ROADMAP FOR NEXT GENERATION INTERSECTION CONFLICT WARNING SYSTEMS (ICWS)

FINAL REPORT

OCTOBER 2, 2019

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(359)

Prepared by:
Athey Creek Consultants

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16. Abstract Intersection Conflict Warning Systems (ICWS) are used to warn drivers on the mainline road of the presence of traffic at stop-controlled intersections and/or warn drivers at stop-controlled approaches of the presence of traffic on mainline roads. ICWS deployments are still relatively new with few deployments prior to 2010, however the number of deployments has increased in the past several years nationwide. The ENTERPRISE Pooled Fund Study has completed several ICWS related projects from 2011 – 2015 including design and guidance for ICWS, system engineering documents for ICWS, and overall coordination and outreach with national standards groups, industry associations, and other pooled fund programs. Building off these previous efforts, ENTERPRISE conducted this project to identify and document issues related to the development and deployment of next-generation approaches to ICWS. This information was utilized to develop a roadmap of prioritized next steps to help guide future ICWS deployment efforts.			
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The cover page photo is provided courtesy of the Minnesota Department of Transportation.

Project Champion

Cory Johnson, Minnesota Department of Transportation, was the ENTERPRISE Project Champion for this effort. The Project Champion serves as the overall lead for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities of the program:

- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Ontario Ministry of Transportation
- Pennsylvania Department of Transportation
- Texas Department of Transportation
- Wisconsin Department of Transportation

Project Participants

ENTERPRISE would like to acknowledge and thank the following transportation agencies who participated by completing a survey and/or provided information via the project webinars:

- Delaware Department of Transportation
- Florida Department of Transportation
- Georgia Department of Transportation
- Illinois Department of Transportation
- Indiana Department of Transportation
- Iowa Department of Transportation
- Kentucky Transportation Cabinet
- Louisiana Department of Transportation and Development
- Maryland Department of Transportation State Highway Administration
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Minnesota St. Louis County
- Mississippi Department of Transportation
- Missouri Department of Transportation
- New Hampshire Department of Transportation
- New Mexico Department of Transportation
- North Carolina Department of Transportation
- Ohio Department of Transportation
- South Dakota Department of Transportation
- Utah Department of Transportation
- Wisconsin Department of Transportation

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1.0 Introduction

Intersection Conflict Warning Systems (ICWS) are used to warn drivers on the mainline road of the presence of traffic at stop-controlled intersections and/or warn drivers at stop-controlled approaches of the presence of traffic on mainline roads. See examples in Figures 1, 2, and 3 below. ICWS deployments are still relatively new with few deployments prior to 2010, however the number of deployments has increased in the past several years nationwide.

Figure 1: ICWS Deployment for both Mainline and Side Street Traffic in St. Louis County, MN

Figure 2: ICWS Deployment for Side Street Traffic in Iowa

Figure 3: ICWS Deployment for Mainline Traffic in Iowa

The ENTERPRISE Pooled Fund Study has completed several ICWS related projects from 2011 – 2015 including design and guidance for ICWS, system engineering documents for ICWS, and overall coordination and outreach with national standards groups, industry associations, and other pooled fund programs. Building off these previous efforts, ENTERPRISE conducted this project to identify and document issues related to the development and deployment of next-generation approaches to ICWS. This information was utilized to develop a roadmap of prioritized next steps to help guide future ICWS deployment efforts.

As a first step for this project, an online literature search was conducted to identify ICWS resources (e.g. ICWS informational booklets, final reports, design or deployment guidance, plan sets, evaluations). To enhance the literature search, a survey was distributed in April 2019 to the state traffic engineer in each state transportation agency. The purpose of the survey was to document how many ICWS have been deployed by each agency, learn about any modifications or issues with ICWS deployments, gather evaluation results, and document ideas to consider for the design or research needs for the next generation ICWS.

The results of the literature search and survey were then used to facilitate a webinar on June 24, 2019 with those agencies that participated in the survey. The purpose of the webinar was to share the survey results, discuss ICWS issues, and discuss potential approaches to address those issues.

The information gathered from the literature search, survey, and webinar were utilized to develop a draft roadmap of ICWS issues mapped to transportation agency practices, key resources and research findings, and potential next step approaches. The draft roadmap was reviewed during a second webinar on August 7, 2019 for input and to prioritize next steps for addressing each ICWS issue. The input received during the webinar was incorporated and a final roadmap was developed. It is anticipated that components of the roadmap priorities will be implemented by transportation agencies whether it is an agency considering a deployment, an agency that has only deployed a few, or agencies that have many ICWS deployments. In addition, other entities such as the Federal Highway Administration (FHWA), pooled funds, or university research entities may implement the roadmap priorities. Figure 4 illustrates the project steps and an anticipated next step for implementing roadmap priorities.

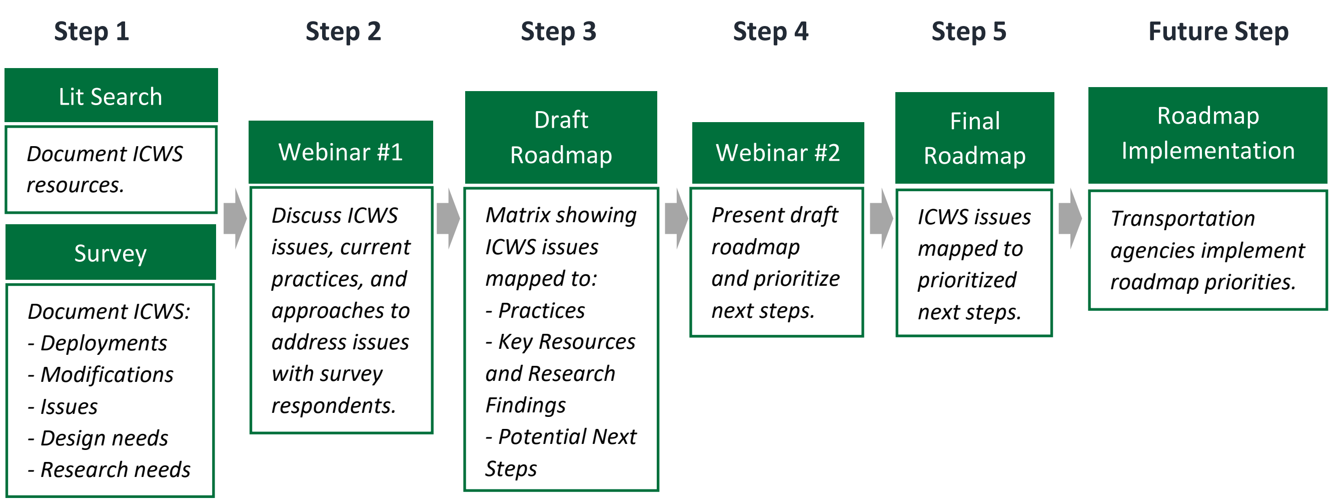


Figure 4: Project Steps

This document includes the following sections:

- 2.0 Literature Search – Summarizes ICWS resources found through an online and Transportation Research International Documentation (TRID) database search, including previous ENTERPRISE ICWS efforts and other relevant literature.
- 3.0 Survey – Presents a summary of responses from a survey distributed to each state to collect information on ICWS deployments.
- 4.0 Project Webinars – Describes two project webinars that were hosted by ENTERPRISE as part of this project to gather input from transportation agencies on ICWS issues, ICWS practices, and approaches to addressing ICWS issues.
- 5.0 Roadmap for Next Generation of ICWS – Provides prioritized next step ICWS approaches for addressing ICWS issues in 5 categories (Planning, Design, Procurement and Installation, Operations and Maintenance, and Evaluation).
- 6.0 Summary – Provides an overall project summary including the next steps to advance the state of practice as the next generation of ICWS are designed and deployed.

2.0 Literature Search

This section summarizes the literature search that was conducted to identify available ICWS resources. The documents gathered were reviewed to start a list of potential issues and questions with developing next generation ICWS.

ENTERPRISE has focused efforts on ICWS since 2011. Following is a brief summary of the previous ICWS projects completed by ENTERPRISE. The deliverables from each project were reviewed for this project.

- Phase 1: Developing Consistency in ITS Safety Solutions - ICWS (2011)
  The purpose of this project was to develop a consistent approach for accelerated, uniform deployment and further evaluation of ICWS, and to recommend preliminary standards for the Manual on Uniform Traffic Control Devices (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, the National Committee on Uniform Traffic Control Devices (NCUTCD), the American Association of State Highway and Transportation Officials (AASHTO), and the National Association of County Engineers (NACE). ICWS design guidance was provided for four types of intersections.
- Phase 2: ICWS Coordination and Systems Engineering (2012 and 2013)
  This project further supported the standardization of ICWS by coordinating among various national standards and association groups and by developing a concept of operations and system requirements for the four types of ICWS intersections identified in Phase 1.
- Phase 3: ICWS Support and Outreach (2015)
  Phase 3 continued coordination with national standards groups, industry associations, and other pooled fund programs that had been engaged through the ENTERPRISE ICWS work. Outreach was conducted through a series of ICWS focused topic webinars. Phase 3 also continued to provide ICWS deployment support to ENTERPRISE members.
- ICWS Planning Guidance (2015)
  ENTERPRISE developed planning guidance (meaning in what situations you should consider deploying a device) for nine Intelligent Transportation System (ITS) devices (e.g. dynamic message signs, variable speed limits, ramp meters). As part of this effort, planning guidance for ICWS was developed in 2015. There were two situations for which ICWS guidelines were developed – Intersections with High Crash Frequencies or Rates and Intersection Characteristics.

In addition, there were approximately 40 ICWS resources gathered by ENTERPRISE during these previous phases. Through the new online search and a review of the TRID database as part of this project, an additional 20 new resources were found. Documents found through this search included ICWS informational booklets, system engineering documents, final reports, guidelines, plan sets, project summaries, project plans, special provisions, test plans, presentations, and evaluations. The ICWS Related Documents were updated on the ENTERPRISE ICWS webpage and were also reviewed to document ICWS next generation issues and questions. See Appendix A for a list of ICWS resources.

The results of the literature search were used to support the development of the ICWS roadmap. Key resources and research findings from the literature search were mapped to ICWS issues in five categories. There may be other categories and issues, however this project is structured on those noted in Table 1 below.

Table 1: ICWS Categories and Issues

Category	Issue
Category 1: Planning	• Issue A: Safety Effectiveness of ICWS • Issue B: ICWS Warrants and Early Design Planning • Issue C: ICWS Standards • Issue D: ICWS Legal Issues and Liability • Issue E: ICWS Cost • Issue F: Connected and Automated Vehicle (CAV) Integration with ICWS
Category 2: Design	• Issue G: ICWS Sign Messaging • Issue H: ICWS Warning/Flashing Actuation • Issue I: ICWS Sign Site Selection • Issue J: ICWS Power • Issue K: ICWS Sign Structures
Category 3: Procurement and Installation	• Issue L: ICWS Equipment • Issue M: ICWS Detection Methods • Issue N: Programming ICWS Controllers
Category 4: Operations and Maintenance	• Issue O: Monitoring of ICWS • Issue P: ICWS Maintenance
Category 5: Evaluation	• Issue Q: Consistent ICWS Data Collection for Analysis and Evaluations • Issue R: Public Response

The literature search produced 3 or more documents related to the following ICWS issues: Issue A. Safety Effectiveness of ICWS, Issue B. ICWS Warrants and Early Design Planning, and Issue G. ICWS Sign Messaging. For example, to assist in understanding the effectiveness of ICWS a key resource found in the literature search states:

> *ICWS was more effective for two-lane at two-lane intersections, major road alerts in advance of the intersection, and a combination of both major and minor alerts with a 32% and 25% reduction in total crashes, respectively. Target frontal impact crashes for these categories were also reduced by 32% and 20% respectively. (Source: NCDOT Traffic Safety Unity Program: Vehicle Entering When Flashing Evaluation (November 2012))*

See Figure 5 for examples of mainline ICWS deployments in North Carolina.

Figure 5: Photos of Mainline ICWS Deployment in North Carolina

There were two or less key resources or research findings supporting the remaining issues listed in Table 1. See Appendix B for the documents found relevant to each ICWS issue. The literature search revealed that there is a need for ICWS research in many different areas. This may be due to ICWS deployments being still relatively new, although it is anticipated that research efforts will increase over the coming years to continue to add to the state of practice.

3.0 Survey

To enhance the literature search described in Section 2.0 an online survey was distributed in April 2019 to the state traffic engineer in each state. The purpose of the survey was to:

- Document how many ICWS are deployed by each agency;
- Document modifications or issues with ICWS deployments;
- Gather evaluation reports; and
- Document ideas to consider for the design or research needs for the next generation ICWS.

Twenty-six responses were received from 20 DOTs and one county agency. The following bullets highlight the survey responses. See Appendix C for complete survey results.

- Seventeen (17) states that responded to the survey have deployed one or more ICWS. The number of ICWS deployments has continued to increase each year since 2010. Figure 6 illustrates which states have ICWS deployments from those agencies that responded to the survey.
    - Prior to 2010, 33 ICWS were deployed
    - Between 2010-2014, 51 ICWS were deployed
    - From 2015-Present, 134 ICWS have been deployed
- There have been modifications to ICWS since initial deployments. Changes made have included detection methods, signage, and actuation duration.
- Common issues noted by respondents with ICWS include maintenance, operations, cost, and remote monitoring of devices.
- Iowa DOT, Minnesota DOT, St. Louis County in Minnesota, Missouri DOT, North Carolina DOT, and Wisconsin DOT have conducted ICWS deployment evaluations.
- Fifteen (15) agencies responded that they are planning for additional ICWS deployments. While intersection safety was noted as the most common reason for additional deployments, other factors include political pressure, positive results based on crash data, and lower cost than traffic signals.
- Of the 3 agencies who responded that they were not planning for additional ICWS deployments, one agency noted that the public does not perceive ICWS as a safety improvement, one agency is willing to consider ICWS if a situation arises where it is a good solution, and one agency is waiting to see how ICWS deployments perform.
- Design questions and research needs noted by respondents included sign placement, sign messages/legends, design and standards, data collection and evaluation, equipment/technology, monitoring and power, and legal issues.

Survey Respondents

- Delaware DOT
- Florida DOT
- Georgia DOT
- Illinois DOT
- Indiana DOT
- Iowa DOT
- Kentucky Transportation Cabinet
- Louisiana DOTD
- Maryland DOT State Highway Administration
- Michigan DOT
- Minnesota DOT
- Minnesota St. Louis County
- Mississippi DOT
- Missouri DOT
- New Hampshire DOT
- New Mexico DOT
- North Carolina DOT
- Ohio DOT
- South Dakota DOT
- Utah DOT
- Wisconsin DOT

The survey results were utilized to provide a list of transportation agency practices that were mapped to each of the ICWS issues noted in Table 1. See Appendix B for the matrix that maps transportation agency practices to ICWS issues gathered.

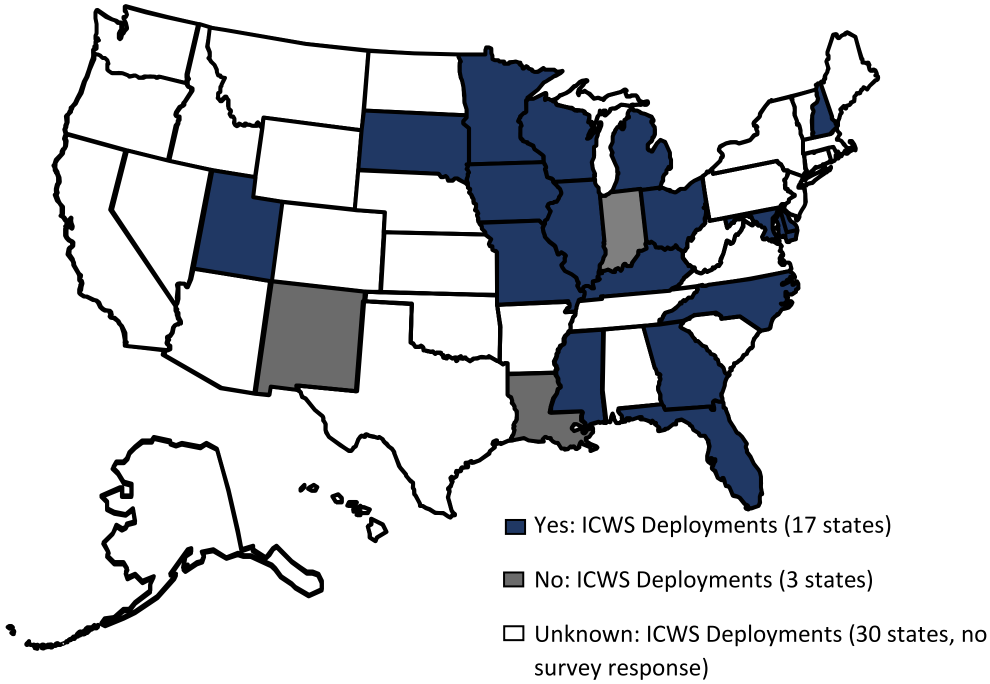


Figure 6: States with ICWS Deployments (Survey Response)

4.0 Project Webinars

The results of the literature search and the survey results described previously were used to facilitate a webinar on June 24, 2019 with those agencies that participated in the survey. The purpose of the webinar was to share the survey results, discuss ICWS issues, and discuss potential approaches to address issues. Approximately 25 individuals representing 21 agencies participated in the webinar.

Following the first webinar, a draft roadmap in matrix format was developed to compile ICWS issues mapped to agency practices, key resources and research findings, and potential next step approaches. This draft matrix was reviewed during a second webinar on August 7, 2019 to gather input and to prioritize the potential next steps. During the webinar as each ICWS issue (listed in Table 1) was reviewed, an interactive survey mechanism was used to gather participant feedback regarding potential next steps. It is important to note that there may be many approaches to address each ICWS issue; however, the following options were provided to webinar attendees to help identify the most appropriate next steps:

- Peer Exchange with Other Agencies
- Best Practices ICWS Documentation
- Evaluation of ICWS Deployments
- Driver Behavior Research
- Guidance

For example, for issues with ICWS maintenance, attendees were asked which of the above options (could select more than one option) would be the most appropriate as the next step to address ICWS maintenance issues. Following participants' selection of one or more next steps, the group's prioritized results were displayed, and discussion was facilitated to further understand the selections and to gather additional details. The information shared during the webinar was compiled and used to develop the final matrix and prioritized next steps for the ICWS roadmap described in the next section (Section 5.0). Figure 7 provides a screen capture of the final matrix. The matrix includes three columns of information. The first column bullet lists transportation agency practices gathered from the survey and discussion during the project webinars, the second column includes relevant key resources and research findings, and the last column lists prioritized next steps for each ICWS issue. See Appendix B or the complete matrix.

Issue A: Effectiveness of ICWS		
Practices: • Based on research in other states, effectiveness increased by adding mainline warning, therefore 4 ICWS locations were retrofitted during the summer of 2019 to add mainline warnings. (Iowa DOT) • Installed ICWS warnings for major road only. Concerns minor road traffic would rely on the sign and not actually look at traffic. (MDOT - Michigan) • First two ICWS deployed warn the main line motorists. Latest system deployed warns the side road. (MDOT - Mississippi) • Sole installation includes detection and active warning for both the major and minor approaches. However, moving towards only	Key Resources and Research Findings: • NCDOT Traffic Safety Unity Program: Vehicle Entering When Flashing Evaluation (November 2012) ICWS was more effective for two-lane at two-lane intersections, major road alerts in advance of the intersection, and a combination of both major and minor alerts with a 32% and 25% reduction in total crashes, respectively. Target frontal impact crashes for these categories were also reduced by 32% and 20% respectively. • Evaluation of ICWS in Minnesota (October 2017) ICWS significantly improved the stopping behavior, gap selection and intersection scanning of drivers. The system did not negatively affect the behavior of drivers by conditioning them to	Potential Next Steps (priority order): **1. Evaluation of ICWS Deployments** » To determine whether mainline ICWS warnings alone are as effective as other configurations (e.g. warnings on minor road only, or warnings on both the mainline and minor road). » To determine if the issue (e.g. gap acceptance, sight distance) has been mitigated with implementation of

Figure 7: Screenshot of ICWS Matrix (See Appendix B for complete ICWS Matrix)

5.0 Roadmap for Next Generation of ICWS

This section provides a roadmap of next steps to consider for the next generation of ICWS deployments. The information used to create the roadmap was generated using information gathered from the literature search, survey, and project webinars. The roadmap is separated into the same five categories (See Figure 8) and related issues described previously and listed below.

- Category 1: Planning
    - Issue A: Safety Effectiveness of ICWS
    - Issue B: ICWS Warrants and Early Design Planning
    - Issue C: ICWS Standards
    - Issue D: ICWS Legal Issues and Liability
    - Issue E: ICWS Cost
    - Issue F: CAV Integration with ICWS
- Category 2: Design
    - Issue G: ICWS Sign Messaging
    - Issue H: ICWS Warning/Flashing Actuation
    - Issue I: ICWS Sign Site Selection
    - Issue J: ICWS Power
    - Issue K: ICWS Sign Structures
- Category 3: Procurement and Installation
    - Issue L: ICWS Equipment
    - Issue M: ICWS Detection Methods
    - Issue N: Programming ICWS Controllers
- Category 4: Operations and Maintenance
    - Issue O: Monitoring of ICWS
    - Issue P: ICWS Maintenance
- Category 5: Evaluation
    - Issue Q: Consistent ICWS Data Collection for Analysis and Evaluations
    - Issue R: Public Response

Figure 8: ICWS Roadmap Categories

ICWS Next Steps

- Evaluation
- Driver behavior research
- Guidance
- Peer exchange
- Best practices

The roadmap (See Figures 9-14) outlines next steps to address each issue in priority order (Priority 1, Priority 2, or Lower Priority). The next steps are grouped into the following areas: evaluation of ICWS deployments, driver behavior research, guidance, peer exchange with other agencies, and best practices ICWS documentation. For example, Figure 9 shows, under Category 1: "Planning," and "Issue A. Safety Effectiveness of ICWS," the "Next Step: Priority 1" is to conduct evaluations of ICWS deployments (to determine whether mainline ICWS warnings alone are as effective as other configurations, etc.) The "Next Step: Priority 2" is to research driver behavior (to understand if motorists rely on the ICWS activations for their own decision-making). In addition, Figure 7 indicates a Lower Priority for "Issue C. Standards". This issue was rated as a lower priority overall, compared to other issues in the roadmap. It is anticipated that agencies would first focus on implementing next steps identified under issues with a Priority 1 or Priority 2 designation.

CATEGORY 1: PLANNING

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
A. Safety Effectiveness of ICWS	**Priority 1: Evaluation of ICWS Deployments** » To determine whether mainline ICWS warnings alone are as effective as other configurations (e.g. warnings on minor road only, or warnings on both the mainline and minor road). » To determine if the issue (e.g. gap acceptance, sight distance) has been mitigated with implementation of ICWS. » To determine the effectiveness of ICWS on crash rates (before and after ICWS installation).	**Priority 2: Driver Behavior Research** » Research driver behavior to understand if motorists rely on the ICWS activations for their own decision-making.	
B. ICWS Warrants and Early Design Planning	**Priority 1: Guidance** » Research to identify at-risk intersection characteristics; continue to utilize results from ongoing ICWS deployment evaluations. » Guidance/warrants on conditions for which ICWS is or is not effective (e.g. volume thresholds, driver profile, at risk intersection characteristics appropriate for ICWS). » Identify frequently used solutions for ICWS, based on at-risk intersection characteristics.		
C. ICWS Standards	This issue was rated as a lower priority overall, compared to other issues in the roadmap.		**Lower Priority: Evaluation of ICWS Deployments** *NOTE: ICWS deployments are less than 10 years in practice, not mature enough for standards.* However, continued **Evaluation of ICWS Deployments** will assist in developing future standards as well as **Best Practices ICWS Documentation** among the states.

Figure 9: ICWS Roadmap - Category 1: Planning

CATEGORY 1: PLANNING (continued)

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
D. ICWS Legal Issues and Liability	**Priority 1: Peer Exchange with Other Agencies** » Potential survey of states to understand whether any lawsuits have been filed. » To learn from states that have had an ICWS lawsuit to understand potential liability. » To understand ICWS legal issues with input from attorneys (discuss legal case study examples to understand potential legal/liability risks.) » To share sign immunity laws among the agencies.	**Priority 2: Driver Behavior Research** » To understand driver interaction with ICWS (e.g. messages, beacons, absence of warnings) to assist engineers in designing the best ICWS solutions.	
E. ICWS Cost	**Priority 1: Evaluation of ICWS Deployments** » Continue evaluating costs in the form of benefit/cost ratio analysis.	**Priority 2: Peer Exchange with Other Agencies** » To share details of ICWS deployments and related costs to assist agencies with the most cost-effective designs.	**Lower Priority: Guidance** *NOTE: ICWS deployments are deployed at a small number of intersections nationwide, with CAV having to navigate intersections with or without an ICWS deployment.* However, **Guidance** would help to understand technologies best suited for communicating with varying levels of connected and automated vehicles.
F. CAV Integration with ICWS	This issue was rated as a lower priority overall, compared to other issues in the roadmap.		

Figure 10: ICWS Roadmap - Category 1: Planning (continued)

CATEGORY 2: DESIGN

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
G. ICWS Sign Messaging	**Priority 1: Driver Behavior Research** » Human factors research to assist in recommending appropriate sign legend, signing configurations, and messages. Compare resulting recommendations to the MUTCD to identify gaps or conflicts.	**Priority 2: Evaluation of ICWS Deployments** » To understand current ICWS sign messages, modifications made, and document lessons learned.	
H. ICWS Warning/ Flashing Actuation	**Priority 1: Driver Behavior Research** » To understand when ICWS warning indication (e.g. beacons) should flash (based on gap acceptance or distance away from intersection) and should beacons run simultaneously for both approaches in coordination with sign messaging/legend.	**Priority 2: Evaluation of ICWS Deployments** » To understand differences in actuation durations related to intersection characteristics and overall effectiveness.	
I. ICWS Sign Site Selection	**Priority 1: Guidance** » Recommend sign placement (e.g. lateral distance from intersection, major and minor approaches, 4-lane divided design vs. 2-lane design).	**Priority 2: Evaluation of ICWS Deployments** » To document sign placement at ICWS deployments, document modifications, summarize lessons learned, and overall effectiveness.	
J. ICWS Power	**Priority 1: Best Practices Documentation** » Document power options (e.g. solar power, battery backup) with lessons learned and experiences for various conditions.		
K. ICWS Sign Structures	This issue was rated as a lower priority overall, compared to other issues in the roadmap.		**Lower Priority: Guidance** *NOTE: There will be upcoming changes to the Manual for Assessing Safety Hardware (MASH) that states will need to incorporate for their structural supports. Until this update is completed, this issue is not a high priority.* However, **Guidance** on ICWS structural support designs would assist states as they plan for ICWS deployments.

Figure 11: ICWS Roadmap - Category 2: Design

CATEGORY 3: PROCUREMENT AND INSTALLATION

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
L. ICWS Equipment	This issue was rated as a lower priority overall, compared to other issues in the roadmap.		**Lower Priority: Best Practices Documentation** *NOTE: ICWS equipment components vary from state to state.* However, **Best Practices Documentation** would assist in understanding lessons learned with ICWS equipment (e.g. equipment used, vendors, reliability/failure rates).
M. ICWS Detection Methods	**Priority 1: Best Practices Documentation** » To understand ICWS detection technology platforms. » Document lessons learned from various detection methods and conditions.		
N. Programming ICWS Controllers	**Priority 1: Peer Exchange with Other Agencies and Best Practices Documentation** » To understand and document challenges and lessons learned regarding programming ICWS controllers.		

Figure 12: ICWS Roadmap - Category 3: Procurement and Installation

CATEGORY 4: OPERATIONS AND MAINTENANCE

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
O. Monitoring of ICWS	**Priority 1: Peer Exchange with Other Agencies and Best Practices Documentation** » To understand and document experiences with remote monitoring.		
P. ICWS Maintenance	**Priority 1: Peer Exchange with Other Agencies and Best Practices Documentation** » To document ICWS maintenance experiences.		

Figure 13: ICWS Roadmap - Category 4: Operations and Maintenance

CATEGORY 5: EVALUATION

Issue	Next Step: Priority 1	Next Step: Priority 2	Next Step: Lower Priority
Q. Consistent ICWS Data Collection for Analysis and Evaluation	**Priority 1: Evaluation of ICWS Deployments** » Consistent data collection parameters (e.g. locations to collect data on the mainline and/or minor road) and evaluation elements (e.g. before and after crash data, before and after speed studies) to assist in analysis of individual locations and comparisons among deployments.		
R. Public Response	**Priority 1: Peer Exchange with Other Agencies** » To understand the public response before and after ICWS deployments, including perceived usefulness of ICWS, any feedback regarding understanding of ICWS messages, or other specific public input.		

Figure 14: ICWS Roadmap - Category 5: Evaluation

6.0 Summary

The purpose of this project was to develop a roadmap of prioritized next steps to help guide future ICWS deployment efforts. This section provides an overall project summary.

ICWS Issues

The ICWS roadmap was structured into 5 categories. For each category a number of ICWS issues are noted. There are other ICWS issues and categories, however this project focused on the following noted in the table below.

Table 2: ICWS Categories and Issues

Category	Issue
Category 1: Planning	• Issue A: Safety Effectiveness of ICWS • Issue B: ICWS Warrants and Early Design Planning • Issue C: ICWS Standards • Issue D: ICWS Legal Issues and Liability • Issue E: ICWS Cost • Issue F: Connected and Automated Vehicle (CAV) Integration with ICWS
Category 2: Design	• Issue G: ICWS Sign Messaging • Issue H: ICWS Warning/Flashing Actuation • Issue I: ICWS Sign Site Selection • Issue J: ICWS Power • Issue K: ICWS Sign Structures
Category 3: Procurement and Installation	• Issue L: ICWS Equipment • Issue M: ICWS Detection Methods • Issue N: Programming ICWS Controllers
Category 4: Operations and Maintenance	• Issue O: Monitoring of ICWS • Issue P: ICWS Maintenance
Category 5: Evaluation	• Issue Q: Consistent ICWS Data Collection for Analysis and Evaluations • Issue R: Public Response

Literature Search

Approximately 60 ICWS resources (e.g. ICWS information booklets, evaluations, final reports) were found through an online search. See Appendix A. The results of the literature search were used to support the development of the ICWS roadmap. Key resources and research findings from the literature search were mapped to the ICWS issues noted in the table above. Nine resources were found related to ICWS Warrants and Early Design Planning and 4 resources were found related to the Safety Effectiveness of ICWS. The remaining issues produced 3 or less documents. The literature search revealed that there is a need for ICWS research in many different areas. Many ICWS deployments are still relatively new which may be one reason for a lack of support resources, however it is anticipated research efforts will increase over the coming years to continue to add to the state of practice.

Survey and Project Webinars

A survey was distributed to each state DOT to gather details on ICWS deployments. Twenty-six responses were received from 21 agencies. See Appendix C for complete survey results. The number of ICWS deployments has continued to increase each year since 2010.

- Prior to 2010, 33 ICWS were deployed
- Between 2010-2014, 51 ICWS were deployed
- From 2015-Present, 134 ICWS have been deployed

The survey gathered information on modifications to ICWS since initial deployments, common issues with ICWS, and design and research needs of respondents. These practices were utilized to support the development of the ICWS roadmap by mapping related practices to ICWS issues. In addition, two webinars were conducted to add to the practices as well as discuss and prioritize next steps for each ICWS issue. See Appendix B.

ICWS Roadmap

The ICWS roadmap identifies next steps to consider for the next generation of ICWS deployments for each ICWS issue noted in the table above by category. See Section 5.0. The following tables compile the priorities of each next step area (peer exchange with other agencies, best practices ICWS documentation, evaluation of ICWS deployments, driver behavior research, and guidance) for Priority 1 and Priority 2. Lower Priorities are not included since it is anticipated transportation agencies will focus initial efforts on next steps with a higher priority. See Section 5.0 for a complete list of priorities. For example, Table 3 provides a listing of all suggested next steps for conducting peer exchanges with other agencies. It is important to note, that the next steps listed under each priority (Priority 1 and Priority 2) are listed in category order, this is not a prioritized order. The purpose of including all priorities together is to have this information in one location as peer exchange opportunities are planned this list could be used to structure agenda topics.

Table 3: Peer Exchange with Other Agencies – Priority 1 and 2 Next Steps

Priority 1	Priority 2
• Category 1: Planning, Issue D: ICWS Legal Issues and Liability » Potential survey of states to understand whether any lawsuits have been filed. » To learn from states that have had an ICWS lawsuit to understand potential liability. » To understand ICWS legal issues with input from attorneys (discuss legal case study examples to understand potential legal/liability risks). » To share sign immunity laws among the agencies • Category 3: Procurement and Installation, Issue N: Programming ICWS Controllers (To be completed in conjunction with Best Practices Documentation. See Table 4) » To understand and document challenges and lessons learned regarding programming ICWS controllers.	• Category 1: Planning, Issue E: ICWS Cost » To share details of ICWS deployments and related costs to assist agencies with the most cost-effective designs.

• Category 4: Operations and Maintenance, Issue O: Monitoring of ICWS (To be completed in conjunction with Best Practices Documentation. See Table 4) » To understand and document experiences with remote monitoring. • Category 4: Operations and Maintenance, Issue P: ICWS Maintenance (To be completed in conjunction with Best Practices Documentation. See Table 4) » To document ICWS maintenance experiences. • Category 5: Evaluation, Issue R: Public Response » To understand the public response before and after ICWS deployments, including perceived usefulness of ICWS, any feedback regarding understanding of ICWS messages, or other specific public input.	

Table 4: Best Practices Documentation – Priority 1 and 2 Next Steps

Priority 1	Priority 2
• Category 2: Design, Issue J: ICWS Power » Document power options (e.g. solar power, battery backup) with lessons learned and experiences for various conditions. • Category 3: Procurement and Installation, Issue M: ICWS Detection Methods » To understand ICWS detection technology platforms. » Document lessons learned from various detection methods and conditions. • Category 3: Procurement and Installation, Issue N: Programming ICWS Controllers (To be completed in conjunction with Peer Exchange with Other Agencies. See Table 3) » To understand and document challenges and lessons learned on programming ICWS controllers. • Category 4: Operations and Maintenance, Issue O: Monitoring of ICWS (To be completed in conjunction with Peer Exchange with Other Agencies. See Table 3) » To understand and document experiences with remote monitoring. • Category 4: Operations and Maintenance, Issue P: ICWS Maintenance (To be completed in conjunction with Peer Exchange with Other Agencies. See Table 3) » To document ICWS maintenance experiences.	N/A

Table 5: Evaluation of ICWS Deployments – Priority 1 and 2 Next Steps

Priority 1	Priority 2
• Category 1: Planning, Issue A: Safety Effectiveness of ICWS » To determine whether mainline ICWS warnings alone are as effective as other configurations (e.g. warnings on minor road only, or warnings on both the mainline and minor road). » To determine if the issue (e.g. gap acceptance, sight distance) has been mitigated with implementation of ICWS. » To determine the effectiveness of ICWS on crash rates (before and after ICWS installation). • Category 1: Planning, Issue E: ICWS Cost » Continue evaluating costs in the form of benefit/cost ratio analysis. • Category 5: Evaluation, Issue Q: Consistent ICWS Data Collection and Analysis and Evaluation » Consistent data collection parameters (e.g. locations to collect data on the mainline and/or minor road) and evaluation elements (e.g. before and after crash data, before and after speed studies) to assist in analysis of individual locations and comparisons among deployments.	• Category 2: Design, Issue G: ICWS Sign Messaging » To understand current ICWS sign messages, modifications made, and document lessons learned. • Category 2: Design, Issue H: ICWS Warning/Flashing Actuation » To understand differences in actuation durations related to intersection characteristics and overall effectiveness. • Category 2: Design, Issues I: ICWS Sign Site Selection » To document sign placement at ICWS deployments, document modifications, summarize lessons learned, and overall effectiveness.

Table 6: Driver Behavior Research – Priority 1 and 2 Next Steps

Priority 1	Priority 2
• Category 1: Planning, Issue B: ICWS Warrants and Early Design Planning » Research to identify at-risk intersection characteristics; continue to utilize results from ongoing ICWS deployment evaluations. » Guidance/warrants on conditions for which ICWS is or is not effective (e.g. volume thresholds, driver profile, at risk intersection characteristics appropriate for ICWS). » Identify frequently used solutions for ICWS, based on at-risk intersection characteristics. • Category 2: Design, Issue G: ICWS Sign Messaging » Human factors research to assist in recommending appropriate sign legend, signing configurations, and messages. Compare resulting recommendations to the MUTCD to identify gaps or conflicts. • Category 2: Design, Issue H: ICWS Warning/Flashing Actuation » To understand when ICWS warning indication (e.g. beacons) should flash (based on gap acceptance or distance away from intersection) and should beacons run simultaneously for both approaches in coordination with sign messaging/legend.	• Category 1: Planning, Issue A: Safety Effectiveness of ICWS » Research driver behavior to understand if motorists rely on the ICWS activations for their own decision-making. • Category 2: Planning, Issue D: Legal Issues and Liability » To understand driver interaction with ICWS (e.g. messages, beacons, absence of warnings) to assist engineers in designing the best ICWS solutions.

Table 7: Guidance – Priority 1 and 2 Next Steps

Priority 1	Priority 2
• Category 2: Design, Issues I: ICWS Sign Site Selection • Recommend sign placement (e.g. lateral distance from intersection, major and minor approaches, 4-lane divided design vs. 2-lane design).	N/A

This project identified a number of ICWS issues and documented key ICWS resources and research findings as well as transportation agency practices relevant to the issues. The result was an ICWS roadmap of suggested next steps in a priority order for transportation agencies to utilize and implement as they consider deploying ICWS whether it is an agency considering deployment, an agency that has only deployed a few, or agencies that have many ICWS deployments. In addition, other entities such as the FHWA, pooled funds, or university research entities may implement the roadmap priorities.

Appendix A: ICWS Related Documents

Table A-1: ICWS Related Documents

Source	Title
AASHTO	• Connected Vehicle Infrastructure Deployment Analysis (June 2011) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/AASHTOConnectedVehicleDeployAnalysis_finalreport.pdf
ENTERPRISE	• ICWS Informational Booklet (September 2015) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/ICWS%20Informational%20Booklet%20093015.pdf • System Requirements for Intersection Conflict Warning Systems (ICWS) Final Report Final Report (May 2013) http://enterprise.prog.org/Projects/2010_Present/icwssyseng/ICWS%20System%20Requirements%20FINAL%20051713.pdf • Concept of Operations for Intersection Conflict Warning Systems (November 2012) http://enterprise.prog.org/Projects/2010_Present/icwssyseng/ICWS%20Concept%20of%20Operations%20FINAL%20110812.pdf • Intersection Conflict Warning Systems-Characteristics Summary (December 2011) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/ICWS%20Characteristics%20Summary%20122011.pdf • Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS) (December 2011) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/Design_and_Eval_Guidance/Guidance%20for%20ICWS%20Version%201-122011.pdf
FHWA	• Intersection Conflict Warning System Human Factors: Final Report (November 2016) https://www.fhwa.dot.gov/publications/research/safety/16061/16061.pdf • Safety Evaluation of Intersection Conflict Warning Systems Final Report (June 2016) https://www.fhwa.dot.gov/publications/research/safety/16035/16035.pdf • Safety Evaluation of Intersection Conflict Warning Systems (ICWS) TechBrief (February 2016) http://www.cmfclearinghouse.org/studydocs/Safety_Eval_ICWS_Techbrief.pdf • Intersection Collision Warning System TechBrief (April 1999) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/VAICWSTechBrief4_99.pdf
Florida DOT	• Florida's Intersection Safety Implementation Plan (ISIP) Presentation (March 2017) www.techtransfer.ce.ufl.edu/Document.asp?DocID=1641 • Innovative Operational Safety Improvements at Unsignalized Intersections - Post-Mounted Flashing Beacons and Vehicle Actuated Variable Message Signs Final Report (August 2008) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/FDOT_C8K21_rpt.pdf
Georgia - Gwinnett County	• Proposed Guidelines for Traffic Actuated Warning Signs at Intersections with Limited Sight Distance (November 1999) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/GAGwinnettCountyProject1999.pdf
Iowa DOT	• Traffic Approaching When Flashing Signs (November 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/IaDOT_Intersection_Warning_and_detection.pdf • Plan Set for Anamosa Intersection (October 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/Anamosa%20Layout.pdf

Source	Title
	• Plan Set for Dyersville Intersection (October 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/Dyersville%20Layout.pdf
Iowa State University Institute for Transportation	• Intersection Conflict Warning System Research Poster (July 2015) https://www.cbirc.iastate.edu/files/2015/09/YES-Poster_Junck.pdf
ITS International	• Putting a Stop to Intersection Indecision (February 2015) https://www.itsinternational.com/sections/nafta/features/putting-a-stop-to-intersection-indecision/
Maine DOT	• Final Technical Report #01-2 Evaluation of the Norridgewock Intersection Collision Avoidance Warning System on Route 201A, Norridgewock, Maine (November 2006) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/MEreport0102f.pdf
Michigan DOT	• Special Provision for Intersection Warning System (December 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/IntersectionWarningSystem_(08-26-09).pdf • Special Provision for Wireless Vehicle Detection (December 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/03T820(420)WirelessVehicleDetectionSystem_(08-26-09).pdf • Intersection Warning System Plans for US-31 and M-77 Sites (August 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/M-77andUS-31_updated10-28.pdf
Minnesota DOT	• Evaluation of Intersection Conflict Warning Systems in Minnesota (October 2017) http://dot.state.mn.us/reAsearch/reports/2017/201738.pdf • Construction Plan for Rural Intersection Conflict Warning System (RICWS) and Lighting (April 2017) http://www.dot.state.mn.us/trafficeng/signals/plansheets/ricws2lane.PDF • Intersection Safety Technologies Guidebook: Intersection Conflict Warning Systems & LED STOP Signs (May 2016) https://www.lrrb.org/pdf/2016RIC10.pdf • Rural Intersection Conflict Warning Systems Project Description (2012-2015) http://www.dot.state.mn.us/its/projects/2011-2015/ricws.html • MnDOT RICWS Safety (June 2015) http://www.dot.state.mn.us/its/projects/2011-2015/rural-intersect-conflict-warn-system/documents/d3ricwssafety.pdf • System Requirements for Rural Intersection Conflict Warning Systems II Deployment (February 2015) http://www.dot.state.mn.us/its/projects/2011-2015/rural-intersect-conflict-warn-system/documents/systemrequirements.pdf • Safe Intersections Project Description (2010-2015) http://www.dot.state.mn.us/guidestar/2006_2010/safeintersections.html • Rural Intersection Conflict Warning System (RICWS) Reliability Evaluation: Final Report (June 2014) https://www.gtt.com/wp-content/uploads/MN-Dot-RICWS-Reliability-Evaluation.pdf • Advanced LED Warning Signs for Rural Intersections Powered by Renewable Energy - Final Report (December 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/MNALERTSystemLRRB201104.pdf • Cooperative Intersection Collision Avoidance Systems-Stop Sign Assist (CICAS) Project (2008) http://www.dot.state.mn.us/guidestar/2006_2010/cicas.html

Source	Title
	• Intersection Warning System Project and Evaluation (2009) http://www.dot.state.mn.us/guidestar/2006_2010/intersection_warning_system.html • A Study of the Rural Intersection Conflict Warning System (RICWS) (September 2019) http://www.dot.state.mn.us/trafficeng/safety/docs/ricws-report.pdf
Minnesota – Wright County	• ITS to Address Non-Signalized Rural Intersection Safety: A County's Perspective Presentation (November 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/MNWright2010PublicEngineersConference.pdf
National Committee on Uniform Traffic Control Devices	• Suggested ICWS Language for 2017 MUTCD (June 2014) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/ConflictWarningSignsSection2C%20XXapprovedbyCOUNCIL6-28-14.pdf
National Highway Traffic Safety Administration	• Crash Factors in Intersection-Related Crashes: An On-Scene Perspective (September 2010) https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811366
National Science Foundation	• Intersection Conflict Warning System (ICWS) Safety Evaluation (August 2016) https://www.cbirc.iastate.edu/files/2016/08/Laura-Condon.pdf
New Hampshire DOT	• Intersection Conflict Warning System Facebook Entry (February 2018) https://www.facebook.com/NHDOT/photos/a.475232275867053.106607.333648210025461/1665348093522126/?type=3
North Carolina DOT	• Presentation of Vehicle Entering When Flashing Evaluation (January 2013) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NC%20TRB%2013-1159%20NCDOT%20VEWF%20Simpson%20Troy%20011413.pdf • Evaluation of the Safety Effectiveness of "Vehicle Entering When Flashing" Signs and Actuated Flashers at 74 Stop-Controlled Intersections in North Carolina (November 2012) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NC%20VEWF%20Evaluation%20-%20FINAL%20111412.pdf • Collision Diagrams for Vehicles Entering When Flashing Evaluation (September 2012) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NC%20VEWF%20Evaluation%20Collision%20Diagrams%20-%20FINAL%20091212.pdf • Design Example (February 2008) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NCOverheadStandardExample2_PlanDesign.TIF • Flasher Standard (July 2004) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/NCSignalsandGeometricsFlasherStandard.pdf
PennDOT	• Crash Avoidance Systems Benefit/Cost Analysis (July 2011) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PA2011CollisionAvoidanceSystemReport.pdf • Crash Avoidance System Presentation with 2008 Crash Data (2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PACASwith2008CrashData.pdf • Collision Avoidance System Evaluation (January 2007) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PA2007CASEvaluation.pdf • Crash Avoidance System Report (November 2003) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PACASreportITS.pdf • Crash Avoidance System Construction Drawings (April 2001) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PACASDrawings.pdf

Source	Title
ScienceDIrect	• Study on the Framework of Hybrid Collision Warning System using Loop Detectors and Vehicle Information (December 2016) https://www.sciencedirect.com/science/article/pii/S0968090X16302078?via%3Dihub
The Urban Transportation Monitor	• Crash Avoidance System Article in Urban Transportation Monitor Nov. 2004 (November 2004) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/PAUrbanTransMonitorCAS2004.pdf
Transportation Research Record	• Evaluation of Intersection Conflict Warning System: A Critical Gap Analysis (June 2018) https://journals.sagepub.com/doi/pdf/10.1177/0361198118777357
University of Minnesota Center for Transportation Studies	• Rural Intersection Conflict Warning System Evaluation and Design Investigation: Final Report (May 2018) https://www.dot.state.mn.us/its/projects/2016-2020/ricwseval/finalreport.pdf
Utah DOT	• Rural Intersection Conflict Warning System Guidelines (February 2018) https://www.nwpassage.info/projects/downloads/13-2-ricws-guidelines-study.pdf
Washington State DOT	• Plan Set US 97 and Cameron Lake Road (March 2013) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WSDOT%20ICWS%20%20US%2097%20&%20Cameron%20Lk%20Rd.pdf • Plan Set for US12 and Jackson Hwy (January 2007) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WAUS12_Jackson_Hwy_SWR_PTSWF.pdf • Prepare to Stop When Flashing System (PTSWF) Pilot Project Interim Guidelines (August 2006) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WAPTSWFSystems8_10_06.pdf • Plan Set for US395 (May 2006) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WAUS395_SCR_PTSWF.pdf • Existing and Planned PTSWF Locations http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WAInstallationofPreparetoStopWhenFlashing2_2_.pdf
Wisconsin DOT	• Wisconsin Intersection Safety Presentation (June 2015) http://www.branson2015mwite.com/uploads/2/6/2/6/26260297/14-wisconsin_intersection_safety.pdf • Rural Intersection Collision Avoidance System Outreach Presentation (March 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WIRICASSeniorCenter031710.pdf • Rural Intersection Collision Avoidance System Brochure (February 2010) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WIricasbrochurefinalforprintFeb2010.pdf • Rural Intersection Collision Avoidance System Project Overview Presentation (February 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WIRICASKick_offV2012809.pdf • Rural Intersection Collision Avoidance System Fact Sheet (January 2009) http://enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/WIricasfactsheet020410.pdf

Appendix B: Matrix

Table C-1 - Category 1: Planning

Issue A: Safety Effectiveness of ICWS		
Practices: • Based on research in other states, effectiveness increased by adding mainline warning, therefore 4 ICWS locations were retrofitted during the summer of 2019 to add mainline warnings. (Iowa DOT) • Installed ICWS warnings for major road only. Concerns minor road traffic would rely on the sign and not actually look at traffic. (MDOT – Michigan) • First two ICWS deployed warn the mainline motorists. Latest system deployed warns the side road. (MDOT – Mississippi) • Sole installation includes detection and active warning for both the major and minor approaches. However, moving towards only providing active warning on the major road with detection only on the minor approaches due to concerns with minor approach traffic relying too heavily on an active warning system and not fully stopping at the intersection. (IDOT – Illinois) • Deployments include systems which warn the side street to look for oncoming traffic and systems which warn mainline to look for entering traffic. (MoDOT) • There has been reduction in crashes at the ICWS locations that have been in place for some time. (Kentucky Transportation Cabinet) • Before and after crash data has been positive. (MDOT – Michigan)	Key Resources and Research Findings: • MnDOT: A Study of the Rural Intersection Conflict Warning System (RICWS) (September 2019) – For both the RICWS and control sites, the analysis indicates that there are no significant differences between the before and after crash rates after the RICWS installation. Therefore, the change in crash reporting is neither reducing nor enhancing the effect of RICWS. • TRB, Iowa State University: Evaluation of Intersection Conflict Warning System: A Critical Gap Analysis (June 2018) – ICWS improved driver gap acceptance at the treatment sites for drivers making both complete and rolling stops. No change in driver behavior was observed at intersections without an ICWS installation. • Evaluation of ICWS in Minnesota (October 2017) – ICWS significantly improved the stopping behavior, gap selection and intersection scanning of drivers. The system did not negatively affect the behavior of drivers by conditioning them to less cautious when the systems were absent. • MnDOT RICWS Safety (June 2015) – MnDOT initiated a study at an intersection with an apparent increase in the number of crashes to determine whether the number of crashes is different than what would have been expected without the RICWS installation and if there is any indication that the RICWS is contributing to the increase. A review of crash data indicated that after installation,	Potential Next Steps (priority order): **1. Evaluation of ICWS Deployments** » To determine whether mainline ICWS warnings alone are as effective as other configurations (e.g. warnings on minor road only, or warnings on both the mainline and minor road). » To determine if the issue (e.g. gap acceptance, sight distance) has been mitigated with implementation of ICWS. » To determine the effectiveness of ICWS on crash rates (before and after ICWS installation). **2. Driver Behavior** » Research driver behavior to understand if motorists rely on the ICWS activations for their own decision-making.

	the annualized number of crashes and the crash rate increased, however, neither increase is statistically significant and there is no information from officer reports to suggest that the RICWS installation contributed to the increase. • NCDOT Traffic Safety Unity Program: Vehicle Entering When Flashing Evaluation (November 2012) – ICWS was more effective for two-lane at two-lane intersections, major road alerts in advance of the intersection, and a combination of both major and minor alerts with a 32% and 25% reduction in total crashes, respectively. Target frontal impact crashes for these categories were also reduced by 32% and 20% respectively. • USDOT FHWA: Stop-Controlled Intersection Safety Through Route Activated Warning System (May 2011) – The addition of a Through Route Activated Warning System shows greater potential to decrease crashes compared to traditional sign and marking enhancements alone. Missouri looked at before and after crash comparisons and found that using a Through Route Activated Warning System reduced the overall average number of crashes by 51% and reduced severe angle crashes by 77%.	
Issue B: ICWS Warrants and Early Design Planning		
Practices: • One ICWS location mainline traffic is constant, side street warning rarely shuts off. (Kentucky Transportation Cabinet) • ICWS at one location removed due to implementation of an all-way stop configuration (DelDOT)	Key Resources and Research Findings: • UDOT Rural Intersection Conflict Warning System Guidelines (February 2018) – Recommends future development of a warrant system to systematically analyze rural high-speed intersections, create an intersection ranking system, and inclusion in	Potential Next Steps (priority order): **1. Guidance** » Research to identify at-risk intersection characteristics; continue to utilize results from ongoing ICWS deployment evaluations

• Correcting the geometric deficiency would be selected as an alternative over ICWS, unless it involves a more significant impedance such as a building obscuring visibility between major and minor street drivers. (NHDOT) • Other strategies such as J-Turns utilizing quick curb or delineators at larger intersections have also been considered along with deploying ICWS. (Maryland DOT) • ICWS is an intermediate-stage intervention in high-speed 2-way stop-controlled intersections with a select crash history/pattern--after trying lower cost treatments (e.g. enhanced pavement markings, signs, channelization) and before higher-order reconstruction (e.g. J-turn). (INDOT) • Pursuing warranting. (UDOT)	a consistently funded program to retrofit rural intersections with ICWS. • Evaluation of Major Street Speeds for Minnesota Intersection Collision Warning Systems (June 2018) – Compared speeds after ICWS installation and noted only a modest impact for mainline drivers. • Evaluation of ICWS in Minnesota (October 2017) – Systems are likely to be continuously activated- and ineffective-at traffic volumes of 1,600-plus vehicles per hour. • USDOT FHWA Safety Evaluation of Intersection Conflict Warning Systems (June 2016) – Analysis at four-lane at two-lane intersections indicated a greater percentage of crash reductions at sites with intersection lighting and for sites with a higher crash frequency in the before period for both warning and minor route. • ENTERPRISE Planning Guidance for ICWS (September 2015) – Two guidelines identified to capture the most common purposes and uses of ICWS: Intersections with High Crash Frequencies and Intersection Characteristics. • ENTERPRISE ICWS System Requirements (May 2013) – Provides system requirements for ICWS for four types of intersections. • ENTERPRISE ICWS Concept of Operations (November 2012) – Provides a concept of operations for ICWS for four types of intersections. • NCDOT Traffic Safety Unity Program: Vehicle Entering When Flashing Evaluation (November 2012) – ICWS appears to more effective for two-lane at two-lane	» Guidance/warrants on conditions for which ICWS is or is not effective (e.g. volume thresholds, driver profile, at risk intersection characteristics appropriate for ICWS) » Identify frequently used solutions for ICWS, based on at-risk intersection characteristics

	intersections than four-lane divided at two-lane intersections. • USDOT FHWA: Stop-Controlled Intersection Safety Through Route Activated Warning System (May 2011) – Through Route Activated Warning Systems have been most successfully deployed in rural areas or areas where the through route speed limit is at least 45 mph. The system is ideal for stop-controlled intersections with a history of total or angle crashes, isolated high-speed stop-controlled intersections with substantial sight distance limitations, and isolated stop-controlled intersections on multi-lane divided high-speed at-grade arterials with the potential for or a history of severe angle crashes where J-Turn treatments are not appropriate safety solutions. • ENTERPRISE Design and Evaluation Guidance for ICWS (December 2011) – Deployment conditions are noted (e.g. crash history exhibits a higher than expected rate and/or severity) for four design layouts. To optimize the effectiveness of ICWS by reducing the likelihood of continuous alert activation, the following maximum ADT volumes should be considered: ○ Major Road ADT typically does not exceed 12,000 ○ Minor Road ADT typically does not exceed 3,000	
Issue C: ICWS Standards		
Practices: • Developing policy to provide district offices with parameters on how to set up ICWS effectively. (IDOT – Illinois)	Key Resources and Research Findings: • UDOT Rural Intersection Conflict Warning System Guidelines (February 2018) – Identifies a proactive approach in determining whether a	Potential Next Steps (priority order): ***NOTE: ICWS deployments are less than 10 years in practice, not mature enough for standards.***

• Design parameters and warrants have been updated through the development of a concept of operations, layout details, specifications. (NHDOT)
• Pursuing standardization. (UDOT)
• No standards for installation, engineering on a case by case basis (MoDOT)
• If satisfied with the pilot ICWS installations, next step is to develop a standardized specification for future installations and to develop criteria for where they would be used, how they would be maintained, and who would be responsible. (NHDOT)
	rural intersection warrants an ICWS through a draft set of criteria and intersection ranking to assess risk factors with a focus on low cost mitigation.
	• PennDOT Collision Avoidance System Evaluation (January 2007) – Recommends the following design considerations for future enhancements:
	  ○ Consider conventional countermeasures first,
	  ○ Place presence loops out of the path of turning vehicles near the intersection,
	  ○ Emphasize coordination with maintenance, and
	  ○ Ensure battery backup systems are in good working order.
		However, continued **1. Evaluation of ICWS Deployments** will assist in developing future standards as well as **2. Best Practices ICWS Documentation** among the states.

Issue D: ICWS Legal Issues and Liability		

Practices:
• Iowa is being sued for not deploying an ICWS at an intersection. (Iowa DOT)
• If engineers have not displayed gross negligence there shouldn't be any legal issues with their attorneys to defend. (Iowa DOT)
• ICWS is a warning device, not a regulatory device. (St. Louis County, MN)
• If an ICWS has been unreliable, the intelligence of the system could be disabled such that it either flashes all the time, or that the beacons are removed in favor of a static sign. (NHDOT)
• If pre-determined response protocol is followed (e.g. sign isn't working and the response and implementation of repairs is completed in a specified time period) there shouldn't be liability. (NHDOT)
	Key Resources and Research Findings: TBD	Potential Next Steps (priority order):
		1. Peer Exchange with Other Agencies
		  » Potential survey of states to understand whether any lawsuits have been filed.
		  » To learn from states that have had an ICWS lawsuit to understand potential liability.
		  » To understand ICWS legal issues with input from attorneys (discuss legal case study examples to understand potential legal/liability risks.)
		  » To share sign immunity laws among the agencies.
		2. Driver Behavior Research
		  » To understand driver interaction with ICWS (e.g. messages, beacons, absence of warnings)

• Moving away from "WHEN FLASHING" message due to liability. Motorist were getting too used to relying on the flasher to pay attention to the message, if it wasn't flashing then they didn't look, and this was causing issues. The messages are relevant without the "WHEN FLASHING" message regardless, so the flasher is only used as an enhancement to the assembly (still activated the same way) but no longer implying it is only relevant when the flasher is active. (MoDOT)		to assist engineers in designing the best ICWS solutions.
Issue E: ICWS Cost		
Practices: • Costs appear to be comparable to the purchase of right-of-way with tree clearing and/or grading to improve sight distance. (NHDOT) • Cost was extremely high to program the first one due to it all being in logic processor within an Econolite Cobolt- roughly $70k for cabinet and controller programming. (ODOT) • Cost is $75k - $125k per intersection (IDOT – Illinois) • Let a contract to develop ICWS system; required high confidence and as low-cost as possible. Minor and major road warning. Winning bid was $108k. ICWS systems are good when you've exhausted low-cost options and are waiting for funding for higher cost fixes (e.g. J-turn); fills a gap between "low-cost" and "higher cost" solutions. (St. Louis County, MN) • $100-200k range. Compared to a traffic signal, ICWS are expensive. But not an equal	Key Resources and Research Findings: • USDOT FHWA Safety Evaluation of Intersection Conflict Warning Systems (June 2016) – Results suggest ICWS strategy can be cost effective in reducing total crashes at four-legged intersections with stop-control on the minor approaches. A 27:1 benefit-cost ratio was found on two-lane intersections while four-lane intersections showed a 10:1 benefit-cost ratio.	Potential Next Steps (priority order): **1. Evaluation of ICWS Deployments** » Continue evaluating costs in the form of benefit/cost ratio analysis. **2. Peer Exchange with Other Agencies** » To share details of ICWS deployments and related costs to assist agencies with the most cost-effective designs.

comparison. Need to change culture and way of thinking about it. (Iowa DOT) • $50k or less. 2-lane to 2-lane intersections mostly. (NCDOT) • ICWS area a lower cost intersection safety improvement than traffic signals. (WisDOT)		
Issue F: Connected and Automated Vehicle (CAV) Integration with ICWS		
Practices: • TBD	Key Resources and Research Findings: • USDOT Stop Sign Gap Assist Safety Application – Application could warn drivers at minor road of unsafe gaps (no major road warning).	Potential Next Steps (priority order): ***NOTE: ICWS deployments are deployed at a small number of intersections nationwide, with CAV having to navigate intersections with or without an ICWS deployment.*** However, **1. Guidance** would help to understand technologies best suited for communicating with varying levels of connected and automated vehicles.

Table C-2 - Category 2: Design

Issue G: ICWS Sign Messaging		

Practices:
• Some motorists have demonstrated confusion over the operation of the sign. (MnDOT)
• Added a unique sign "INTERSECTION AHEAD MULTIPLE FATALITES USE CAUTION" in advance of the minor road stop two years after the initial ICWS deployment at US65/IA 330. (Iowa DOT)
• Moving away from "WHEN FLASHING" message due to liability. Motorist were getting too used to relying on the flasher to pay attention to the message, if it wasn't flashing then they didn't look, and this was causing issues. The messages are relevant without the "WHEN FLASHING" message regardless, so the flasher is only used as an enhancement to the assembly (still activated the same way) but no longer implying it is only relevant when the flasher is active. (MoDOT)
• Due to sight distance restrictions in one direction, a supplemental changeable message sign (CMS) was installed for side street traffic to indicate the direction of that mainline traffic was approaching. (Kentucky Transportation Cabinet)
	Key Resources and Research Findings:
	• UDOT Rural Intersection Conflict Warning System Guidelines (February 2018) – Several signing systems are used by state DOTs. Commonly used sign messaging includes:
	  ○ "Traffic Approaching When Flashing" – uses standard, accepted components, and is widely used throughout the U.S.
	  ○ "Traffic Approaching" blank-out with "When Flashing" – widely used and provides a direct message to drivers with an effective dynamic component
	  ○ "Entering Traffic When Flashing" – uses standard, accepted components and widely used throughout the U.S.
	  ○ "Watch for Entering Traffic" with "When Flashing" – a relatively simple system that utilizes components recommended by the Regulatory and Warning Sign Technical Committee (RWSTC).
	• University of Minnesota CTS Rural Intersection Conflict Warning System Evaluation and Design Investigation (May 2018) – 120 teenage, middle aged, and older drivers participated in a simulation study to evaluate the safety effectiveness of ICWS sign options at rural through-stop intersections. The study identified a variation of the original sign that may have comparable safety benefits with fewer potential risks and suggested future real-
		Potential Next Steps (priority order):
		1. **Driver Behavior Research**
		  » Human factors research to assist in recommending appropriate sign legend, signing configurations, and messages. Compare resulting recommendations to the MUTCD to identify gaps or conflicts.
		2. **Evaluation of ICWS Deployments**
		  » To understand current ICWS sign messages, modifications made, and document lessons learned.

	world tests be conducted and include spacing. • USDOT FHWA Safety Evaluation of Intersection Conflict Warning Systems (June 2016) – For two-lane at two-lane intersections, the ICWS strategy appeared to be slightly more effective when the "WHEN FLASHING" message was present. No difference in effectiveness was observed for four-lane at two-lane intersections. • ENTERPRISE Design and Evaluation Guidance for ICWS (December 2011) – Suggests message sets and sign combinations to consider when deploying ICWS.	
Issue H: ICWS Warning/Flashing Actuation		

Practices:
• Duration of minor road warning flashes:
  ○ 6 seconds. (MnDOT)
  ○ 12-15 seconds. (Iowa DOT)
  ○ 6-7 seconds (minimum gap time). If flashing too long, the next vehicle may think a vehicle is approaching after it passes. (St. Louis County, MN)
• The duration of the actuated flashing period interval was shortened due to complaints from the public that there was no traffic on the side street approach. (MDOT State Highway Administration – Maryland)
• At a location with sight limit restrictions in approach of the intersection, a component was added to flash the sign on the primary road when there were slow moving vehicles on the primary road itself (e.g. left turning vehicles) (MDOT – Michigan)
	Key Resources and Research Findings:
	• NCDOT Safety Evaluation of Intersection Conflict Warning Systems – Reported that North Carolina deployments with alerts on the major road in advance of the intersection and locations with both major and minor road alerts were most effective.
		Potential Next Steps (priority order):
		1. **Driver Behavior Research**
		  » To understand when ICWS warning indication (e.g. beacons) should flash (based on gap acceptance or distance away from intersection) and should beacons run simultaneously for both approaches in coordination with sign messaging/legend.
		2. **Evaluation of ICWS Deployments**
		  » To understand differences in actuation durations related to intersection characteristics and overall effectiveness.

Issue I: ICWS Sign Site Selection		
Practices: • Need for proper layout for sign site selection issues. For example, during early ICWS installation by the time the motorist reached the conflict point the other motorist was long gone, resulting in the perception the system was malfunctioning. However, it was a sign site selection issue than a system issue. (MoDOT) • No design process will replace (or be more effective than) staking out the sign locations with the contractor in the field. (Iowa DOT)	Key Resources and Research Findings: • USDOT FHWA Safety Evaluation of Intersection Conflict Warning Systems (June 2018) – Two-lane at two-lane intersections with an ICWS installed on the major road showed a reduction in crashes, especially when a post-mounted ICWS is installed in advance of the intersection. • ENTERPRISE Design and Evaluation Guidance for ICWS (December 2011) – Suggests sign placement when deploying ICWS and provides layout illustrations.	Potential Next Steps (priority order): **1. Guidance** » Recommend sign placement (e.g. lateral distance from intersection, major and minor approaches, 4-lane divided design vs. 2-lane design). **2. Evaluation of ICWS Deployments** » To document sign placement at ICWS deployments, document modifications, summarize lessons learned, and overall effectiveness.
Issue J: ICWS Power		
Practices: • No solar power or battery backup. (NCDOT) • If using solar, you may need to increase monitoring of your system. (St. Louis County, MN) • All ICWS have solar power for some components. 8 systems in place. 50% failure during first winter with solar power. Solar panel wasn't large enough. Batteries provided by vendor were not cold-weather, and they froze out. Replacing solar panels and installing -40 degree temp rated batteries. (St. Louis County, MN) • No solar power; if using need to put pressure on vendor to prove it will work. (Iowa DOT)	Key Resources and Research Findings: TBD	Potential Next Steps (priority order): **1. Best Practices Documentation** » Document power options (e.g. solar power, battery backup) with lessons learned and experiences for various conditions.
Issue K: ICWS Sign Structures		
Practices: • ICWS sign structure blown down, replaced with a 3-post mount. (WisDOT)	Key Resources and Research Findings: TBD	Potential Next Steps (priority order): *NOTE: There will be upcoming changes to the Manual for Assessing Safety Hardware (MASH) that states will need to incorporate for their structural supports.*

• Structural supports require breakaway standards, but they not stable enough for ICWS. (MnDOT)		*Until this update complete this issue is not a high priority.* However, **1. Guidance** on ICWS structural support designs would assist states as they plan for ICWS deployments.

Table C-3 - Category 3: Procurement and Installation

Issue L: ICWS Equipment		
Practices: • ICWS can be built with traditional signal equipment. (NHDOT) • Components are pieced together to create an ICWS. (MnDOT) • Blank out signs are not robust and have failed frequently. (MnDOT) • Using in-house equipment has been more reliable and quicker turnarounds when equipment needs replacing. (Kentucky Transportation Cabinet) • Keeps a spare control cabinet on-hand, to deploy rapidly as needed. (St. Louis County, MN)	Key Resources and Research Findings: TBD	Potential Next Steps (priority order): ***NOTE: ICWS equipment components vary from state to state.*** However, **1. Best Practices Documentation** would assist in understanding lessons learned with ICWS equipment (e.g. equipment used, vendors, reliability/failure rates).
Issue M: ICWS Detection Methods		
Practices: • Utilize radar detection, as non-intrusive as possible for ICWS deployments. Radar has been accurate (at least 95%, have done research). There has been some occasional issues with flashing longer than intended (e.g. takes another vehicle to stop it); it is just a reality with radar. (St. Louis County, MN) • The radar detection occasionally results in false positives. (St. Louis County, MN) • Moved away from intrusive detectors and now use radar. The radar unit needs to be placed	Key Resources and Research Findings: • UDOT Rural Intersection Conflict Warning System Guidelines (February 2018) – Based on available research, two types of detection methodology have been used: detection based on time and detection based on speed/distance. UDOT primarily utilizes radar for signal projects and recommends the same be used for Utah's ICWS. Radar allows both distance and speed to be determined.	Potential Next Steps (priority order): **1. Best Practices Documentation** » To understand ICWS detection technology platforms. » Document lessons learned from various detection methods and conditions.

high (20-30 ft.) with a 4” square tube support. (MDOT – Mississippi) • Planning to deploy video detection where pavement is not good for loops and conditions are not appropriate for radar. (Iowa DOT) • Detection methods have been modified. (FDOT) • Generation 1 design for 5 installations was replaced with a Generation 2 design that replaced the detection system. (MnDOT) • Changed out detection from puck transducers to radar. Puck transducers failed. (MDOT – Mississippi) • It was desired to deploy radar detection, as opposed to loops, to keep it our standard detection. However, due to the vertical geometrics, in pavement loops were best. (ODOT - Ohio)		
Issue N: Programming ICWS Controllers		
Practices: • It is extremely complicated to program controllers. There is a lot of variation in what and where to flash, and difficult to test. (Iowa DOT) • Looked at potential software to run ICWS but didn’t end up using it; difficult to make a signal controller do something it’s not intended for. It would be better if vendors offered customized software. (MnDOT) • 2070 ATC Controllers and MaxTime software is used all ICWS locations in Kentucky. (Kentucky Transportation Cabinet) • Generation 1 design for 5 installations was replaced with a Generation 2 design that replaced the control equipment with hardened equipment. (MnDOT)	Key Resources and Research Findings: TBD	Potential Next Steps (priority order): **1. Peer Exchange with Other Agencies and 2. Best Practices Documentation** » To understand and document challenges and lessons learned regarding programming ICWS controllers.

Table C-4 - Category 4: Operations and Maintenance

Issue O: Monitoring of ICWS		
Practices: • Added cell modems and cameras for remote health monitoring to reduce trips to the field. (MnDOT) • A central signal system can monitor ICWS controllers. MnDOT's are now they are tied into the central signal system (MaxView.) (MnDOT) • Decided not to do remote monitoring. Staff regularly drive the routes, and the public has been vocal about reporting issues. (St. Louis County, MN) • There are remote communications to view input/output status, but unable to monitor the health of the individual sign and beacons. (Kentucky Transportation Cabinet) • If field devices can talk, central software not available to receive data from the signal controller. (Iowa DOT) • Offerings from vendors in terms of alerts and data for the purposes of monitoring status seem minimal. (NHDOT) • Our current devices are not remote monitored, but the future devices will be. The issue is that passers-by cannot necessarily discern a false positive or false negative, even those trained on its operation such as police officers or maintenance patrols. (NHDOT) • No remote monitoring. (NCDOT) • It is currently being proposed to operate all new systems from a central hub, where continuous automated monitoring of the devices can be implemented with human intervention as needed. (NHDOT)	Key Resources and Research Findings: • MnDOT RICWS Reliability Evaluation Final Report (June 2014) – Validated sign activations using video captured at the site.	Potential Next Steps (priority order): 1. **Peer Exchange with Agencies and 2. Best Practices Documentation** » To understand and document experiences with remote monitoring.

Issue P: ICWS Maintenance		
Practices: • Rural districts, do not have time or priority to operate or maintain at a real time level. (MnDOT) • Maintenance of the systems involving elements that are not standard to our traditional traffic signal systems (e.g. solar panels, microcontrollers, various detection methodologies we don't otherwise use) require excessive training and refresher training to field staff since they are working with elements they do not normally encounter with traditional signal work. (NHDOT) • Added complexity with ICWS (flasher, power systems, and detection) compared to a static sign. (MoDOT) • Utilizes a traffic systems maintenance service contract in place, with services on per work order basis. Transfers maintenance responsibility externally. If issues with a system, email contractor with the issue. Performance requirements state a time frame for contractor to report the diagnosis, then to report a proposed solution. Initial response is failure reported/diagnosis (24-48 hours), then next is how it should be repaired (this is tougher to define). St. Louis County, MN • Utilizes a maintenance contract. (Iowa DOT)	Key Resources and Research Findings: • Development of a New Intersection Conflict Warning System in St. Louis County, Minn. (June 2019) – St. Louis County in Minnesota recognized that they needed outside support to operate, diagnose, and maintain the ICWS and created a "Traffic Systems Maintenance" contract that provided a contracted resource to support the operation of countywide ICWS. This service contract operates on a "per work order basis" and has proven to be cost-effective in the operation of ICWS within St. Louis County.	Potential Next Steps (priority order): **1. Peer Exchange with Agencies and Best Practices Documentation** » To document ICWS maintenance experiences.

Table C-5 - Category 5: Evaluation

Issue Q: Consistent ICWS Data Collection for Analysis and Evaluations		
Practices: • After central software is installed for controllers to collect and store hi-res data, an evaluation will be conducted. (Kentucky Transportation Cabinet)	Key Resources and Research Findings: • UDOT Rural Intersection Conflict Warning System Guidelines (February 2018) – Recommends future development of a warrant system to systematically analyze rural high-speed intersections and create an intersection ranking system for inclusion in a consistently funded program to retrofit intersections with RICWS. • ENTERPRISE Design and Evaluation Guidance for ICWS (December 2011) – Encourages and establishes some common parameters for evaluation of existing and future ICWS deployments.	Potential Next Steps (priority order): **1. Evaluation of ICWS Deployments** » Consistent data collection parameters (e.g. locations to collect data on the mainline and/or minor road) and evaluation elements (e.g. before and after crash data, before and after speed studies) to assist in analysis of individual locations and comparisons among deployments.
Issue R: Public Response		
Practices: • TBD	Key Resources and Research Findings: • MnDOT Rural Intersection Conflict Warning System Evaluation and Design Investigation (May 2018) – Drivers were unsure what action to take if the ICWS activated when they were already in the course of the crossing maneuver and demonstrated more conservative driving behavior such as false starts or sudden pullovers. • PennDOT Collision Avoidance System Evaluation (January 2007) – A public survey found that 97% of the 224 survey participants found the collision avoidance system to be beneficial and 93% believed similar systems should be installed at additional locations.	Potential Next Steps (priority order): **1. Peer Exchange with Other Agencies** » To understand the public response before and after ICWS deployments, including perceived usefulness of ICWS, any feedback regarding understanding of ICWS messages, or other specific public input.

Appendix C: Survey Results

April 2019 ENTERPRISE ICWS Survey Results

Q1 – Please provide your contact information.

- 26 responses from 21 agencies

Agency	Number of Responses
Delaware DOT	1
Florida DOT	1
Georgia DOT	2
Illinois DOT	1
Indiana DOT	1
Iowa DOT	1
Kentucky Transportation Cabinet	2
Louisiana DOTD	1
Maryland DOT State Highway Administration	1
Michigan DOT	1
Minnesota DOT	2
Minnesota St. Louis County	1
Mississippi DOT	1
Missouri DOT	1
New Hampshire DOT	2
New Mexico DOT	1
North Carolina DOT	1
Ohio DOT	1
South Dakota DOT	1
Utah DOT	1
Wisconsin DOT	2

Q2 – Do you have any ICWS deployed in your state?

- Yes: 22 responses from 18 agencies
- No: 3 responses from 3 agencies

Agencies Responding Yes		
Delaware DOT	Maryland DOT State Highway Administration	New Hampshire DOT
Florida DOT	Michigan DOT	North Carolina DOT
Georgia DOT	Minnesota DOT	Ohio DOT
Illinois DOT	Minnesota St. Louis County	South Dakota DOT
Iowa DOT	Mississippi DOT	Utah DOT
Kentucky Transportation Cabinet	Missouri DOT	Wisconsin DOT

Agencies Responding No	What are your reasons for not deploying ICWS?
Indiana DOT	Have none in operation at this time, but ICWS for 36 sites/intersections across the state is currently in design, scheduled for construction spring 2020.
Louisiana DOTD	Wanting to but waiting on another section to write a spec
New Mexico DOT	First we need establish the need.

Q3 – For each of the time periods below, approximately how many ICWS did you deploy?

- 18 responses from 15 agencies

Agency	2015 - Present	2010 - 2014	Prior to 2010
Delaware DOT	1	2	0
Florida DOT	9	5	0
Illinois DOT	1	0	0
Iowa DOT	3	5	0
Kentucky Transportation Cabinet	10	0	0
Maryland DOT State Highway Administration	3	0	0
Michigan DOT	2	1	0
Minnesota DOT	54	5	0
Minnesota St. Louis County	9	1	1
Mississippi DOT	3	0	0
New Hampshire DOT	0	1	2

North Carolina DOT	30	30	30
Ohio DOT	1	0	0
South Dakota DOT	2	0	0
Utah DOT	4	1	0
Wisconsin DOT	2	0	0

Q4 – Have there been any modifications (e.g. technology upgrades, design parameters, deployment configurations) in your ICWS deployments?

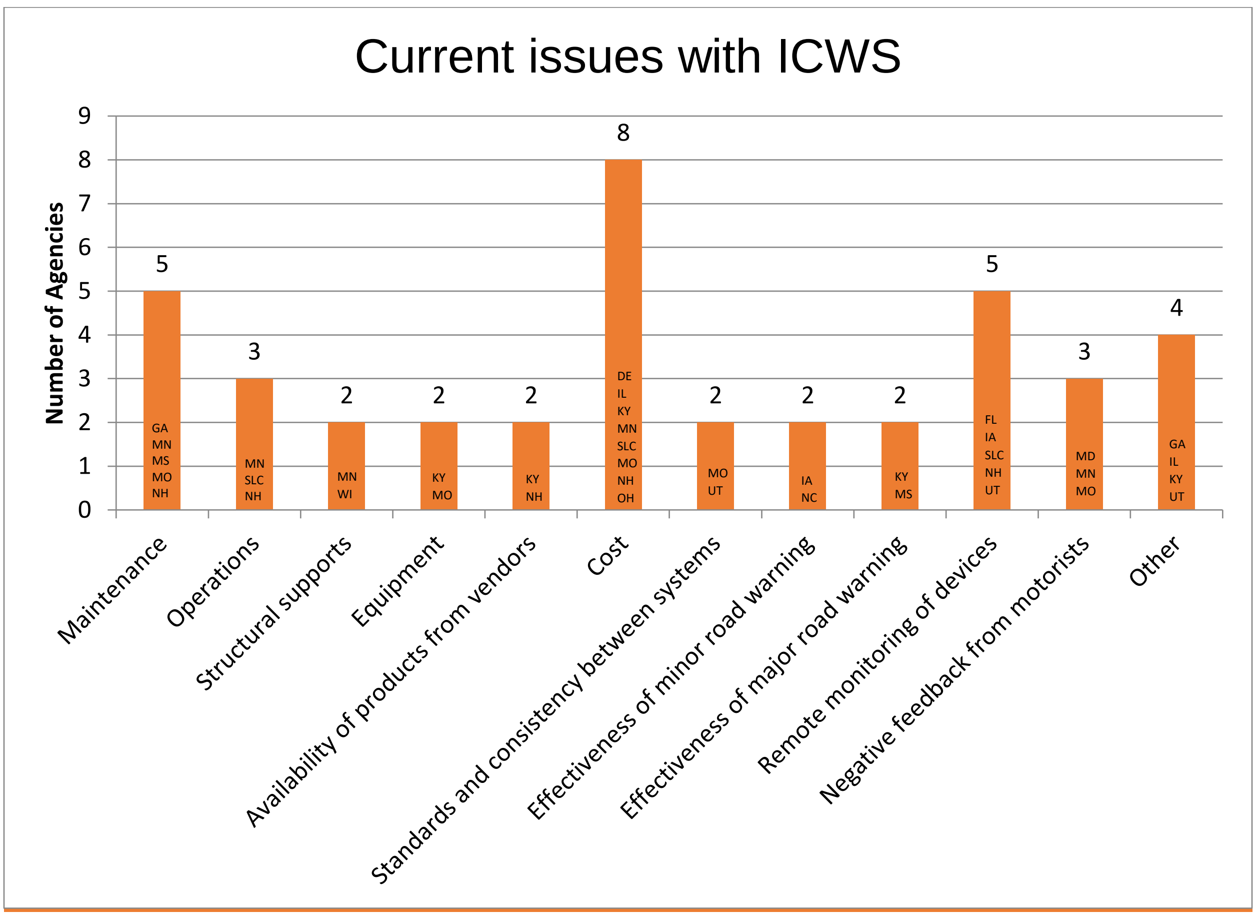
- Yes: 13 responses from 12 agencies
- No: 8 responses from 7 agencies

Agency	Changes made by Agency
Delaware DOT	Removed one system due to the implementation of an all-way stop configuration. Removed one location to install an all-way stop condition.
Florida DOT	Detection methods.
Iowa DOT	Two years after initial deployment at US 65/IA 330, we added a unique sign in advance of the sideroad stop that said, "INTERSECTION AHEAD MULTIPLE FATALITIES USE CAUTION".
Kentucky Transportation Cabinet	Not to our standard installation, but we recently installed one with supplemental changeable message signs for side street traffic to indicate the direction that mainline traffic was approaching. This was done due to a sight distance restriction in one direction. The use of 2070 ATC controllers and MaxTime software. This is for all locations. Directional blankout signs in conjunction with LED enhanced blinker signs. This application is for when sight distance is a concern.
Maryland DOT State Highway Administration	We have modified the duration of the actuated flashing period interval due to some complaints from the public.
Michigan DOT	We added a component to flash the sign on the primary road when there were slow moving vehicles on the primary road itself (i.e. left turning vehicles). This feature was added at a location with sight limit restrictions in approach of the intersection.
Minnesota DOT	We had a Gen 1 design for 5 installations and then we replaced that design with a Gen 2 design. Primarily changed the detection system and control equipment with hardened equipment. Prior to these 50 cited above we tried a variety of configurations at a couple intersections each to get to our final production design. Since deploying the 50 we have had hardware issues with the sign and have had traveler confusion with the sign message and have tested at least one alternate way to operate the same sign.
Mississippi DOT	Changed out detection form puck transducers to radar - pucks failed.
Missouri DOT	Actual numbers in the field are not known as they were installed by our districts and not cataloged. We have systems which warn the side street to look for

Agency	Changes made by Agency
	oncoming traffic and systems which warn mainline to look for entering traffic. Originally, most also state "WHEN FLASHING", however, we are moving away from this message due to liability. Motorists were getting too use to relying on the flasher to pay attention to the message, if it wasn't flashing then they didn't look and this was causing issues. Our messages are relevant without the WHEN FLASHING regardless, so the flasher is only used as an enhancement to the assembly (still activated the same way) but no longer implying it is only relevant when the flasher is active.
New Hampshire DOT	Design parameters and warrants have been updated through the development of a concept of operations, layout details, specifications.
North Carolina DOT	We have updated our CMF sheet to reflect the NCDOT safety study results. This study showed stronger results at 2-lane at 2-lane intersections and with advance signing on the mainline or a combination of signs on the major and minor approach. As a result, these are the types of deployments that are being implemented now.
Ohio DOT	Copied Minnesota's design.
Utah DOT	Standardization of components, solar power options.

Q5 – What current issues do you have with ICWS? Select all that apply.

- 17 responses from 16 agencies



Agency	Other issue
Georgia DOT	Liability
Illinois DOT	Illinois DOT is just starting to deploy these systems and our most significant issue is determining what the most effective design setup is along with overall cost.
Kentucky Transportation Cabinet	Sign Output Monitoring
Utah DOT	Still understanding the impacts of the system. Performance measurement will come as the system matures.

Q6 – Please describe specific ICWS issues for the responses selected in Question 5?

- 18 responses from 16 agencies

Agency	Description of ICWS Issue (s) from response to Question 5	Issue(s) Selected from Question 5
Delaware DOT	*No additional comment provided*	• Cost
Florida DOT	Remote monitoring is only available by few vendors making it expensive.	• Remote monitoring of devices
Georgia DOT	Perceived liability if the system goes dark (stops working).	• Maintenance • Other – Liability
Illinois DOT	We are in the process of developing an ICWS policy to provide our district offices parameters on how these systems should be set up to provide the most effectiveness. Our sole installation includes detection and active warning for both the major and minor approaches. However, we are leaning towards only providing active warning on the major road with detection only on the minor approaches. This is over concerns with minor approach traffic relying too heavily on an active warning system and not fully stopping at the intersection.	• Cost • Other - Design
Iowa DOT	Effectiveness of minor road warning: Based on recent research, effectiveness increased by adding mainline warning, therefore we will be retrofitting 4 locations during the summer of 2019. Remote monitoring of devices: We don't have remote monitoring at any of our locations because of either field devices cannot talk, or if they can, we don't have central software to receive data from the signal controller.	• Effectiveness of minor road warning • Remote monitoring of devices
Kentucky Transportation Cabinet	We've had some issues with equipment when dealing with vendors. It took a couple of months to get the LED enhanced blinker signs replaced that were incorrectly wired and worded. We are also currently waiting for manufactured blankout signs to be replaced that were taken out by a storm. Using in-house equipment (flashing beacons) has been more reliable and has resulted in quicker turnarounds when equipment needs replacing. We have an ICWS location where mainline traffic is constant. As a result, the side-street warning sign rarely shuts	• Equipment • Availability of products from vendors • Cost • Effectiveness of major road warning

Agency	Description of ICWS Issue (s) from response to Question 5	Issue(s) Selected from Question 5
	off. Still concerned with Sign Output Monitoring. We have remote communications to all of our systems and can view input and output status but we have not found a way to monitor the health of the individual signs and beacons.	• Other – Sign output monitoring
Maryland DOT State Highway Administration	A minor complaint we have received is with the duration of the flashing period. Some people complain that the ICWS is actuated when there is no traffic on the side street approach. We have made some adjustments at a couple locations to shorten the actuated period.	• Negative feedback from motorists
Michigan DOT	We have not installed warnings for the minor road; only the major road. We've had concerns that minor road traffic would rely on it to determine when to proceed across or onto the primary road and not actually look for traffic.	• *No issue category selected*
Minnesota DOT	Structural supports required breakaway standards but still were not stable enough. M and O is an issue as the rural districts do not have time or priority to operate a real time traffic system or maintain to that real time level. Blank out signs are not robust and fail frequently. The structural supports are not adequate, and we need to find an alternate design. The systems are expensive. Some motorists have demonstrated confusion over the operation of the sign.	• Maintenance • Operations • Structural supports • Cost • Negative feedback from motorists
Minnesota St. Louis County	All of St. Louis County's ICWS utilize solar power and radar detection. We are working through a process to upgrade the solar engines. The radar detection occasionally results in false positives.	• Operations • Cost • Remote monitoring of devices
Mississippi DOT	First two systems that were installed warn the mainline motorists. Latest system warns the side road.	• Maintenance • Effectiveness of major road warning
Missouri DOT	The issues are primarily related to the added complexity of such a system, the flasher, power systems and detection that are involved compared to a static sign, basically the added complexity. For this reason, they are used sparingly at locations were more traditional devices are not effective enough. Depending on the installation, we have had issues where the system was working correctly, but by the time the motorist reached the conflict point the other motorist was long gone, resulting in the perception the system was malfunctioning. This was related to relevant sight distance and was more of a sign site selection issue than a system issue. This is not a common issue and one that took place on early installations, but is does highlight the need for proper layout.	• Maintenance • Equipment • Cost • Standards and consistency between systems • Negative feedback from motorists

Agency	Description of ICWS Issue (s) from response to Question 5	Issue(s) Selected from Question 5
New Hampshire DOT	Maintenance of the systems involving elements that are not standard to our traditional traffic signal systems (e.g. solar panels, microcontrollers, various detection methodologies we don't otherwise use) would require excessive training and refreshers to our field staff since they are working with elements they do not normally encounter with traditional signal work. Operation of the systems has traditionally been the responsibility of municipalities and has resulted in inconsistencies in deployments and operational characteristics. It is currently being proposed to operate all new systems from a central hub, where continuous automated monitoring of the devices can be implemented with human intervention as needed. While the systems can be built with traditional signal equipment, there appear to be very few vendors of packaged systems, and the offerings in terms of alerts and data for the purposes of monitoring status seem minimal. Based on preliminary estimates, the costs appear to be comparable to the purchase of right-of-way with tree clearing and/or grading to improve sight distance. Correcting the geometric deficiency would likely be selected as an alternative over ICWS, unless it involves a more significant impedance such as a building obscuring visibility between major and minor street drivers. Our current devices are not remote monitored, but the future devices will be. The issue is that passers-by cannot necessarily discern a false positive or false negative, even those trained on its operation such as police officers or maintenance patrols.	• Maintenance • Operations • Availability of products from vendors • Cost • Remote monitoring of devices
North Carolina DOT	As stated earlier, NCDOT performed a safety study and did not find effectiveness at the minor road warning sites.	• Effectiveness of minor road warning
Ohio DOT	Still hasn't been finalized and fully running yet--by Summer 2019 it will be. Cost was extremely high to program the first one due to it all being in logic processor within an Econolite Cobalt--roughly $70k for cabinet and controller programming. We hope cost is down since we will have the intersection file now.	• Cost

Agency	Description of ICWS Issue (s) from response to Question 5	Issue(s) Selected from Question 5
South Dakota DOT	*No comment provided*	• *No issue category selected*
Utah DOT	Our first installation was based on work done in another state and was pursued by one of our regions. The work we are pursuing at this point is mostly standardization and warranting.	• Standards and consistency between systems • Remote monitoring of devices • Other – system impacts and performance measurement
Wisconsin DOT	One of the sign structures was blown down by a storm - it was replaced with a 3-post mount. Two other times, the same sign structure was hit by a motorist. Central office has not heard of any issues, but that does not mean there haven't been any. I have reached out to the regions and when I hear back from them, I will follow-up with an email to answer this question.	• Structural supports

Q7 – Has your agency conducted any evaluations of the ICWS deployments?

- Yes: 6 agencies
  - Iowa DOT
  - Minnesota DOT
  - St. Louis County – Minnesota
  - Missouri DOT
  - North Carolina DOT
  - Wisconsin DOT
- No: 12 agencies

Q8 – Is your agency planning for additional ICWS deployments?

- Yes: 15 responses from 14 agencies
- No: 3 responses from 3 agencies

Yes – Please describe why or why not	
Delaware DOT	Looking to add additional ICWS devices as traffic studies recommend to improve intersection safety.
Florida DOT	As a countermeasure for high speed rural intersections.
Georgia DOT	Unsure at this time.
Illinois DOT	We feel these systems can reduce crashes at rural high-speed intersections. We have also received some political pressure to install these systems.

Yes – Please describe why or why not	
Iowa DOT	No specific locations are identified right now, however, each year we review the top 50 rural intersections for safety treatments and ICWS is always an option.
Kentucky Transportation Cabinet	We are actively (but slowly) implementing more ICWS'. We are seeing positive results with a reduction in crashes at the locations we've had in place for some time. We will be conducting an evaluation when have our central software for our controllers and can collect and store the hi-res data needed for a full evaluation.
Michigan DOT	Although we haven't performed an official evaluation, the before/after crash data has been positive. We think this is a great tool for dealing with problem intersections that would otherwise require very expensive projects to improve safety.
Minnesota DOT	MnDOT district and county safety plans suggest RICWS for more intersections. We want to fix the issues we have experienced before expanding. Additional design improvements will need to be made and a crash evaluation conducted to see long term effects.
Minnesota St. Louis County	The goal is to continue to treat at-risk intersections.
Missouri DOT	Only on a case by case basis as needed, this is not a common implementation for us. With respect to question 7, there are no formal studies on effectiveness, more case by case evidence the issues were addressed, and no further treatment or countermeasures were required.
New Hampshire DOT	We will be deploying 3 new ICWS's next year based on the new spec requiring remote monitoring. The locations have been identified through the HSIP program, and the projects are being advanced as a pilot study based on a new concept of operations. If successful, the program would continue based on this new design and warrants developed as a result of the pilot study that would be used to select future locations.
South Dakota DOT	We have one more location that will be getting an ICWS in 2023.
Utah DOT	We know we have areas where we believe these solutions will be beneficial. Again, we are still working on warranting provisions and site identification.
Wisconsin DOT	Possibly two other locations may have ICWS (TRAWS in our state) installed. They are seen as a lower cost intersection safety improvement than traffic signals. There are not any we are aware of in design, but there have been discussions with our region offices on other locations. The 2 systems that we have in operation are minor road detection for mainline traffic on a rural 4-lane divided expressway. Some of the other locations we are considering are on 2-lane/2-lane intersections.

No – Please describe why or why not	
Maryland DOT State Highway Administration	The public does not perceive the ICWS as a safety improvement. Often times the public would like a full blown traffic signal. We will continue to deploy ICWS where possible but I do not see this as a systemic practice until we can overcome the challenges with the public. We have also used other strategies like J-Turns utilizing quick curb or delineators at larger intersections.

Mississippi DOT	We are not adverse to ICWS, but it is not something we plan for. If another situation arises that ICWS might be a good solution, then we will consider it at that time.
Ohio DOT	Not sure yet. Need to see how it performs.

Q9 – As part of this research effort, we are gathering design questions and research needs that agencies may have as they consider deploying additional ICWS in the future. Please describe any ICWS design or research needs to consider before designing and deploying the next generation of ICWS.

- 16 responses from 14 agencies

Agency	Questions and Research Needs
Delaware DOT	Effectiveness in sign legends, sign placement (lateral distance from intersection, major vs. minor approaches), potential legal issues if system fails, etc.
Illinois DOT	We would like research focused on recommendations for which intersection approaches receive active warning. Are there issues with providing active warning for the minor approaches? We are looking into using the advance detection on the minor approaches to also activate a flashing LED or internally illuminated stop sign as an additional safety countermeasure. We would be curious to know if other agencies have installed battery backup systems and remote monitoring and if those have been successful. We would also be interested in any designs that help reduce cost as we are currently looking at $75k - $125k per intersection. Also, any variables where ICWS may not be appropriate or effective (ADT, speed, etc.).
Iowa DOT	Research should be done to determine when the beacons should begin to flash when a vehicle is approaching (based on gap acceptance? or based on a distance away from intersection?) What is appropriate legend on the signs (both ML and Sideroad)? Should it be a blank out or static sign? Where is the best/appropriate location for the sideroad warning sign? Should sideroad beacons run simultaneously for both approaches, even though one leg has vehicles approaching (or should each leg run independently)?
Kentucky Transportation Cabinet	I would consider using in-house materials or backups for manufactured equipment. I would also consider mainline traffic. If traffic is constant, the side-street sign will operate more like an intersection beacon than an ICWS.
Maryland DOT State Highway Administration	One item that we have debated internally is the message on the ICWS. Our original ICWS had the message "When Flashing." Our two most recent systems did not include this message.
Michigan DOT	Reliability - What % of the time are the warnings triggered as intended? Driver Behavior - After time, does traffic come to rely on the activations for their own decision-making? Safety - Before/After crash data and an expected crash reduction factor.
Minnesota DOT	Long term effectiveness for crash reductions need to be conducted. Short term benefits are pretty good, but the system should not be placed at all problem intersections. Variations to a standard design need to be identified and agreed on. Are mainline warning systems effective by themselves? How much value is added by having the minor road warning? The minor road warning is the most complicated and has the most serious fail safe considerations. If the major road only warning alone provides almost as much benefit, a lot of

Agency	Questions and Research Needs
	money and maintenance headaches could be avoided by only implementing the major road warning.
Minnesota St. Louis County	Detection technology platforms. Solar power options
Mississippi DOT	Main-line or side-road warning? What is the nationwide trend, and are there certain situations where one is favored over the other?
Missouri DOT	We really have no standards for these installations, they are basically engineered on a case by case basis, and again, are not a frequently used solution. However, there FHWA Traffic Control Pooled Fund did a research project on intersection conflict warning systems and I think that was published in 2016
New Hampshire DOT	One of our biggest needs is to develop warrant criteria for use in determining whether it is an appropriate technology for a given location. For example, if side street traffic is so busy that the mainline beacons flash all the time, it is probably not really effective. We will also be looking for information on speed data collection, specifically, the most appropriate location to collect the data on the mainline to capture the influence of the device. The data we will be collecting for our pilot study includes: Before/after speed studies, Maintenance logs, Alarm & communication records, Actuation data, Public feedback, Before/after crash reports
Ohio DOT	We wanted to deploy radar detection, as opposed to loops, to keep it our standard detection. However, due to the vertical geometrics, in pavement loops were best.
Utah DOT	What are the best technologies to employ with these solutions for communication with the varying levels of vehicle automation.
Wisconsin DOT	Is there any traffic criteria (mainline / side street volumes, crash history, etc.) that are used to decide if an ICWS should be installed? Some of our questions have revolved around the following: - 4-lane divided design vs. 2-lane design - Standard operation guidelines for the system (i.e., what do we assume for perception-reaction times? Do we assume a vehicle can stop at the intersection or just slow down to a certain speed?, etc.) - Is there a need for battery backup? - Crash testing - Standard signing/messaging

Q10 – Please provide any additional information you would like to share on current and future ICWS.

- 9 responses from 7 agencies

Agency	Additional Comment
Indiana DOT	Beyond the 30+ being let for construction in early 2020, the agency plans to install others in future years. We see ICWS as an intermediate-stage intervention in high-speed 2-way stop-controlled intersections with a select crash history/pattern--after trying lower cost treatments (e.g. enhanced pavement markings, signs, channelization) and before higher-order reconstruction (e.g. J-turn).
Iowa DOT	Would like to know if all 50 states are deploying ICWS? Would a one-day peer-to-peer workshop be beneficial to have, or a webinar, if all else fails.
Louisiana DOTD	Where to place, conditions for placement, solar vs non solar issues, sign configurations

New Hampshire DOT	I would like to find out which vendors sell ICWS kits (e.g. TAPCO is one that we know of). I would like to hear what experiences other states have had with ICWS systems in terms of O&M, as I have heard that some systems have been unreliable causing DOTs (OR, MO, WI) to disable the system's intelligence such that it either flashes all the time, or that the beacons are removed in favor of a static sign. My understanding is that disabling the intelligence eliminates the liability associated with false positives/negatives. Our three pilot locations should be advertised in CY 2019 with construction completed in CY 2020. Our plan is to evaluate the communication operation and other features of the installations. While we would like to evaluate the crash reduction impact, we do not believe that we will have enough data for a meaningful evaluation. If we are satisfied with the pilot installations, our next step would be to develop a standardized specification for future installations and to develop criteria for where they would be used, how they would be maintained, and who would be responsible. We have three locations in the design phase through our HSIP program. We have been following a Systems Engineering approach and have developed a Concept of Operations that would require communication back to a central hub/dispatch center so that we are made aware of any failures that would result in false negative messages to motorists. The ConOps included a number of other requirements as well.
New Mexico DOT	How do you decide the need and do you believe by implementing these devices you have mitigated the issues at the location?
Ohio DOT	Our ICWS is going to be in southern Ohio in at US-68 and SR-123: https://goo.gl/maps/uKKQffxMeQo . The overhead flashers will be removed. This was installed as a pilot after a serious accident that included one fatal.
Wisconsin DOT	- The information provided are for Wisconsin DOT owned ICWS. There may be other ICWS installed in Wisconsin on county highways or local roads that are maintained by the counties or municipalities. - We are interested if other states have completed studies about the effectiveness of ICWS.