

# ENTERPRISE Transportation Pooled Fund Study TPF-5 (231)



## Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS)

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16. Abstract Intersection crashes continue to represent a significant share of transportation fatalities and serious injuries throughout the country. In addition to intersection lighting, signing and geometric improvements, organizations have turned to ITS as another tool for improving safety. Over the past several years, a variety of mainline and cross street oriented intersection conflict warning systems (ICWS) have been developed and tested in many states across the country. Some systems have been developed using local expertise, while others have been supported by the USDOT Cooperative Intersection Collision Avoidance Systems program. No specific guidance has been available for these systems in regard to placement, size, messaging, failsafe, etc. This has resulted in a fairly broad range of approaches and with the states' growing experience there is now an opportunity to work together in moving toward standardization.  Bringing together organizations that have developed and deployed ICWS, the purpose of this project was to develop a consistent approach for more uniform deployment and further evaluation of ICWS, and to recommend preliminary guidance for MUTCD consideration. This work was initiated through a webinar and two in-person workshops. Participants included ENTERPRISE pooled fund states, other states that have deployed systems, FHWA, NCUTCD, AASHTO and NACE. Based on the information assembled, this guidance provides technical insight and recommended practice for the design and evaluation of ICWS.			
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Several of these individuals also served as liaisons with regulatory and association groups including the National Association of County Engineers, National Committee on Uniform Traffic Control Devices, American Association of State Highway and Transportation Officials Subcommittee on Traffic Engineering and American Traffic Safety Services Association.

# Table of Contents

Introduction ..... 1

Purpose ..... 2

Typical System Components ..... 4

Glossary of Terms..... 4

Design Guidance ..... 6

    ICWS 1: Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection..... 7

    ICWS 2: Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection ..... 8

    ICWS 3: Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection..... 9

    ICWS 4: Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection ..... 10

Evaluation Guidance ..... 11

Next Steps ..... 15

Bibliography ..... 22

Web Site References..... 22

# Introduction

Intersection crashes continue to represent a significant share of transportation fatalities and serious injuries throughout the country. The Federal Highway Administration (FHWA) offers a number of resources to address these crashes through their [Intersection Safety Program](#)<sup>1</sup>. In addition to lighting, signing and geometric improvements, organizations are turning to Intelligent Transportation Systems (ITS) as another resource for reducing intersection crashes. Over the past several years, a variety of major and minor road oriented Intersection Conflict Warning Systems (ICWS) have been developed and tested in states across the country. Some systems have been developed using local expertise, while others have been supported by the USDOT Cooperative Intersection Collision Avoidance Systems (CICAS) program. No specific guidance has been available for these systems in regard to placement, size, messaging, failsafe, etc. As illustrated in Figure 1, this has resulted in a fairly broad range of approaches and with the states' growing experience there is now an opportunity to work together in moving toward standardization. A broader summary of these and other deployments is included in [Appendix A](#) and additional details are available through the ENTERPRISE web site for this project.

**Figure 1 Intersection Conflict Warning Systems**



In February 2011, FHWA released a document summarizing the state of practice for through route (or major road) activated warning systems. The document, "[Stop-Controlled Intersection Safety: Through Route Activated Warning Systems \(FHWA-SA-11-15\)](#)"<sup>2</sup>, presents the details of system deployments in the states of North Carolina and Missouri. It also presents noteworthy practices for signing, site selection, design and operation of major road oriented systems. In addition to these major road systems, there are several systems designed to provide alerts to the minor road driver. Most of these systems are primarily designed to address poor sight distance or gap acceptance by providing an alert about the presence of cross traffic. There are still others designed to reduce speed on the major road to minimize crash severity. In some locations, ICWS may also serve as a remedial step before or in place of traffic signals or geometric changes such as an interchange or roundabout.

In general, traditional warning signs are used to call attention to unexpected conditions on or adjacent to a road open to public travel and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations (Federal Highway Administration, 2009). ICWS offer a substantial warning to drivers as they provide real-time, dynamic information about intersection conditions to support driver decision and, ultimately, reduce intersections crashes.

# Purpose

Bringing together organizations that have developed and deployed all types of ICWS, the [ENTERPRISE<sup>3</sup>](#) transportation pooled fund sponsored a project to develop a consistent approach for accelerated, uniform deployment and further evaluation of these systems, and to recommend preliminary standards for the Manual of Uniform Traffic Control Devices. The project, [Developing Consistency in ITS Safety Solutions – Intersection \(Conflict\) Warning Systems<sup>4</sup>](#), assembled information from the organizations listed in Table 1 to better understand what types of systems have been deployed and what may be known about their effectiveness. The information gathered includes a variety of useful reference documents such as evaluation reports, plans sets, special provisions and concepts of operation. All documents are available through the project web page under [Related Documents/Links<sup>5</sup>](#).

**Table 1 Sources of Intersection Conflict Warning System Information**

FHWA	Florida DOT
Gwinnett County, Georgia	InterSafe (Europe)
Iowa DOT	Maine DOT
Michigan DOT	Minnesota DOT
North Carolina DOT	Missouri DOT
Scott County, Minnesota	Pennsylvania DOT
Washington State DOT	Virginia DOT
Washington County, Minnesota	Wisconsin DOT
Wright County, Minnesota	AASHTO Connected Vehicle Program

Based on the information assembled to-date about federal, state and locally sponsored experience with ICWS, this document provides an initial version of design and evaluation guidance to support future deployment of these systems. As defined in Part 1 of the MUTCD, “Guidance is a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate” (Federal Highway Administration, 2009). In keeping with that definition, this design and evaluation guidance is intended to offer technical insight and recommended practice for designing and evaluating ICWS. It does not mandate the deployment of such systems, nor does it limit the engineering or policy discretion of the transportation agencies who may consider deploying these systems.

This guidance offers insight to current practice and is expected to evolve as more systems are deployed and further evaluation is conducted. It is also expected to serve as preliminary guidance for what may eventually be included in the MUTCD and Highway Safety Manual.

To substantiate and encourage MUTCD and Highway Safety Manual consideration of this guidance, ENTERPRISE engaged representatives from its pooled fund member states, other states that have deployed ICWS, FHWA, [AASHTO Subcommittee on Traffic Engineering<sup>6</sup>](#), [National Committee on Uniform Traffic Control Devices<sup>7</sup>](#) and the [National Association of County Engineers<sup>8</sup>](#). These representatives participated in a webinar and two workshops which were used to share information about experiences with ICWS and to discuss the content of this initial design and evaluation guidance document.

The remainder of this document presents the following design and evaluation guidance for ICWS:

- Typical system components;
- Glossary of terms and symbols;
- Recommended layouts;
- Evaluation guidance; and,
- Next steps.

# Typical System Components

ICWS may include some or all of the following components depending upon the sophistication of the warning provided to drivers. For example, some warnings may depend upon simple detection of vehicle presence and to activate a beacon on a static sign. In contrast, other warnings may require vehicle speed and traveling direction to deliver a message indicating which direction a vehicle is approaching from and how quickly it may arrive.

**Detection:** Used to detect vehicle presence and sometimes speed, detectors typically include:

- Radar
- Pneumatic road tubes
- Light beams
- Acoustic
- Ultrasonic
- Magnetic
- Piezo-electric
- Video
- Inductive Loops
- Radio

**Warning:** Dynamically activated based on the detection of a vehicle, these components may consist of:

- Static sign
- Beacon
- Dynamic message sign
- Illuminated static sign elements

**System Communication:** Forms of communication used to transmit data among components – most often detection and warning – may include:

- Cellular
- Internet – Wireless Access Points
- Radio
- Fiber optic
- Copper wire

**Data Management:** The storage of system performance is done with variety of on/off-site databases or data storage devices.

**System Monitoring:** Various monitoring systems (e.g., physical observation, pager alerts, etc.) may be used to detect fluctuations in system performance as a method of operation.

**Power:** Operation of the detection, warning and system communication require power and the most common sources are grid, battery and solar.



# Glossary of Terms

There are many terms used in the variety of systems that have been developed to-date. Following is a list of such terms and their associated meanings. Where possible, the terms most commonly used and defined in the [MUTCD](#)<sup>9</sup> are suggested as the most appropriate terms of reference (Federal Highway Administration, 2009). Where other terms are used, they and their sources are noted as such.

- **Actuation:** Initiation of a system change through the operation of any type of detector.
- **Beacon:** A highway traffic signal with one or more signal sections that operates in a flashing mode.
- **Detector:** A device used for determining the presence or passage of vehicles or pedestrians.
- **Engineering Judgment:** The evaluation of available pertinent information and the application of appropriate principles, provisions, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. Engineering judgment shall be exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer.
- **Gap:** The (critical) gap is defined as the minimum time interval in the major road traffic stream that allows intersection entry for one minor road vehicle (Transportation Research Board, 2000).
- **Intersection Conflict Warning System:** Typically comprised of static signing, detection and dynamic elements, these systems are used to provide substantial warnings to drivers at intersections where poor sight distance or gap acceptance have contributed to high crash rates. Also referred to as Dynamic Warning System, Collision Countermeasure System, Cooperative Intersection Collision Avoidance System, Stop Sign Assist, Crash Avoidance Systems, Intersection Warning System, Traffic Actuated Warning Signs, and Intersection Movement Assist.
- **Major Road:** The roadway normally carrying the higher volume of vehicular traffic. Also referred to as Through Route and Mainline.
- **Median:** The area between two roadways of a divided highway measured from edge of traveled way to edge of traveled way. The median excludes turn lanes. The median width might be different between intersections, interchanges and at opposite approaches of the same intersection.
- **Minor Road:** The roadway normally carrying the lower volume of vehicular traffic. Also referred to as Cross Street and Stop Approach.
- **Sight Distance:** The length of roadway ahead visible to the driver (American Association of State and Highway Transportation Officials, 1994).
- **Traffic Conflict:** A traffic event involving the interaction of two or more road users, usually motor vehicles, where one or both drivers take evasive action such as braking or swerving to avoid a collision (Federal Highway Administration, 1989).

- **Traffic:** Pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while used for purposes of travel on any highway or private road open to public travel.
- **Vehicle:** Every device in, upon, or by which any person or property can be transported or drawn upon a highway, except trains and light rail transit operating in exclusive or semi-exclusive alignments. Light rail transit equipment operating in a mixed-use alignment, to which other traffic is not required to yield the right-of-way by law, is a vehicle.
- **Warning Sign:** A sign that gives notice to road users of a situation that might not be readily apparent.

# Design Guidance

Based on the information gathered about the systems deployed and practice to-date, the next several pages present recommended design guidance for ICWS. The guidance is presented according to which road the alert is directed at and the number of lanes at the intersection.

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

The layouts contained within this document offer preliminary illustrations and may not represent all the ICWS that are or may be deployed. Systems may be combined, modified, enhanced or simplified as further deployments and evaluation are completed. This guidance reflects current practice related to deployment conditions, intended driver use, placement, sign combinations and message sets. It does not mandate the deployment of such systems, nor does it limit the engineering judgment or policy discretion of the transportation agencies who may consider deploying these systems.

This guidance offers insight to current practice and is expected to evolve as more systems are deployed and further evaluation is conducted. For example, additional detail regarding conditions/warrants, most effective sign combinations and anticipated benefits will be added as information becomes available.

## ICWS 1: Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

### Conditions

- Crash history exhibits a higher than expected rate and/or severity.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.
- Appendix A contains additional information regarding road volumes, posted speeds and potential benefits from individual deployments.

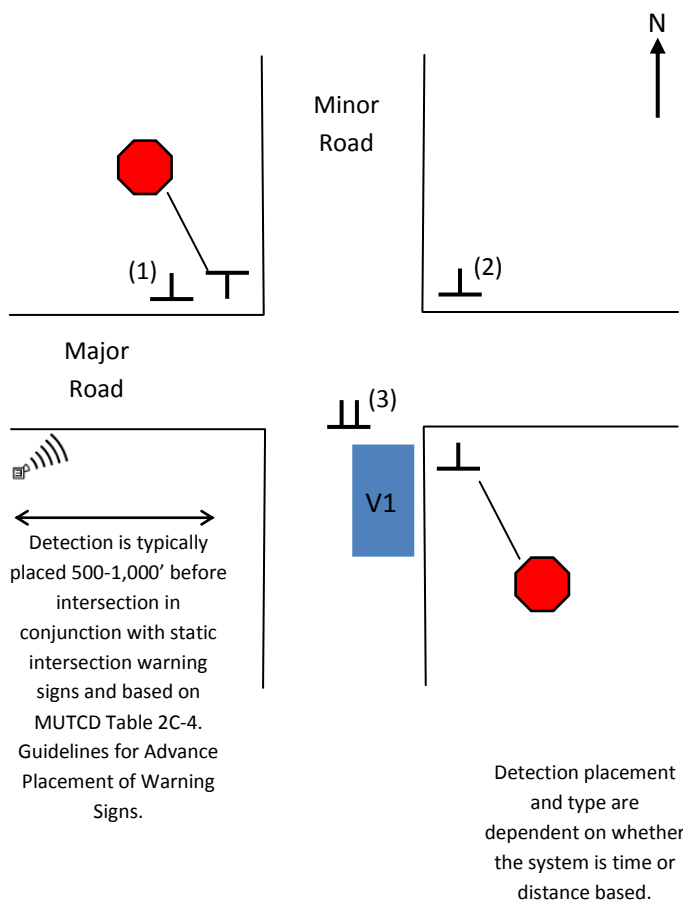
### Intended Driver Use

The system provides drivers on the minor road with an additional warning of vehicle presence on the major road.

The system may also provide drivers with an indication of which direction major road traffic is approaching from.

### Layout

Illustrations are not drawn to scale and are shown from the minor road, northbound vehicle (V1) perspective. Refer to Options for sign placement and other details.



### Options

#### Placement

Warning signs may be placed on the far-side opposite corner (1) from STOP, far-side corner (2) from STOP or suspended above the minor road (3) in the intersection.

#### Sign combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes. Following are sign combinations that have been used.



#### Message Sets

- VEHICLES APPROACHING (ENTERING)
- CROSS TRAFFIC
- LOOK FOR TRAFFIC

Messages may also be combined with WHEN FLASHING plaque.

### Notes and References

Systems have been deployed in Missouri, Minnesota, North Carolina and Georgia on state and local roadways. See Appendix A, signs 1-5, for further details.

## ICWS 2: Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection

### Conditions

- Crash history exhibits a higher than expected rate and/or severity.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.
- Appendix A contains additional information regarding road volumes, posted speeds and potential benefits from individual deployments.

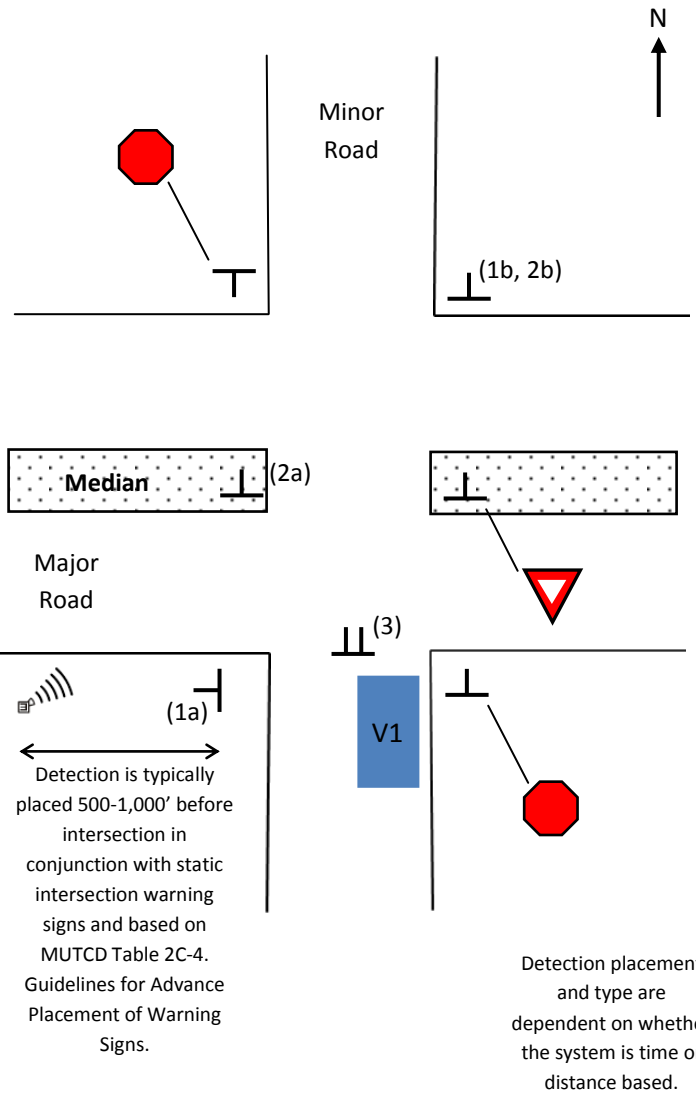
### Intended Driver Use

The system provides drivers on the minor road with an additional warning of vehicle presence on the major road.

The system may also provide drivers with an indication of which direction major road traffic is approaching from and how quickly it may be approaching.

### Layout

Illustrations are not drawn to scale and are shown from the minor road, northbound vehicle (V1) perspective. Refer to Options for sign placement and other details.



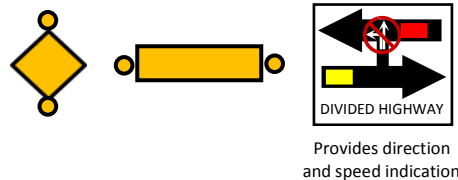
### Options

#### Placement

There is a set of two warning signs for this layout. The first sign may be placed left from STOP (1a) or on the far-side opposite corner from STOP within the median (2a). The second sign may be placed on the far side corner from YIELD (1b, 2b). Signing may also be suspended above the minor road (3) in the intersection.

#### Sign combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes. Following are sign combinations that have been used.



#### Message Sets

- VEHICLES APPROACHING (ENTERING)
- CROSS TRAFFIC
- LOOK FOR TRAFFIC
- Vehicle symbol left / right

Messages may also be combined with WHEN FLASHING plaque.

### Notes and References

Systems have been deployed in Iowa, North Carolina, Missouri, Minnesota and Wisconsin on state and local roadways. See Appendix A, signs 1-2, for further details.

## ICWS 3: Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

### Conditions

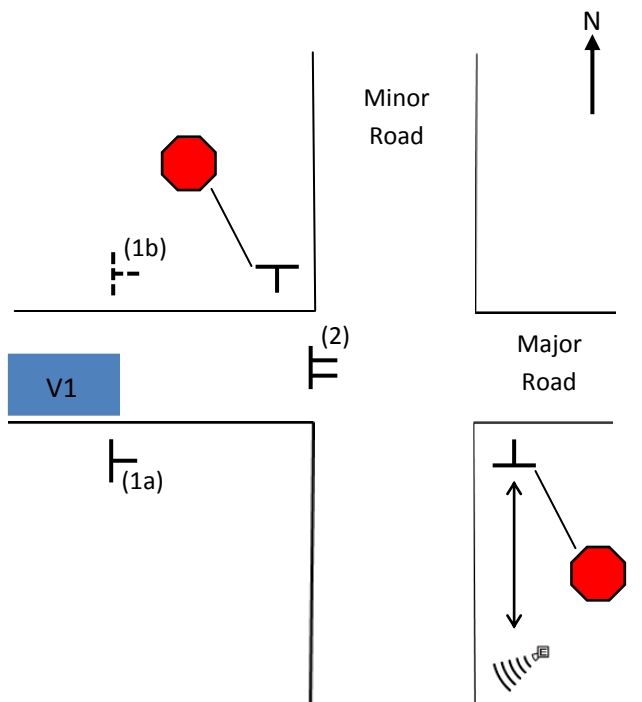
- Crash history exhibits a higher than expected rate and/or severity.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.
- Appendix A contains additional information regarding road volumes, posted speeds and potential benefits from individual deployments.

### Intended Driver Use

The system provides drivers on the major road with an additional warning of cross traffic presence. This may allow them to reduce speed or take defensive action.

### Layout

Illustrations are not drawn to scale and are shown from the major road, eastbound vehicle (V1) perspective. Refer to Options for sign placement and other details.



Detection placement and type are dependent on whether the system is time or distance based.

Detection is typically placed at or 500' before intersection in conjunction with static STOP AHEAD warning signs and based on MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs

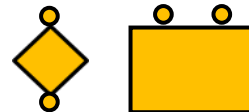
### Options

#### Placement

For a 2-lane major road, one sign may be placed on the right side (1a). For a multi-lane major road, an additional sign may be placed on the left side (1b). Signage may also be suspended above the major road (2) in the intersection.

#### Sign Combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes. Following are sign combinations that have been used.



#### Message Sets

- VEHICLE ENTERING
- WATCH FOR ENTERING TRAFFIC
- CROSSING TRAFFIC

Messages may also be combined with WHEN FLASHING plaque.

### Notes and References

Systems have been deployed in Minnesota, Michigan, Missouri and North Carolina. See Appendix A, signs 6-8, for further details.

Additional information about Missouri and North Carolina systems is available in FHWA-SA-11-15, "[Stop-Controlled Intersection Safety: Through Route Activated Warning System.](#)"<sup>10</sup>

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

## Conditions

- Crash history exhibits a higher than expected rate and/or severity.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.
- Appendix A contains additional information regarding road volumes, posted speeds and potential benefits from individual deployments.

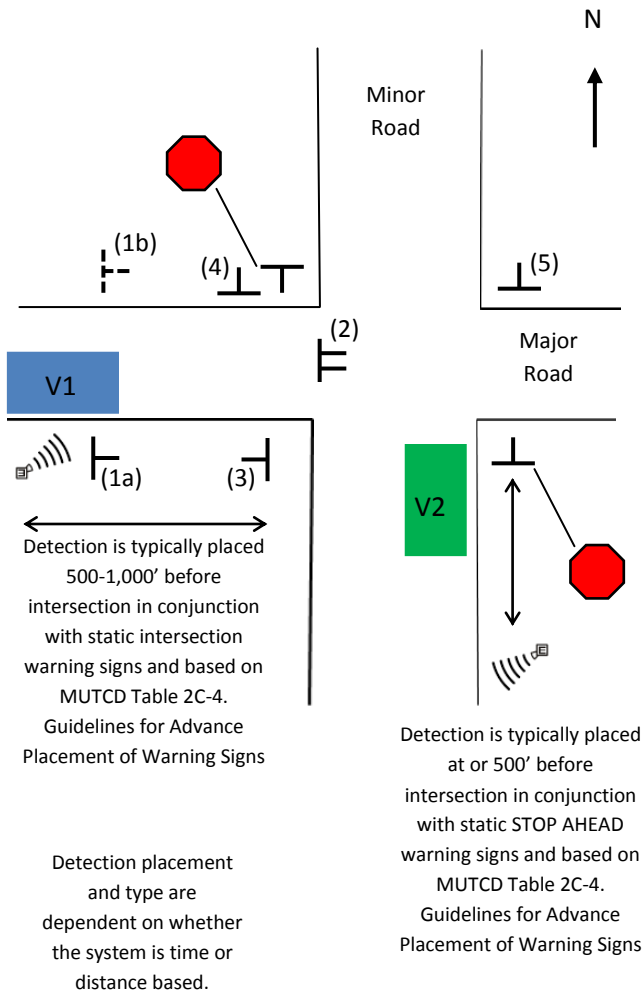
## Intended Driver Use

System provides drivers on the major road with additional warning of cross traffic presence. It also provides drivers on the minor road with a similar warning of vehicle presence on the major road.

Combined, the system may allow major road drivers to take defensive action and provide minor road drivers with an indication of which direction major road traffic is approaching from.

## Layout

Illustrations are not drawn to scale and are shown from both the major road, eastbound vehicle (V1) and the minor road, northbound vehicle (V2) perspectives. Refer to Options for sign placement and other details.



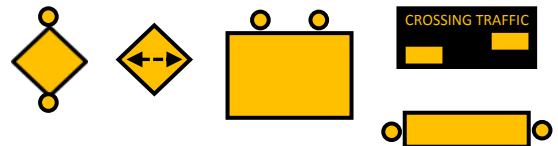
## Options

### Placement

For a 2-lane *major* road, one sign may be placed on the right side (1a). For a multi-lane major road, an additional sign may be placed on the left side (1b). Signage may also be suspended above the major road (2). Warning signs for the *minor* road may be placed left from STOP (3), on the far-side opposite corner (4) from STOP, OR on the far-side corner (5) from STOP.

### Sign Combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes. Following are sign combinations that have been used.



### Message Sets

- VEHICLE ENTERING
- WATCH FOR ENTERING TRAFFIC
- CROSSING TRAFFIC
- LOOK FOR TRAFFIC

Messages may also be combined with WHEN FLASHING plaque.

## Notes and References

Systems have been deployed in Maine, Minnesota, Missouri, North Carolina and Pennsylvania. See Appendix A, signs 9-13, for further details.

# Evaluation Guidance

The remainder of this guidance is focused on the evaluation of ICWS. Not all systems currently deployed have been formally evaluated for their effectiveness, and for those that have been evaluated, a variety of approaches have been used to assess their effectiveness, including:

- **Crash estimation.** Simple before/after and long-term analysis of observed or predicted crash data. Although there are several methods of effectiveness evaluation, this is a traditional approach that is well understood, accepted and widely used. North Carolina has used the approach to evaluate numerous sites that have had ICWS deployed for several years.
- **Benefit cost analysis.** Expected reductions in crashes and crash severity are converted to monetary values and then compared to the implementation and operational costs of an intersection conflict warning system. Pennsylvania uses a structured approach to the traffic safety benefit cost analyses conducted in the state, including the analysis of two ICWS (also referred to as Crash Avoidance Systems) deployments.
- **Conflict studies.** The [traffic conflict technique](#)<sup>11</sup> is a commonly used approach that provides a surrogate or indirect measurement of safety effect. It consists of observation and measurement of traffic conflicts using rates (e.g., conflicts per 1,000 vehicles) or severity (e.g., time to collision). Higher severity scores are assigned to traffic conflicts with a low time to collision and a high risk of collision. Minnesota utilized this approach in one of its ICWS projects.
- **Market research.** Using a representative sample of road users to survey them about their perceptions of system attributes (e.g., understandability, effectiveness, etc.). Minnesota combined this approach with the traffic conflict technique in their Intersection Warning System project.
- **Human factors research.** Study of road user interaction – physical and mental – with a system. The University of Minnesota has conducted extensive human factors research related to driver behavior and ICWS through the Cooperative Intersection Collision Avoidance Systems-Stop Sign Assist project.

Reports and additional information from the states that have used these approaches are available on the [ENTERPRISE project web site](#).<sup>12</sup> More detailed information regarding the conduct of safety effectiveness evaluations is also available in the [Highway Safety Manual](#),<sup>13</sup> Volume 1, Part B-Roadway Safety Management Process, Chapter 9-Safety Effectiveness Evaluation. This manual was released in 2010 as a comprehensive reference tool for screening and diagnosing network safety problems, selecting countermeasures, appraising economic impacts, prioritizing projects and evaluating safety effectiveness. Volume 3, Part D-Crash Modification Factors, Chapter 14-Intersections contains information about specific intersection safety countermeasures and corresponding crash modification factors. However, there is limited information available about intersection conflict warning systems. At the time of its publication, the Highway Safety Manual referred to advanced static warning signs and beacons as a treatment that appears to reduce crashes but the extent of the crash effect is uncertain.

This evaluation guidance is intended to encourage and establish some common parameters for the evaluation of existing and future ICWS deployments. It also is intended to serve as the basis for



developing a broader national evaluation of the systems. It is expected that a nationwide, observational before/after study could be conducted within the next 1-2 years using the comparison group method to leverage the higher numbers of ICWS treatment and non-treatment sites. Initiating a common evaluation framework will influence local data collection, and that will allow data to eventually be pooled across multiple jurisdictions and analyzed to better understand the collective effectiveness of ICWS and the best options for standardization.

For localized, smaller scale evaluations, the Empirical-Bayes method may be used to determine safety effectiveness. In this method, fewer sites are required and safety performance factors are used for comparison in place of non-treatment sites. Detailed information about conducting safety effectiveness evaluations can be found in the Highway Safety Manual, Volume 1, Part B-Roadway Safety Management Process, Chapter 9-Safety Effectiveness Evaluation.

Based on the [ITS Evaluation Guidelines](#)<sup>14</sup> published by FHWA, the basic elements of evaluation presented in the remainder of this section include an evaluation goal, strategy, hypotheses and high-level test plan parameters.

- **Goal.** *To determine the safety impact of the four ICWS configurations at various types of stop-controlled intersections.* There are a number of subtleties that will affect this goal including intersection geometry, sign placement, message set, dynamic elements, etc. These will be acknowledged in the test parameters as details that must be identified, understood, controlled for and potentially further evaluated in separate studies.
- **Strategy.** ICWS typically consist of static signing, detection and dynamic elements, which are used to provide drivers – on the major and/or minor road – with a substantial warning of a potential conflict at the intersection. The intent is to provide drivers on the major road with additional warning of cross traffic presence. It also provides drivers on the minor road with a similar warning of vehicle presence on the major road. This additional warning is expected to help drivers avoid crashes. Drivers, along with transportation engineers, standards development organizations and the traffic control device industry, are key stakeholders in the evaluation of ICWS impacts. Safety is the most relevant area of impact to establish measures of effectiveness around. Several measures of effectiveness may be used but the three most critical and relevant to all ICWS deployed at present and in the future are:
  1. Reduction in total crashes
  2. Reduction in target (right angle) crashes
  3. Reduction in the severity of crash related injuries
- **Hypotheses.** Building off the evaluation goal and measures of effectiveness, the following hypotheses are proposed as a reflection of the outcomes expected from the deployment of ICWS. These hypotheses may be used to develop individual test plans around within a national evaluation effort.
  1. If **major road alerts** are provided, then major road speeds should decrease and so should crashes and crash/injury severity.

2. If **minor road alerts** are provided, then minor road drivers should choose safer gaps and crashes will be reduced.
  3. If **both major and minor road alerts** are provided, then crashes should be reduced more than if major road only or minor road only alerts are provided.
  4. If **major road volumes are below 3,000 AADT**, then an alert on the minor road only should be most effective at reducing crashes.
  5. If **major road volumes are above 3,000 AADT**, then an alert on the major road only should be most effective at reducing crashes.
  6. If **major road volumes are over 10,000 AADT**, then alerts on both the major and minor road should be most effective at reducing crashes.
  7. If **major road volumes are so high that a warning becomes nearly constant**, then additional information regarding direction of travel or speed of approaching vehicles must be provided.
  8. If **minor road drivers understand that the ICWS alerts them when cross traffic is present**, then they may disregard the STOP sign and crashes may increase.
- **Test Plan Parameters.** Test plan parameters must be identified, understood and controlled for, as necessary, during evaluation. Parameters related to the evaluation of ICWS include but are not limited to the following items. The items noted here are intended as a minimum set of parameters that agencies should gather data around when installing ICWS. Using these parameters to outline a dataset will address localized evaluation needs and support a broader, national evaluation of ICWS.
    1. Crash data three years pre- and post-installation of ICWS (total crashes, target crashes, injury severity, driver ages)
    2. Intersection geometry (number and use of lanes, legs, divided)
    3. Sight distance to intersection on both minor and major road
    4. Traffic volume (minor/major/entering)
    5. Posted speeds
    6. Roadway jurisdiction(s)
    7. Traffic control (existing)
    8. Other safety improvements (e.g., lighting, rumble strips, pavement markings)
    9. ICWS configuration 1-4
    10. Sign placement (e.g., overhead, roadside, far corner from STOP)
    11. Sign message set
    12. Dynamic element (e.g., flashing beacon, LEDs, dynamic message sign)

### 13. Detection type and placement

The ENTERPRISE project web page includes an example of a [North Carolina evaluation dataset](#)<sup>15</sup> collected around parameters such as these. Within this dataset are further links to the summary evaluation reports prepared by North Carolina during their analysis. In addition to the Highway Safety Manual, these evaluation tools offer examples that may be used by other agencies to complete localized ICWS evaluation.

In addition to the evaluation elements and Highway Safety Manual referenced above, there are several additional resources that may be further referenced for evaluation techniques and intersection safety. The six major areas of the AASHTO [Strategic Highway Safety Plan](#)<sup>16</sup> (Drivers, Vehicles, Special Users, Highways, Emergency Medical Services, and Management) are subdivided into 22 goals, or key emphasis areas, that impact highway safety. One of the 22 emphasis areas addresses the improvement of safety at intersections where it is noted that a key to improving overall intersection safety is to address safety problems at unsignalized intersections.

Building on the Strategic Highway Safety Plan, the National Cooperative Highway Research Program Report 500, [Volume 05: A Guide for Addressing Unsignalized Intersection Collisions](#)<sup>17</sup> provides additional guidance to transportation agencies that want to implement safety improvements at unsignalized intersections and includes a variety of strategies that may be applicable to particular locations. Providing automated real-time systems to inform drivers of the suitability of available gaps for making turning and crossing maneuvers, is identified as a strategy for assisting drivers in judging gap sizes at unsignalized intersections. Installing flashing beacons at stop-controlled intersections is further identified in the guide to improve driver awareness of intersections as viewed from the intersection approach. Both of these strategies relate to ICWS and at the time of publication in 2003, the guide identified them as experimental. The Highway Safety Manual was released in 2010 as a further supplement to NCHRP Report 500. As noted above, the manual provides tools to conduct quantitative safety analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts and construction costs.

The [Crash Mitigation Factor Clearinghouse](#)<sup>18</sup> is another excellent resource that was recently initiated by FHWA. A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure – ICWS, for example – at a specific site. It is important to note that a CMF represents the long-term expected reduction in crashes and this estimate is based on the crash experience at a limited number of study sites; the actual reduction may vary. The clearinghouse offers transportation professionals a central, web-based repository of CMFs and related information and resources.

These resources are noted as valuable references for localized evaluation of ICWS, as well as key references for further development of a national ICWS evaluation.

## Next Steps

The evaluation and design guidance presented in this document reflect the recommended practices for deploying ICWS to-date. There is still a great deal to be learned about these systems to standardize design in a way that maximizes the safety impact. As the ENTERPRISE project that prompted the development of this guidance concludes in January 2012, it is important to share the information and findings with other organizations involved in ICWS related work. To facilitate that sharing of information over the next several months, the following steps were identified by the transportation professionals who participated in the development of this guidance.

### *Federal Highway Administration*

It will be important to update the FHWA MUTCD team and Office of Safety. The update should summarize webinar/workshop proceedings and the resulting document, “Design and Evaluation Guidance for Intersection Conflict Warning Systems.” There should also be suggestions and discussion of potential next steps for future deployments, moving toward national evaluation, formally engaging the MUTCD process, etc. FHWA division staff in each of the states should also be updated again on the results of the work and potential next steps.

### *National Association of County Engineers*

The next annual meeting for NACE is scheduled for April 1-5, 2012 in Lexington, KY. It would be good to continue working with Minnesota’s county engineers who are active at the national level to see if there could be a presentation or committee meeting discussion on ICWS.

### *National Committee on Uniform Traffic Control Devices*

There are two potential NCUTCD technical committees that could address ICWS – Guide/Motorist Information Signs or Regulatory/Warning Signs. These and other technical committees will be meeting January 18-19, 2012 at the TRB Annual Meeting in Washington, DC. Tom Heydel, Wisconsin, is a member of the Regulatory/Warning Signs technical committee and is willing to share the Design and Evaluation Guidance for Intersection Conflict Warning Systems document with the committee. He will suggest that a task force be formed to consider next steps related to the MUTCD. Typically, language in the MUTCD will relate to the signs specifically and then reference other documents, such as the Traffic Control Devices Handbook and Highway Safety Manual, for recommended conditions of use, deployment considerations, etc. It will also be useful to share the guidance with the Regulatory/Warning Sign Committee chair, Bruce Ibarguen, Maine. Maine is one of the states that have deployed an ICWS and they have participated in this project.

### *AASHTO Subcommittee on Traffic Engineering*

SCOTE will also meet in January during the TRB Annual Meeting. Each state was encouraged to share information about the ICWS, particularly the design and evaluation guidance, with their SCOTE representative in advance of the January meeting.

### *American Traffic Safety Services Administration*

As state and local agencies continue planning for future deployment of intersection conflict warning systems, several questions arise for industry in relation to product availability, standardization, costs and so forth. Because ATSSA was unable to participate directly in the ENTERPRISE project, they agreed to a written exchange of information about future ICWS deployments and answers to industry related questions from the transportation agencies. Jon Jackels, Minnesota and ENTERPRISE project champion, will share industry questions with Roger Wentz, ATSSA president and CEO.

### *Traffic Control Devices TPF-5(065)*

The Traffic Control Devices (TCD) Consortium focuses on systematic evaluation of novel TCDs, employing a consistent process that addresses human factors and operations issues for each TCD idea. This could be an avenue for further human factors research into sign placement and legend. The group has their next annual meeting in April 2012 in Kansas. Missouri, North Carolina, Pennsylvania, Kansas and Iowa are members of this pooled fund and could propose this research. More information about the pooled fund is available online through the [Transportation Pooled Fund Program](#)<sup>19</sup>; search for the TPF number 5(065).




### *Evaluation of Low Cost Safety Improvements TPF-5(099)*

The goal of this pooled fund is to develop reliable estimates of the effectiveness of the safety improvements that are identified as strategies in the National Cooperative Highway Research Program (NCHRP) Report 500 Guides. This group may be an option for coordinating a national evaluation of ICWS. Several states participating in the workshop are also members of the pooled fund – Iowa, Kansas, Minnesota, Missouri, North Carolina, Pennsylvania and Wisconsin. They are scheduled to hold their next annual meeting in March or April 2012. More information about the pooled fund is available online through the Transportation Pooled Fund Program; search for the TPF number 5(099).




### *ENTERPRISE TPF-5(231)*

ENTERPRISE is currently considering another ICWS related project in its 2012 work plan. The scope of the project has evolved from deployment among member states to national evaluation. If other pooled funds are better suited to coordinating a national evaluation, it may be suggested that ENTERPRISE 1. Co-sponsor a national evaluation or 2. Rescope its next project to have more of a coordination and marketing focus to further support ICWS evaluation and standardization. More information about the pooled fund is available online through the Transportation Pooled Fund Program; search for the TPF number 5(231). You can also visit ENTERPRISE online at [www.enterpriseprog.org](http://www.enterpriseprog.org).



## Appendix A – Intersection Conflict Warning Systems: Characteristics Summary (as of October 2011)

Sign	Roadway/Intersection Characteristics	Sign/Detection Placement	Message Set
<p>1. Minor Road</p> 	<p><b>Iowa – Dyersville</b> – US 20 (4-lane; 9,000 ADT) and 7<sup>th</sup> St (2-lane; 735 ADT)</p> <p><b>Iowa – Anamosa</b> – US 151 (4-lane; 10,050 ADT) and Old Dubuque Rd (2-lane; 1,385 ADT)</p> <p><i>Problem: Gap acceptance</i></p> <p><b>Missouri – Lowry City</b> – MO 13 (4-lane; 10,000 ADT) and 1<sup>st</sup> St (2-lane)</p> <p><b>Missouri – Osceola</b> – MO 13 (4-lane; 10,000 ADT) and Truman Rd (2-lane)</p> <p><b>Missouri</b> – 8 other locations</p> <p><i>Problem: Gap acceptance</i></p>	<p><b>Sign (with yellow flashers):</b> 50-200' to the left of STOP and second on far-side corner from median YIELD; on major road</p> <p><b>Detection (loops):</b> 1000' before intersection on major road</p>	<p>TRAFFIC APPROACHING WHEN FLASHING</p>
<p>2. Minor Road</p> 	<p><b>Minnesota – Goodhue County</b> – US 52 (4-lane; 17,500 ADT) and Co Rd 9 (2-lane)</p> <p><b>Minnesota – Mille Lacs County</b> – US 169 (4-lane; 11,200 ADT) and Co Rd 11 (2-lane)</p> <p><b>Minnesota – Lyon County</b> – MN 23 (4-lane; 6,200 ADT) and Co Rd 7 near Marshall</p> <p><b>Wisconsin – Minong</b> – US53 (4-lane; 4,400 ADT) and WI 77 (2-lane; 2,850 ADT)</p> <p>Posted speed 65 MPH</p> <p><i>Problem: Gap acceptance</i></p>	<p><b>Sign (DMS):</b> First on far-side, opposite corner from STOP and second on far-side corner from median STOP/YIELD</p> <p><b>Detection (radar):</b> First approximately 800' and second approximately 150' before intersection</p>	<p>Symbol: Divided highway with color and do not enter indicators</p>
<p>3. Minor Road</p> 	<p><b>Minnesota – Hennepin County</b> – Co Rd 47 (2-lane; 3,150 ADT) and Lawndale Ln (2-lane; 100 ADT)</p> <p>Posted speed 40 MPH</p> <p><i>Problem: Sight distance</i></p>	<p><b>Sign (with yellow LED arrow-shaped flashers):</b> Far-side corner from STOP</p> <p><b>Detection (radar):</b> 750' before intersection</p>	<p>LOOK FOR TRAFFIC</p>

## Appendix A – Intersection Conflict Warning Systems: Characteristics Summary (as of October 2011)

Sign	Roadway/Intersection Characteristics	Sign/Detection Placement	Message Set
<p>4. Minor Road</p> 	<p><b>Minnesota – Washington County</b> – Manning Ave/CSAH 15 (2-lane) and McKusick Rd/CR 64 (2-lane)</p> <p>Posted speed 55 MPH</p> <p><i>Problem: STOP running</i></p>	<p><b>Sign (8 LED lights on STOP):</b> At STOP</p> <p><b>Detection (radar):</b></p>	<p>STOP, CROSS TRAFFIC DOES NOT STOP</p>
<p>5. Minor Road</p> 	<p><b>Georgia – Gwinnett County</b> – Lester Rd (2-lane; 9,800 ADT) and Cutler Dr (2-lane residential)</p> <p><b>Georgia – Gwinnett County</b> – 17 other locations with major road and both major/minor road systems</p> <p>Posted speeds 25-45 MPH</p> <p><i>Problem: Sight distance</i></p>	<p><b>Sign (with red flashers):</b> Far-side, left from STOP</p> <p><b>Detection (loops):</b> Approximately 500' before intersection</p>	<p>VEHICLE APPROACHING, IF NO LIGHT SIGNAL NOT WORKING</p>
<p>6. Major Road</p> 	<p><b>North Carolina – Pender County</b> – US 421 (4-lane; 4,400 ADT) and NC 210 (2-lane; 1,900 ADT) – Category 3</p> <p>Posted speed 55 MPH</p> <p><i>Problem: Gap acceptance</i></p> <p>North Carolina – 21 other locations; variety of 2-lane and 4-lane roadways</p>	<p><b>Sign (with yellow flashers):</b> May be single or dual placement for multi-lane roads; placed using MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs</p> <p><b>Detection (loops):</b> 250-400' from intersection based on design speed</p>	<p>VEHICLE ENTERING (WHEN FLASHING)</p>

## Appendix A – Intersection Conflict Warning Systems: Characteristics Summary (as of October 2011)

Sign	Roadway/Intersection Characteristics	Sign/Detection Placement	Message Set
<p>7. Major Road</p> 	<p><b>Minnesota – Milaca</b> – US 169 (4-lane; 11,200 ADT) and Co Rd 11 (2-lane) Posted speed 65 MPH</p> <p><b>Michigan – Benzie County</b> – US 31 (2-lane; 8,200 ADT) and Grace/Love Rd (2-lane) Posted speed 45 MPH</p> <p><b>Michigan – Germfask</b> – M-77 (2-lane; 1,900 ADT) Posted speed 45 MPH</p> <p><i>Problem: Gap acceptance and sight distance</i></p>	<p><b>Sign (with yellow flasher):</b> 850-1,000' before intersection</p> <p><b>Detection (magnetic):</b> 400-450' from STOP on minor road; at STOP bar; in median; in major road left turn lane</p>	<p>CAUTION CROSSING TRAFFIC WHEN FLASHING</p>
<p>8. Major Road</p> 	<p><b>Missouri – Tunas</b> – Missouri 73 (2-lane; 2,100 ADT) and Routes E/D (2-lane; 400 ADT) Posted speed 55 MPH</p> <p><b>Missouri - Louisburg</b> – US 65 (2-lane; 5,100 ADT) and Missouri 64 (2-lane; 1,200 ADT) Posted speed 45 MPH</p> <p><i>Problem: Sight distance</i></p> <p><b>Missouri - 7 other locations</b></p>	<p><b>Sign (with yellow flashers):</b> 600-800' before intersection</p> <p><b>Detection (loops):</b> Actuated at minor road STOP</p>	<p>WATCH FOR ENTERING TRAFFIC VEHICLES ENTERING WHEN FLASHING</p>
<p>9. A-Major Road    B-Minor Road</p> 	<p><b>North Carolina – Brassfield</b> – NC 96/Brassfield Rd (2-lane; 1,300 ADT) and NC 96/Horseshoe Rd (2-lane; 4,000 ADT) – Category 1 Posted speed 55 MPH</p> <p><i>Problem: Gap acceptance</i></p> <p><b>North Carolina</b> – 46 other locations; variety of 2-lane and 4-lane roadways</p>	<p><b>Sign (with yellow flashers):</b> May be placed at or before intersection on major or minor road</p> <p><b>Red flashers</b> in conjunction with STOP</p> <p><b>Detection (loops):</b> 250-400' from intersection based on design speed</p>	<p>VEHICLE ENTERING (WHEN FLASHING)</p> <p>Occasionally, VEHICLE ENTERING FROM RIGHT (LEFT) WHEN FLASHING</p> <p>Occasionally, WATCH FOR APPROACHING VEHICLE</p>



## Appendix A – Intersection Conflict Warning Systems: Characteristics Summary (as of October 2011)

Sign		Roadway/Intersection Characteristics	Sign/Detection Placement	Message Set
10. A-Major Road	B-Minor Road	<p><b>Minnesota – St. Louis County – W Tischer Rd/Co Rd 2 (2-lane; 980 ADT) and Eagle Lake Rd/Co Rd 246 (2-lane; 550 ADT)</b></p> <p>Posted speed 45-55 MPH</p> <p><i>Problem: Sight distance</i></p>	<p><b>Sign-Major (with spot LED flashers):</b> 525' before intersection</p> <p><b>Sign-Minor (with spot LED flashers):</b> Far-side corner from STOP</p> <p><b>Detection (radar and passive infrared):</b> 2 radar detectors on minor road installed at STOP; 2 passive infrared detectors on major road 460' and 645' before intersection</p>	<p>Major: CROSS TRAFFIC, WHEN FLASHING</p> <p>Minor: VEHICLE APPROACHING, WHEN FLASHING</p>
11. A-Major Road	B- Minor Road	<p><b>Minnesota – Wright County:</b></p> <ul style="list-style-type: none"> <li>• CSAH 8 @ CSAH 35 (2-lane; 1,850 ADT)</li> <li>• CSAH 6 @ CSAH 35 (2-lane; 1,125 ADT)</li> <li>• CSAH 9 @ CR 107 (2-lane; 1,113 ADT)</li> </ul> <p>Posted speed 55 MPH</p> <p><i>Problem: Gap acceptance</i></p> <p><b>Minnesota – Scott County – CSAH 42 @ CSAH 17</b></p>	<p><b>Sign-Major (with yellow flashers):</b> 600-800' before intersection</p> <p><b>Sign-Minor (with yellow LED arrow-shaped flashers):</b> Far-side corner from STOP</p> <p><b>Detection (radar):</b> 600' before intersection on major road</p>	<p>Major: Intersection symbol</p> <p>Minor: LOOK FOR TRAFFIC</p>

## Appendix A – Intersection Conflict Warning Systems: Characteristics Summary (as of October 2011)

Sign		Roadway/Intersection Characteristics	Sign/Detection Placement	Message Set
12. A-Major Road	B-Minor Road	<p><b>Pennsylvania – Butler County</b> – S.R. 38 (2-lane; 3,200 ADT) and S.R. 138/North Washington Rd (2-lane; 825 ADT) Posted speed 35 MPH</p> <p><b>Pennsylvania – Butler County</b> – S.R. 38 (2-lane; 3,200 ADT) and S.R. 1010/Hooker Rd (2-lane; 950 ADT) Posted speed 35 MPH <i>Problem: Sight distance</i></p> <p><b>Virginia – Prince William County</b> – Fleetwood Dr and Aden Rd/S.R. 646</p>	<p><b>Sign-Major (with DMS):</b> 200-500' from intersection</p> <p><b>Sign-Minor (DMS):</b> Far-side corner from STOP</p> <p><b>Detection (loops):</b> 300-1,000' before intersection</p>	<p>Major: Vehicle symbol and TRAFFIC AHEAD</p> <p>Minor: Vehicle symbol and CROSSING TRAFFIC</p>
13. A-Major Road	B-Minor Road	<p><b>Maine – Norridgewock</b> – Route 201A (2-lane; 5,000 ADT) and Sophie May Ln/River Rd (2-lane; 3,000 ADT) Posted speed 25 MPH <i>Problem: Sight distance</i></p>	<p><b>Sign-Major (with yellow flashers):</b> On bridge, north of intersection</p> <p><b>Sign-Minor (with DMS):</b> Far-side corner from STOP</p> <p><b>Detection (loops):</b> Based on the time of travel required for a vehicle traveling at the speed limit (using 85<sup>th</sup> percentile speeds) to reach the intersection</p>	<p>Major: TRAFFIC ENTERING WHEN FLASHING</p> <p>Minor: Vehicle symbol and VEHICLES ENTERING – FROM LEFT – FROM RIGHT</p>

Additional information about these systems is available at

[http://www.enterprise.prog.org/Projects/2010\\_Present/developingconsistencyIWS/iws\\_relateddocuments.html](http://www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/iws_relateddocuments.html).

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- Transportation Research Board for the National Academies. (2000). *Highway Capacity Manual 2000*. Washington DC.

# Web Site References

The following web addresses are noted in the order they appear within the document.

- 
- <sup>1</sup> <http://safety.fhwa.dot.gov/intersection/>
  - <sup>2</sup> <http://safety.fhwa.dot.gov/intersection/resources/fhwasa11015/>
  - <sup>3</sup> <http://www.enterprise.prog.org/>
  - <sup>4</sup> [http://www.enterprise.prog.org/Projects/2010\\_Present/developingconsistency.html](http://www.enterprise.prog.org/Projects/2010_Present/developingconsistency.html)
  - <sup>5</sup> [http://www.enterprise.prog.org/Projects/2010\\_Present/developingconsistencyIWS/iws\\_relateddocuments.html](http://www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/iws_relateddocuments.html)
  - <sup>6</sup> <http://scote.transportation.org/Pages/default.aspx>
  - <sup>7</sup> <http://nctcd.org/>
  - <sup>8</sup> <http://www.countyengineers.org/>
  - <sup>9</sup> [http://mutcd.fhwa.dot.gov/pdfs/2009/pdf\\_index.htm](http://mutcd.fhwa.dot.gov/pdfs/2009/pdf_index.htm)
  - <sup>10</sup> <http://safety.fhwa.dot.gov/intersection/resources/fhwasa11015/traws.pdf>
  - <sup>11</sup> <http://www.fhwa.dot.gov/publications/research/safety/88027/88027.pdf>
  - <sup>12</sup> [http://www.enterprise.prog.org/Projects/2010\\_Present/developingconsistency.html](http://www.enterprise.prog.org/Projects/2010_Present/developingconsistency.html)
  - <sup>13</sup> <http://safety.transportation.org/>
  - <sup>14</sup> [http://www.its.dot.gov/evaluation/eguide\\_resource.htm](http://www.its.dot.gov/evaluation/eguide_resource.htm)
  - <sup>15</sup> [http://www.enterprise.prog.org/Projects/2010\\_Present/developingconsistencyIWS/NCVehiclesEnteringWhenFlashingDataset072610.xls](http://www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NCVehiclesEnteringWhenFlashingDataset072610.xls)
  - <sup>16</sup>
  - <sup>17</sup> [http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rpt\\_500v5.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf)
  - <sup>18</sup> <http://www.cmfclearinghouse.org/>
  - <sup>19</sup> <http://www.pooledfund.org/>