	CSAH 14[1]	28,790	46	4	1.5	0.6	2.9	32 (70%)
US 52	TH 57	17,770	14	1	0.7	0.6	1.5	7 (50%)
US 52	***CSAH 9***	***17,990***	***20***	***1***	***1.0***	***0.6***	***2.4***	***13 (65%)***
US 52	CSAH 86	21,320	18	0	0.8	0.6	1.5	10 (56%)
US 52	CSAH 47[2]	27,380	24	4	0.8	0.6	1.9	15 (63%)
US 52	CSAH 48[3]	30,220	26	3	0.8	0.6	1.6	10 (38%)
US 53	CSAH 52	9,820	9	1	0.8	0.7	1.8	5 (56%)
US 61	Orrin Street (Winona, MN)	17,490	20	1	1.0	0.6	1.6	14 (70%)
US 71	CSAH 52	11,870	18	1	1.4	0.7	2.2	12 (67%)
US 169	CSAH 11	10,940	13	1	1.2	0.7	2.5	10 (77%)
US 169	CSAH 21	13,310	12	0	0.8	0.6	1.6	4 (33%)
US 212	TH 5/25 (West Junction)	12,170	12	0	0.9	0.6	1.6	6 (50%)
MN 5	Granada Avenue (Oakdale, MN)	14,120	22	1	1.4	0.6	2.5	11 (50%)
MN 5	CSAH 6	15,950	16	0	0.9	0.6	1.5	8 (50%)
MN 13	TH 19	7,960	8	0	0.9	0.7	1.8	3 (38%)
MN 23	CSAH 7	7,910	9	1	1.0	0.7	2.7	3 (33%)
MN 60	CR 118	8,380	8	0	0.9	0.7	1.3	1 (13%)
MN 65	***177th Avenue (Ham Lake, MN)***	***28,370***	***21***	***2***	***0.7***	***0.6***	***1.3***	***8 (38%)***

Source: Mn/DOT 2000 – 2002 Crash Data

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[1] Intersection is being replaced with an interchange as part of the US 52 Design-Build.

[2] An overpass is programmed for construction in FY 2004.

[3] Intersection is located near a traffic signal recently installed at CSAH 46. The proximity of the traffic signal may alter the available gaps at CSAH 48, thereby changing the crash patterns at the intersection.

Chapter 4.
Candidate Intersections for IDS Research Modeling

General information on the candidate intersections has been summarized in **Table 4-1**. It is already known that the three candidate intersections have high crash rates, high crash frequencies, and a high number of right angle crashes, but it was decided to investigate each intersection further for specific information pertinent to the IDS technology and also to learn of any unusual circumstances at the intersections.

4.1 At-Fault Drivers

For each candidate intersection, all crash reports from 2000 to 2002 were reviewed to identify the driver who caused the accident, also known as the at-fault driver. The age of the at-fault driver was reviewed since the IDS technology may have its greatest benefit in assisting older drivers in particular (see **Figure 4-1**). Of the three intersections, the US 52 and CSAH 9 intersection has a noticeable problem with older drivers. The intersection of US 10 and CR 43 has an overrepresentation of young drivers, possibly related to a nearby high school.

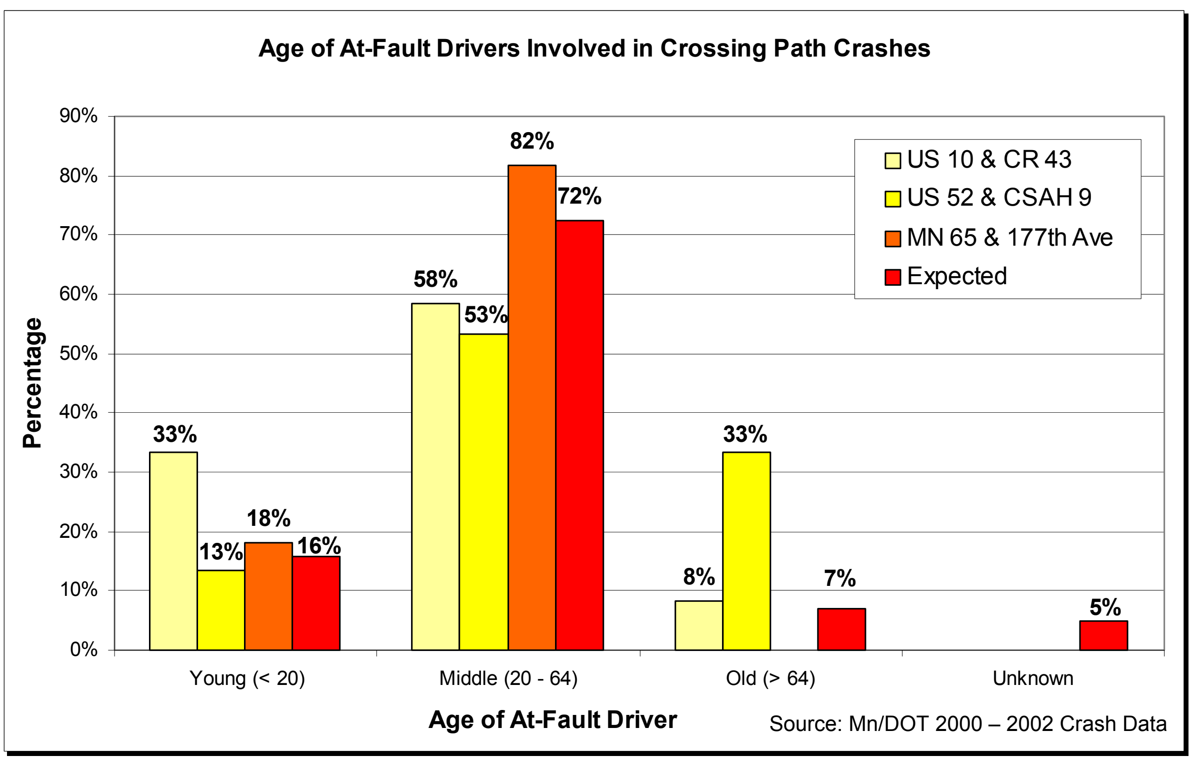

Figure 4-1: At-Fault Driver's Age

Table 4-1: Candidate Intersections for IDS Research Modeling

	US 10 & CR 43 (Big Lake, MN)	US 52 & CSAH 9 (Goodhue County)	MN 65 & 177th Avenue (Ham Lake, MN)
County	Sherburne	Goodhue	Anoka
Total Crashes	18	20	21
Fatal + "A" Injury Crashes	1	1	2
Crash Rate	0.9	1.0	0.7
Severity Rate	1.9	2.4	1.3
Right Angle Crashes	11 (61%)	13 (65%)	8 (38%)
Mainline Traffic Volumes (2002)	24,000 vpd (West approach) 19,600 vpd (East approach)	17,500 vpd (both approaches)	28,500 vpd (both approaches)
Minor Street Traffic Volumes (1999)	650 vpd (South approach) 3500 vpd (North approach)	840 vpd (West approach) 650 vpd (East approach)	unknown
Mainline Speed Limit	45 or 50 mph	65 mph	65 mph
Minor Street Speed Limit	45 mph	55 mph	35 mph
Intersection Street Lighting	None	None	Businesses with lighting located near intersection
Notes	Located near edge of Big Lake, MN with frontage road intersections located near the intersection on the CR 43 approaches.	Intersection is known to have sight distance restrictions because the northbound and southbound alignments have different profiles.	West approach is connection to a frontage road that is parallel to MN 65.

NOTE: Speed limits were taken from crash data and may not be accurate.

For each at-fault driver, the distance from the crash location to the at-fault driver's residence was also estimated to determine if the crash problem could have been caused by the driver's unfamiliarity with the area (see **Table 4-2**). At all three candidate intersections, approximately 75 percent or more of the at-fault drivers lived within 30 miles of the crash location. Only the intersection of US 52 and CSAH 9 has a median distance greater than ten miles. This indicates that the crash problem at the candidate intersections is probably not due to the drivers' unfamiliarity with the area.

Table 4-2: Distance from Crash Location to At-Fault Driver's Residence

	US 10 & CR 43 (Big Lake)	**US 52 & CSAH 9 (Goodhue County)**	**MN 65 & 177th Avenue (Ham Lake)**
Median	5 miles	19 miles	9 miles
Average	17 miles	40 miles	11 miles
Minimum	1 mile	5 miles	3 miles
Maximum	201 miles	306 miles	37 miles
Percent of distances ≤ 30 mi.	89%	74%	95%

4.2 Right Angle Crash Severity

None of the three candidate intersections had a fatal crash between January 1, 2000 and December 31, 2002. However, the number of right angle crashes resulting in a serious ("A") or moderate ("B") injury was higher than expected (see **Figure 4-2**). Despite the lack of fatal crashes at the candidate intersections, the increase in the two injury crash categories with the highest severity ratings indicate that these intersections are still good candidates for the possible correction of severe crashes.

4.3 Crash Location and Contributing Factors

From the review of the crash records (see **Appendix B**), it was observed that right angle crashes at the candidate intersections tended to occur on the far side of the intersection (see **Figure 4-3**). [NOTE: A far-side crash would be when the vehicle safely negotiates the first two lanes it crosses, but is involved in a crash when leaving the median to either cross or merge into traffic in the second set of lanes.] The primary cause of the high number of far-side crashes was not evident from review of the crash records. It has been speculated that drivers are using a one-step process for crossing rather than a two-step process. When a driver enters the median, rather than stopping to reevaluate if the gap is still safe, it is believed that drivers simply proceed into the far lanes without stopping.

The review of the crash records at the candidate intersections also revealed that none of the right angle crashes were caused by the at-fault driver not recognizing that he/she was approaching a STOP controlled intersection (see **Figure 4-4**). Instead, nearly 90% of the right angle crashes were due to the inability of the driver to either notice the oncoming traffic or to properly select an acceptable gap in the traffic stream.

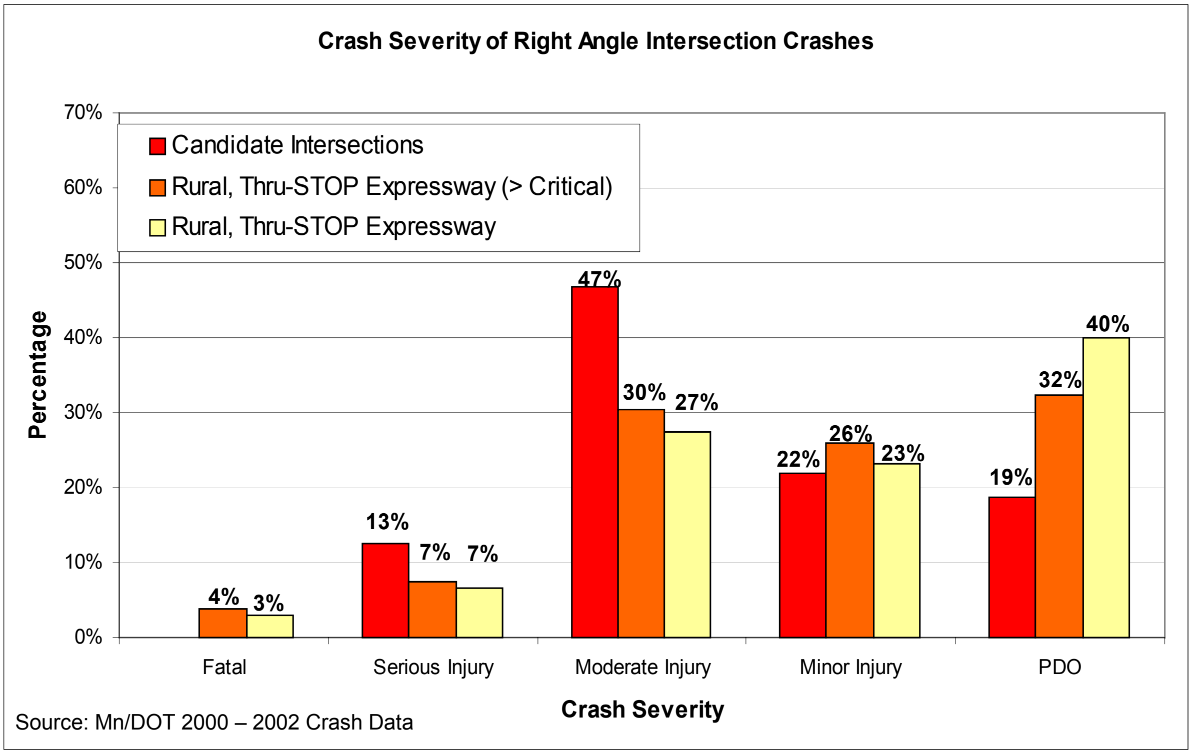

Figure 4-2: Candidate Intersections have a Crash Severity Problem

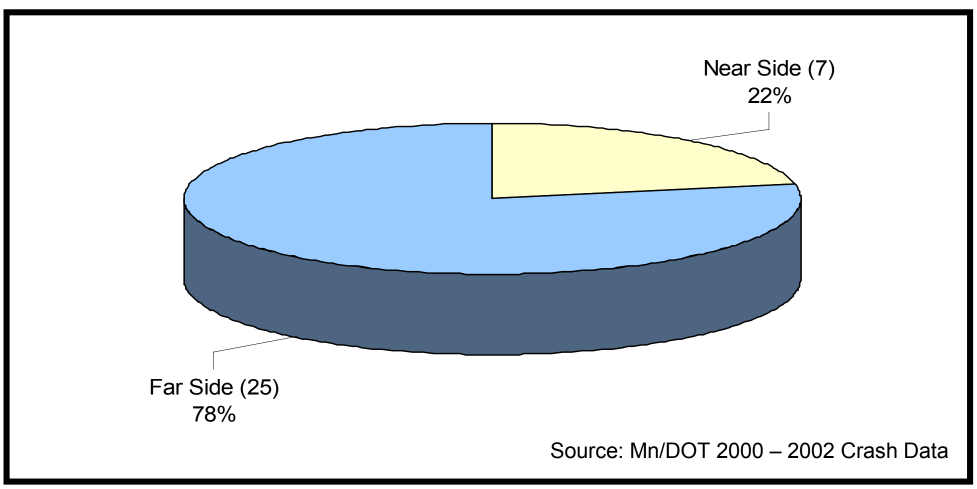

Figure 4-3: Crash Location at the Candidate Intersections

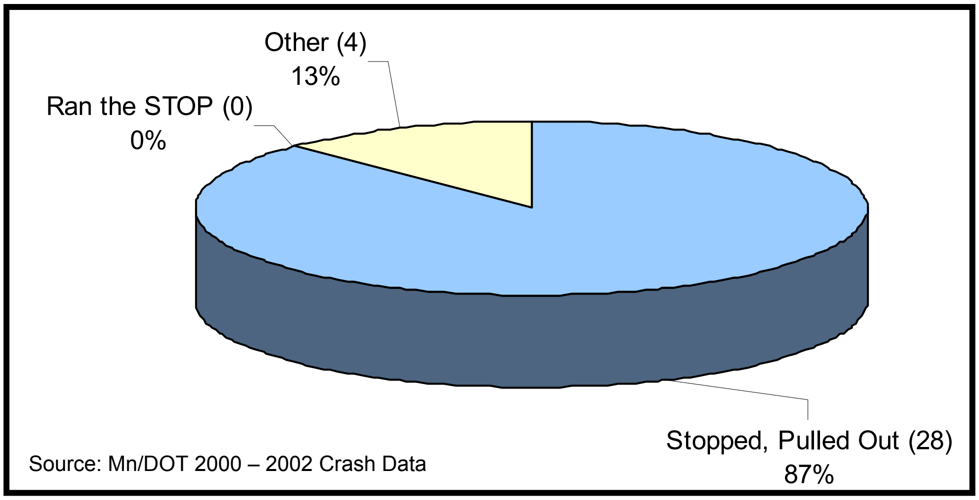

Figure 4-4: Contributing Factors at the Candidate Intersections

4.4 Supplementary Information

To make sure that the high number of crashes at the candidate intersections were not caused by environmental conditions, the light, weather, and roadway surface conditions were reviewed for each crash (see **Table 4-3**, **4-4** and **4-5**). At all three intersections, the percentage of crashes that occurred during poor environmental conditions (i.e., raining or snowing) or during poor pavement conditions (i.e., wet, snowy, or icy) was approximately the same as the expected value and in many cases slightly less than the expected value.

An analysis of light conditions found approximately 25 percent of Minnesota's crashes occur during periods of darkness. For the 23 rural expressway thru-STOP intersections over the critical crash rate, the average percentage of nighttime crashes slightly increased to 26 percent. At the three candidate intersections, the percentage of nighttime crashes was approximately equal to or less than the expected percentage (see **Table 4-5**). At the US 52 and CSAH 9 intersection, the percentage of crashes that occurred at night was 10 percentage points less than what is expected statewide and 9 percentage points less than the group of intersections over the critical crash rate. When the thru-STOP intersections on the US 52 corridor that are over the critical crash rate were reviewed, the US 52 and MN 47 intersection had the lowest percentage of nighttime crashes, but this intersection already has street lighting in place. Of the remaining corridor intersections over the critical rate, none have street lighting in place and the US 52 and CSAH 9 intersection has the lowest occurrence of nighttime crashes.

4.5 Recommended Intersection for Testing of IDS Technology

The intersection recommended for testing of IDS technology is US 52 and CSAH 9. Like the other two candidate intersections, it has a high crash frequency, high crash severity, and a high percentage of crashes are right angle crashes. Along with the other two candidate intersections, the light, weather and roadway surface conditions distributions are also close to the expected percentages. There were several factors that did set this intersection apart as a better test intersection than US 10 & CR 43 and MN 65 & 177th Avenue. First, US 52 and CSAH 9 was the only one of the candidate intersections that had a higher than expected involvement of elderly drivers. Since it is believed that older drivers will get the greatest benefit from the IDS technology, this was an important factor in selection of the intersection. The second reason for selecting US 52 and CSAH 9 is that the intersection is many miles from any city, making it a typical rural intersection. Finally, there was local support from engineers at Goodhue County and Mn/DOT District 6 to improve the intersection.

Table 4-3: Weather Condition Distribution for Crashes at Candidate Intersections

	Expected (*11*)	US 10 & CR 43 (Big Lake, MN)	US 52 & CSAH 9 (Goodhue County)	MN 65 & 177th Avenue (Ham Lake)
Clear	57%	55%	55%	71%
Cloudy	23%	33%	30%	14%
Rain		----	15%	5%
Snow	16%	6%	----	10%
Blowing		6%	----	----

Source: Mn/DOT 2000-2002 Crash Data

Table 4-4: Roadway Surface Condition Distribution for Crashes at Candidate Intersections

	Expected (*11*)	US 10 & CR 43 (Big Lake)	US 52 & CSAH 9 (Goodhue County)	MN 65 & 177th Avenue (Ham Lake)
Dry	68%	78%	75%	71%
Wet	12%	17%	15%	5%
Snow	6%	5%	----	5%
Ice	11%	----	5%	9%
Debris	---	----	----	5%
Unknown	3%	----	5%	5%

Source: Mn/DOT 2000-2002 Crash Data

Table 4-5: Light Condition Distribution for Crashes at Candidate Intersections

	Expected (*11*)	US 10 & CR 43 (Big Lake, MN)	US 52 & CSAH 9 (Goodhue County)	MN 65 & 177th Avenue (Ham Lake, MN)
Daylight	65%	72%	85%	62%
Sunrise	7%	----	----	10%
Dark	25%	28%	15%	24%
Unknown	3%	----	----	4%

Source: Mn/DOT 2000-2002 Crash Data

Chapter 5.
Economic Feasibility of Deployment

To quantify the possible benefits associated with deployment of IDS technology, a general estimate of savings from a reduction in crashes was prepared. The quantification of benefits was limited to the rural, four-legged, thru-STOP intersections over the critical crash rate (104 on two-lane roadways and 23 on expressways). To estimate the potential crash reduction, it was assumed that the IDS technology would decrease the crash rate at these intersections to the overall average crash rate for all rural thru-STOP intersections (0.4 crashes per MEV). Based on this methodology, a 65% reduction (270 crashes per year) is expected at these 127 intersections. Based on the crash severity distribution, this could result in the elimination of 5 fatal, 12 serious injury, 54 moderate injury, 62 minor injury, and 137 property damage only crashes, representing an annual crash cost savings of $25.7 million per year (see **Table 5-1**).

Table 5-1: Potential Annual Crash Cost Savings from IDS Deployment for All Rural Thru-STOP Intersections with Crash Rates Over the Critical Crash Rate

Crash Type	Annual Crash Reduction	Mn/DOT Crash Cost (*12*)	Annual Crash Cost Savings
Fatal	5	$3,400,000	$17,000,000
Serious Injury	12	$270,000	$3,240,000
Moderate Injury	54	$58,000	$3,132,000
Minor Injury	62	$29,000	$1,798,000
Property Damage Only	137	$4,200	$575,400
Total	**270**		**$25,745,400**

Figure 5-1 breaks down the 590 fatal crashes that occurred in Minnesota during 2002. In 2002, approximately half of all fatal crashes occurred on the state highway system while the remainder occurred on county and local roads. For both the state and local road systems, a majority of the fatal crashes, approximately three-quarters, occurred in rural areas. The number of fatal crashes that occurred at thru-STOP intersections on the state highway system is less than 50. Given the high number of rural intersections versus the small number of fatalities occurring at these intersections, predicting and preventing fatalities at specific intersections would be extremely difficult. Therefore, a comprehensive plan or technology that could be deployed at a set of intersections, especially those with a poor safety record, would most likely prevent the greatest number of fatal crashes.

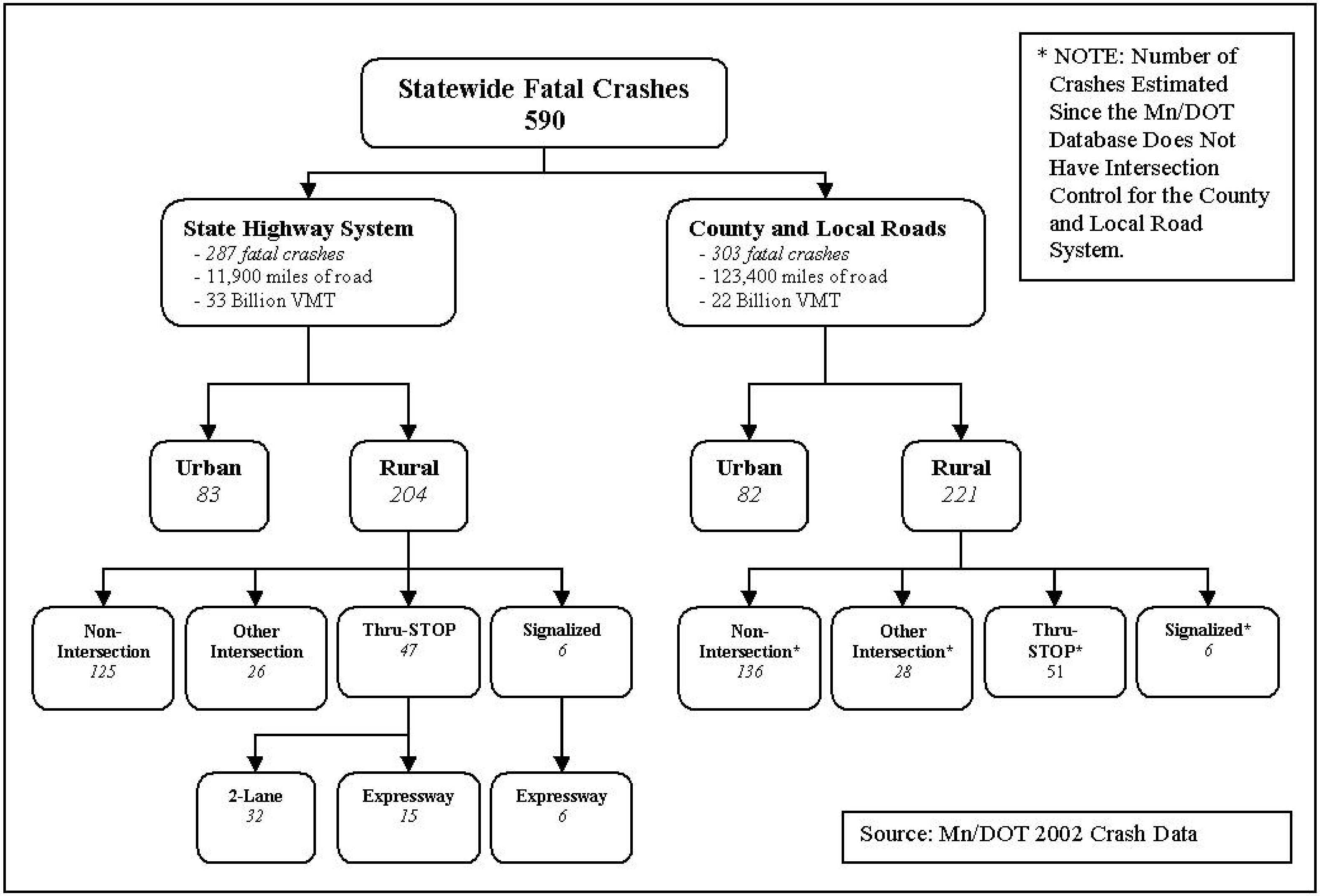

Figure 5-1: Breakdown of 2002 Fatal Crashes in Minnesota

Chapter 6.
Conclusions

The purpose of this study was to provide researchers developing IDS technology with specific information regarding the patterns and primary causative factors associated with crashes along Minnesota' rural State highway system, specifically those that occurred at thru-STOP intersections. A further goal was to identify a specific intersection that is an good candidate for testing of the developed technology. In accomplishing these tasks, the following key observations were made.

Conclusions from Minnesota – GES Comparison:

1. Junction related crashes for Minnesota's rural expressways (45%) and two-lane roadways (37%) accounted for a smaller portion of all crashes than was reported in the GES (60%). This difference also held true at all 3,700 rural intersection locations in the database.
2. Of all Minnesota crashes occurring on rural two-lane roadways, 19% were found to be crossing path crashes. For rural expressways, the percentage of crossing path crashes increased to 21%. This represents a significant portion of rural crashes in Minnesota, but is slightly lower than what was reported in the GES (25%).
3. From the GES, 74% of all intersection crashes were reported to occur at controlled intersections. For rural Minnesota expressways, the percentage of intersection crashes that occurred at a controlled intersection was 73%, nearly identical to the GES. For rural two-lane roadways, only 54% of the intersection crashes occurred at a controlled intersection.

Conclusions from Review of Minnesota Crash Data:

1. Crash frequencies appear to increase as volume and the number of access points increase along segments of rural roadways.
2. Rural expressway thru-STOP intersections have crash and severity rates similar to all rural thru-STOP intersections.
3. The percentage of intersection related crashes has been observed to increase along segments of rural expressways with higher traffic volumes on rural expressways.
4. Rural expressway thru-STOP intersections have a different crash type distribution than that for all rural thru-STOP intersections – most notably a greater number of right angle crashes.
5. In a study of rural thru-STOP intersections on two-lane roadways, selection of inadequate gaps was the cause in twice as many right angle crashes as was the driver's inability to recognize the intersection and stop.
6. Right angle crashes tend to have a greater concentration of severe crashes and the likelihood of right-angle crashes may increase as entering volumes increase.

Conclusions from High Crash Location Screening Process:

1. Use of critical crash rates allows for easy identification of intersections with unusually high crash frequencies and severity.
2. Intersections over the critical crash rate have a different crash type distribution – an increase in the percentage of right angle crashes, which tend to be more severe crashes.

Conclusions from Review of Candidate Intersections

1. At the intersection of US 52 and CSAH 9, older drivers were overrepresented in crossing path crashes.
2. Of the crashes that occurred at the candidate intersections, most at-fault drivers lived within 30 miles of the intersection.
3. Even in the absence of fatal crashes at the candidate intersections, the number of serious and moderate injury crashes was higher than expected.
4. At the candidate intersections, 78 percent of right angle crashes occurred on the far side of the intersection.
5. Intersection recognition by vehicles on the minor approach was not a cause of right angle crashes at the candidate intersection.
6. Reduced visibility or poor roadway conditions were not major causes of right angle crashes.
7. Based on a review of crash rate, crash frequency and percentage of crossing path crashes, the intersection of US 52 and Goodhue County State Aid Highway 9 was recommended to serve as the model for further research and simulation testing of possible IDS designs.

Conclusions from Economic Feasibility

1. At 127 high crash intersections, IDS technology may help eliminate 270 crashes per year if each intersection's crash rate is lowered to the average crash rate for rural thru-STOP intersections. An annual reduction of 270 crashes could result in the elimination of 5 fatal and 12 serious injury crashes per year.
2. Total monetary savings from a crash reduction could amount to $25.4 million.

References

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Appendix A
Site Photos for Candidate Intersections

Figure A-1: Northbound US 52 at CSAH 9 (Goodhue County)

Figure A-2: Southbound US 52 at CSAH 9 (Goodhue County)

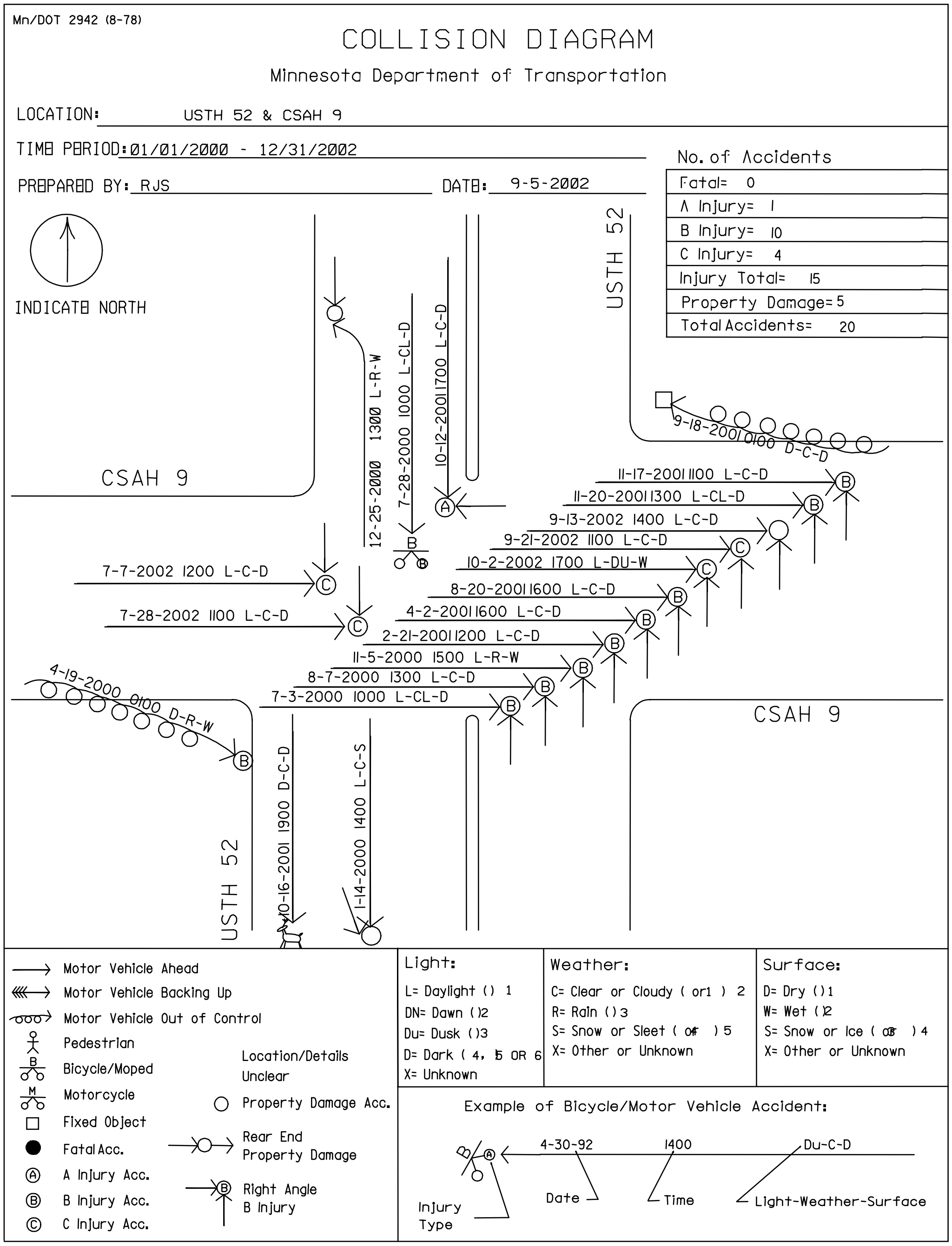
Figure A-3: Westbound US 10 at CR 43 (Big Lake)

Figure A-4: Eastbound US 10 at CR 43 (Big Lake)

Figure A-5: Northbound MN 65 at 177th Avenue (Ham Lake)

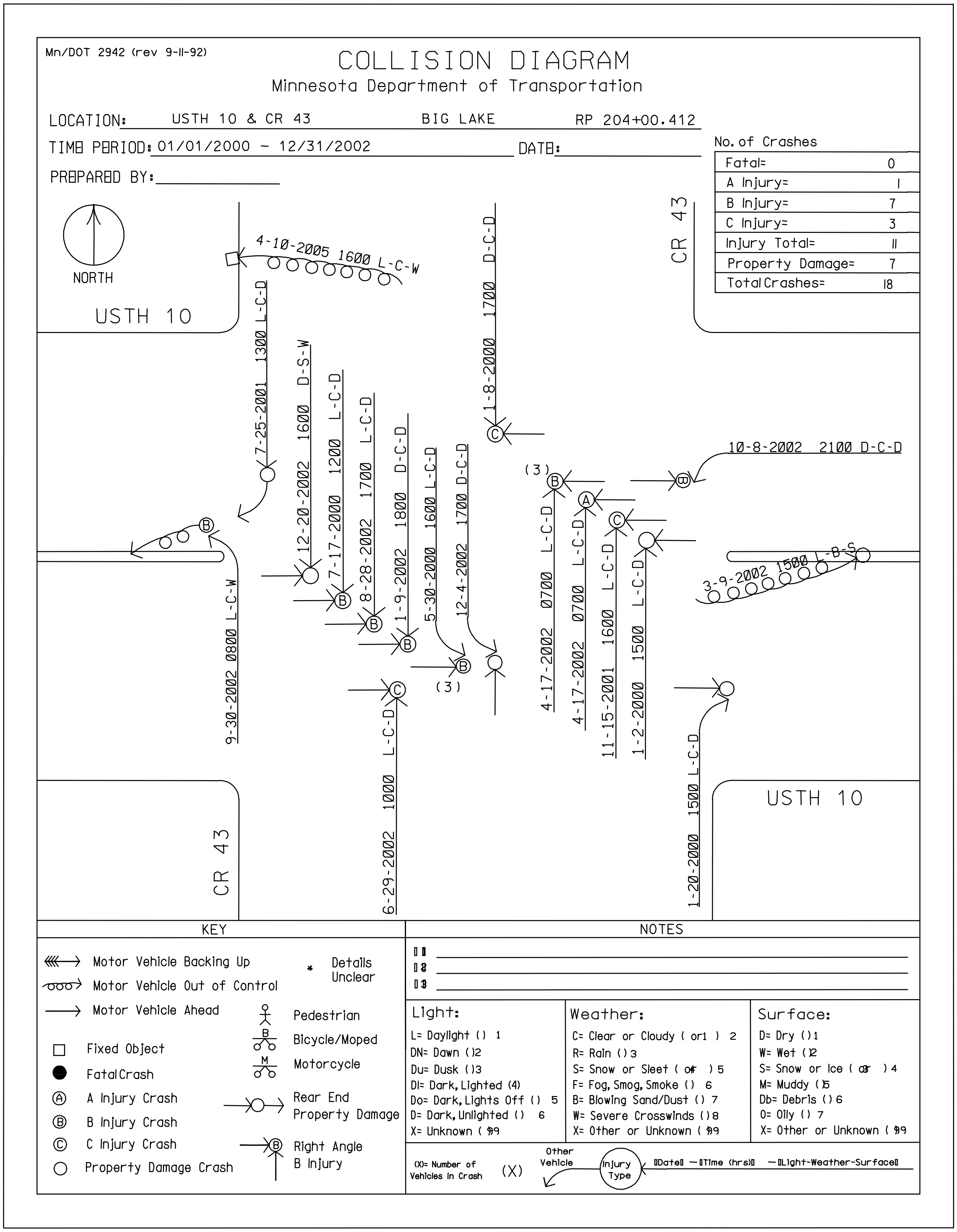
Figure A-6: Southbound MN 65 at 177th Avenue (Ham Lake)

Appendix B
Crash Diagrams for Candidate Intersections



Mn/DOT 2942 (8-78)
COLLISION DIAGRAM
Minnesota Department of Transportation
LOCATION: USTH 52 & CSAH 9
TIME PERIOD: 01/01/2000 - 12/31/2002
PREPARED BY: RJS
DATE: 9-5-2002
No. of Accidents
Fatal= 0
A Injury= 1
B Injury= 10
C Injury= 4
Injury Total= 15
Property Damage= 5
Total Accidents= 20
INDICATE NORTH
USTH 52
CSAH 9
Light:
L= Daylight () 1
DN= Dawn ()2
Du= Dusk ()3
D= Dark (4, 5 OR 6
X= Unknown
Weather:
C= Clear or Cloudy (or1) 2
R= Rain () 3
S= Snow or Sleet (or) 5
X= Other or Unknown
Surface:
D= Dry ()1
W= Wet ()2
S= Snow or Ice (or) 4
X= Other or Unknown
Motor Vehicle Ahead
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Acc.
A Injury Acc.
B Injury Acc.
C Injury Acc.
Location/Details Unclear
Property Damage Acc.
Rear End Property Damage
Right Angle B Injury
Example of Bicycle/Motor Vehicle Accident:
4-30-92
1400
Du-C-D
Injury Type
Date
Time
Light-Weather-Surface

Figure B-1



Mn/DOT 2942 (rev 9-11-92)
COLLISION DIAGRAM
Minnesota Department of Transportation
LOCATION: USTH 10 & CR 43 BIG LAKE RP 204+00.412
TIME PERIOD: 01/01/2000 - 12/31/2002
DATE:
PREPARED BY:
No. of Crashes
Fatal= 0
A Injury= 1
B Injury= 7
C Injury= 3
Injury Total= 11
Property Damage= 7
Total Crashes= 18
NORTH
USTH 10
CR 43
USTH 10
CR 43
4-10-2005 1600 L-C-W
7-25-2001 1300 L-C-D
12-20-2002 1600 D-S-W
7-17-2000 1200 L-C-D
8-28-2002 1700 L-C-D
1-9-2002 1800 D-C-D
5-30-2000 1600 L-C-D
12-4-2002 1700 D-C-D
1-8-2000 1700 D-C-D
10-8-2002 2100 D-C-D
(3)
(3)
4-17-2002 0700 L-C-D
4-17-2002 0700 L-C-D
11-15-2001 1600 L-C-D
1-2-2000 1500 L-C-D
3-9-2002 1500 L-B-S
9-30-2002 0800 L-C-W
6-29-2002 1000 L-C-D
1-20-2000 1500 L-C-D
KEY
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Motor Vehicle Ahead
Details Unclear
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Crash
A Injury Crash
B Injury Crash
C Injury Crash
Property Damage Crash
Rear End Property Damage
Right Angle B Injury
NOTES
Light:
L= Daylight () 1
DN= Dawn () 2
Du= Dusk () 3
Dl= Dark, Lighted (4)
Do= Dark, Lights Off () 5
D= Dark, Unlighted () 6
X= Unknown () 9
Weather:
C= Clear or Cloudy () 2
R= Rain () 3
S= Snow or Sleet () 5
F= Fog, Smog, Smoke () 6
B= Blowing Sand/Dust () 7
W= Severe Crosswinds () 8
X= Other or Unknown () 9
Surface:
D= Dry () 1
W= Wet () 2
S= Snow or Ice () 4
M= Muddy () 5
Db= Debris () 6
O= Oily () 7
X= Other or Unknown () 9
(X)= Number of Vehicles in Crash
(X)
Other Vehicle
Injury Type
Date — Time (hrs) — Light-Weather-Surface

Figure B-2

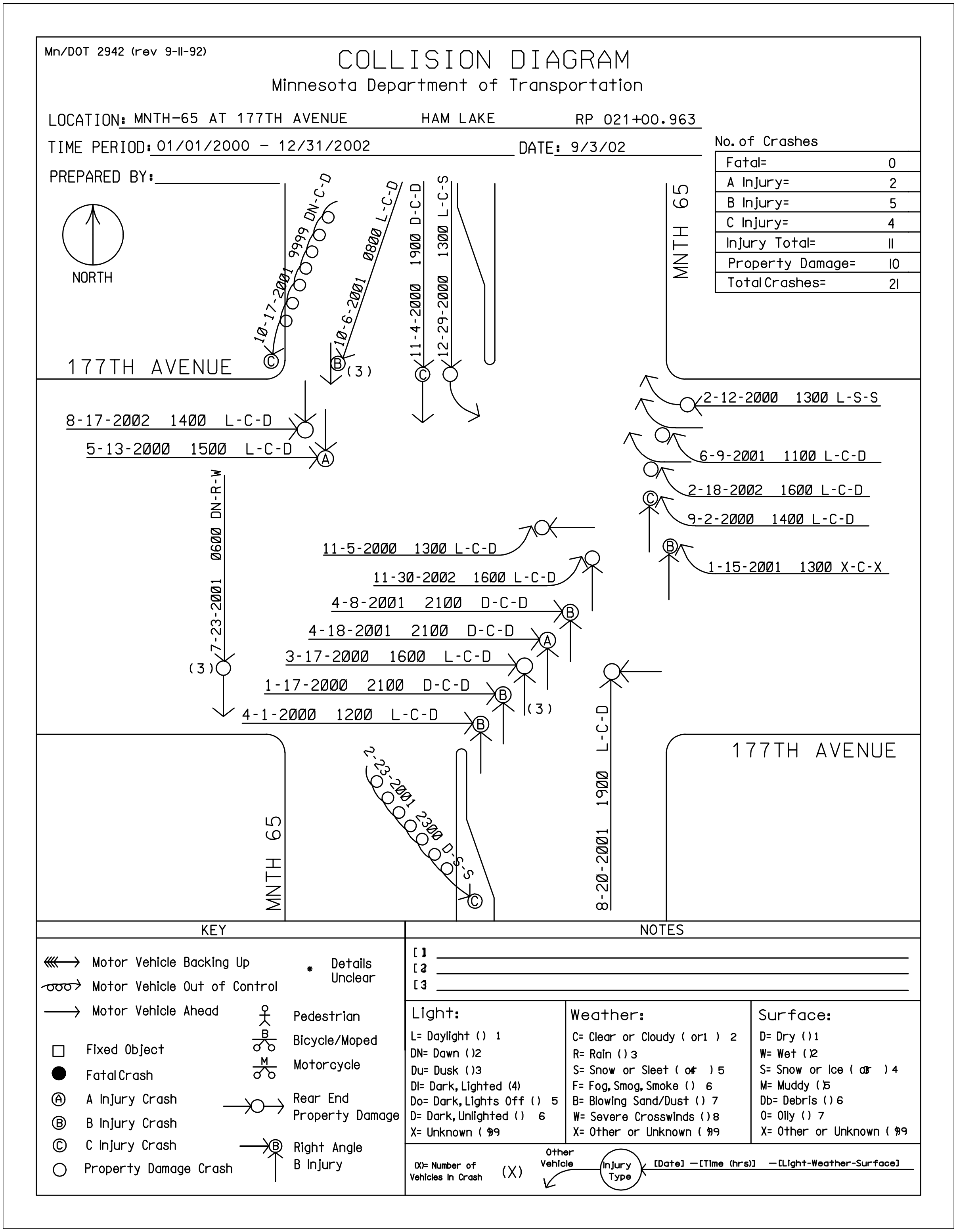

Mn/DOT 2942 (rev 9-11-92)
COLLISION DIAGRAM
Minnesota Department of Transportation
LOCATION: MNTH-65 AT 177TH AVENUE HAM LAKE RP 021+00.963
TIME PERIOD: 01/01/2000 - 12/31/2002 DATE: 9/3/02
PREPARED BY:
No. of Crashes
Fatal= 0
A Injury= 2
B Injury= 5
C Injury= 4
Injury Total= 11
Property Damage= 10
Total Crashes= 21
NORTH
177TH AVENUE
MNTH 65
10-17-2001 9999 DN-C-D
10-6-2001 0800 L-C-D
11-4-2000 1900 D-C-D
12-29-2000 1300 L-C-S
8-17-2002 1400 L-C-D
5-13-2000 1500 L-C-D
2-12-2000 1300 L-S-S
6-9-2001 1100 L-C-D
2-18-2002 1600 L-C-D
9-2-2000 1400 L-C-D
1-15-2001 1300 X-C-X
7-23-2001 0600 DN-R-W
11-5-2000 1300 L-C-D
11-30-2002 1600 L-C-D
4-8-2001 2100 D-C-D
4-18-2001 2100 D-C-D
3-17-2000 1600 L-C-D
1-17-2000 2100 D-C-D
4-1-2000 1200 L-C-D
2-23-2001 2300 D-S-S
8-20-2001 1900 L-C-D
KEY
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Motor Vehicle Ahead
Details Unclear
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Crash
A Injury Crash
B Injury Crash
C Injury Crash
Property Damage Crash
Rear End Property Damage
Right Angle B Injury
NOTES
Light:
L= Daylight ( ) 1
DN= Dawn ( )2
Du= Dusk ( )3
Dl= Dark, Lighted (4)
Do= Dark, Lights Off ( ) 5
D= Dark, Unlighted ( ) 6
X= Unknown ( )9
Weather:
C= Clear or Cloudy (or1) 2
R= Rain ( ) 3
S= Snow or Sleet (or) 5
F= Fog, Smog, Smoke ( ) 6
B= Blowing Sand/Dust ( ) 7
W= Severe Crosswinds ( ) 8
X= Other or Unknown ( )9
Surface:
D= Dry ( ) 1
W= Wet ( )2
S= Snow or Ice (or) 4
M= Muddy ( )5
Db= Debris ( ) 6
O= Oily ( ) 7
X= Other or Unknown ( )9
(X)= Number of Vehicles in Crash
Other Vehicle
Injury Type
[Date] — [Time (hrs)] — [Light-Weather-Surface]

Figure B-3