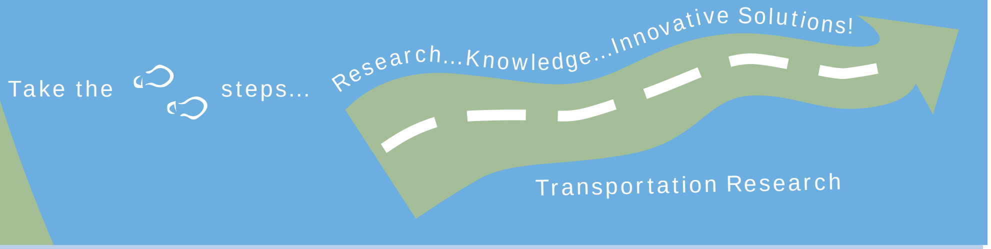
MINNESOTA DEPARTMENT OF TRANSPORTATION

RESEARCH

2008-53

Overview of Rural Intersection Crashes at Candidate Intersections for the Intersection Decision Support (IDS) System

Report #9 in the Series: Toward a Multi-State Consensus on Rural Intersection Decision Support



Technical Report Documentation Page

1. Report No.
MN/RC 2008-53

2.

3. Recipients Accession No.

4. Title and Subtitle
Overview of Rural Intersection Crashes at Candidate Intersections for the Intersection Decision Support (IDS) System

5. Report Date
November 2008

6.

7. Author(s)
Howard Preston, Richard Storm, Max Donath, Craig Shankwitz, Ginny Crowson

8. Performing Organization Report No.

9. Performing Organization Name and Address

CH2M HILL
1295 Northland Drive
Suite 200
Mendota Heights, MN 55120

ITS Institute
University of Minnesota
111 Church Street SE
Minneapolis, MN 55455

10. Project/Task/Work Unit No.

11. Contract (C) or Grant (G) No.
(c) 81655 (wo) 106

12. Sponsoring Organization Name and Address
Minnesota Department of Transportation
395 John Ireland Boulevard Mail Stop 330
St. Paul, Minnesota 55155

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes
http://www.lrrb.org/PDF/200853.pdf
Report #9 in the Series: Toward a Multi-State Consensus on Rural Intersection Decision Support

16. Abstract (Limit: 200 words)

The Intersection Decision Support (IDS) research project is sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), whose objective is to improve intersection safety. The Minnesota team's focus is to develop a better understanding of the causes of crashes at rural unsignalized intersections and then develop a technology solution to address the cause(s).

In the original study, a review of Minnesota's rural crash records and of past research identified poor driver gap selection as a major contributing cause of rural intersection crashes. Consequently, the design of the rural IDS technology has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the available gaps in the traffic stream to the driver.

In order to develop an IDS technology that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation initiated a State Pooled Fund study, in which nine states cooperated in intersection-crash research. This report provides an overview of the crash analysis phase of the pooled fund study for all participating states. This includes patterns identified in severity, driver, and type of error as well as countermeasures previously tried by states.

17. Document Analysis/Descriptors
Intersection Decision Support
Safety
Rural Roadways
Thru-STOP intersections
Rural intersections
Rural crashes

18. Availability Statement
No restrictions. Document available from:
National Technical Information Services,
Springfield, Virginia 22161

19. Security Class (this report)
Unclassified

20. Security Class (this page)
Unclassified

21. No. of Pages
41

22. Price

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Final Report

Prepared by

Howard Preston, P.E.
Richard Storm, P.E., PTOE™
CH2M HILL

Max Donath
Craig Shankwitz
ITS Institute
University of Minnesota

Ginny Crowson
Minnesota Department of Transportation

November 2008

Published by

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

Acknowledgements

This work was sponsored by Mn/DOT, US DOT FHWA, and the Infrastructure Consortium under CFMS 58795, and State Pooled Fund Project TPF-5(086). The authors of this report would like to acknowledge and thank the states participating in the Intersection Decision Support Pooled Fund study. With the support of the following listed states, we have been able to further our study and gain a better understanding of crossing path crashes at rural unsignalized intersections:

- California
- Georgia
- Iowa
- Michigan
- Minnesota
- Nevada
- New Hampshire
- North Carolina
- Wisconsin

Some of the key individuals from the participating states that assisted in this work include Bernie Arseneau and Ray Starr (Minnesota); Richard Lange and Marc Bowker (Wisconsin); Carrie Simpson, Shawn Troy and Al Grandy (North Carolina); Dale Lighthizer and James Schultz (Michigan), Tom Welch and Troy Jerman (Iowa); Norm Cressman and Yancy Bachmann (Georgia); Subramanian Sharma and Jim Irwin (New Hampshire); Kelly Anrig and Jim Ceragioli (Nevada); and Pete Hansra and Tom Schriber (California). In each State there were many additional individuals that assisted in the collection of crash data and officer reports, performing field reviews, and reviewing the technical reports. While there are too many individuals to mention all, this study would not have been possible without their assistance.

Finally, we wish to acknowledge the late Jim Klessig of Mn/DOT, who previously served as administrative liaison of the pooled fund, and Deb Fick, who presently serves as the administrative liaison.

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Executive Summary

A FHWA consortium with Minnesota, California, and Virginia initiated the Intersection Decision Support (IDS) research project, with the objective to improve intersection safety. The Minnesota team focused on developing a technology solution to address the cause of crashes at rural unsignalized intersections. In the original study, a review of Minnesota's rural crash records and of past research identified crossing path crashes as overrepresented at rural intersections and poor driver lag selection as a major contributing cause. Consequently, the design of the IDS system has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the safety of the lags in the traffic stream to the driver.

To develop an IDS system that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation (Mn/DOT) initiated an IDS Pooled Fund study in which nine states are cooperating on intersection-crash research. The participating states are:

- California
- Georgia
- Iowa
- Michigan
- Minnesota
- Nevada
- New Hampshire
- North Carolina
- Wisconsin

The first phase of the IDS Pooled Fund project was a review of intersection crash data from each participating state, applying methods developed from the analysis of Minnesota's rural intersection crashes during the original IDS research. Six states focused on rural expressways; these included: California, Iowa, Minnesota, Nevada, North Carolina, and Wisconsin. Georgia, Michigan and New Hampshire instead addressed intersections on rural two-lane highways.

In each state, the analysis of crossing path crashes resulted in a recommendation for a location to deploy the mobile vehicle surveillance system. The subsequent phase instrumented one candidate intersection in each participating state, as a means to acquire data regarding driver behavior at rural intersections over a wide geographical base.

This report documents the initial phase of the IDS Pooled Fund project, providing an overview of 490 crossing path crashes that were studied, and that were potentially correctable by the IDS technology. Some of the findings from the candidate intersections include:

- In each state, rural intersections could be identified where the crash problem was predominantly crossing path crashes; identifying this as a national issue.
- Crossing path crashes tended to be more severe than all intersection crashes. Expressway intersections had a higher percentage of the target crashes resulting in a fatality or injury; thought to be due to the higher travel speeds.
- At least 70 percent of crossing path crashes in each state were associated with lag recognition.
- In most cases, young and old drivers accounted for more at-fault drivers than expected based on national trends.

1. Introduction

Previous research has shown that crashes at intersections are overrepresented, even though intersections make up only a small portion of the nation's highways. Kuciemba and Cirillo (1) found that more than 30 percent of all crashes occur at intersections. NHTSA's Traffic Safety Facts (2) indicates that 21.5 percent of all fatal crashes were identified as intersection related, with 67.0 percent of these occurring at unsignalized intersections (stop sign, no controls, other sign).

Figure 1-1 (3) illustrates that fatal crashes at unsignalized intersections are predominately angle crashes (a.k.a. crossing-path crashes), which is a crash type oftentimes the result of poor lag selection. The following studies demonstrate that crossing-path crashes at rural unsignalized intersections are most often caused by either the inability of a driver on a minor street approach to recognize the intersection (which results in a run–the-STOP-sign violation) or the driver's inability to recognize and select a safe lag in the major street traffic stream.

Note: Differences between "gap" and "lag" should be clarified. A gap is defined "as the time headway between two vehicles on the major road," and a lag is defined as the "portion of the gap which remains when the minor road vehicle first arrives at the stop line or begins to move onto the major road." A driver at a stop controlled intersection makes a go/no go decision primarily based on the available "lag" (4).

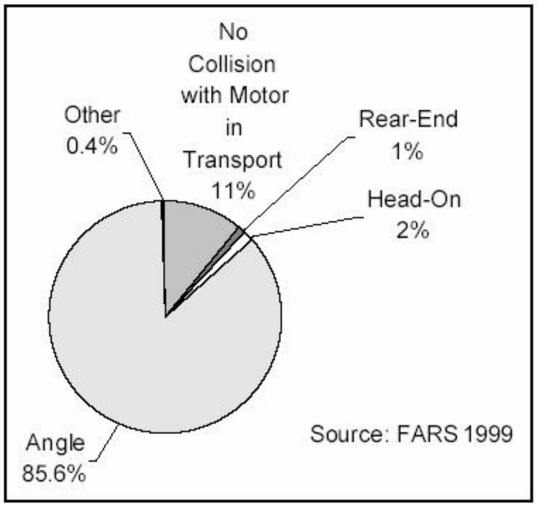

FIGURE 1-1
Fatal Intersection Crash Type Distribution (3)

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 lag (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 lags (5). 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. (6) 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 lag detection or lag selection.

A Minnesota study of thru-STOP (controlled) intersections for two-lane roadways in rural Minnesota (7) reviewed police records to determine primary causes of crashes at this type of intersection. The review of crash reports revealed that 26 percent of right-angle crashes were caused by the driver on the minor street failing to stop because they did not recognize they were approaching an intersection (see **Figure 1-2**). For the same set of intersections, 57 percent of the right-angle crashes were related to selecting an unsafe lag and 17 percent were classified as other or unknown. This review of records lends additional credence to the hypothesis that lag selection is the key contributing factor to right angle crashes at thru-STOP rural intersections.

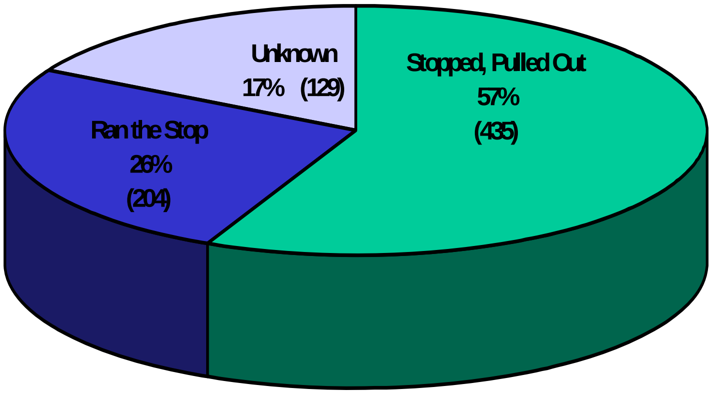

FIGURE 1-2
Right Angle Crash Distribution at 2-Lane/2-Lane Rural Thru-STOP Intersections (7)

1.1. National Efforts to Address Rural, Unsignalized Intersection Crashes

To address the overrepresentation of intersection crashes, the American Association of State Highway and Transportation Officials (AASHTO) identified design and operational improvements of highway intersections as one of the twenty-two key emphasis areas in their Strategic Highway Safety Plan (SHSP) (8). Development and use of new technologies at high-priority intersections was identified in the SHSP as an initiative to address intersection crashes.

In NCHRP Report 500 (3), Objective 17.1 D cites providing assistance to drivers to judge lag sizes at unsignalized intersections as a critical objective for improving safety at these locations. Methods proposed therein include:

- Using automated real-time information systems to inform drivers when a safe lag exists,
- Placing roadside markers and/or pavement markings to assist drivers in judging available lags, and
- Re-timing nearby signals to create gaps in the traffic stream.

1.2. State and Federal Efforts to Address the Problem

A consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA) developed the original Intersection Decision Support (IDS) research project to improve intersection safety. Each of the three states focused on a different aspect of intersection safety. The objective of the Minnesota effort was to develop an IDS system to assist driver with the lag acceptance task at rural intersections. In the original IDS research project, intersections in rural Minnesota were scanned to identify locations where crossing path crashes were overrepresented. This research eventually led to the selection of an intersection in southeast Minnesota (US 52 and Goodhue County State Aid Highway 9) where vehicle surveillance equipment was also deployed to observe driver behavior.

To develop a nationally deployable system and achieve national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation initiated a State Pooled Fund study TPF-5 (086), in which nine states—California, Georgia, Iowa, Michigan, Minnesota, Nevada, New Hampshire, North Carolina, and Wisconsin—are cooperating on analyses of intersection crash sites and of driver lag acceptance behavior at sites with safety issues.

1.3. Research Objective

The objective of this phase of the IDS Pooled Fund research effort was to perform a scan of the crash data for each state to locate rural intersections where crossing path crashes were a problem, essentially confirming that this is a national problem and not isolated to Minnesota. Officer crash reports were reviewed to identify the types of driver errors that may have led to the crashes occurring. Additionally, in this phase of the IDS Pooled Fund study, the research team performed a field scan of candidate locations to review the intersection design, identify previous countermeasures used by states, and if there were any potential design elements that may been a contributing factor in the crashes. The crash analysis and field scan resulted in a recommended location where the mobile vehicle surveillance equipment was to be located.

Having completed this phase of the IDS Pooled Fund study for all nine states, this report provides an overview for all nine states. This includes countermeasures seen during the field scans and patterns or lessons learned from the crash analyses.

2. Typical Countermeasures for Rural Intersections

A typical crossing path crash (i.e., right angle crash) at a rural unsignalized intersection is most often caused by the driver's (on a minor street approach) inability to recognize the intersection (which consequently results in a run the STOP sign violation), or his/her inability to recognize and select a safe lag in the major street traffic stream. A typical belief among many engineers is that intersection recognition has been the bigger problem; therefore, traditional safety countermeasures deployed at rural high crash intersections include:

- Upgrading traffic control devices, including larger STOP signs; multiple STOP signs; and advance warning signs and pavement markings
- Using minor geometric improvements, including free right-turn islands; center splitter-islands; and off-set right-turn lanes
- Installing supplementary devices, including flashing beacons mounted on the STOP signs; overhead flashing beacons; street lighting; and transverse rumble strips

All of these countermeasures are relatively low cost and easy to deploy and help assist drivers with intersection recognition, but do not address what previous research has found to be the underlying problem in most crossing path crashes—lag recognition and acceptance.

2.1. Addressing Lag Recognition Solutions

The concept of lag recognition being a key factor contributing to rural intersection safety appears to be a recent idea. As a result, there are relatively few devices in the traffic engineer's safety toolbox to assist drivers with lag recognition and they mainly consist of a few high cost geometric improvements and a variety of lower cost strategies that are considered to be experimental because they have not been widely used in rural applications. **Figure 2-1** illustrates the range of strategies currently available to address safety deficiencies associated with lag recognition problems, organized in order of the estimated cost to deploy (based on Minnesota conditions and typical implementation costs). The strategies include:

- The use of supplemental devices such as street light poles to mark the threshold between safe and unsafe lags
- Minor geometric improvements to reduce conflicts at intersection such as inside acceleration lanes, channelized median openings to eliminate certain maneuvers (sometimes referred to as a J-Turn), or revising a 4-legged intersection to create off-set T's
- Installing a traffic signal to assign right-of-way to the minor street
- Major geometric improvements such as roundabout or grade separated interchanges to eliminate to reduce crossing conflicts. (Refer to *Rural Expressway Intersection Synthesis of Practice and Crash Analysis* for a review of various alternatives [9].)

The use of these strategies may not be appropriate, warranted or effective in all situations, especially on high-speed rural expressways where in some locations the number of crashes increased (10). Furthermore, a review of intersections in Minnesota found that the average signalized intersection has approximately twice the crash rate when compared to the average unsignalized intersection (11). Also, the cost of construction or additional right-of-way may be prohibitive at some locations. All of this combined with the recommendation in AASHTO's

SHSP to investigate the use of technology to address intersection safety led to this ongoing research project aimed at developing a cost-effective IDS system.

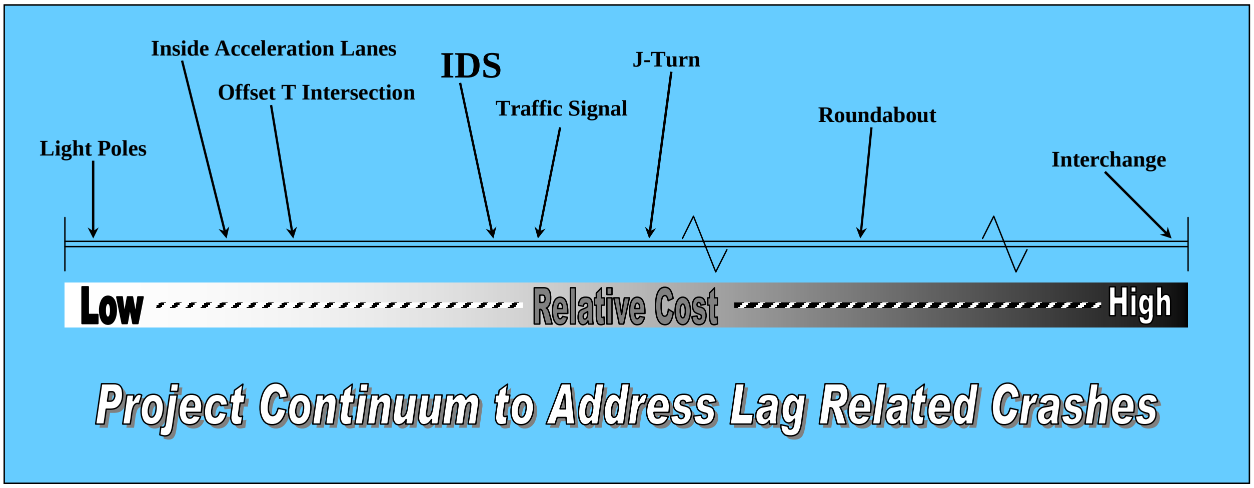

FIGURE 2-1
Lag Selection Related Safety Strategies

The IDS system is intended to be a relatively low-cost strategy (similar to the cost of a traffic signal), but takes advantage of new lower cost technologies, using roadside sensors and computers to track vehicles on the major road approaches, computers to process the tracking data and measure available lags (12), and a driver interface to provide minor road traffic with real-time information (13).

The subsequent phase of the IDS Pooled Fund study was to instrument candidate intersections in order to acquire data regarding lag acceptance behavior of drivers at rural intersections. Instrumentation of test intersections and subsequent analysis (14) in multiple states will determine whether regional differences exist. An understanding of these regional differences can be used to adjust alert and warning timing on a regional basis, ensuring system deployability on a national basis.

2.2. Intersection Safety Countermeasures Seen During Field Scans

Field scans conducted in the IDS Pooled Fund States found a variety of intersection designs, approach geometry, land use and countermeasures (15-23). Since many of the locations selected for further study were previously known to have a crash problem, the Department of Transportation (DOT) had attempted to address the safety concerns. Many of the countermeasures seen during the field scans could be categorized into one of four categories.

- *Increase Intersection Visibility to Heighten Awareness of Drivers on Stopped Approaches:* A variety of devices were used to increase the minor street driver's awareness. Some of the more common examples include STOP AHEAD signs, intersection lighting, and dual STOP signs. In some specific states, use of overhead red-yellow flashers, splitter islands (see **Figure 2-2**), and enhanced junction signing were common.

FIGURE 2-2
Splitter Island at an Iowa Intersection Used to Increase Approach Visibility

- *Increase Intersection Visibility to Heighten Awareness of Drivers on Through Approaches:* At some locations, the states used countermeasures that were intended to increase the awareness of drivers on the mainline. While this doesn't aid in gap selection, a driver that is more aware may be able to take action to avoid a collision if a vehicles pull into their path.

  This was a less common approach to improving intersection safety, but the countermeasures observed include advanced intersection warning signs, intersection lighting and overhead red-yellow flashers—the last two countermeasures were also mentioned for minor street drivers. The most unique device was a warning sign with dynamic flashers that would activate when a vehicle was stopped on the minor street approach (see **Figure 2-3**).

FIGURE 2-3
Dynamic Mainline Warning Flashers at a North Carolina Intersection Used to Alert Mainline Drivers

- *Place Additional Reminders in the Median:* Rural expressway are unique in that drivers on the minor street that are turning left or crossing have to safely navigate two intersections—the nearside intersection with traffic approaching from the left and the farside intersection with traffic approaching from the right. Along rural expressway, a YIELD sign is a common practice seen in many states. But a few states tried to provide drivers with additional reminders with yield pavement markings or STOP sign and stop bar in wide medians (e.g., locations instrumented in Wisconsin and California). Another countermeasure observed were supplemental LOOK RIGHT signs mounted under the YIELD sign combined with LOOK RIGHT pavement marking messages. This is a hybrid strategy reminding the driver of the need to select a lag, but not providing the driver any assistance with the task.

FIGURE 2-4
Strategies Used to Improve Median Recognition

- *Aid Drivers with Lag Identification and Selection:* In a limited number of cases, countermeasures were observed that have the ability to address the lag identification and selection. In one instance, an inside acceleration lane had been constructed for vehicles turning left from the minor street. At two locations, offset right-turn lanes had been constructed, which can remove turning traffic for a driver's sight line allowing them to better see approaching thru traffic. A third countermeasure used was supplemental signs mounted under a STOP signing reminding the drivers that cross[ing] traffic does not stop. Like the LOOK RIGHT signs and markings in the medians, this is a hybrid strategy that reminds a driver to select a gap but does not help the driver with the task.

A key field observation was how the candidate locations were often located near/in a horizontal curve, a crest vertical curve, or both. This is not considered to be proof that the curves were the cause of the crash, especially since the curves rarely restricted the sight distance to below the recommended AASHTO values. However, curves can make the task of spotting an approaching vehicle or judging their speed more difficult, but is a problem that can be addressed by the proposed IDS system.

3. Crash Analysis for Pooled Fund States

3.1. General Approach

An analysis based on the critical crash rate and a severity measure methodology was pursued to identify the intersections at which driver behavior data will be collected. The preferred, comprehensive methodology was first developed using Minnesota's crash record system (15). This process is graphically depicted in **Figure 3-1**.

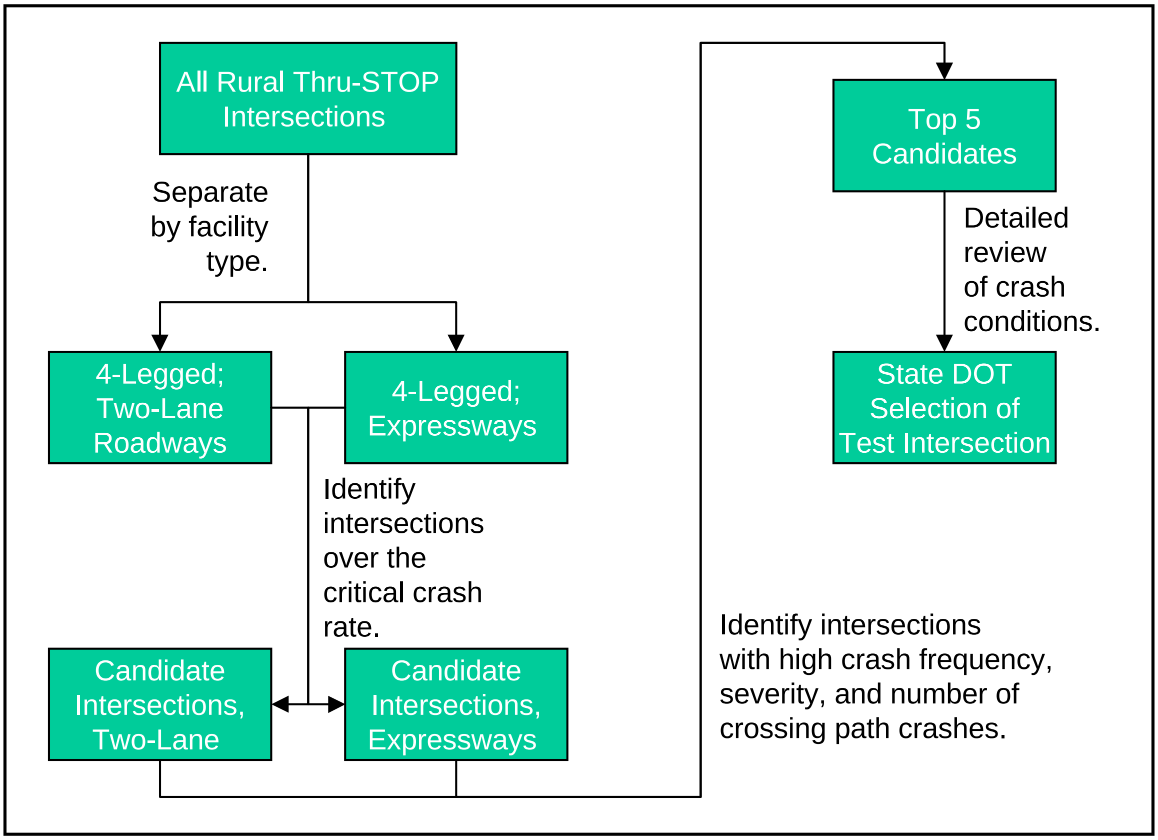

FIGURE 3-1
Preferred Crash Analysis Process

3.1.1. Intersection Crash Review Preferred Methodology

Identifying candidate intersections for a potential field test of the technology used three screens. The first screen was to select rural intersections where the crash rate was equal to or greater than the critical crash rate. Following, the list of intersections was reviewed to identify the locations with the greatest number and most severe crossing path crashes. Finally, a detailed review for the crossing path crashes was done to identify the crashes where the contributing factors may have been mitigated by the proposed IDS system. The location in each state that best met these three criteria was the recommended location to deploy the mobile vehicle surveillance system. Additional information about these three screens follows:

Critical Crash Rate –

- Definition. The critical crash rate (crashes per million entering vehicles) is:

  $R_c = R_a + K (R_a / m)^{1/2} + 0.5/m$,

  where:

  R_a = system wide average crash rate (crashes per million entering vehicles)
  K = constant based on Level of Confidence (for 95 percent level of confidence, K = 1.645),
  m = vehicle exposure (for intersections: years * daily entering vehicles * 365 / 10^6).

- Application. The first screen of intersection crash records was used to identify rural thru-STOP intersections that have a crash rate greater than its critical crash rate. Any intersection with a crash rate equal to or above the critical crash rate is statistically significant and can be identified as an intersection with a crash problem due to an existing safety deficiency. Intersections having crash rates higher than the critical rate were identified as potential candidates for further study.

Number and Severity of Correctable Crashes – Once the list of intersections meeting the first criterion was identified, this second screen identified intersections where a relatively high number and percentage of crashes are potentially correctable by the IDS technologies. In Minnesota's crash record system, right angle crashes were most often related to poor lag selection. Candidate intersections that had a high number and percentage of right-angle collisions and that tended to be more severe were evaluated.

Crash Conditions and At-Fault Driver Characteristics – The IDS technology is expected to significantly benefit older drivers because of evidence that they are most challenged in selecting lags in cross traffic. Therefore, the at-fault driver age was reviewed to identify intersections where older drivers were over represented. Other aspects of the crashes that were reviewed include whether the crashes were typically a problem with intersection recognition or lag recognition and the crash location (near lanes or far lanes). Weather and road conditions were reviewed to determine whether weather played a role in the crashes that occurred at the candidate locations.

3.1.2. Strengths and Weaknesses of State Data

To the maximum extent possible, the crash analysis methodology was applied to the intersection crash data provided by the participating IDS Pooled Fund states. Crash information from the crash database in each state was requested. Upon receipt and review, each state was provided a list of intersections with crash rates above the critical level or the intersections that had the greatest problem with crossing path crashes as well as a recommendation for the experimental intersection.

While implementing this process, it was determined that some states lacked certain data in their crash reporting/recording systems, specifically information on

- Traffic control devices (unsignalized versus signalized),
- Location (rural versus urban), and/or
- Geometric features (four-leg or T- intersection).

In these instances, modifications to the preferred methodology were developed to allow for the computation of similar statistics (16-23). For example, the computation of a critical crash rate depends on the system wide average crash rate. If a system wide crash rate was unavailable, available alternatives were used, including:

1. Using the Minnesota average for the other states,
2. Computing an average intersection crash rate for a corridor, or
3. Reviewing a select number of intersections based solely on fatality and severity rates.

Appendix A summarizes the issues experienced during the process of reviewing the intersection crash records for the pooled fund states, as well as the resolution developed to overcome the limitations of that particular state's crash record system.

3.2. Target Crash Types

The General Estimates System (GES) crash database is a national sample of police-reported crashes used in many safety studies. In the GES, five crossing path crash types have been identified (see **Figure 3-2**), they are:

- 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), and
- Straight Crossing Path (SCP).

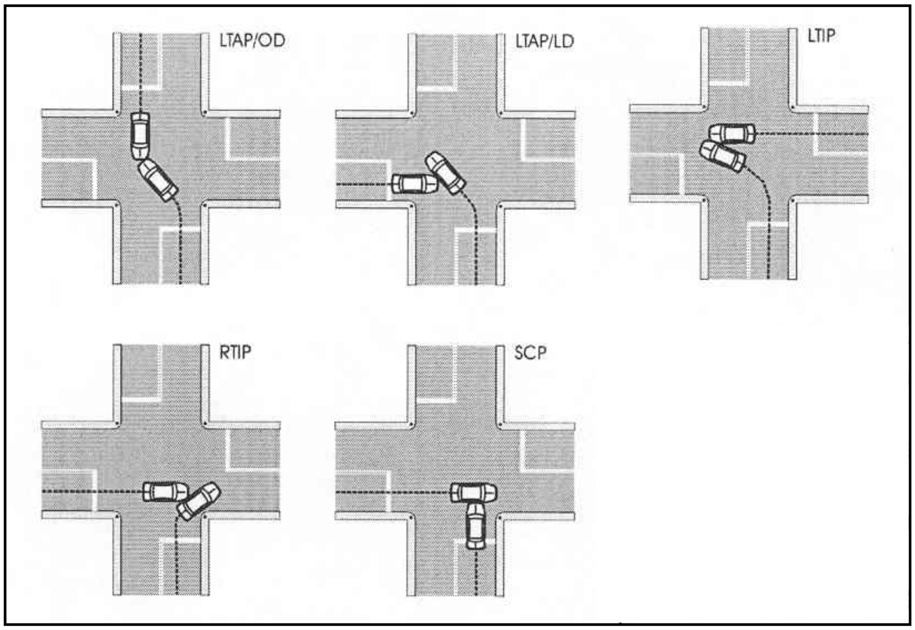

FIGURE 3-2
GES Crossing Path Crash Types

At this time, the IDS system under development is intended to address the crossing path crash types involving at least one vehicle from the major and minor street (i.e., target crashes), which includes all five GES crash types except for LTAP/OD. This research has not focused on the

LTAP/OD crash type at unsignalized rural intersections because they are generally a relatively small problem at many locations.

3.3. Pooled Fund State Crash Analysis

For the candidate intersections studied in each of the partner states, each of the candidate intersections was investigated further for specific information, to learn of any unusual circumstances at the intersections, and to determine feasibility for the data collection process. For the purposes of this report, these findings have been compiled by either expressway or two-lane highway for the candidate intersections. The individual summary tables for each participating IDS Pooled Fund partner state is provided in **Appendix B**.

In total, the 490 target crossing path crashes at 38 intersections across the nine states were studied. By road type, rural expressways accounted for 344 target crossing path crashes at 25 intersections (six states). The six states where expressway intersections were studied include California, Iowa, Minnesota, Nevada, North Carolina, and Wisconsin. That leaves 146 target crossing path crashes for 13 intersections for the three states—Georgia, Michigan and New Hampshire—that chose to study two-lane highways.

Out of the 38 intersections studied (**Table 3-1**), 67% of all crashes at the intersections were determined to be the target crossing path crashes. By facility type, the target crash type represented 61% of all crashes at two-lane highway intersections and 70% for expressway intersections. This indicates that the target crash type is an overwhelming problem at the rural intersections reviewed, and likely at many rural intersections not studied. However, it is also important to keep in mind that the primary problem will not be crossing path crashes at all rural intersections, especially since the screening method was designed to find locations skewed towards crossing path crashes.

A comparison of crash severity, driver error type, at-fault driver age, and crash location for the crashes identified as potentially correctable is provided in the following sections.

TABLE 3-1
Total and Target Crash Summary at Candidate Intersections

State	No. Intersections Studied	Focus Road Type	Total Crashes	Target Crashes	Percent Target Crashes
California	3	Expressway	61	22	36%
Georgia	4	Two-Lane	102	67	66%
Iowa	6	Expressway	80	57	71%
Michigan	6	Two-Lane	100	60	60%
Minnesota	3	Expressway	59	37	63%
Nevada	2	Expressway	31	20	65%
New Hampshire	3	Two-Lane	39	19	49%
North Carolina	5	Expressway	113	99	88%
Wisconsin	6	Expressway	144	109	76%
Two-Lane Total	**13**		**241**	**146**	**61%**
Expressway Total	**25**		**488**	**344**	**70%**
IDS Study Total	**38**		**729**	**490**	**67%**

3.3.1. Crash Severity

Compared to the 2006 national crash severity distribution of all non-signalized intersection crashes (2), there is a higher percentage of fatal and injury crashes indicating the target crashes at the candidate locations tended to be more severe (**Figure 3-3**). Furthermore, crossing path crashes at expressways tended to be on average even more severe than two-lane highways. This may be due to the higher travel speeds that are common on most rural expressways.

The black bars in **Figure 3-3** show the range of the state averages. Generally, the fatal and injury crash percentage was at or above the national average for all IDS Pooled Fund states.

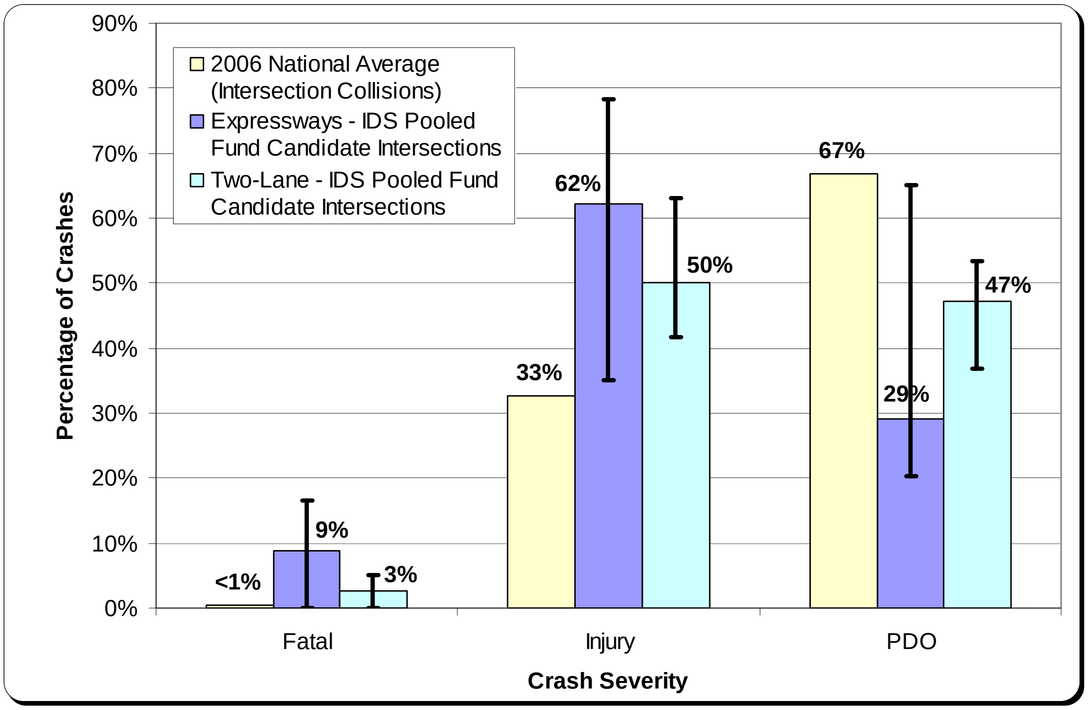

FIGURE 3-3

Crash Severity Distribution for Target Crashes at Candidate Intersections

Note: In this study, rural expressways accounted for 344 crossing path crashes at 25 intersections. Rural two-lane highways accounted for 146 crossing path crashes at 13 intersections. The black bars show the range of the state averages.

3.3.2. Driver Error Type

Whenever possible, law enforcement crash reports were reviewed to determine which crossing path crashes were related to lag selection. If officer reports were not available for confidentiality reasons, information from the crash data was used to best estimate if the error was lag selection, intersection recognition, or other/unknown. When officer reports weren't available, information from the crash database that was used included driver contributing factor, vehicle travel speed, or vehicle movements (i.e., a minor street vehicle turning onto the major highway would had to have recognized the intersection but failed to select a safe gap).

In **Figure 3-4**, the percentage of crossing path crashes related to lag selection is shown by the bars. The black bars represent the range (maximum and minimum) for individual intersections reviewed in the state. **Figure 3-4** indicates that lag selection played a key role in the crossing path crashes at the IDS candidate intersections. In fact, lag selection error was the primary contributing factor for at least 70 percent of the crossing path crashes in each of the nine states. Michigan and New Hampshire were the only states where lag selection was just less than a 70 percent contributing factor, but, if one intersection is removed from the Michigan data set, then the percentage increases to nearly 80 percent. The pattern in the IDS Pooled Fund states closely mirrors the information discovered in the initial Minnesota study (15) and from the literature review.

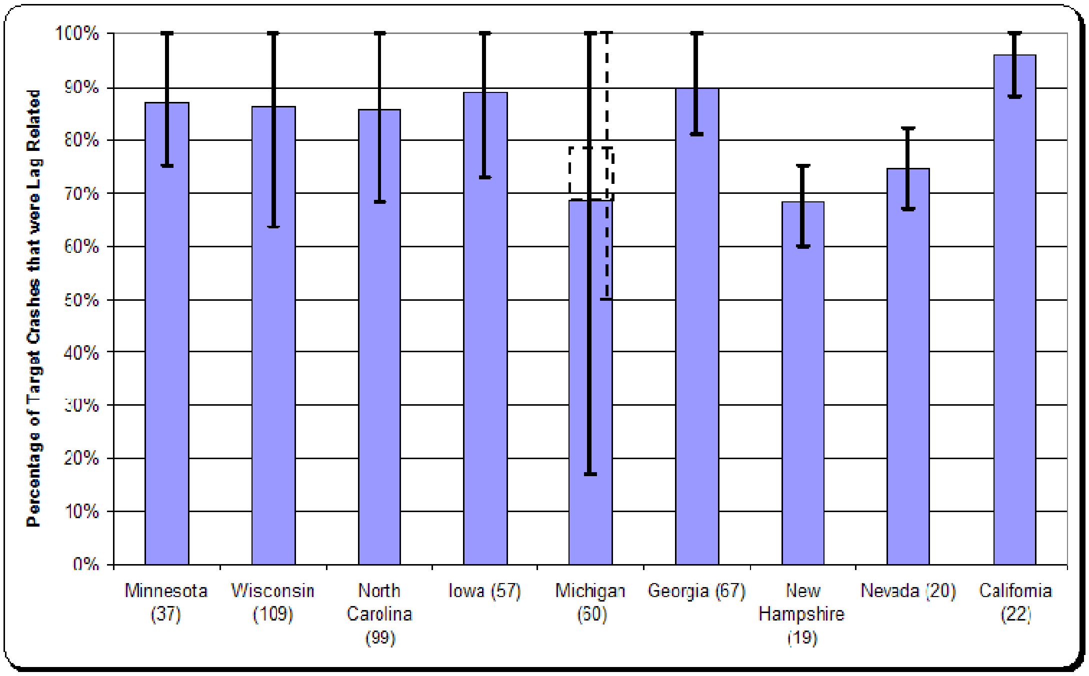

FIGURE 3-4

Percentage of Target Crashes Where Driver Made a Lag Selection Error at Candidate Intersections.

Note: Dashed line represents Michigan average with outlier intersection excluded. Numbers in parentheses is the number of crashes studied in each state. The black bars represent the range of intersections reviewed in the state.

3.3.3. At Fault Driver Age

Data collected from candidate intersections indicate that driver age appears to be a factor in crossing path crashes at the candidate intersections. To determine the at-fault driver, the officer reports were relied on as much as possible. Otherwise driver contributing factors were used to determine the driver most responsible for causing the crash. **Figure 3-5** show the age distribution for the candidate intersections along with the 2006 national age distribution for all drivers who were involved in a crash (2). It is important to keep in mind that the national averages represent all drivers involved in a crash, not just those responsible for the crash.

The age distribution for expressways and two-lane intersections were nearly identical. Compared to the national average, at-fault drivers in the target crashes tended to be older than expected, for both expressway and two-lane highway intersections. For young drivers, the two-lane highways were slightly overrepresented while expressways matched the national average.

The black bars in **Figure 3-5** show the range of the state averages. For older driver, all IDS Pooled Fund states had an average that exceeded the national average. The bars also reveal that younger drivers were less problem in some states, but in other states young drivers represented twice the national average. Regardless, the number of drivers in the middle age category was at least ten percentage points below the national average.

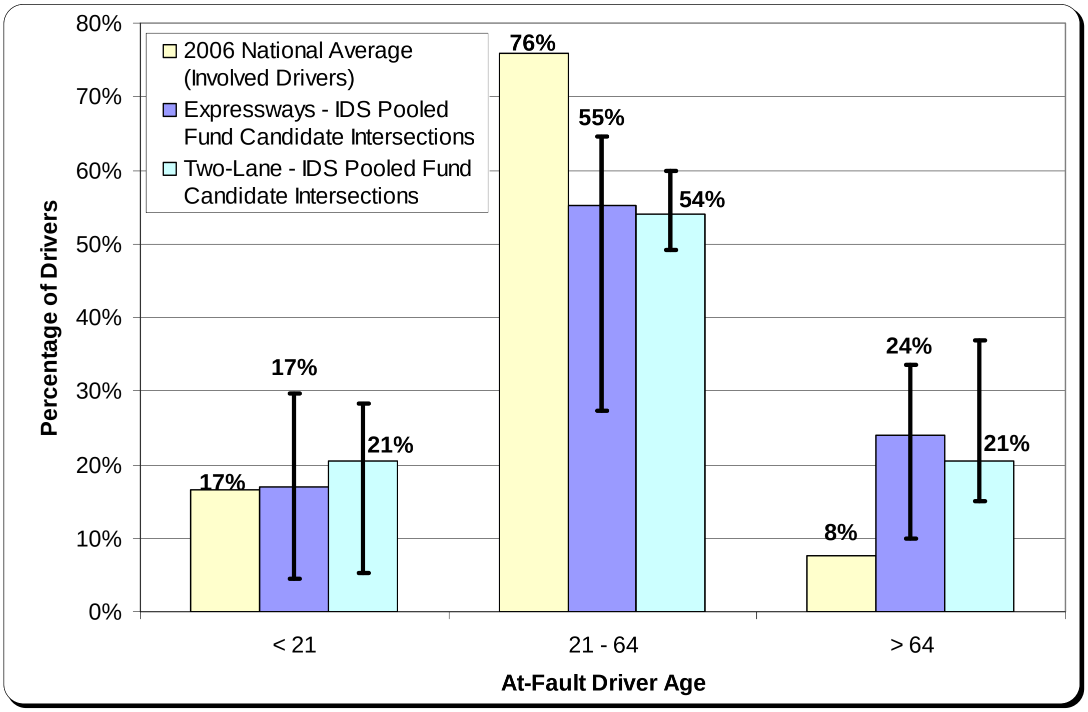

FIGURE 3-5

At-Fault Driver Age Distribution for Target Crashes at Candidate Intersections

Note: Values for "Unknown" age are not shown. In this study, rural expressways accounted for 344 crossing path crashes at 25 intersections. Rural two-lane highways accounted for 146 crossing path crashes at 13 intersections. The black bars show the range of the state averages. The black bars show the range of the state averages.

3.3.4. Crash Location

During the initial Minnesota analysis (focused on rural four-lane expressways), a pattern was observed that most of the target crashes were considered to be far-side crashes—73 percent of the crossing path crashes occurred on the far side of the intersection and only 27 percent were on the near side (15). In these far-side crashes, the vehicle safely crossed the first two lanes of traffic, but was 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 records, but it was 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 lag is still safe, it is believed that the drivers proceed into the far lanes without stopping. Data collected by the mobile vehicle surveillance system was meant to show how drivers treat the far-side of the intersection and to clarify the importance this may have in crossing path crashes and what, if any, difference exists between near and far side crashes.

This is not a topic included in national crash reports, which restricts the comparison of the candidate intersections to only the states that participated in the IDS Pooled Fund study. At expressway intersections, 61 percent of the target crash type was on the far side of an intersection, which decreased to 54 percent for two-lane highways (see **Figure 3-6**). While expressway intersections do tend to have more far-side crashes, the black bars that represent the range in state averages also shows that the experience in expressway states does widely vary.

Conversely, not only were two-lane highways closer to an even split, the range in the three states was narrower.

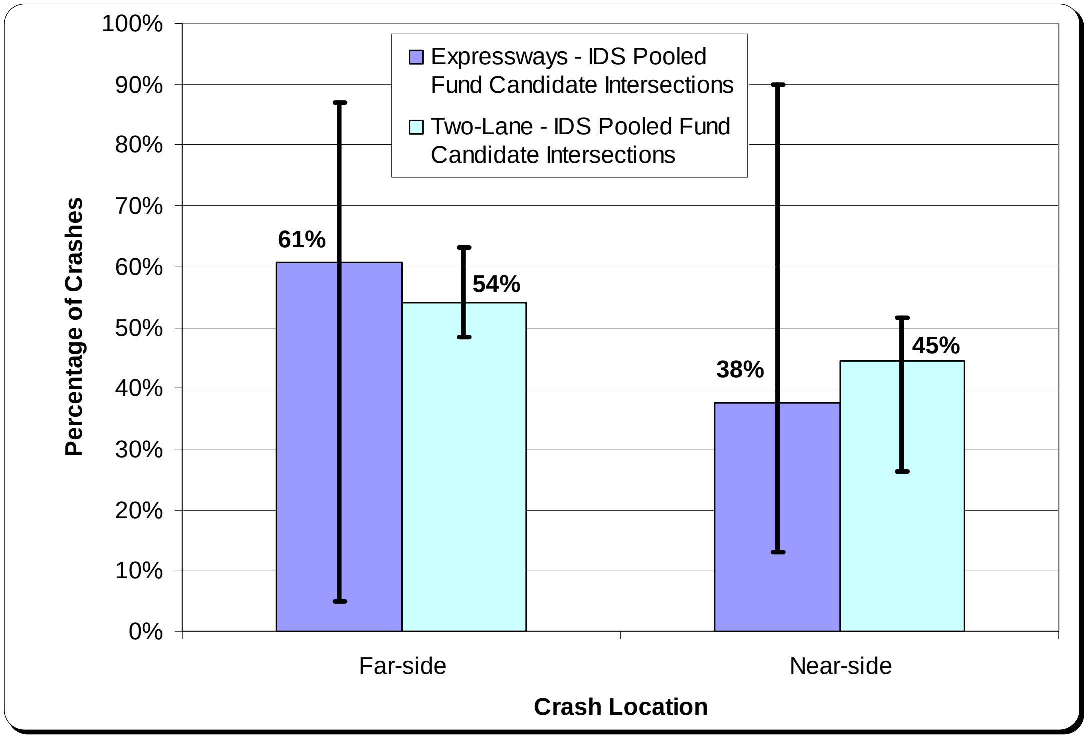

FIGURE 3-6
Crash Location for Target Crashes at Candidate Intersections

Note: Values for "Unknown" locations are not shown. In this study, rural expressways accounted for 344 crossing path crashes at 25 intersections. Rural two-lane highways accounted for 146 crossing path crashes at 13 intersections. The black bars show the range of the state averages. The black bars show the range of the state averages.

Similar research performed for rural expressway intersections in Iowa (24) has the potential to partially explain the wide variation in the candidate expressway intersections. The Iowa study looked at 30 intersections and found that the seven intersections located on horizontal curves often had different patterns in the crashes. In fact, many of these curves were a by-pass around the city, with the leg on the inside of the curve leading to the city and carrying a higher volume. The Iowa study did not look at only crossing path crashes, but still found that nearly 53 percent of crashes were far-side, 30 percent near side, and 17 percent other (i.e., fixed object, rear end) when the intersection was not located in a curve. For the seven intersections located in the curve, the far-side, near-side, and other crashes were each nearly 33 percent.

4. Concluding Remarks

The IDS Pooled Fund study [TPF-5 (086)] was initiated by the University of Minnesota and the Minnesota Department of Transportation to develop an IDS system that has the potential to be nationally deployed. The literature review completed for the original IDS research (a FHWA consortium with Minnesota, California, and Virginia) identified that for rural intersection crashes, crossing path crashes were over represented and a common error contributing to the crash event was a driver's inability to recognize and select a safe lag in the major street traffic stream. Consequently, the design of the IDS system has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the safety of the lags in the traffic stream to the driver.

This phase of the IDS Pooled Fund research set out to identify one candidate intersection to deploy the mobile vehicle surveillance system in each participating state. This was done by analyzing the crash data for each state to locate rural intersections where crossing path crashes were a problem. Following, officer crash reports were reviewed to identify the types of driver errors that may have led to the crashes occurring. Additionally, the research team performed a field scan of candidate intersections. This report documented the common countermeasures seen during the field scan patterns or lessons learned from the crash analyses.

4.1. Intersection Safety Countermeasures Seen During Field Scans

Field scans conducted in the IDS Pooled Fund States found a variety of intersection designs, approach geometry, land use and countermeasures. Since many of the locations selected for further study were previously known to have a crash problem, the local state Department of Transportation (DOT) had attempted to address the safety concerns. Many of the countermeasures seen during the field scans could be categorized into one of four categories.

- Increase intersection visibility to heighten awareness of drivers on stopped approaches
- Increase intersection visibility to heighten awareness of drivers on through approaches
- Place additional reminders in the median
- Aid drivers with lag identification and selection

The first two types of countermeasures were the most common countermeasures seen during the field scan and do not address the underlying problem with lag identification and acceptance. In the few locations where devices were used to address lag selection, most were reminders to drivers to look for crossing traffic, but do not actually provide assistance with the task.

It was also observed that the candidate intersections were often located near/in a horizontal curve, a crest vertical curve, or both. This is not considered to be proof that the curves were the cause of the crash, especially since the curves rarely restricted sight distance to below the recommended AASHTO values. However, curves can make the task of spotting an approaching vehicle or judging their speed more difficult, but is a problem that can be addressed by the proposed IDS system.

4.2. Pooled Fund State Crash Analysis

Six states focused on rural expressway intersections—California, Iowa, Minnesota, Nevada, North Carolina, and Wisconsin—where a total of 25 intersections were studied and 344 crossing path crashes. Georgia, Michigan and New Hampshire addressed intersections on rural two-lane highways—a total of 13 intersections with 146 crossing path crashes. The key findings from the candidate intersections include:

- In each state, rural intersections could be identified where the crash problem was predominantly crossing path crashes; identifying this as a national issue.
- Crossing path crashes tended to be more severe than all intersection crashes. Expressway intersections had a higher percentage of the target crashes resulting in a fatality or injury; thought to be due to the higher travel speeds.
- At least 70 percent of crossing path crashes in each state were associated with lag recognition.
- In most cases, young and old drivers accounted for more at-fault drivers than expected based on national trends.

4.3. Summary

Each pooled fund state could identify multiple intersections where crossing path crashes is a safety issue, indicating that this is a national problem. However, the field scan of the candidate locations revealed that traffic engineers have few countermeasures they can use to address the underlying problem, especially a strategy that is neither a traffic signal nor high-cost (e.g., interchange, roundabout, or J-turn). Therefore, many of these locations would benefit from a low-cost technology based solution that helps drivers identify and select a lag in the traffic stream that is large enough to allow a merging or crossing movement.

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Appendix A

Crash Analysis Process for IDS Pooled Fund States

TABLE A-1
Pooled Fund Study States Crash Analysis Process

State	Modification To Crash Analysis Process
California	California provided crash records for 23 rural thru-STOP intersections along four rural expressway corridors. From these 23 intersections, the crash summary statistics provided by CALTRANS identified five locations where there was a relatively high crash frequency of broadside crashes — the target crash type. However, unusual geometry and recent safety improvement projects eliminated two intersections and a third location was eliminated because a detailed review revealed that the broadside crashes were left-turn head-on crashes—currently not a target crash type. After working with the District, it became apparent there was not sufficient room in the right-of-way to safely place the mobile vehicle surveillance system. Following this decision, little time remained before the mobile system had to be taken down from the previous site and moved to a California intersection. Therefore, CALTRANS worked with the Districts to identify and directly select a rural intersection that had a known safety issue and sufficient room for the equipment. Because of the low number of locations to make the selection from, critical crash rate was not used as a criterion.
Georgia	Rural, unsignalized intersections with a high number of crashes (≥ 20) were identified statewide. For these intersections only, entering volumes were collected and an intersection crash rate was computed. Since a statewide expected crash rate was unavailable for calculating a critical crash rate, Minnesota's statewide rate was used as a surrogate.
Iowa	A statistical model to estimate the expected crash severity index was developed for Iowa's rural, expressway intersections. The top 20 locations were selected where the actual and expected severity index was the greatest. From these locations, the intersections with the greatest number of crossing path crashes were selected.
Michigan	Michigan's system can not readily produce summary statistics for all rural intersections. Instead, candidate intersections were identified manually in the counties surrounding the Lansing area by staff from the Michigan Department of Transportation (MDOT). Criteria used by MDOT to select intersections for analysis were based on rural, unsignalized intersections with a minimum crash frequency of three or more angle crashes in a three year period and a minimum posted speed limit of 55 mph for the major (thru) street. Since a statewide expected crash rate was unavailable for calculating a critical crash rate, Minnesota's statewide rate was used as a surrogate.
Nevada	The Nevada Department of Transportation (NDOT) originally focused on two-lane rural highways, but their scan through their GIS system identified no intersections that had a frequency of crossing path crashes that warranted further investigation (it was hypothesized that the low volumes in rural Nevada means there are few crossing conflicts which results in fewer crossing path crashes). As a result, the focus was shifted to Nevada's expressway system, specifically four corridors that previously had traffic safety issues. From the crash data for the four corridors, 25 intersections were identified where at least one crash had occurred during the study period. Using the crash information, the five intersections with the highest frequency and percentage of angle crashes were identified. At three locations, detailed review found that a majority of the angle crashes were actually left-turn head-on crashes (i.e., LTAP/OD) and were then no longer further considered. The final location was selected from among the remaining two locations. Because of the low number of locations to make the selection from, critical crash rate was not used as a criterion.

TABLE A-1
Pooled Fund Study States Crash Analysis Process

State	Modification To Crash Analysis Process
New Hampshire	In New Hampshire, there is no database of intersection characteristics that is linked to the crash records which means the State is unable to automatically identify and query intersections (including crash records) based on physical characteristics and type of traffic control. The modified approach began with the New Hampshire Department of Transportation (NHDOT) providing a GIS crash database along with a GIS road network that included the physical attributes of the segments. Using GIS software, intersections crashes were queried if they occurred along a rural, two-lane US or State highway. Using the queried crashes, the 20 intersections with the highest crash frequency were identified. Several locations had to be removed from further consideration after learning the intersection crash rate was below the computed critical crash rate, the intersections were signalized, aerial photography revealed the locations were T-intersections or in an urban area, or recent safety improvements had been made; leaving a total of three intersections to select from. Finally, since a statewide expected crash rate was unavailable for calculating a critical crash rate, Minnesota's statewide rate was used as a surrogate.
North Carolina	North Carolina's system can not readily produce summary statistics for all rural intersections. So instead, candidate intersections were selected from North Carolina's Highway Safety Improvement Program (HSIP). The HSIP does not identify the State's most dangerous locations; instead, the program identifies locations that "exceed minimum warranting criteria developed by safety engineers for particular crash types and patterns that warrant further analysis and investigation." Intersections were considered a candidate if they met the criteria I-1 (Frontal Impact Crashes) and I-5 (Chronic Crash Pattern). Candidate intersections were further screened by searching for intersections where the main line is a four-lane divided roadway (i.e., expressway) with a 55 mph speed limit and where no safety improvement projects had recently been implemented. Finally, since a statewide expected crash rate was unavailable for calculating a critical crash rate, Minnesota's statewide rate was used as a surrogate.
Wisconsin	Since identification of intersection crashes could only be done manually, candidate intersections were selected from a 70-mile portion of U.S. 53 (Rice Lake to Superior). This corridor was selected by Wisconsin DOT staff because they had knowledge of several intersections with crossing path crash problems. Also, an expected (or average) crash rate for use in computing the critical crash rate was estimated from the 74 intersections located along the corridor.

Appendix B

Crash Summaries for Candidate Locations

TABLE B-1
California Intersection Summary

Performance Measure	US 101 & Ocean Drive (Ventura County) *	US 101 & La Conchita Road (Ventura County) *	US 395 & Gill Station Coso Road (Inyo County) ♦
Crash Frequency	24	32	5
Crash Severity			
Fatal	0 (0%)	0 (0%)	2 (40%)
Injury	10 (42%)	14 (44%)	3 (60%)
PDO	14 (58%)	18 (56%)	0 (0%)
Daily Entering ADT	67,000	67,000	6,150
Crash Rate	0.2	0.3	0.4
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.5	0.5	0.8
Correctable Crash Type	9 (38%)	8 (25%)	5 (100%)
Crash Severity			
Fatal	0 (0%)	0 (0%)	2 (40%)
Injury	3 (33%)	6 (75%)	3 (60%)
PDO	6 (67%)	2 (25%)	0 (0%)
At-Fault Driver			
< 21	0 (0%)	0 (0%)	1 (20%)
21 – 64	2 (22%)	1 (12%)	3 (60%)
> 64	5 (56%)	0 (0%)	1 (20%)
Unknown	2 (22%)	7 (88%)	0 (0%)
Crash Location			
Farside	1 (11%)	0 (0%)	5 (100%)
Nearside	8 (89%)	8 (100%)	0 (0%)
Unknown	0 (0%)	0 (0%)	0 (0%)
Contributing Factors			
Int Recg	0 (0%)	0 (0%)	0 (0%)
Lag Recg	9 (100%)	7 (88%)	5 (100%)
Other	0 (0%)	1 (12%)	0 (0%)

* Crashes at the candidate intersections occurred between July 1, 2001 through June 30, 2006.

♦ Crashes at the candidate intersection occurred between January 1, 2004 through December 31, 2006.

TABLE B-2
Georgia Intersection Summary

Performance Measure	GA 12 & GA 83 (#1) *	GA 21 & GA 275 (#2) ♦	GA 54 & GA 154 (#3) ♦	GA 61 and GA 140 (#4) *
Crash Frequency	26	21	21	34
Crash Severity				
Fatal	0 (0%)	0 (0%)	0 (0%)	1 (3%)
Visible Inj	3 (12%)	7 (33%)	1 (5%)	8 (24%)
Complaint Inj	6 (23%)	8 (38%)	5 (24%)	8 (24%)
PD	17 (65%)	6 (29%)	15 (71%)	17 (50%)
Daily Entering ADT	9,275	15,065	12,900	8,620
Crash Rate	1.3	1.3	1.5	1.9
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.7	0.7	0.7	0.7
Correctable Crash Type	15 (58%)	15 (71%)	10 (48%)	27 (79%)
Crash Severity				
Fatal	0 (0%)	0 (0%)	0 (0%)	1 (4%)
Visible Inj	3 (20%)	4 (27%)	1 (10%)	7 (26%)
Complaint Inj	5 (33%)	6 (40%)	3 (30%)	7 (26%)
PD	7 (47%)	5 (33%)	6 (60%)	12 (44%)
At-Fault Driver				
< 21	2 (13%)	8 (53%)	5 (50%)	4 (15%)
21 – 64	6 (40%)	6 (40%)	3 (30%)	18 (67%)
> 64	6 (40%)	1 (7%)	2 (20%)	5 (19%)
Unknown	1 (7%)	0 (0%)	0 (0%)	0 (0%)
Crash Location				
Farside	3 (20%)	10 (67%)	6 (60%)	19 (70%)
Nearside	12 (80%)	5 (33%)	4 (40%)	8 (30%)
Contributing Factors				
Int Recg	0 (0%)	1 (7%)	0 (0%)	2 (7%)
Lag Recg	14 (93%)	13 (86%)	10 (100%)	22 (81%)
Other	1 (7%)	1 (7%)	0 (0%)	3 (11%)

* Crashes at the candidate intersections occurred between January 1, 2000 through December 31, 2005.

♦ Crashes at the candidate intersections occurred between January 1, 2000 through December 31, 2002.

TABLE B-3

Iowa Intersection Summary

Performance Measure	US 30 & T-Avenue (#1) *	US 61 & Hershey Road (#2) ♦	US 151 & CR X-20 (#3) ♦	IA 163 & NE 70th Street (#4) ♦	US 218 & CR G-36 (#5) ♦	US 218 & CR C-57 (#6) ♦
Crash Frequency	14	13	11	14	13	15
Crash Severity						
Fatal	0 (0%)	2 (15%)	0 (0%)	1 (7%)	0 (0%)	1 (7%)
"A" Inj	2 (14%)	2 (15%)	2 (18%)	0 (0%)	2 (15%)	4 (27%)
"B" Inj	0 (0%)	2 (15%)	0 (0%)	7 (50%)	2 (15%)	2 (13%)
"C" Inj	3 (22%)	2 (15%)	4 (36%)	3 (21%)	4 (31%)	1 (7%)
PD	9 (64%)	5 (38%)	5 (45%)	3 (21%)	5 (38%)	7 (47%)
Daily Entering ADT	12,800	13,310	8,830	16,050	13,670	20,060
Crash Rate	1.0	0.9	1.1	0.8	0.9	0.7
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.7	0.8	1.0	0.8	0.8	0.7
Correctable Crash Type (See Sec. 5.1)	10 (71%)	11 (85%)	5 (45%)	11 (79%)	9 (69%)	11 (73%)
Crash Severity						
Fatal	0 (0%)	2 (18%)	0 (0%)	1 (9%)	0 (0%)	1 (9%)
"A" Inj	2 (20%)	2 (18%)	2 (40%)	0 (0%)	1 (11%)	4 (36%)
"B" Inj	0 (0%)	1 (9%)	0 (0%)	6 (55%)	2 (22%)	2 (18%)
"C" Inj	0 (0%)	2 (18%)	2 (40%)	2 (18%)	2 (22%)	0 (0%)
PD	8 (80%)	4 (36%)	1 (20%)	2 (18%)	4 (44%)	4 (36%)
At-Fault Driver						
< 21	1 (10%)	0 (0%)	1 (20%)	2 (18%)	0 (0%)	3 (270%)
21 – 64	4 (40%)	7 (64%)	2 (40%)	5 (45%)	8 (89%)	7 (64%)
> 64	5 (50%)	4 (36%)	2 (40%)	4 (36%)	1 (11%)	1 (9%)
Crash Location						
Farside	3 (30%)	3 (27%)	4 (80%)	7 (64%)	1 (11%)	5 (45%)
Nearside	4 (40%)	7 (64%)	0 (0%)	4 (36%)	8 (89%)	6 (55%)
Unknown	3 (30%)	1 (9%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)
Contributing Factors						
Int Recg	0 (0%)	2 (18%)	0 (0%)	2 (18%)	1 (11%)	0 (0%)
Lag Recg	10 (100%)	8 (73%)	5 (100%)	9 (82%)	7 (78%)	11 (100%)
Other	0 (0)%)	1 (9%)	0 (0%)	0 (0%)	1 (11%)	0 (0%)

* Crashes at the candidate intersection occurred between January 1, 2002 through December 31, 2004.

♦ Crashes at the candidate intersections occurred between January 1, 2001 through December 31, 2003.

TABLE B-4
Michigan Intersection Summary

Performance Measure	M-50 & Vermontville Road (#1)	M-100 & Mount Hope Highway (#2)	M-37 & Peach Ridge Avenue (#3)	M-50 & 64th Street (#4)	M-44 & Ramsdell Drive (#5)	M-20 & Vance Road (#6)
Crash Frequency	12	12	17	12	21	26
Crash Severity						
Fatal	1 (8%)	1 (8%)	1 (6%)	0 (0%)	0 (0%)	0 (0%)
“A” Inj	0 (0%)	2 (17%)	2 (12%)	3 (25%)	3 (14%)	1 (4%)
“B” Inj	3 (25%)	2 (17%)	0 (0%)	3 (25%)	1 (5%)	1 (4%)
“C” Inj	3 (25%)	2 (17%)	3 (18%)	2 (18%)	1 (5%)	4 (15%)
PD	5 (42%)	5 (42%)	11 (65%)	4 (33%)	16 (76%)	20 (77%)
Daily Entering ADT	6,925	7,115	26,875	8,090	8,730	18,700
Crash Rate	1.6	1.5	0.6	1.4	2.2	1.3
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.8	0.8	0.6	0.8	0.8	0.7
Correctable Crash Type (See Sec. 5.1)	6 (50%)	10 (83%)	15 (88%)	7 (58%)	12 (57%)	10 (38%)
Crash Severity						
Fatal	1 (17%)	1 (10%)	1 (7%)	0 (0%)	0 (0%)	0 (0%)
“A” Inj	0 (0%)	2 (20%)	2 (13%)	3 (43%)	2 (17%)	0 (0%)
“B” Inj	2 (33%)	2 (20%)	0 (0%)	1 (14%)	1 (8%)	0 (0%)
“C” Inj	2 (33%)	2 (20%)	3 (20%)	1 (14%)	1 (8%)	1 (10%)
PD	1 (17%)	3 (30%)	9 (60%)	2 (29%)	8 (67%)	9 (90%)
At-Fault Driver						
< 21	2 (33%)	2 (20%)	2 (13%)	1 (14%)	2 (17%)	1 (10%)
21 – 64	3 (50%)	5 (50%)	11 (73%)	6 (86%)	8 (67%)	3 (30%)
> 64	0 (0%)	3 (30%)	1 (7%)	0 (0%)	1 (8%)	4 (40%)
Unknown	1 (17%)	0 (0%)	1 (7%)	0 (0%)	1 (8%)	2 (20%)
Crash Location						
Farside	4 (67%)	4 (40%)	7 (47%)	0 (0%)	10 (83%)	4 (40%)
Nearside	2 (33%)	6 (60%)	8 (53%)	7 (100%)	2 (17%)	6 (60%)
Contributing Factors						
Int Recg	4 (67%)	4 (40%)	2 (13%)	0 (0%)	0 (0%)	0 (0%)
Lag Recg	1 (17%)	5 (50%)	13 (87%)	4 (57%)	12 (100%)	10 (100%)
Other	1 (17%)	1 (10%)	0 (0%)	3 (43%)	0 (0%)	0 (0%)

Note: Crashes at the candidate intersections occurred between January 1, 2001 and December 31, 2003.

TABLE B-5

Minnesota Intersection Summary

Performance Measure	US 10 & CR 43 (Big Lake, MN)	US 52 & CSAH 9 (Goodhue County)	MN 65 & 177th Avenue (Ham Lake, MN)
Crash Frequency	18	20	21
Crash Severity			
Fatal	(%)	(%)	(%)
Injury	(%)	(%)	(%)
PDO	(%)	(%)	(%)
Daily Entering ADT	11, 940	9,125	28,500
Crash Rate	0.9	1.0	0.7
Expected Rate	0.4	0.4	0.4
Critical Crash Rate	0.6	0.6	0.6
Correctable Crash Type	12 (67%)	14 (70%)	11 (52%)
Crash Severity			
Fatal	0 (0%)	0 (0%)	0 (0%)
Injury	9 (75%)	13 (93%)	7 (64%)
PDO	3 (25%)	1 (7%)	4 (36%)
At-Fault Driver			
< 21	6 (50%)	3 (21%)	2 (18%)
21 – 64	5 (42%)	8 (58%)	9 (82%)
> 64	1 (8%)	3 (21%)	0 (0%)
Unknown	0 (0%)	0 (0%)	0 (%)
Crash Location			
Farside	9 (75%)	12 (86%)	6 (55%)
Nearside	3 (25%)	2 (14%)	5 (45%)
Unknown	0 (0%)	0 (0%)	0 (0%)
Contributing Factors			
Int Recg	0 (0%)	0 (0%)	0 (0%)
Lag Recg	9 (75%)	12 (86%)	11 (100%)
Other	3 (25%)	2 (14%)	0 (0%)

Note: Crashes at the candidate intersections occurred between January 1, 2000 and December 31, 2002.

TABLE B-6

Nevada Intersection Summary

Performance Measure	US 50 & Sheckler Cutoff (Churchill County)	US 395 & Muller Lane (Douglas County)
Crash Frequency	16	15
Crash Severity		
Fatal	0 (0%)	0 (0%)
Injury	5 (31%)	2 (13%)
PDO	11 (69%)	13 (87%)
Daily Entering ADT	12,950	32,000
Crash Rate	0.7	0.3
Expected Rate	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.6	0.5
Correctable Crash Type[♦]	11 (69%)	9 (60%)
Crash Severity		
Fatal	0 (0%)	0 (0%)
Injury	5 (45%)	2 (22%)
PDO	6 (55%)	7 (78%)
At-Fault Driver		
< 21	4 (36%)	1 (11%)
21 – 64	6 (55%)	5 (56%)
> 64	1 (9%)	1 (11%)
Unknown	0 (0%)	2 (22%)
Crash Location		
Farside	0 (0%)	1 (11%)
Nearside	11 (100%)	7 (78%)
Unknown	0 (0%)	1 (11%)
Contributing Factors		
Int Recg	0 (0%)	0 (0%)
Lag Recg	9 (82%)	6 (67%)
Unknown	2 (18%)	3 (33%)

Note: Crashes at the candidate intersections occurred between January 1, 2002 and December 31, 2006.

TABLE B-7

New Hampshire Intersection Summary

Performance Measure	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Crash Frequency*	19	11	9
Crash Severity			
Fatal	0 (0%)	0 (0%)	0 (0%)
Injury	10 (53%)	5 (45%)	4 (44%)
PDO	9 (47%)	6 (55%)	5 (56%)
Daily Entering ADT	9,700	5,625	10,250
Crash Rate	1.8	1.8	0.8
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.8	0.9	0.8
Correctable Crash Type♦	10 (77%)	5 (56%)	4 (67%)
Crash Severity			
Fatal	0 (0%)	0 (0%)	0 (0%)
Injury	7 (70%)	3 (60%)	2 (50%)
PDO	3 (30%)	2 (40%)	2 (50%)
At-Fault Driver			
< 21	0 (0%)	1 (20%)	0 (00%)
21 – 64	4 (40%)	3 (60%)	3 (75%)
> 64	5 (50%)	1 (20%)	1 (25%)
Unknown	1 (10%)	0 (0%)	0 (0%)
Crash Location			
Farside	5 (50%)	3 (60%)	4 (100%)
Nearside	3 (30%)	2 (40%)	0 (0%)
Unknown	2 (20%)	0 (0%)	0 (0%)
Contributing Factors			
Int Recg	2 (20%)	1 (20%)	0 (0%)
Lag Recg	7 (70%)	3 (60%)	3 (75%)
Unknown	1 (10%)	1 (20%)	1 (25%)

* Based on crash data from January 1, 2003 through December 31, 2005

♦ Based on crash data from January 1, 2003 through December 31, 2004

TABLE B-8
North Carolina Intersection Summary

Performance Measure	US 74 and SR 2210	US 74 and SR 1574	NC 87 and SR 1150 (123)	NC 87 and SR 1700 (131)	US 74 and SR 1152
Crash Frequency	20	21	19	25	28
Crash Severity					
Fatal	2 (10%)	0 (0%)	3 (16%)	0 (0%)	1 (4%)
“A” Inj	0 (0%)	2 (10%)	0 (0%)	1 (4%)	2 (7%)
“B” Inj	7 (35%)	7 (33%)	6 (32%)	8 (32%)	10 (36%)
“C” Inj	5 (25%)	6 (29%)	6 (32%)	12 (48%)	7 (25%)
PD	6 (30%)	6 (29%)	4 (21%)	4 (16%)	8 (29%)
Entering ADT	11,150	10,400	10,000	8,000	18,800
Crash Rate	1.6	1.8	1.7	2.9	1.4
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.7	0.8	0.8	0.8	0.7
Correctable Crash Type	19 (95%)	18 (86%)	18 (95%)	22 (88%)	22 (79%)
Crash Severity					
Fatal	2 (11%)	0 (0%)	3 (17%)	0 (0%)	1 (5%)
“A” Inj	0 (0%)	2 (11%)	0 (0%)	1 (5%)	1 (5%)
“B” Inj	7 (37%)	6 (33%)	6 (33%)	8 (36%)	9 (41%)
“C” Inj	4 (21%)	6 (33%)	6 (33%)	11 (50%)	6 (27%)
PD	6 (32%)	4 (22%)	3 (17%)	2 (9%)	5 (23%)
At-Fault Driver					
< 21	3 (16%)	1 (6%)	5 (28%)	4 (18%)	3 (14%)
21 – 64	15 (79%)	15 (83%)	8 (44%)	13 (59%)	13 (59%)
> 64	1 (5%)	2 (11%)	5 (28%)	5 (23%)	4 (18%)
Crash Location					
Farside	19 (100%)	15 (83%)	15 (83%)	18 (82%)	19 (86%)
Nearside	0 (0%)	3 (17%)	3 (17%)	4 (18%)	3 (14%)
Contrb. Factors					
Int Recg	2 (11%)	1 (6%)	0 (0%)	1 (5%)	0 (0%)
Lag Recg	13 (68%)	14 (78%)	18 (100%)	19 (86%)	21 (95%)
Unknown	4 (21%)	3 (17%)	0 (0%)	2 (9%)	1 (5%)

Note: Crashes at the candidate intersections occurred between January 1, 2001 and December 31, 2003.

TABLE B-9

Wisconsin Intersection Summary

Performance Measure	CTH V Barron County	CTH B Washburn County	CTH E Washburn County	U.S. 63 (N. Jct.) Washburn County	STH 77 Washburn County	CTH B Douglas County
Crash Frequency	23	22	30	19	30	20
Crash Severity						
Fatal	4 (17%)	3 (14%)	0 (0%)	3 (16%)	5 (17%)	3 (15%)
Injury	15 (65%)	13 (59%)	18 (60%)	6 (32%)	15 (50%)	10 (50%)
PD	4 (17%)	6 (27%)	12 (40%)	10 (53%)	10 (33%)	7 (35%)
Daily Entering ADT	10,570	10,720	9,000	10,400	6,800	7,700
Crash Rate	0.9	0.9	1.4	0.8	1.9	1.1
Expected Rate	0.3	0.3	0.3	0.3	0.3	0.3
Critical Crash Rate	0.5	0.5	0.5	0.5	0.6	0.5
Correctable Crash Type	22 (96%)	19 (86%)	20 (67%)	11 (58%)	22 (73%)	15 (75%)
Crash Severity						
Fatal	4 (18%)	3 (16%)	0 (0%)	3 (27%)	5 (23%)	3 (20%)
Injury	15 (68%)	12 (63%)	14 (70%)	3 (27%)	11 (50%)	8 (53%)
PD	3 (14%)	4 (21%)	6 (30%)	5 (45%)	6 (27%)	4 (27%)
At-Fault Driver						
< 21	1 (5%)	2 (11%)	3 (16%)	3 (27%)	1 (5%)	8 (53%)
21 – 64	12 (55%)	13 (68%)	8 (42%)	5 (45%)	9 (43%)	6 (40%)
> 64	9 (41%)	4 (21%)	8 (42%)	3 (27%)	11 (52%)	1 (7%)
Crash Location						
Farside	16 (73%)	15 (79%)	7 (35%)	3 (27%)	12 (55%)	13 (87%)
Nearside	6 (27%)	4 (21%)	13 (65%)	8 (73%)	10 (45%)	2 (13%)
Contributing Factors						
Int Recg	1 (5%)	0 (0%)	0 (0%)	3 (27%)	0 (0%)	0 (0%)
Lag Recg	20 (91%)	19 (100%)	17 (85%)	7 (64%)	17 (77%)	15 (100%)
Unknown	1 (5%)	0 (0%)	3 (15%)	1 (9%)	5 (23%)	0 (0%)

Note: Crashes at the candidate intersections occurred between January 1, 1998 and June 30, 2004.