



# RESEARCH

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

Report #4 in the Series: Toward a Multi-State  
Consensus on Rural Intersection Decision Support

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

Report #4 in the Series: Toward a Multi-State Consensus on  
Rural Intersection Decision Support

**Final Report**

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

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## **Executive Summary**

The objective of the Intersection Decision Support (IDS) research project, sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), 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 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 system 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.

Based on the Minnesota crash analysis, one intersection was identified for instrumentation (collection of driver behavior information) and the IDS system is under development. Also underway, alternative Driver Infrastructure Interfaces (DII) designs are being tested in a driving simulator at the University of Minnesota.

In order 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 initiated a State 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 facet of this pooled fund project is a review of intersection crash data from each participating state, applying methods developed in previous IDS research. The crash data will be used to understand rural intersection crashes on a national basis, and to identify candidate intersections for subsequent instrumentation and study. The second facet is a participatory design process to design and refine candidate intersection Driver Infrastructure Interfaces. The third facet is to instrument candidate intersections in participating states, as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. States choosing to instrument intersections will be well positioned to reap the benefits of the new Cooperative Intersection Collision Avoidance System (CICAS) research funded by the United States Department of Transportation (USDOT). The CICAS Stop Sign Assist Program will investigate the human factors and technical considerations associated with the proposed IDS approach used to communicate with the driver at the intersection. A planned Field Operational Test will be designed to evaluate the performance of these systems.

### **Review of Iowa's Intersections**

This report documents the initial phase of the pooled fund study for the State of Iowa. The crash analysis focused on thru-STOP intersections of rural four-lane highways throughout Iowa. The Iowa Department of Transportation (IaDOT) used crash data from January 1, 2001 through

December 31, 2003 and from January 1, 2002 through December 31, 2004, to identify 20 potential intersections for further review. A statistical model developed by Iowa State University's Center for Transportation Research and Education (ISU CTRE) was used to determine if the severity rate at the twenty intersections is greater than what would be expected. From the list of twenty intersections, the research team selected the six intersections with the highest number of crossing path crashes. The six intersections that best fit these criteria were:

- US 30 & T Avenue
- US 61 & Hershey Road
- US 151 & CR X-20
- IA 163 & NE 70<sup>th</sup> Street
- US 218 & CR G-36
- US 218 & CR C-57

Field visits in April 2005 and May 2006 revealed that the IaDOT had deployed a wide variety of strategies at each intersection, including some or all of the following: STOP AHEAD sign, second STOP sign placed on left side of roadway, intersection lighting, overhead red-yellow flashers, splitter islands, STOP sign flasher, and multiple STOP signs. However, all of these strategies are most effective at addressing crashes in which the driver fails to recognize he/she is approaching the intersection and runs the STOP sign, but provide the driver with no assistance in gap recognition and selection.

Looking at the crash data, these strategies did prove effective at reducing run-the-STOP crashes since there were few of these crash types. Instead, the crossing path crashes at the six candidate intersections were predominately associated with a driver's poor gap identification and selection.

Using the crash factors of at-fault driver age, crash severity, contributing factors associated with the driver, along with several other factors, the intersection selected as the overall best candidate for test deployment of the IDS system was US 30 & T Avenue. Several candidate intersections were ruled out for further consideration because safety improvements were already programmed to occur within the next ten years. Based on the remaining intersections, US 30 & T Avenue had the highest number of correctable crashes, the highest number of gap recognition crashes, and the highest number of crashes involving older at-fault drivers.

# 1. Project Background

The objective of the Intersection Decision Support (IDS) research project, sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), 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 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 (1,2,3). Consequently, the design of the rural IDS system 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.

Based on the Minnesota crash analysis, one intersection was identified for instrumentation (collection of driver behavior information) and the IDS system under development. Also underway, alternative Driver Infrastructure Interface (DII) designs are being tested in a driving simulator at the University of Minnesota.

In order 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 initiated a State Pooled Fund study, in which nine states are cooperating on intersection-crash research. The participating states are:

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The first facet of this pooled fund project is a review of intersection crash data from each participating state, applying methods developed in previous IDS research. The crash data will be used to understand rural intersection crashes on a national basis, and to identify candidate intersections for subsequent instrumentation and study. The second facet is a participatory design process to design and refine candidate intersection Driver Infrastructure Interfaces. The third facet is to instrument candidate intersections in participating states, as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. States choosing to instrument intersections will be well positioned to reap the benefits of the new Cooperative Intersection Collision Avoidance System (CICAS) research funded by the United States Department of Transportation (USDOT). The CICAS Stop Sign Assist Program will investigate the human factors and technical considerations associated with the proposed IDS approach used to communicate with the driver at the intersection. A planned Field Operational Test will be designed to evaluate the performance of these systems.

This report documents the initial phase of the pool fund study for the State of Iowa. Following is a description of the crash analysis performed for Iowa and a recommendation of an intersection for design of an IDS system for possible deployment.

## 1.1. Typical Countermeasures for Rural Intersections

A typical 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 gap in the major street traffic stream.

Traditional safety countermeasures deployed at rural high crash intersections include:

- Upgrading traffic control devices
  - Larger STOP signs
  - Multiple STOP signs
  - Advance warning signs and pavement markings
- Minor geometric improvements
  - Free right turn islands
  - Center splitter islands
  - Off-set right turn lanes
- Installing supplementary devices
  - Flashing beacons mounted on the STOP signs
  - Overhead flashing beacons
  - Street lighting
  - Transverse rumble strips

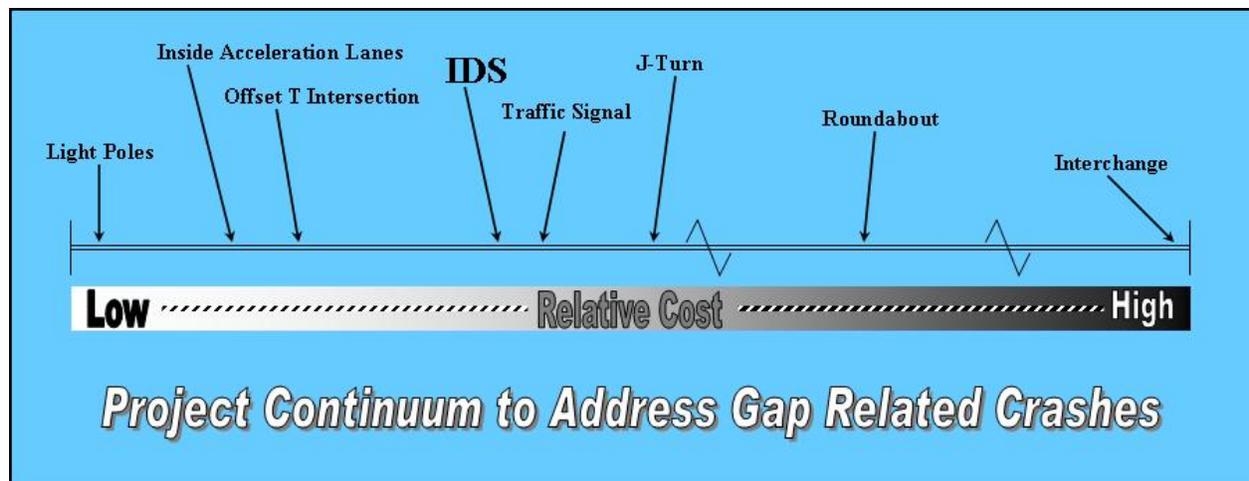
All of these countermeasures are relatively low cost and easy to deploy, but are typically designed to assist drivers with intersection recognition and have not exhibited an ability to address gap recognition problems. Yet, up to 80% of crossing path crashes are related to selection of an insufficient gap (1). In addition, a Minnesota study of rural thru-STOP intersections for rural two-lane roadways found only one-quarter 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 (2). At the same set of intersections, 56% of the right angle crashes were related to selecting an unsafe gap while 17% were classified as other or unknown.

The concept of gap 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 gap 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 1-1** illustrates the range of strategies currently available to address safety deficiencies associated with gap 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 gaps
- 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 (4).)

The use of these strategies may not be appropriate, warranted or effective in all situations. Also, the construction cost or right of way may prove to be prohibitive at some locations. All of this combined with a recommendation in AASHTO’s Strategic Highway Safety Plan to investigate the use of technology to address rural intersection safety led to the on-going research to develop a cost-effective Intersection Decision Support (IDS) system, including a new driver interface. The IDS system is intended to be a relatively low cost strategy (similar to the cost of a traffic signal), but at the same time is technologically advanced, using roadside sensors and computers to track vehicles on the major road approaches, computers to process the tracking data and measure available gaps and then using the driver interface to provide minor road traffic with real-time information.



**FIGURE 1-1**  
Gap Selection Related Safety Strategies

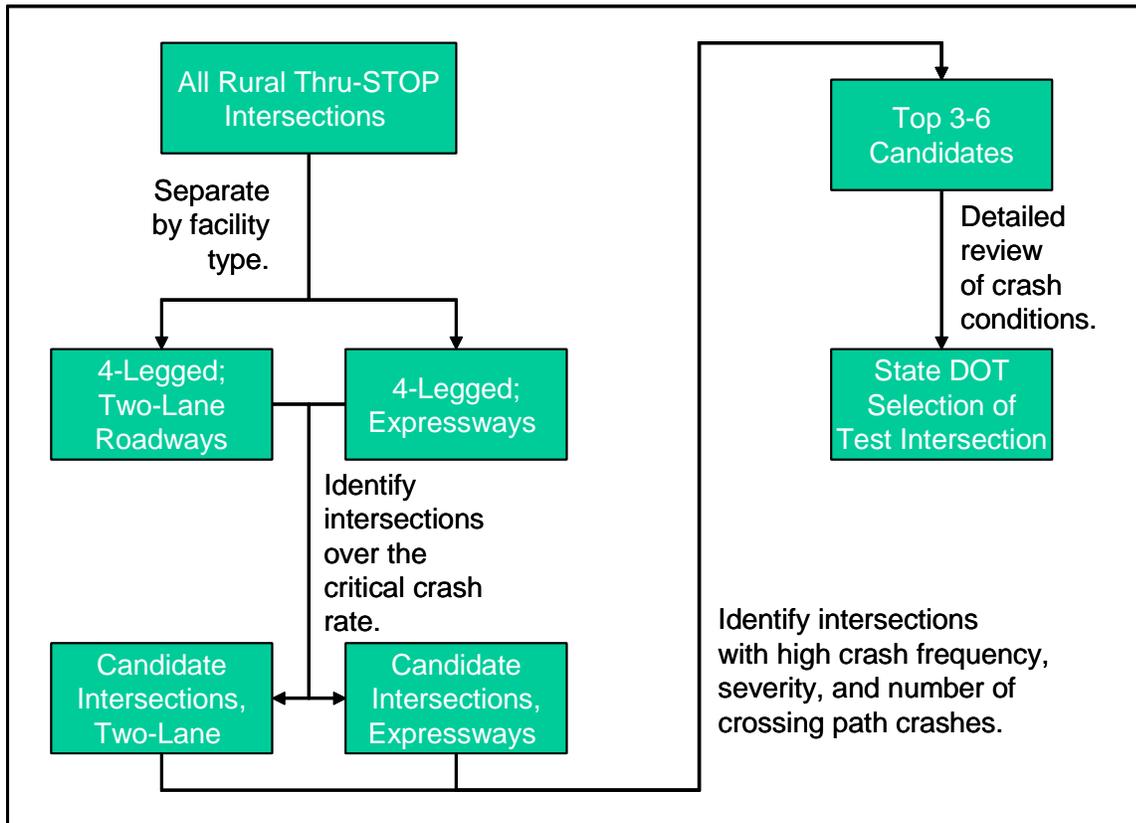
## 2. Crash Analysis Methods for Candidate Intersection Identification and Identification of Top 6 Candidate Intersections

A comprehensive method for intersection identification was developed using Minnesota's crash record system (see **Figure 2-1**). The method was applied to all rural, thru-STOP intersections in Minnesota, as this is the most frequent intersection situation in Minnesota. This intersection type is also the most likely where a driver will have to judge and select a gap at a rural intersection (i.e., stopped vehicle on the minor approach). The approach to identify the intersection selected for a potential field test of the technology used the three screening steps described in the following:

- **Critical Crash Rate** – The first screen was to identify the rural thru-STOP intersections that have a crash rate greater than the critical crash rate. The critical crash rate is a statistically significant rate higher than the statewide intersection crash rate. Therefore, any intersection with a crash rate equal to or above the critical crash rate can be identified as an intersection with a crash problem due to an existing safety deficiency.
- **Number and Severity of Correctable Crashes** – Once the intersections meeting the first criteria were identified, this second screen was performed to identify intersections where a relatively high number and percentage of crashes were potentially correctable by the IDS system being developed. In Minnesota's crash record system, "right angle" crashes were the crash type most often related to poor gap selection. Therefore the ideal candidate intersections had a high number & percentage of right angle collisions and tended to have more severe crashes. This screen was used to identify the top three candidate intersections for the final screen.
- **Crash Conditions and At-Fault Driver Characteristics** – The IDS system is believed to have the greatest benefit for older drivers. 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 gap recognition and the crash location (near lanes or far lanes).

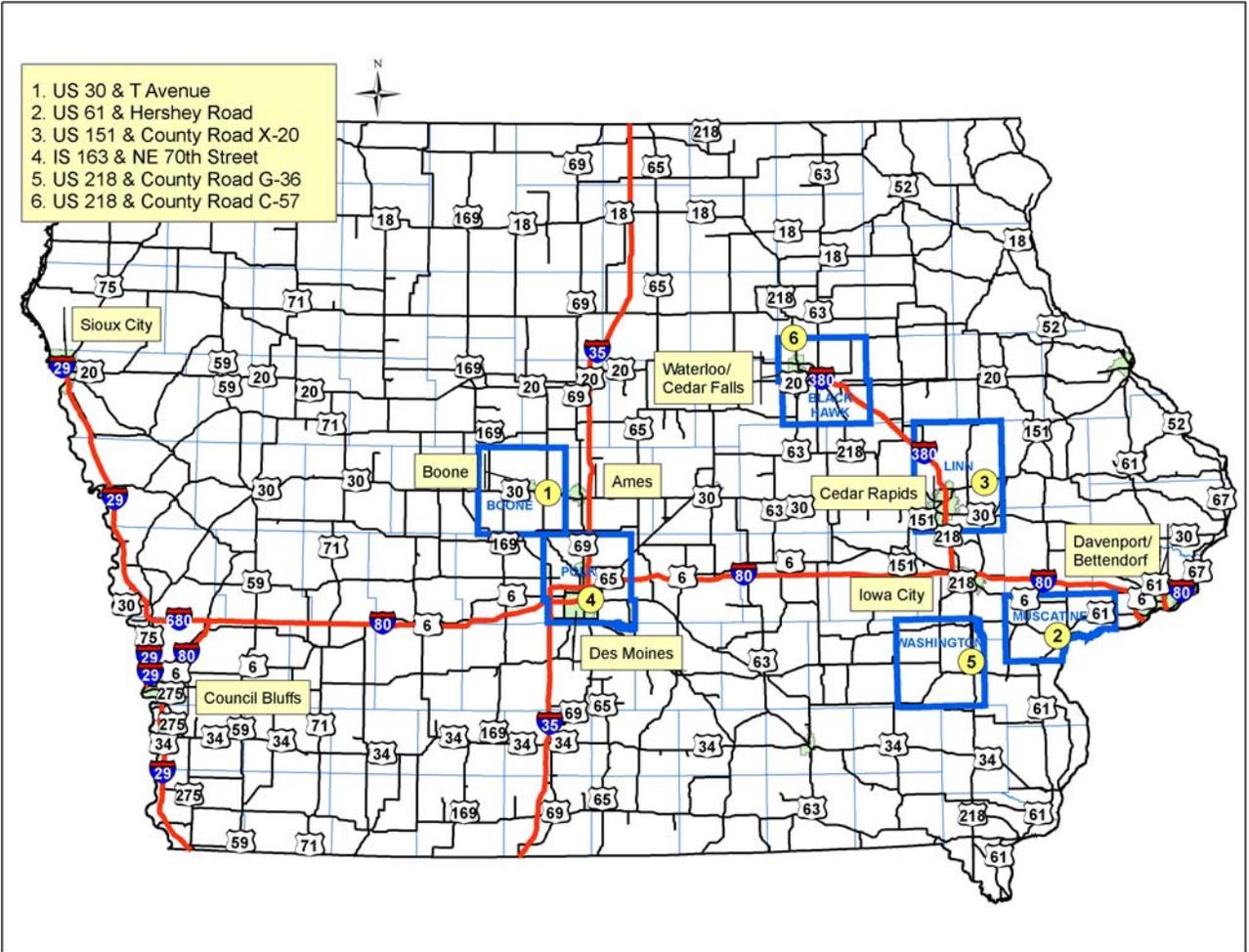
In Iowa, application of the preferred process was not used because Iowa State University had already developed a statistical model to estimate the expected crash severity index for Iowa's rural, expressway intersections (4). Rather than using the methodology developed in Minnesota, the decision was made to remain consistent with the Iowa Department of Transportation's (IaDOT) current practices and use the Iowa State University statistical method for selecting intersections. Using the Iowa Statistical Model, the top 20 locations were selected where the difference between the actual and expected severity index was the greatest. From these locations, six intersections with the greatest number of failure to yield crashes were selected. The six intersections that best fit these criteria were:

1. US 30 & T Avenue
2. US 61 & Hershey Road
3. US 151 & CR X-20
4. IA 163 & NE 70<sup>th</sup> Street
5. US 218 & CR G-36
6. US 218 & CR C-57



**FIGURE 2-1**  
Preferred Crash Analysis Process

The locations of these six intersections are shown in **Figure 2-2**. Similar to Minnesota, North Carolina, and Wisconsin, all of the candidate intersections are located on rural expressways. However, many of the locations were a few miles outside of a major urban area, so in a few instances the area may be described as suburban. During the field review, it also appeared that several intersections experienced heavy commuter traffic, likely people working in the urban areas but who live in nearby bedroom communities.



**FIGURE 2-2**  
 Candidate Intersection Locations

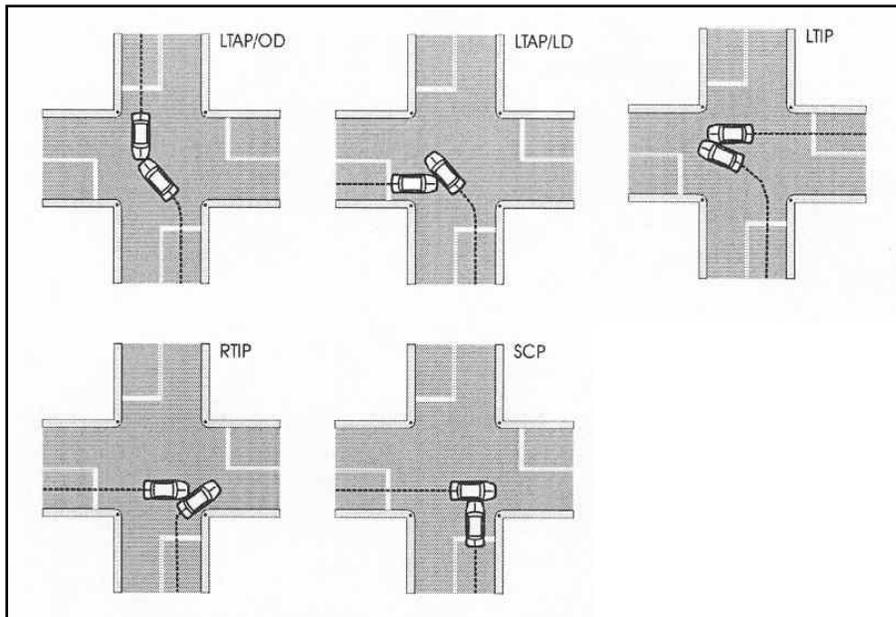
### 3. Crash Record Review of Candidate Intersections

It was already known that the candidate intersections had high crash rates, high crash frequencies, and a high number of angle crashes, but the decision was made to investigate each intersection further for specific information pertinent to the IDS system and also to learn of any unusual circumstances at the intersections. At the candidate intersections, the factors reviewed included at-fault driver age, crash severity, crash location, contributing factors, and the effects of weather. For all of these summaries, the focus is on correctable crossing path crashes only (see following section for definition), which are the crash types that have the greatest potential to be corrected by the IDS device.

#### 3.1. Correctable 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 3-1**), 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 3-1**  
GES Crossing Path Crash Types

At this time, the IDS system under development is intended to address the crash types involving at least one vehicle from the major and minor street, 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 expected to be a relatively small problem. However, it is

believed the system could be adapted to address LTAP/OD crashes if an intersection had a significant number of these crashes. For example, LTAP/OD crashes involving two vehicles from the minor street may be reduced if the device is designed to detect potential conflicts with vehicles from the opposing approach.

At the candidate intersections, the number and percent of correctable crashes is summarized in **Table 3-1**. As listed in **Table 3-1**, approximately 50% or more of the crashes at the six identified intersections are potentially correctable. The intersections of US 61 & Hershey Road (#2); IA 163 & NE 70<sup>th</sup> Street (#4); and US 218 and CR C-56 (#6) had the most correctable crashes during the study period, each with 11 crashes.

**TABLE 3-1**  
Potential Correctable Crashes for IDS System at Candidate Intersections

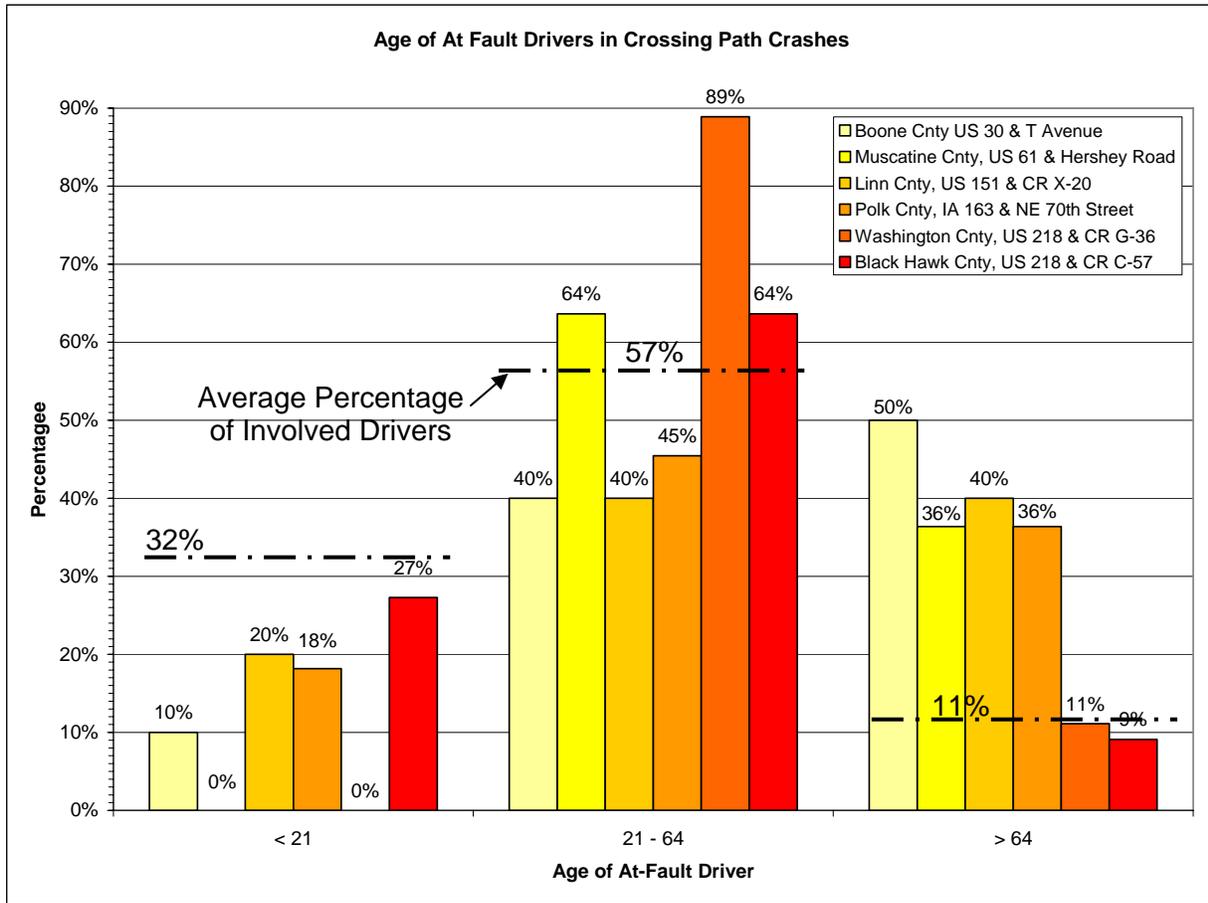
	US 30 & T-Avenue (#1)	US 61 & Hershey Road (#2)	US 151 & CR X-20 (#3)	IA 163 & NE 70 <sup>th</sup> Street (#4)	US 218 & CR G-36 (#5)	US 218 & CR C-57 (#6)
Number of Crashes	14	13	11	14	13	15
Number of Correctable Crashes	10	11	5	11	9	11
Percent of Crashes that are Correctable	71%	85%	45%	79%	69%	73%

NOTE: Correctable crashes have been defined as SCP, LTAP/LD, LTIP, and RTIP.

### 3.2. At-Fault Drivers

Crash reports from for the US 30 and T Avenue (#1) intersection are from January 1, 2002 to December 31, 2004; the crash data for the other five candidate intersections (#2-#6) is from January 1, 2001 to December 31, 2003. This data was reviewed to identify the driver whose action caused the accident, also known as the at-fault driver. The age of the at-fault driver is important since the IDS system may have its greatest benefit in assisting older drivers (see **Figure 3-2**). From the 2000 Iowa Crash Facts, 32% of involved drivers were under the age of 24, 57% between the age of 25 and 64, and 11% over the age of 64. Iowa Crash Facts lists involved drivers and not specifically at-fault drivers. Because of the differences between involved drivers and at-fault drivers, comparisons between statewide involvement rates and the at-fault age distributions at the six candidate intersections must be carefully considered.

Based on the statewide age distributions, the intersections of US 30 & T Avenue (#1), US 61 & Hershey Avenue (#2), US 151 and CR X-20 (#3), and US 163 and NE 70<sup>th</sup> (#4) have an older driver involvement rate considerably above the expected value (see **Figure 3-2**). The involvement of older drivers at the intersections of US 218 with CR G-36 (#5) and CR C-57 (#6) are close to the expected percentage. Young drivers were not overly represented at any of the intersections.



**FIGURE 3-2**

**At-Fault Driver Age of Correctable Crash Types at Candidate Intersections**

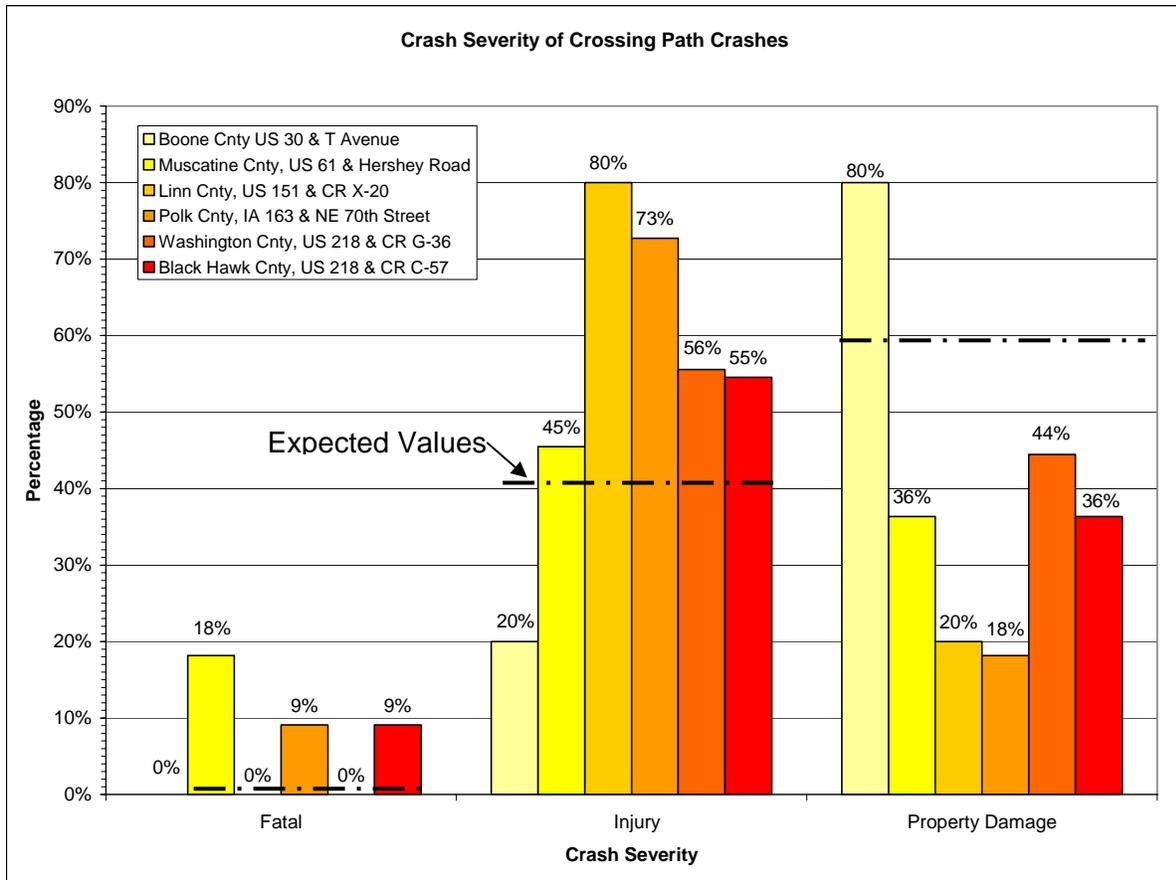
Source: Expected values based on involved driver age of all crashes reported in 2000 Iowa Crash Facts

Note: The Iowa Crash Facts included drivers 24 years and under as young drivers. The Average Percentage of Involved Drivers (the dashed line) shown above in the < 21 set of crashes includes drivers up to age 24. The average percentage of involved drivers (represented by the dashed line) for the 21-64 year age range includes drivers 25-64. Instead of changing the age ranges of at-fault drivers at the candidate intersections to match the Iowa Crash Facts, they were left as is to be consistent with the analysis performed at other IDS Pooled Fund states.

**3.3. Crash Severity**

Another goal of the IDS system is to address the most serious intersections crashes, especially fatal crashes. Therefore, the candidate intersection to be considered should have a high distribution of fatal and injury crashes. The 2000 Iowa Crash Facts shows that fatal crashes represent approximately 0.6% of all of crashes, with injury crashes at 39.6% and property damage (PD) crashes representing 59.8% of all crashes. **Figure 4-3** shows that the US 61 & Hershey Road intersection (#2) had the highest percentage of fatal crashes (18%); while the intersections at IA 163 & NE 70<sup>th</sup> Street (#4) and US 218 & CR C-57 (#6) also had a higher than expected percentage of fatal crashes (both at 9%). No fatal crashes had occurred at the other three intersections. A higher than expected percentage of injury crashes occurred at the candidate intersections, with the exception of the intersection US 30 & T Avenue (#1). US 61 & Hershey

Road (#2) (at 80%) and US 151 & CR X-20 (#3) (at 73%) had the highest percentage of injury crashes. The percentage of injury crashes at US 30 & T Avenue (#1) was only 20%, which is much lower than expected.



**FIGURE 3-3**  
Crash Severity of Correctable Crash Types at Candidate Intersections

NOTE: Expected values based on crash severity of all crashes reported in 2003 Michigan Traffic Crash Facts

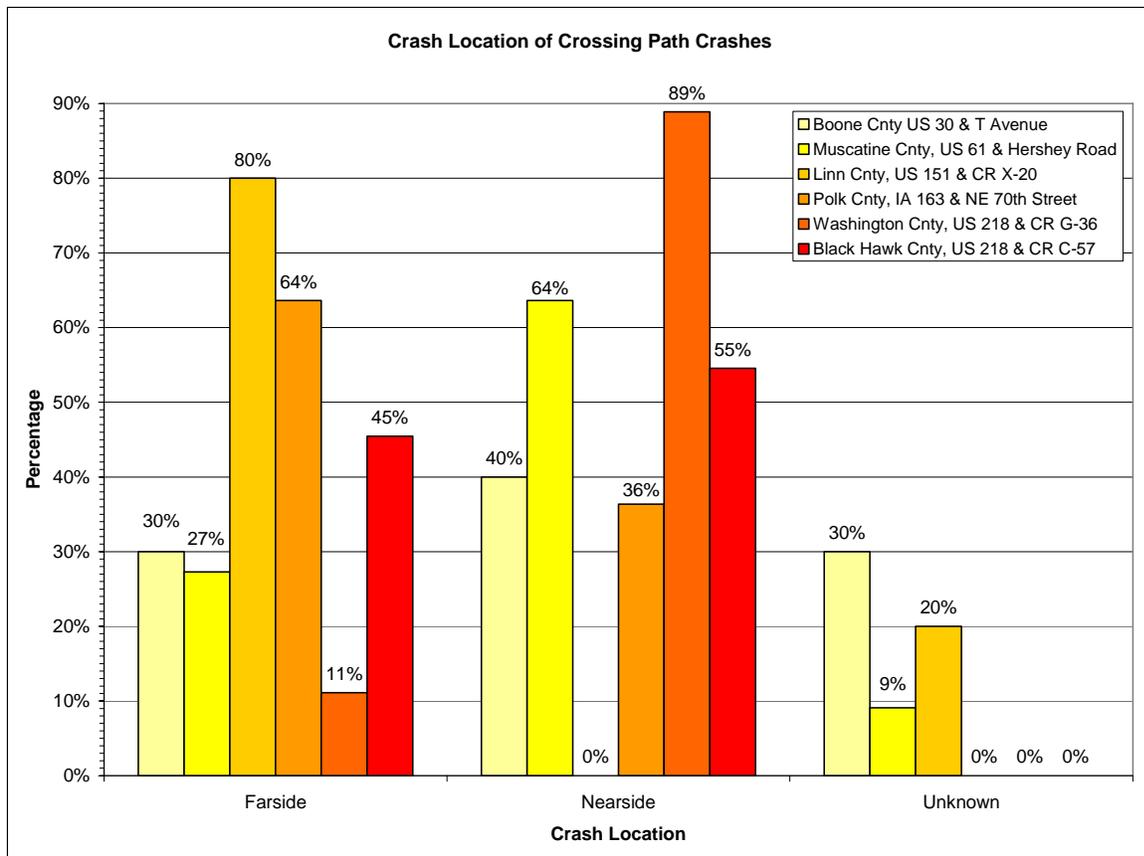
### 3.4. Crash Location and Contributing Factors

From the initial review of Minnesota’s crash records (3), it was observed that crossing path crashes at the candidate intersections were predominately on the far side of the intersection. [NOTE: For the divided expressway in Minnesota, a far-side crash occurs when the stopped 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. However, it was speculated that drivers used a one-step process for crossing rather than a two-step process. When a driver enters the median, rather than stopping to reevaluate whether the gap is still safe (a two-step process), it is believed that drivers simply proceed into the far lanes without stopping (a one-step process). At the selected intersection in Minnesota (U.S. 52 and Goodhue County 9), vehicle detection equipment has already been installed along with video cameras. The information recorded at the intersection will be used to quantify how drivers typically cross this

and similar intersections. Even though it is still unknown how this may affect the device’s final design, the decision was made to still document this crash characteristic.

For the pooled fund study to date, rural expressway intersections in North Carolina and Wisconsin have been reviewed. At the candidate intersections in these states, the pattern was similar to what was observed in Minnesota with a majority of crossing path crashes occurring in the far lanes.

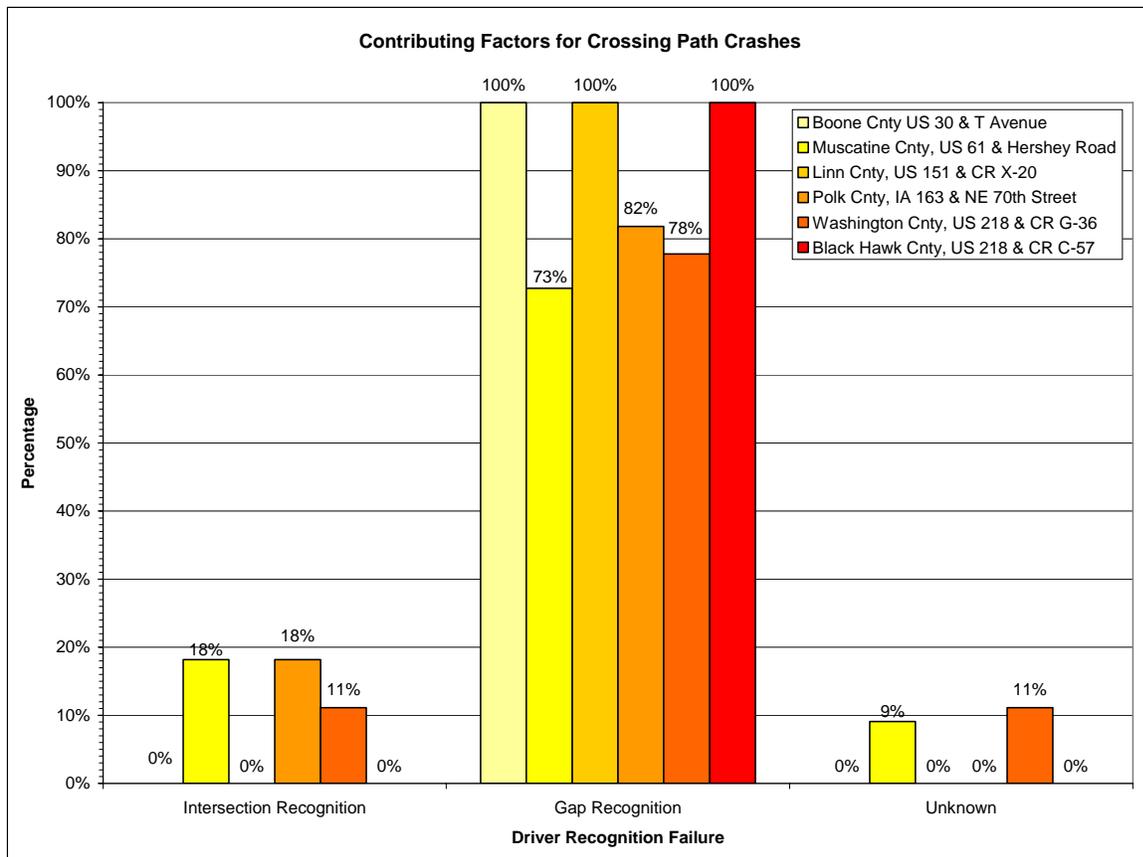
At the Iowa candidate intersections (see **Figure 3-4**), two sites had a majority of the crossing path crashes on the farside (US 151 & CR X-20 (#3) with 80% and IA 163 & NE 70<sup>th</sup> Street (#4) with 64%). Intersections #1, #2, and #5 had more nearside crashes than farside crashes. However, at US 30 & T Avenue, 30% of the crash locations could not be determined from the crash record summary. The US 218 & CR C-57 intersection (#6) had a nearly equal split between farside and nearside crashes, with slightly more nearside crashes.



**FIGURE 3-4**  
Crash Location of Correctable Crash Types at Candidate Intersections

Another important crash characteristic is whether the at-fault driver failed to recognize the intersection (i.e., ran-the-STOP) or failed to select a safe gap (i.e., stopped, pulled out). Since the IDS device is intended to help drivers with selecting safe gaps, crashes where the driver ran-the-STOP may not be correctable. The IADOT’s crash database was examined in order to classify the crashes as either intersection recognition or gap recognition. One hundred percent of the crossing path crashes were gap recognition crashes at the intersections of US 30 & T Avenue

(#1), US 151 & CR X-20 (#3), and US 218 & CR C-57 (#6) (see **Figure 3-5**). The majority (between 73 % and 82%) of crossing path crashes at the other three intersections were also gap recognition crashes.



**FIGURE 3-5**  
Contributing Factors of Correctable Crash Types at Candidate Intersections

### 3.5. Effect of Weather, Road Condition, and Light Condition

The final factors reviewed for the crossing path crashes at each candidate intersection were the weather, road, and light conditions. If the crashes tended to occur during adverse weather conditions (i.e., snow, rain, dark), then deployment of a new technology may have a limited benefit unless it can be coordinated with a local Road Weather Information System (RWIS) station.

As shown below in **Table 3-2**, the percentage of crashes occurring during “good” weather (i.e., clear or cloudy weather) at all six candidate intersections crashes was higher than expected. US 61 & Hershey Road (#2) was the only intersection that had a slightly higher than expected distribution of crashes during poor weather, with 9% of crashes at this intersection occurring during rain (expected = 5%).

**Table 3-3** shows the percentage distribution of crashes based on roadway surface conditions. All six candidate intersections had a higher percentage of crashes on dry roads than the expected and a lower percentage of crashes on snowy or icy roads than expected. Between 80% and 100% of

the crashes on the candidate intersections occurred on dry roads (54% expected). Two candidate intersections had a higher than expected percentage (12%) of crashes occurring on wet pavement. Twenty percent of the crashes at US 30 & T Avenue occurred on wet pavement; 18% of the crashes at US 61 & Hershey Road occurred on wet pavement. None of the crashes reported at the six candidate intersections occurred on snowy or icy pavement.

**TABLE 3-2**

Weather Condition Distribution for Crossing Path Crashes at Candidate Intersections

	Expected	US 30 & T-Avenue (#1)	US 61 & Hershey Road (#2)	US 151 & CR X-20 (#3)	IA 163 & NE 70 <sup>th</sup> Street (#4)	US 218 & CR G-36 (#5)	US 218 & CR C-57 (#6)
Clear or Cloudy	74%	100%	91%	80%	100%	100%	91%
Rain	5%	0%	9%	0%	0%	0%	0%
Snow or Sleet	8%	0%	0%	0%	0%	0%	0%
Other/Unknown	13%	0%	0%	20%	0%	0%	9%

NOTE: Expected values based on all crashes reported in 2000 Iowa Crash Facts

**TABLE 3-3**

Roadway Surface Condition Distribution for Crossing Path Crashes at Candidate Intersections

	Expected	US 30 & T-Avenue (#1)	US 61 & Hershey Road (#2)	US 151 & CR X-20 (#3)	IA 163 & NE 70 <sup>th</sup> Street (#4)	US 218 & CR G-36 (#5)	US 218 & CR C-57 (#6)
Dry	54%	80%	82%	100%	91%	89%	82%
Wet	12%	20%	18%	0%	9%	11%	9%
Snow or Ice	20%	0%	0%	0%	0%	0%	0%
Other/Unknown	14%	0%	0%	0%	0%	0%	9%

NOTE: Expected values based on all crashes reported in 2000 Iowa Crash Facts

The percentage of crashes reported during daylight conditions at all six intersections was above the expected distribution (see **Table 3-4**). Further, none of the intersections had a higher than expected number of crashes that occurred during dark conditions. The only noticeable discrepancy was that 9% of the crossing path crashes at US 61 & Hershey Road (#2) and US 218 & CR C-57 (#6) occurred either at dawn or at dusk, compared to 5% expected.

**TABLE 3-4****Light Condition Distribution for Crossing Path Crashes at Candidate Intersections**

	<b>Expected</b>	<b>US 30 &amp; T-Avenue (#1)</b>	<b>US 61 &amp; Hershey Road (#2)</b>	<b>US 151 &amp; CR X-20 (#3)</b>	<b>IA 163 &amp; NE 70<sup>th</sup> Street (#4)</b>	<b>US 218 &amp; CR G-36 (#5)</b>	<b>US 218 &amp; CR C-57 (#6)</b>
Daylight	65%	90%	73%	100%	73%	100%	91%
Dawn or Dusk	5%	0%	9%	0%	0%	0%	9%
Dark	29%	10%	18%	0%	18%	0%	0%
Other/ Unknown	1%	0%	0%	0%	9%	0%	0%

NOTE: Expected values based on all crashes reported in 2000 Iowa Crash Facts

## 4. Field Review

Field reviews of five candidate intersections (#2-#6) were performed in April 2005. A field review of intersection US 30 & T Avenue (#1) was completed in May 2006. Some of the general observations made during the field reviews include:

- The typical minor street approach (stopped approach) was improved with some device to increase driver awareness (e.g., splitter islands, overhead red/yellow flashers, STOP AHEAD sign, STOP sign flashers, a second STOP sign (posted on the left side of the road), or an overhead flasher). All of these treatments are aimed at addressing intersection recognition, rather than gap recognition
- Lighting is installed at the intersections, which means that power is readily available to operate an IDS system.
- The intersection sight distance was typically at or above the recommended values.
- On the stopped approaches, if a channelized right turn lane was provided, a supplemental STOP sign was placed on the outside of the turn lane.

Following is a brief description of each of the intersections. For each intersection, crash diagrams are included in **Appendix A** and aerial photos are in **Appendix B**.

### 4.1. US 30 & T Avenue (#1)

US 30 is a typical four-lane expressway located in a rural area of Boone County. T Avenue approaches from the north, while the south leg of the intersection is a gravel road to provide access for residents. The intersection's most notable characteristic is that the intersection is located on a curve (see **Figures 4-1 & 4-2** as well as **Figure B-1** in **Appendix B**), which creates complications for drivers stopped on the minor street (T Avenue) looking for vehicles approaching from both directions on US 30.



**FIGURE 4-1**  
Looking East When Stopped on T Avenue.



**FIGURE 4-2**  
Looking West When Stopped on T Avenue

**Figure 4-1** also shows an offset right turn lane from westbound US 30 to northbound T Avenue. The offset right turn lane was likely constructed to allow for an easier right turn while

negotiating the curve, but it also provides the added benefit of removing turning vehicles out of the line of sight for a driver that stops when trying to cross or turn onto US 30. The intersection median has a stop bar and centerline striping added (see **Figure 4-3**) along with the typical YIELD sign (not shown in **Figure 4-3**). The southbound approach of T Avenue has an oversized STOP sign with a STOP sign mounted red flasher (see **Figure 4-4**). It was also noted that lighting had been installed in two quadrants of the intersection (SW quadrant lighting visible in **Figure 4-4**).



**FIGURE 4-3**  
Median Design at US 30 and T Avenue (YIELD sign not shown).



**FIGURE 4-4**  
T Avenue Southbound Approach to US 30

#### 4.2. US 61 & Hershey Road (#2)

US 61 and Hershey Road is located near city of Muscatine. The intersection is located on a vertical grade, just south of a crest curve, which is also combined with a horizontal curve (see **Figure 4-5**). Despite this, the available sight distance still meets guidelines. Other improvements to the intersection include offset right turn lanes (**Figure 4-5**), intersection ahead warning signs on US 61 (**Figure 4-6**), and street lighting. Improvements for the Hershey road approaches include STOP AHEAD signs, overhead red/yellow flashers (**Figure 4-7**), and CROSS TRAFFIC DOES NOT STOP signs mounted below STOP signs (**Figure 4-7**). Finally, the intersection has a narrow width median, such that a vehicle would likely have troubles safely waiting in the median for a safe gap. Therefore, a one-step maneuver to cross the intersection is more likely to be used by drivers.

#### 4.3. US 151 & CR X-20 (#3)

US 151 & CR X-20 is located to the east of the Cedar Rapids area. The intersection occurs along a horizontal curve and also at the top of a crest curve, but sufficient sight distance is provided at the intersection (see **Figure 4-8**). Safety improvements at this intersection include a light in the northeast quadrant (**Figure 4-9**), STOP AHEAD signs, and multiple STOP signs (see **Figure 4-8**). The intersection was located close enough to Cedar Rapids that during the evening commute, traffic demand would be high enough such that multiple vehicles would be in the median (**Figure 4-10**).



**FIGURE 4-5**  
Crest Vertical and Horizontal  
Curve to the North of Hershey  
Road (Looking North from  
West Approach of Hershey  
Road).



**FIGURE 4-6**  
Intersection Ahead  
Warning on US 61.



**FIGURE 4-7**  
West Hershey Road  
Approach



**FIGURE 4-8**  
Looking East at US 151 from North Approach of CR X-20. (Note the large radius horizontal and vertical curves. )



**FIGURE 4-9**  
Looking North from CR X-20 at US 151 Intersection.



**FIGURE 4-10**  
Looking North at Traffic Negotiating Crossing at US 151 and CR X-20.

#### 4.4. IA 163 & NE 70<sup>th</sup> Street (#4)

The intersection of IA 163 and NE 70<sup>th</sup> Street is east of the Des Moines metro area. The area could be described as suburban, especially since a signalized intersection is within one mile on both direction of IA 163. Similar to other intersections reviewed, this location is close to a crest vertical (**Figure 4-11**) curve, but sight distance requirements are still met.

Other noted improvements included intersection lighting in all four quadrants of the intersections, STOP AHEAD signs, oversized STOP and YIELD signs (**Figure 4-12**), and a splitter island on one of the minor street approaches (**Figure 4-3**).



**FIGURE 4-11**  
Looking East (left) and West (right) from North Approach of NE 70<sup>th</sup> Street.



**FIGURE 4-12**  
Looking North at Vehicles Crossing IA 163.



**FIGURE 4-13**  
Southbound Approach of NE 70<sup>th</sup> Street. (Note the median on NE 70<sup>th</sup> Street and general sign clutter.)

#### 4.5. US 218 & County Road G-36 (#5)

US 218 & CR G-36 was the only location that was an isolated rural intersection. On the west approach of CR G-36, a small park-n-ride lot has been provided (see **Figure 4-14**). Other safety improvements at the intersection included STOP AHEAD signs on the county road approaches and lighting in all four quadrants of the intersection.



**FIGURE 4-14**

Park-n-Ride Lot at US 218 and CR G-36.

As typically seen during the field reviews, the intersection had adequate sight distance despite being between two crest vertical curves (**Figure 4-15**).



**FIGURE 4-15**

Looking North (left) and South (right) from West Approach of CR G-36.

#### 4.6. US 218 & County Road C-57 (#6)

US 218 & CR C-57 is located north of Cedar Falls. Along this portion of US 218, an active railroad line is parallel to and approximately 100 feet from the edge of the highway. This creates an at-grade crossing on CR C-57 very close to the intersection (**Figure 4-16**). At this location, several safety improvements have been put into place, including: oversized STOP sign, red flasher mounted on the STOP sign, CROSS TRAFFIC DOES NOT STOP sign mounted below the STOP sign, STOP AHEAD signs, and intersection lighting (most countermeasures visible in **Figure 4-16**). However, one unique feature at the intersection was the use of yellow centerline striping with a STOP sign in the median instead of a YIELD sign (**Figure 4-17**).



**FIGURE 4-16**

Looking East at CR C-57 Approach to US 218.

**FIGURE 4-17**

Median Design at US 218 and CR C-57.



## 5. Summary and Intersection Recommendation

A summary of the pertinent crash statistics has been summarized in **Table 5-1** for the six candidate intersections.

**TABLE 5-1**  
Candidate Intersection Summary

Performance Measure	US 30 & T-Avenue (#1)	US 61 & Hershey Road (#2)	US 151 & CR X-20 (#3)	IA 163 & NE 70 <sup>th</sup> Street (#4)	US 218 & CR G-36 (#5)	US 218 & CR C-57 (#6)
Crash Frequency	14	13	11	14	13	15
Crash Severity						
Fat	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						
Fat	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%)
Gap 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%)

The following is a set of general observations from the analysis and review of Iowa’s candidate intersections.

- IaDOT has applied many strategies in the traffic safety toolbox at each of these intersections. Generally, these strategies (minor street improvements such as STOP AHEAD sign, oversized STOP sign, overhead red/yellow flasher, CROSS TRAFFIC DOES NOT STOP

sign, and street lights) have been very effective at reducing intersection recognition crashes at many of these locations, but have not been effective at addressing gap related crashes – a crash type which is over represented at the highest crash frequency intersections in the State.

- The crash characteristics for the subset of high crash frequency intersections examined are very similar to the data for comparable intersections in Minnesota. The intersections have a crash rate greater than the critical crash rate (statistically significantly different than the expected value), the distribution of crash types skewed to angle crashes, gap related, more severe than expected, and typically not caused by weather and/or light conditions.
- There is a complicating geometric or traffic pattern at each of the intersections – vertical curve, horizontal curve, etc. However, the actual intersection sight distance at each intersection appears to be consistent with AASHTO guidelines.

### **5.1. Recommended Intersection for Deployment**

It was discovered after selecting and reviewing the six candidate intersections, that several of them had already been programmed for improvements within the next five years. Below is a list of the candidate intersections programmed for improvements:

- US 61 & Hershey Road (#2)—side road over with “button-hook” ramps with right-in-right-out movements planned for 2007.
- IA 163 & NE 70<sup>th</sup> Street (#4)—project to resurface, restore, and rehabilitate the highway and a safety project planned for 2007.
- US 218 & CR G-36 (#5)—interchange to be built in 2008.
- US 218 & CR C-57 (#6)—Interchange planned at neighboring location (CR C-50) and this location likely to be improved in the near future.

**Recommended Site:** Of the remaining two intersections, US 30 & T Avenue (#1) had twice as many crashes that were considered correctable when compared to US 151 & CR X-20 (#3). Also, all of these crashes were classified as a problem with gap recognition instead of intersection recognition. Furthermore, there appears to be strong initial support from the IaDOT to a technology based safety mitigation strategy, especially since the intersection has no short-term improvements programmed. Therefore, the intersection recommended for data collection and potential deployment of the IDS system is US 30 & T Avenue (#1). At this time, it is expected that the next phase of the study (deployment of the temporary vehicle surveillance system at this intersection) will occur in the fall of 2006.

### **5.2. Other Recommendations**

The University of Minnesota could design an IDS system for any of the remaining candidate intersections if the IaDOT wished to implement additional intersections. But if no further intersections are instrumented, then US 151 and CR X-20 may benefit from traditional mitigation strategies to address the high number of crossing path crashes (especially those related to gap recognition). The following recommendation is presented for the IaDOT’s consideration.

Several options may be available to mitigate the crash problem. These include short-term low-cost countermeasures focused on traffic control devices. This may include providing the mainline driver with increased warning of entering vehicles, such as the dynamic warning device used in North Carolina (please refer to the North Carolina report for more information) or using freeway style guide signs for advance junction warning. An interim, moderate-cost geometric consideration is construction of a J-Turn. Examples of J-Turns can be found in Maryland and North Carolina, both states have found these to be successful. The design of a J-Turn is to add a median in the intersection that only allows left turns from the mainline to the minor streets. Vehicles on the minor streets that wish to turn left or go straight across, instead would have to make a right turn, followed by a u-turn. Several examples of median u-turn designs are available from Maryland and North Carolina. Finally, a long-term, high-cost solution for consideration would be an interchange, possibly a one-quadrant interchange instead of a full-interchange.

However, further investigation is required to determine if these recommendations are feasible solutions or if another strategy may be optimal.

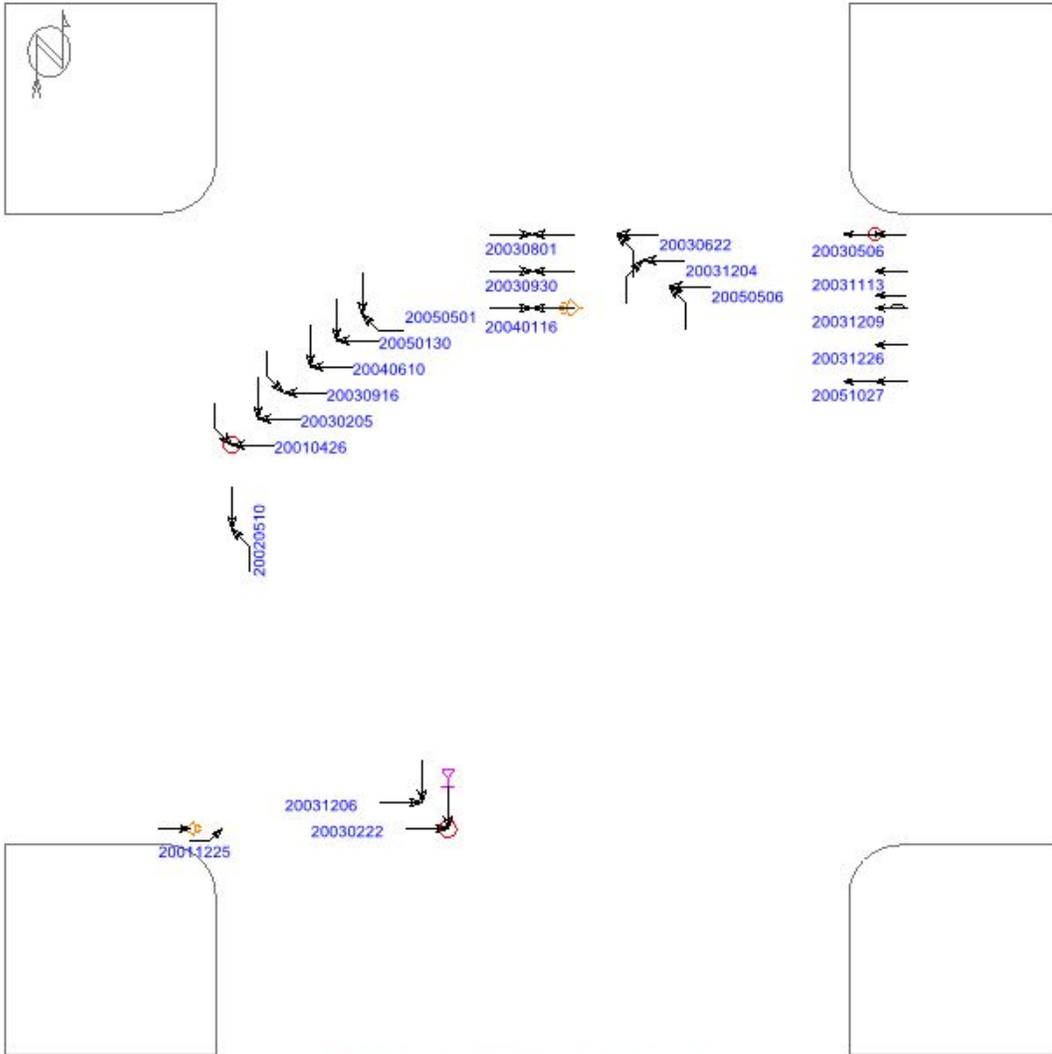
## References

1. W.J Najm, J.A. Koopmann and D.L. Smith. *Analysis of Crossing Path Crash Countermeasure Systems*. Proceedings of the 17<sup>th</sup> International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, The Netherlands. June 2001.
2. K.A. Harder, J. Bloomfield, B.J. Chihak. *Crashes at Controlled Rural Intersection*. Report MN/RC-2003-15. (St. Paul: Local Road Research Board, Minnesota Department of Transportation. July 2003.)
3. H. Preston, R. Storm, M. Donath, C. Shankwitz. *Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support*. Report MN/RC-2004-31. (St. Paul: Minnesota Department of Transportation. May 2004.)
4. T. Maze, N. Hawkins, G. Burchett. *Rural Expressway Synthesis of Practice and Crash Analysis*. CTRE Project 03-157. (Ames: Iowa Department of Transportation. October 2004.)

**Appendix A**  
**Intersection Crash Diagrams**

# US 30 and T-Avenue

2001 to 2005



(2) crashes could not be placed in this schematic

- |              |                  |              |                |
|--------------|------------------|--------------|----------------|
| ← Straight   | ▭ Parked         | × Pedestrian | Fixed objects: |
| ← Stopped    | ⚡ Erratic        | ⊗ Bicycle    | □ General      |
| ← Unknown    | ⚡ Out of control | ○ Injury     | ▣ Signal       |
| ↔ Backing    | ↔ Right turn     | ⊙ Fatality   | ▣ Tree         |
| ↔ Overtaking | ↔ Left turn      | 👤 Nighttime  | ◁ 3rd vehicle  |
| ↔ Sideswipe  | ↔ U-turn         | 🚰 DUI        | * Extra data   |
|              |                  |              | ▣ Pole         |
|              |                  |              | ▣ Curb         |
|              |                  |              | ⊗ Animal       |

Pd' Programming, Inc. 05/09/2006

Source: Iowa Department of Transportation

# COLLISION DIAGRAM

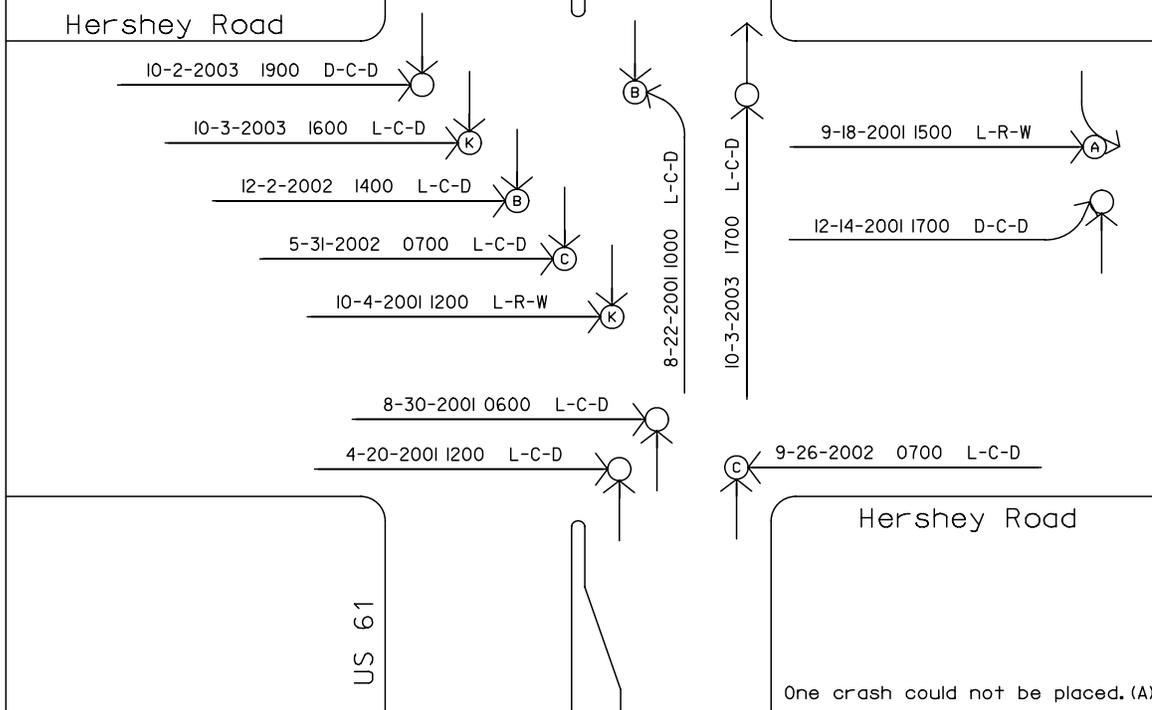
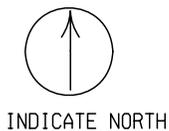
LOCATION: US 61 & HERSHEY ROAD (MUSCATINE COUNTY) 1 OF 1

TIME PERIOD: 01/01/2001 - 12/31/2003

PREPARED BY: RJS DATE: 12-31-2004

**No. of Accidents**

Fatal=	2
Major Injury (A)=	2
Minor Injury (B)=	2
Possible Injury (C)=	2
Injury Total=	6
Property Damage=	5
Total Accidents=	13



<ul style="list-style-type: none"> <li>→ Motor Vehicle Ahead</li> <li>←←← Motor Vehicle Backing Up</li> <li>↘ Motor Vehicle Out of Control</li> <li>⊙ Pedestrian</li> <li>⊙ Bicycle/Moped</li> <li>⊙ Motorcycle</li> <li>□ Fixed Object</li> <li>⊙ Fatal Acc.</li> <li>⊙ Major Injury Acc.</li> <li>⊙ Minor Injury Acc.</li> <li>⊙ Possible Injury Acc.</li> </ul>	<p><b>Light:</b></p> <ul style="list-style-type: none"> <li>L= Daylight</li> <li>DN= Dawn</li> <li>Du= Dusk</li> <li>D= Dark</li> <li>X= Unknown</li> </ul>	<p><b>Weather:</b></p> <ul style="list-style-type: none"> <li>C= Clear or Cloudy</li> <li>R= Rain</li> <li>S= Snow or Sleet</li> <li>X= Other or Unknown</li> </ul>
<ul style="list-style-type: none"> <li>• Location/Details Unclear</li> <li>○ Property Damage Acc.</li> <li>⊙ Rear End Property Damage</li> <li>⊙ Right Angle Major Injury</li> </ul>	<p style="text-align: center;"><b>Example of Bicycle/Motor Vehicle Accident:</b></p> <p style="text-align: center;">Injury Type      Date      Time      Light-Weather-Surface</p>	

# COLLISION DIAGRAM

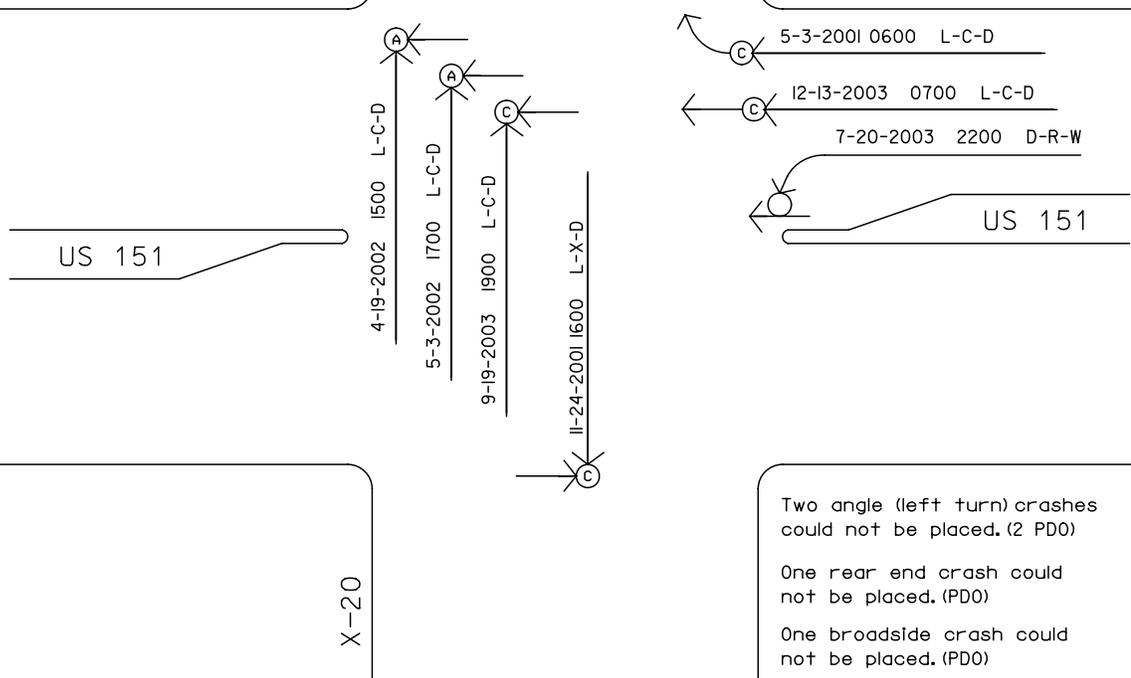
LOCATION: US 151 & COUNTY X-20 (LINN COUNTY) 1 OF 1

TIME PERIOD: 01/01/2001 - 12/31/2003

PREPARED BY: RJS DATE: 12-31-2004



No. of Accidents	
Fatal=	0
Major Injury (A)=	2
Minor Injury (B)=	0
Possible Injury (C)=	4
Injury Total=	6
Property Damage=	5
Total Accidents=	11



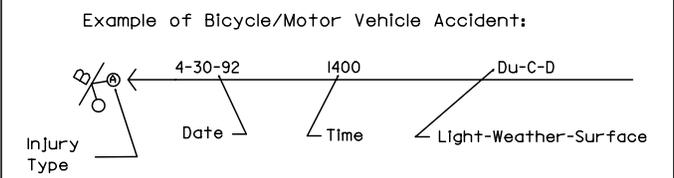
Two angle (left turn) crashes could not be placed. (2 PDO)  
 One rear end crash could not be placed. (PDO)  
 One broadside crash could not be placed. (PDO)

- Motor Vehicle Ahead
- ←←← Motor Vehicle Backing Up
- ⊞ Motor Vehicle Out of Control
- ⊙ Pedestrian
- ⊙ Bicycle/Moped
- ⊙ Motorcycle
- Fixed Object
- ⊙ Fatal Acc.
- ⊙ Major Injury Acc.
- ⊙ Minor Injury Acc.
- ⊙ Possible Injury Acc.
- Location/Details Unclear
- Property Damage Acc.
- ⊙ Rear End Property Damage
- ⊙ Right Angle Major Injury

**Light:**  
 L= Daylight  
 DN= Dawn  
 Du= Dusk  
 D= Dark  
 X= Unknown

**Weather:**  
 C= Clear or Cloudy  
 R= Rain  
 S= Snow or Sleet  
 X= Other or Unknown

**Surface:**  
 D= Dry  
 W= Wet  
 S= Snow or Ice  
 X= Other or Unknown



# COLLISION DIAGRAM

LOCATION: IA 163 & NE 70TH STREET (POLK COUNTY) 1 OF 1

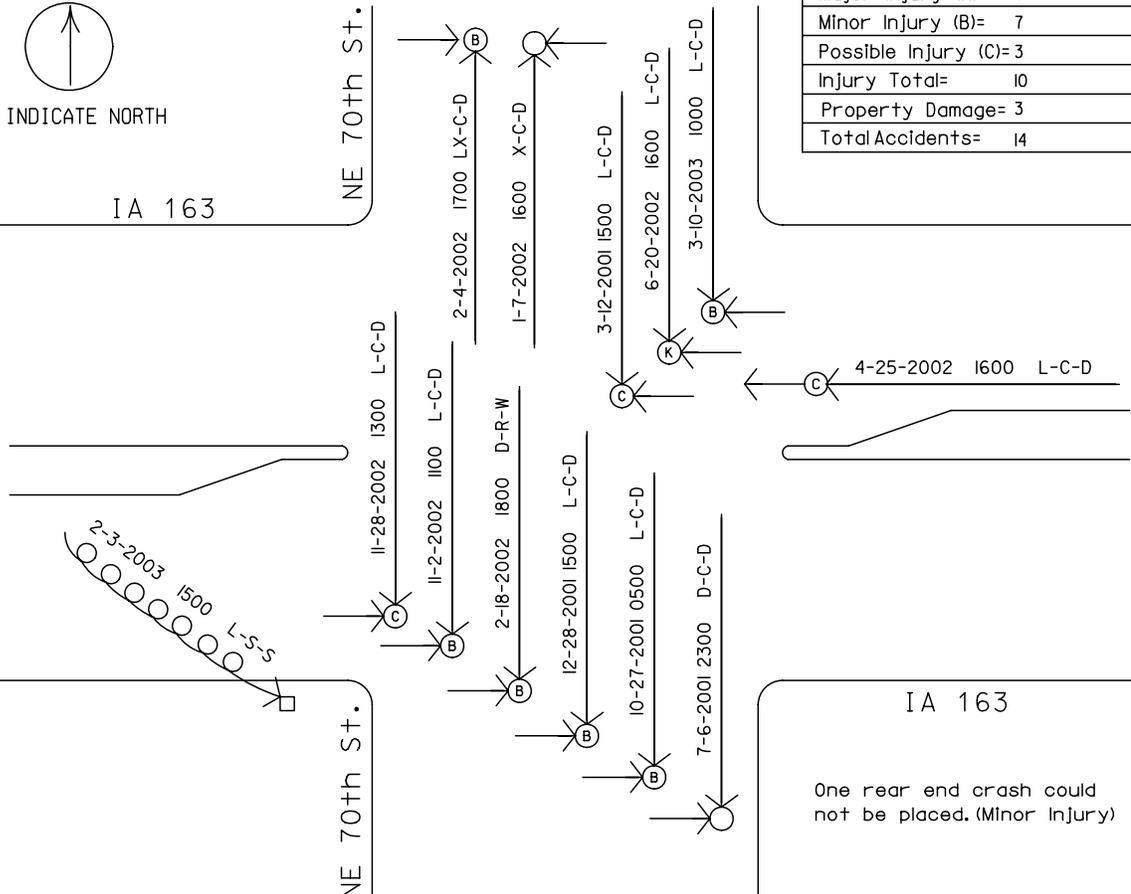
TIME PERIOD: 01/01/2001 - 12/31/2003

PREPARED BY: RJS DATE: 12-31-2004



IA 163

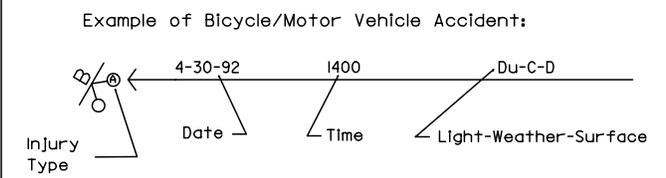
NE 70th St.



No. of Accidents	
Fatal=	1
Major Injury (A)=	0
Minor Injury (B)=	7
Possible Injury (C)=	3
Injury Total=	10
Property Damage=	3
Total Accidents=	14

- Motor Vehicle Ahead
- ←←← Motor Vehicle Backing Up
- ⊞ Motor Vehicle Out of Control
- ⊙ Pedestrian
- ⊙ Bicycle/Moped
- ⊙ Motorcycle
- Fixed Object
- ⊙ Fatal Acc.
- ⊙ Major Injury Acc.
- ⊙ Minor Injury Acc.
- ⊙ Possible Injury Acc.
- Location/Details Unclear
- Property Damage Acc.
- ⊙ Rear End Property Damage
- ⊙ Right Angle Major Injury

<b>Light:</b> L= Daylight DN= Dawn Du= Dusk D= Dark X= Unknown	<b>Weather:</b> C= Clear or Cloudy R= Rain S= Snow or Sleet X= Other or Unknown	<b>Surface:</b> D= Dry W= Wet S= Snow or Ice X= Other or Unknown
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# COLLISION DIAGRAM

LOCATION: US 218 & COUNTY G-36 (WASHINGTON COUNTY)

1 OF 2

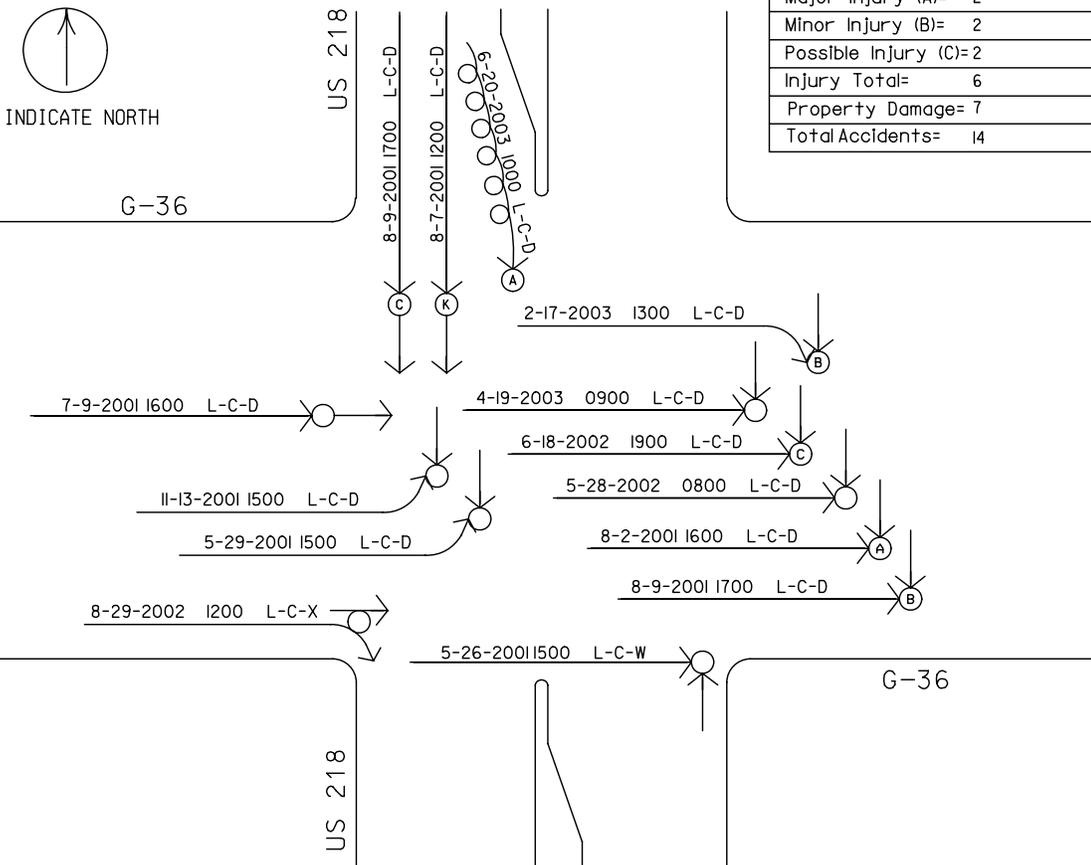
TIME PERIOD: 01/01/2001 - 12/31/2003

PREPARED BY: RJS

DATE: 12-31-2004

**No. of Accidents**

Fatal=	1
Major Injury (A)=	2
Minor Injury (B)=	2
Possible Injury (C)=	2
Injury Total=	6
Property Damage=	7
Total Accidents=	14



<ul style="list-style-type: none"> <li>→ Motor Vehicle Ahead</li> <li>←←← Motor Vehicle Backing Up</li> <li>↘ Motor Vehicle Out of Control</li> <li>♣ Pedestrian</li> <li>♣ Bicycle/Moped</li> <li>♣ Motorcycle</li> <li>□ Fixed Object</li> <li>⊗ Fatal Acc.</li> <li>⊕ Major Injury Acc.</li> <li>⊖ Minor Injury Acc.</li> <li>⊙ Possible Injury Acc.</li> </ul>	<p><b>Light:</b></p> <p>L= Daylight DN= Dawn Du= Dusk D= Dark X= Unknown</p> <p><b>Weather:</b></p> <p>C= Clear or Cloudy R= Rain S= Snow or Sleet X= Other or Unknown</p> <p><b>Surface:</b></p> <p>D= Dry W= Wet S= Snow or Ice X= Other or Unknown</p>	<p><b>Location/Details Unclear</b></p> <p>•</p> <p><b>Property Damage Acc.</b></p> <p>○</p> <p><b>Rear End Property Damage</b></p> <p>→⊗</p> <p><b>Right Angle Major Injury</b></p> <p>→⊕</p>
<p>Example of Bicycle/Motor Vehicle Accident:</p> <p>Injury Type      Date      Time      Light-Weather-Surface</p>		

# COLLISION DIAGRAM

LOCATION: US 218 & COUNTY C-57 (BLACK HAWK COUNTY) 1 OF 1

TIME PERIOD: 01/01/2001 - 12/31/2003

PREPARED BY: RJS

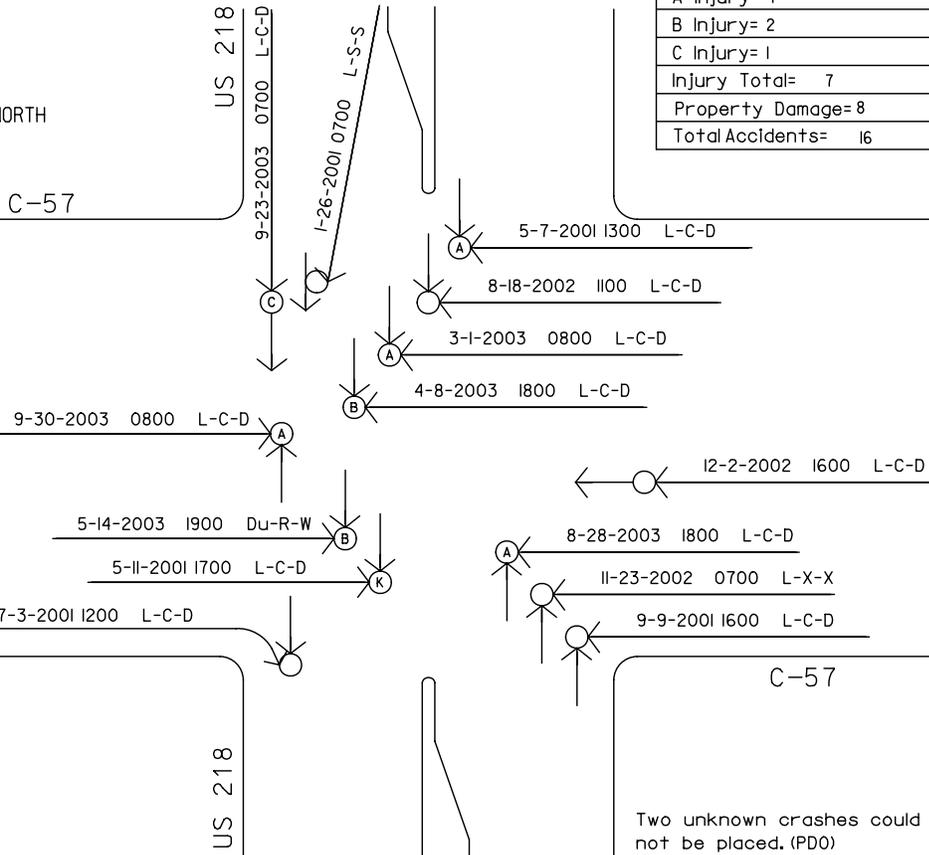
DATE: 12-03-2004

**No. of Accidents**

Fatal=	1
A Injury=	4
B Injury=	2
C Injury=	1
Injury Total=	7
Property Damage=	8
Total Accidents=	16



INDICATE NORTH



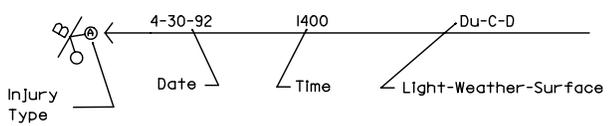
- Motor Vehicle Ahead
- ←←← Motor Vehicle Backing Up
- ⊞ Motor Vehicle Out of Control
- ⊙ Pedestrian
- ⊙ Bicycle/Moped
- ⊙ Motorcycle
- Fixed Object
- ⊙ Fatal Acc.
- ⊙ Location/Details Unclear
- Property Damage Acc.
- ⊙ Rear End Property Damage
- ⊙ Right Angle

**Light:**  
 L= Daylight  
 DN= Dawn  
 Du= Dusk  
 D= Dark  
 X= Unknown

**Weather:**  
 C= Clear or Cloudy  
 R= Rain  
 S= Snow or Sleet  
 X= Other or Unknown

**Surface:**  
 D= Dry  
 W= Wet  
 S= Snow or Ice  
 X= Other or Unknown

**Example of Bicycle/Motor Vehicle Accident:**



**Appendix B**  
**Aerial Photographs**



**FIGURE B-1**

Aerial Photo of US 30 & T Avenue (#1)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)



**FIGURE B-2**

Aerial Photo of US 61 & Hershey Road (#2)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)



**FIGURE B-3**

Aerial Photo of US 151 & County Road X-20 (#3)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)



**FIGURE B-4**

Aerial Photo of IA 163 & NE 70<sup>th</sup> Street (#4)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)



**FIGURE B-5**

Aerial Photo of US 218 & County Road G 36 (#5)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)



**FIGURE B-6**

Aerial Photo of US 218 & County Road C 57 (#6)

Source: Color-Infrared Orthophotos (2002) from the Iowa Geographic Map Server (<http://cairo.gis.iastate.edu/>)