Rural Intersection Conflict Warning System Guidelines

Final Report

This report provides conflict warning system selection guidelines for potential conflicts associated with rural high-speed intersections.

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Prepared for:

UDOT Region 4 Traffic & Safety

Prepared by:

Civil Science, Inc.

Introduction

The main objective in implementing Rural Intersection Conflict Warning Systems (RICWS) is to reduce the number of rural intersection crashes. Traditional warning signs help drivers to anticipate unexpected intersection conditions, but at times are inadequate because of intersection geometry and other localized characteristics. A number of stop-controlled crashes in a "typical state" occur on these high-speed rural intersections. For these reasons, numerous government agencies have implemented RICWS solutions to notify drivers of oncoming traffic when sight distance or gap acceptance are not satisfactory. These provide dynamic, real-time notifications of oncoming traffic to drivers who would otherwise enter the intersection at their own discretion.

This report summarizes research collected from the ENTERPRISE Intersection Conflict Warning Systems Study, Minnesota DOT (MNDOT), other DOTs such as North Carolina (NCDOT) and Missouri (MoDOT), UDOT's RICWS experience, and the Federal Highway Administration. The report provides draft guidelines for individual intersection assessment and future implementation of RICWS in the State of Utah throughout Region 4. It is important to note that RICWS is an attempt to provide a low-cost solution to a condition that traditionally has warranted costly auxiliary lane and/or signalized intersection improvements.

Background

Intersection crashes continue to account for a large part of transportation fatalities and serious injuries across the country. The Federal Highway Administration reports roughly 2.5 million intersection accidents (roughly 40% of all crashes), mostly from left turns, with roughly 20% of fatal crashes occurring at intersections (www.fhwa.dot.gov). Data obtained from the ENTERPRISE Intersection Conflict Warning Systems Study indicates that in 2013, there were 6,947 fatalities across the nation related to intersections, accounting for 23% of the total fatal crashes in 2013.

As a result of this, various government agencies throughout the United States have developed RICWS at rural intersections for testing, research, and use. Multiple state DOTs have implemented warning systems, and each utilized their own specific warning system components, which has created a non-standard, varied approach to addressing warning system design. The ENTERPRISE Program, with support from the USDOT FHWA Office of Safety, prepared a Pooled Fund Study, a research project that brought together many of these government agencies in an effort to develop a uniform deployment for this type of system. Based on the available research, it appears that the next step in the development of intersection conflict warning systems will be to develop standard guidelines to present to the research and design community for inclusion in the Manual for Uniform Traffic Control Devices (MUTCD).

Multiple DOTs have been trailblazers in the development of RICWS. Two of these have been the Minnesota Department of Transportation (MNDOT) and the North Carolina Department of Transportation (NCDOT). Ken Hansen and Brad Estochen with MNDOT have been invaluable resources in providing MNDOT's experiences, research, and steps to determining RICWS feasibility and design. This report references much of the data from these DOTs and the research gathered by the ENTERPRISE Program.

RICWS WARRANTS

There have been two broad guidelines that MNDOT has utilized in determining intersection warrants for RICWS. The two approaches used are:

- **Reactive Approach** – The reactive approach identifies specific intersections that have had a history of fatalities and accidents and therefore warrant an immediate remedy, such as an RICWS treatment, to mitigate safety issues. According to Ken Hansen of the MNDOT, many local District Engineers utilizing traditional engineering judgement prescribe to this approach, an approach that is more simplistic in its assessment, and more obvious in its result.
- **Proactive Approach** – To determine whether it achieves a RICWS warrant, the proactive approach develops a set of criteria and determines a ranking for each intersection regardless if accident data is available or not. The proactive approach is a risk assessment of factors related to fatal/serious injury and crash potential, with a focus on low cost mitigation. For example, MNDOT developed a set of criteria for a RICWS warrant and then scored intersections within the state. All intersections with a score between a determined range warranted an intersection warning system.

The MNDOT's experience translated into several improvement phases which retrofitted over 50 intersections with a RICWS. MNDOT is currently monitoring and modifying these RICWS systems as they better understand issues and improve operational functionality.

Based on data from the ENTERPRISE Study and other related references, a draft set of criteria for a Proactive Approach would include (Athey Creek Consultants):

1. Volume (ADT) of the major and minor road
2. Engineering judgement related to a specific intersection
3. Limited sight distance and/or poor gap acceptance
4. Intersection skew angle greater than 15 degrees
5. Presence of a horizontal and/or vertical curve at the intersection
6. Railroad crossing at one of the minor intersection legs
7. Commercial development present in one or more of the intersection quadrants
8. A minor leg approach that does not have a stop sign within five miles of the intersection
9. Crashes and/or crash rate at the intersection is higher than expected over a 5-year period

Other factors that should be considered include excessive speed, substandard intersection geometry, lane configuration, lighting, current signing obstructions, profile grades, and areas with tourism traffic that could be unfamiliar with state or federal traffic control measures. Brad Estochen, MNDOT State Traffic Safety Engineer, indicated that unique factors such as railroad crossings can become determining drivers in deciding whether to install RICWS. In the MNDOT case, railroad crossings became so time consuming and costly that they opted to identify different improvements to address potential issues at these specific locations.

In addition to RICWS, there are also other options available to address rural intersection hazards. These include increased lighting, signing (LED), and rumble strips perpendicular to the travelled way, among others. Analysis of safety deficiencies should not preclude the evaluation or use of these potential improvements.

A recommendation for future consideration by UDOT Region 4 would be to develop a warrant system to systematically analyze rural high-speed intersections, create an intersection ranking system, and ultimate inclusion in a consistently funded program to retrofit intersections with RICWS.

Intersection Design Guidelines

Once an intersection has been identified as a potential candidate for warning system improvements, research and literature to-date identifies a process by which sign placement and messaging can be designed for the subject intersection. Ken Hansen emphasized that the MNDOT quickly realized that, although they could develop guidelines to design an Intersection Conflict Warning System, it was very important to understand that each intersection is very unique in its own way, and still requires a thorough engineering effort to complete a successful design and installation. Merely having a technician check a set of design guideline boxes and then proceed to the installation phase is not an effective approach. However, installing simple improvements to mitigate known issues for the interim condition is a low cost first step to implementing more permanent solutions like RICWS. Interim implementation should be closely scrutinized and monitored to assess responses from and impacts to the travelling public.

The ENTERPRISE Study, in conjunction with MNDOT's research and experience, developed a general list by which to begin the design of an Intersection Conflict Warning System at a given intersection. This list helps to select the appropriate sign placement for a specific type of intersection, aids in selection of sign messages and dynamic sign elements, and helps in selection of detection. In addition, an RICWS project should address several secondary components as identified in the list below. The general list is as follows:

1. General intersection scenario identification (see Section 1 below)
2. Sign placement, message selection, dynamic element selection
3. Detection selection
4. Power supply assessment
5. System monitoring, system communication, and data management assessment

1. General Intersection Scenarios

Research and documented design efforts indicate that there are four intersection scenarios typically encountered in applying a warning system on a rural, high-speed intersection. These scenarios are introduced in the ENTERPRISE Phase 1 and 2 Studies (Athey Creek Consultants) as follows:

1. Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection
2. Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection
3. Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection
4. Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

These general scenarios can be used as a starting point for implementing warning system components on a specific intersection. Literature points out that there will always be exceptions to these scenarios. A design process should begin with a determination of which roadways need warning system improvements using the criteria listed earlier in the RICWS Warrants Section, followed by a selection of the most appropriate scenario to begin detailed design. As indicated above, Ken Hansen from the MNDOT stated that these are merely guidelines, and careful analysis should be applied to each intersection to address specific project challenges.

Determining which legs of an intersection to retrofit with detection and warning systems has been an ongoing and extensive debate around the country among traffic experts. Research indicates that selection can revolve around traffic volumes (ADT) on the major road as generally summarized below:

- A minor-road-only alert may be most effective where major road volumes are less than 3,000 AADT.
- A major-road-only alert may be most effective where major road volumes are above 3,000 AADT and less than 10,000 AADT.
- Alerts on both major and minor roads may be effective where major road volumes are above 10,000 AADT and less than 12,000 AADT. However, Brad Estochen with MNDOT indicated that higher main line volumes between 10,000 and 12,000 AADT did not provide as much benefit.
- Major road volumes that are above 12,000 AADT typically cause nearly constant warnings and should be assessed for alternative treatments other than RICWS.

Minor road warnings are more difficult to quantify. Again, Brad Estochen with MNDOT indicated that no conclusions have been made regarding the need for minor road warnings. Some experts believe there is no benefit, while others, including Brad, feel that warning systems on the minor road are just as critical as those on major roads; if not more so. Many experts also feel that warning systems on major legs are not effective. No definitive conclusions have been published to-date that indicate where warning systems should be placed at an intersection (major only, minor only, major and minor). Each leg of the intersection should be equally evaluated using sound engineering judgment and supported by effective technical data. Intersections with approaching legs that exhibit similar volumes of traffic are another exception to recommended RICWS implementation. Intersections of this variety require careful engineering analysis and judgement to determine if an RICWS is appropriate. Literature appears to support the idea that treatments other than an RICWS may be appropriate for this type of intersection.

On the following pages, the descriptions of each of the above-mentioned four scenarios and associated graphics were published in the ENTERPRISE Organization's report entitled, "Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS)", by Athey Creek Consultants, December 2011, Pages 7-10. It is important to note that each of the provided examples utilizes a four-legged intersection. A T-intersection will function in the same manner by simply removing one of the minor legs from the example graphic.

Scenario 1 - Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

In Scenario 1, the minor road is stop controlled with warning signs placed either on the far side opposite corner depicted by (1) in the referenced figure below, or the far side near corner as depicted by (2) in the figure. A third option includes placement of an overhead sign as depicted by (3). "V1" represents a stopped or approaching vehicle on the minor road. Detection is used on the major road, triggering the minor road warning signs and alerting minor road vehicles of oncoming traffic, and possible direction of traffic. Usage of warning signs and dynamic messages are addressed in subsequent sections in this report (Athey Creek Consultants).

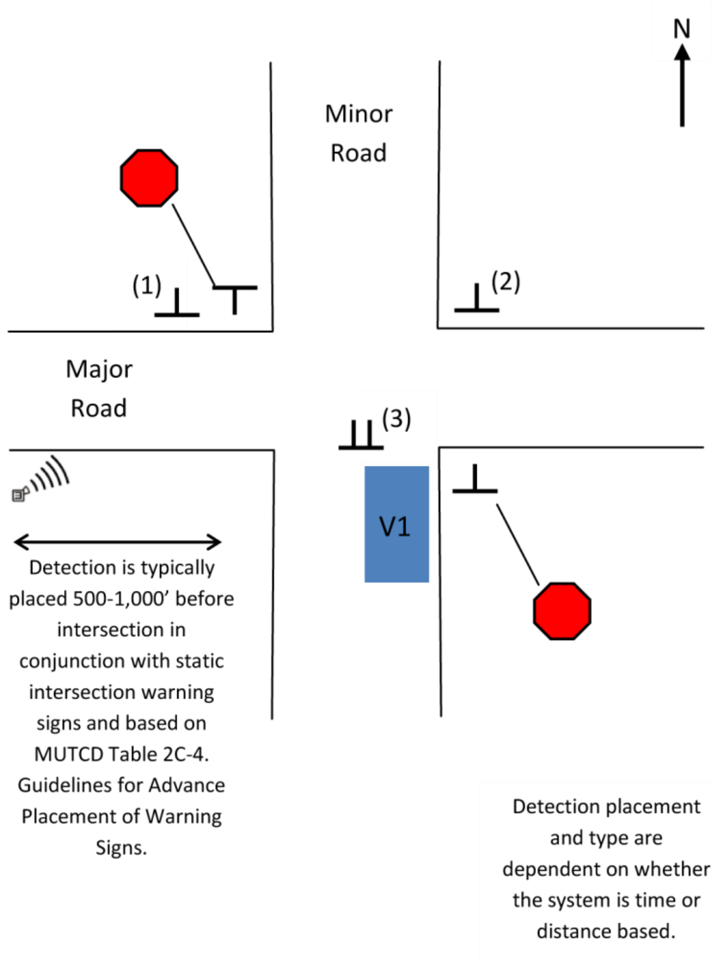


Figure 1: Scenario 1

Scenario 2 - Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection

In Scenario 2, the minor road contains two warning signs to address the median separated nature of the major road, one for crossing the near-side lanes, and one for crossing the far side lanes. The near side warning signs are placed either left of the minor road vehicle as depicted by (1a) in the figure below, or the opposite corner from the stop sign as depicted by (2a). A yield sign warns the minor road driver once it has crossed the near-side lanes, in conjunction with warning signs for far-side traffic. These far-side warning signs are typically placed on the far-side corner of the intersection as depicted by (1b, 2b). “V1” represents a stopped or approaching vehicle on the minor road. Detection is used on the major road, triggering the minor road warning signs and alerting minor road vehicles of oncoming traffic, and possible direction of traffic. Usage of warning signs and dynamic messages are addressed in subsequent sections in this report (Athey Creek Consultants).

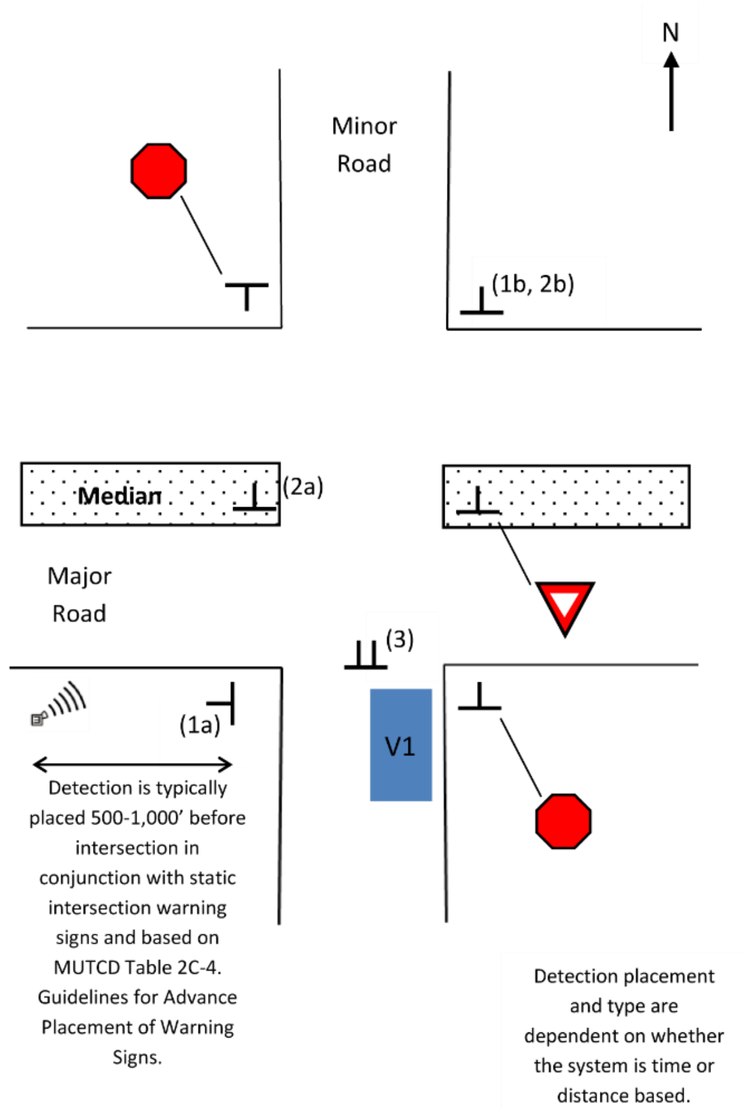


Figure 2: Scenario 2

Scenario 3 - Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

In Scenario 3, warning signs are placed on the major road as depicted by (1a) in the figure below, with an additional sign placement depicted by (1b) for major roads that have multiple travel lanes in one direction. “V1” represents an approaching vehicle on the major road. Detection is used on the minor road, alerting major road vehicles if vehicles are approaching or are at the minor road stop sign. Warning signs may also indicate possible direction of traffic. Usage of warning signs and dynamic messages are addressed in subsequent sections in this report. An overhead sign as depicted by (2) along the major road, was determined by several studies to be ineffective for major road traffic (Athey Creek Consultants).

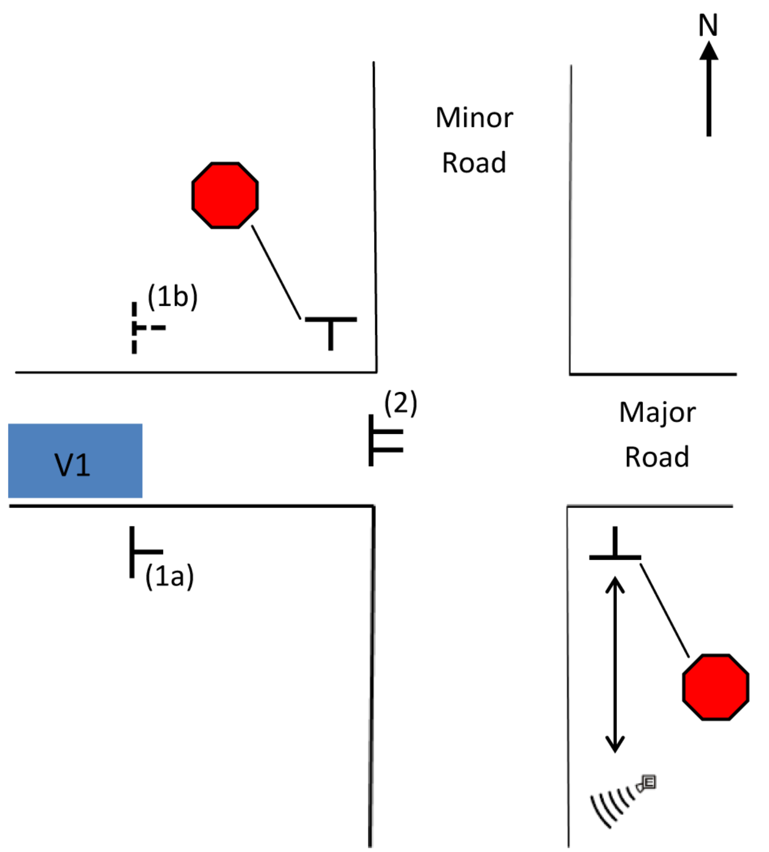


Figure 3: Scenario 3

Scenario 4 - Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

In Scenario 4, warning signs are placed on both the major and minor roadways. Sign placements are similar to Scenarios 1 through 3 (depicted by (1a), (1b), (4) and (5), with the exception of placing a minor road warning sign at the opposite corner of the intersection as depicted by (3) in the figure below). "V1" represents an approaching vehicle on the major road, and "V2" represents a stopped or approaching vehicle on the minor road. Detection is used on both the major and minor roads. Warning signs may also indicate possible direction of traffic. Usage of warning signs and dynamic messages are addressed in subsequent sections in this report. An overhead sign as depicted by (2) along the major road, was determined by several studies to be ineffective for major road traffic (Athey Creek Consultants).

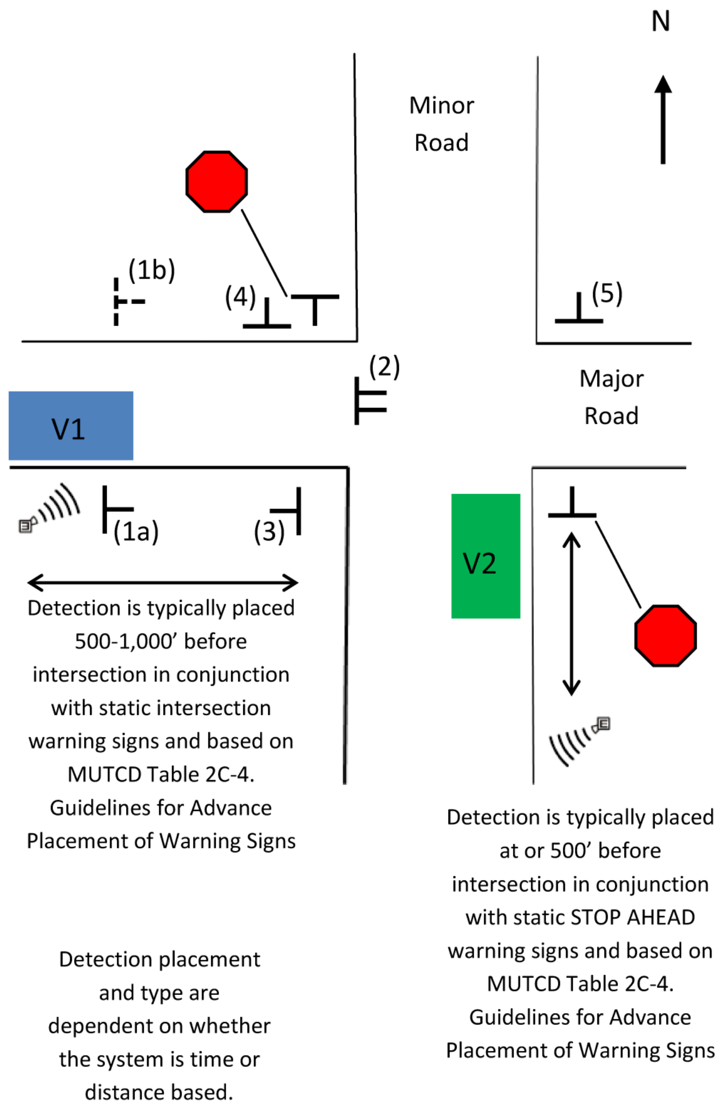


Figure 4: Scenario 4

2. Sign Placement & Selection, Dynamic Element Selection

Until the publishing of the ENTERPRISE Study, various state DOT's incorporated numerous, varied signing and dynamic elements into their warning system designs. The ENTERPRISE Study inventoried the various options implemented throughout the United States and suggested that standards for an RICWS be drafted and submitted for inclusion in the Manual on Uniform Traffic Control Devices (MUTCD). Although the National Committee on Uniform Traffic Control Devices (NCUTCD) Regulatory and Warning Sign Technical Committee (RWSTC) provided proposed language to be implemented into the MUTCD, nothing has been finalized as of the writing of this report.

Static Signs Versus Dynamic Blank-out Signs

One outstanding item delaying the standardization of RICWS systems is the debate surrounding the selection of either a static sign combined with a flashing beacon, or a dynamic blank-out sign combined with a flashing beacon. According to MNDOT personnel, the issues related to this debate are as follows:

- Crash reduction numbers don't appear to differentiate between static and blank-out signs (or any sign combinations for that matter).
- Blank-out sign reliability appears to still be an issue. Suppliers in Minnesota have assured MNDOT that the latest blank-out signs are functioning reliably, but the verdict is still out.
- Blank-out signs are a difficult technology for some traffic experts to accept. National standards related to blank-out signs are still being debated.
- Blank-out signs experience power outage, create additional maintenance, and malfunction periodically, which all relates to a higher cost and lower motorist confidence.
- Blank-out signs in theory capture the attention of motorists more so than static signs do.

Post Mounted Versus Overhead Systems

The literature primarily identifies post mounted ICWS components. Several studies indicate that overhead systems are not effective on the major road. Example overhead signs in the literature appeared to be primarily wire-suspended systems located very close to the intersection. The location of the signs, not the overhead signs themselves, appeared to be the limiting factor. Overhead signs are typically more expensive to install and maintain, and post-mounted signs appear to achieve positive crash reduction numbers.

System Redundancy and Malfunction

A key component of the signing and notification system needs to include a level of redundancy if the system is not functioning properly, and an active warning protocol should the system malfunction. Warning systems that do not function fail to alert the traveling public to potential dangers, and limit confidence and willingness to comply with the warning system. As an example, UDOT Traffic and Safety has modified certain existing systems to constantly flash when a malfunction occurs, providing an active response to motorists until the issue can be resolved, versus a non-functioning system that provides no active response at all until addressed. This question of redundancy with the warning system also applies to the detection component of the system.

Systems Inventory

The tables on the following pages provide an inventory summary of the various static and dynamic signs used throughout the United States as depicted in the ENTERPRISE Study. The tables are separated by Minor and Major Road signing. Each table indicates the type, with a visual example, followed by specific notes related to the signage. Specific systems utilized consistently by other DOTs are highlighted at the end of each table.

Minor Road Signing

TABLE 1 - Minor Road Signing Options

Type of Sign	Example	Remarks
1. "Traffic/Vehicle Approaching When Flashing"		This type of sign implementation appears to be the most common form used throughout the United States.
2. "Cross Traffic Does Not Stop" with Blank-out		The first RICWS in Utah, utilized on the SR-202 and SR-201 intersection. Drivers may not correlate the dynamic nature of the blank-out sign with oncoming traffic, but the message does provide awareness of oncoming traffic. Radar detection is based on stopping site distance. The illustrated improvement was replaced by a signal, due to roadway modifications.
3. "Cross Traffic Does Not Stop" with Flashing Stop Sign		The detection component triggers the flashing red LED lights on the stop sign. Drivers may not correlate the dynamic nature of the flashing lights with oncoming traffic. The flashing stop sign lights provide some level of awareness, although not to the level of other dynamic systems.

Type of Sign	Example	Remarks
4. “Look for Traffic” with Flashing Arrows		This system not only indicates when oncoming traffic is present, but also indicates the direction of oncoming traffic, an additional indicator that other systems do not have. Not used very often according to literature. MNDOT utilized several of these, but apparently replaced the system with other options.
5. “Traffic Approaching” Blank-out with “When Flashing” Sign		The blank-out sign in this system provides an indicator that is more dynamic than some traditional systems. MNDOT uses these consistently on the minor road.
6. “Crossing Traffic” with Vehicle Sign (Right or Left)		Functions in a similar fashion to the “Look for Traffic” with Flashing Arrows sign. Although unique, this sign may be more complicated and costly than is required, and may not be as readily available from suppliers.

Type of Sign	Example	Remarks
7. "Divided Highway" with Color and Variable Do Not Enter Symbols		Uses lighted portions of the sign to indicate direction of oncoming traffic, and indicates whether gap acceptance is sufficient. It appears that MNDOT has removed these signs, opting for more efficient, cost effective systems.
8. "Watch For Approaching Vehicle When Flashing" Overhead Sign		This system may be mounted on wire or mast arm configurations. Cost related to additional components, right of way, and utility conflicts may be a limiting factor. Not effective for major road because of location and speed (see Major Road table below).
9. W1-7 Sign with "Traffic Approaching" Blank-out Sign		Utilized on SR-12 junction with US-89. The flashing message should provide an intuitive message to the driver that conflicting traffic is approaching.

Minor Road Signing Recommendations – Although most of the above-listed systems meet the requirements of an advance warning system, it is the intent of this report to highlight several viable systems that have been selected and utilized consistently by other state DOT's. It should be noted that the available research does not rank the systems or indicate a superior product. Each system provides a unique warning and could be utilized to fulfill the needs of the RICWS. For this report, highlighted systems include:

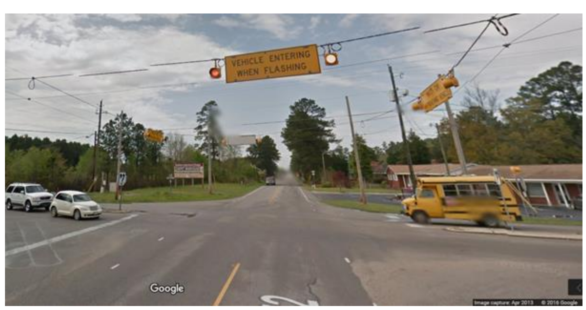
- **Option 1** (from Table 1) **– "Traffic Approaching When Flashing" System** – uses standard, accepted national components, and is widely used throughout the United States.

- **Option 5** (from Table 1) **– "Traffic Approaching" Blank-out with "When Flashing" System** – this system is widely used, especially by MNDOT, and provides a direct message to drivers with a very effective dynamic component.

Major Road Signing

TABLE 2 - Major Road Signing Options

Type of Sign	Example	Remarks
1. "Entering Traffic When Flashing", "Vehicle Entering When Flashing"		This type of sign implementation appears to be the most common form used throughout the United States on the major road of an intersection. MNDOT utilizes this system on major roads.
2. W2-1 Intersection Sign with Flashing Yellow Above		Provides a less clear message to the driver than signage that includes messaging. Does not give the driver an active message regarding traffic ahead.
3. "Traffic Entering When Flashing" Mounted on a Structure	Standard signs and flashing beacons placed on an existing overhead structure	This option isn't typically practical. Existing structures are rarely situated in the appropriate locations. One example in Maine was recently removed when the structure was replaced.

Type of Sign	Example	Remarks
4. "Watch For Entering Traffic"		Utilized in Provo Canyon on US-189 at SR-92/Sundance Turnoff. Provides a standard approach, and sometimes appears to be more passive in nature because it lacks the "When Flashing" component. Also utilized on SR-12.
5. "Vehicles Entering" With Arrows Indicating Direction	A hybrid of the "Crossing Traffic" sign indicated above in the Minor Road inventory	Very few examples. Indicating to the major road vehicle which direction traffic is approaching may not be necessary.
6. "Cross Traffic" with "When Flashing", "Caution Cross Traffic" with "When Flashing"		This sign may not convey an active message such as, "Entering Traffic". This may not have a noticeable impact on drivers. Other than the message difference, this sign is very similar to other listed systems.
7. "Vehicles Entering When Flashing" Overhead Sign		Several studies indicate that this treatment is not effective, primarily because the overhead signs were not installed far enough in advance to allow an appropriate reaction. Cost can be a limiting factor. A similar system was installed on the major road (US-89) on the US-89 intersection with SR-12.

Major Road Signing Recommendations – Although most of the above-listed systems meet the requirements of an advance warning system, MNDOT and other sources appear to consistently utilize two systems, which are highlighted below. It should be noted that the available research does not rank the systems or indicate a superior product. Each system provides a unique warning and could be utilized to fulfill the needs of the ICWS. For this report, highlighted systems include:

- **Option 1** (from Table 2) **- "Entering Traffic When Flashing" System with two flashing beacons** – uses standard, accepted national components and is widely used throughout the United States.
- **Option 4** (from Table 2) **- "Watch For Entering Traffic", add "When Flashing" System** – a relatively simple system that utilizes components recommended by the Regulatory and Warning Sign Technical Committee (RWSTC).

3. Detection Selection

A variety of detection systems and implementations are available for use in a warning system of this type. Based on available research, two types of detection methodology have been used. These include:

- Detection based on time
- Detection based on speed/distance

Timed Detection

According to Ken Hansen from the MNDOT, the North Carolina Department of Transportation (NCDOT) was one of the initial states to implement these types of warning systems. NCDOT used a simple time-based detection system that limited their ability to detect and track vehicles and make modifications based on speed limit changes. The system utilized a single detection component placed at a determined distance away from the intersection. Although inexpensive and simple to implement, this methodology does not account for speed changes after initial detection (higher than the posted speed limit), and the system must be replaced when posted speed limits change.

Speed/Distance Detection

MNDOT utilizes signal components and a dual detection system based on distance and speed. The dual functionality allows the system to better track accurate speeds and distance from the intersection. Their design placed detection further back on the major roadway to better detect oncoming traffic and to accommodate changes to speed. For instance, the MNDOT is changing their rural highway speed limit from 55 mph to 60 mph. The flexibility and location of their detection systems will allow them to use the existing system with minimal modifications.

System Redundancy and Malfunction

As described in Section 2, warning systems must address malfunctions in an active way by providing a level of redundancy and/or a constant active warning until the malfunction is addressed. The detection component within the system is no different and requires a level of redundancy to accurately perform on a consistent basis. This issue should be addressed individually for each system installation.

The following table provides feedback on the detection components used by other DOTs for warning systems.

TABLE 3 – Detection System Options

Type of Detection	Intended Use	Remarks
1. Inductive Loop: • 6-ft x 6-ft square or 6-ft diameter circle under the pavement for vehicle detection.	Loops, along with radar, are the most common type of detection system. May be used on either major or minor road.	The most accurate among detection technologies. Requires underground wiring. UDOT recommends installation only in new pavement applications.
2. Wireless Magnetometer (Puck): • In-pavement-mounted magnetic sensors to detect vehicles using low-power radio technology.	Use for roads in place of saw cutting. Allows for easy installation and can be used for other types of detection.	Has the same detection characteristics as a 6-ft x 6-ft induction loop. No longer recommended by UDOT for new construction.
3. Wireless Radar: • Radar unit is mounted and will detect vehicles on approach to provide feedback to warning system.	Radar, along with loops, is the most common type of detection system. May be used on either major or minor road.	The location of radar detectors upstream of the intersection and in relation to the stop bar on the minor road varies greatly between different example sites. Radar provides for greater system flexibility.

Detection System Recommendations – UDOT primarily utilizes radar components for signal projects, and it is recommended that the same be used for intersection conflict warning systems. Radar allows both distance and speed to be determined. Inductive loop combinations could be utilized in situations where traffic poses a consistent shielding effect on the detection zone(s). The connection between detection and warning signs should be completed with conduit and cable, not radio communication, unless individual cases warrant differently.

4. Power Supply

The intent of a RICWS is to realize a benefit by improving key accident indicators at a relatively low cost. One key element in the design of a warning system is the supply of power to operate the various components of the system. This element applies a cost to the project. Availability of power within close proximity to the system is ideal. Where power is not readily available through traditional third-party utility companies, consideration should be given to solar power. Solar power theoretically eliminates the need for traditional power but is considered by some to introduce some level of unreliability. Warning systems that do not function consistently lose effectiveness and user confidence.

5. System monitoring, system communication, and data management

An effective warning system requires effective maintenance and data collection. The following components should also be considered in designing a warning system:

1. System Monitoring and Communication – either on site or remotely. A warning system needs to function consistently in order to identify warning scenarios at all times, especially at night. Having the ability to monitor when the system is not operating appropriately, especially from a remote location, allows for timely and efficient maintenance.
2. Data Management – Collection of system data should be considered in system design for various reasons such as system optimization, system upgrades, additional research.

Providing monitoring, system communication and management of data should be scalable based on specific location. Options ranging from very simple low maintenance/low complexity support systems to more complex, real time monitoring support systems, should be standardized and then applied to specific locations based on accessibility, availability of supporting telecommunications infrastructure, and available power source. A key focus for these support systems should be the ability to run diagnostics and identify system failures and malfunctions in a timely manner, to keep the overall system functioning in a consistent way that fosters confidence in the traveling public. UDOT utilizes several design tools to accomplish these objectives. This report does not discuss each of those design tools in detail, but indicates that these components should be considered to complete an effective warning system design.

Summary

Rural Intersection Conflict Warning Systems have been utilized in multiple states, particularly in Minnesota. This report summarizes findings from several of these states. General design guidelines are provided, and can be utilized to begin an intersection design. Care should be taken to address the unique nature of each intersection. A variety of static signing and dynamic warning systems can be utilized to achieve the aims of an RICWS. This report highlights specific components that can be used on both the major and minor roadways at a high speed rural intersection.

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