Rural Intersection Conflict Warning Systems Deployment

Test Plan

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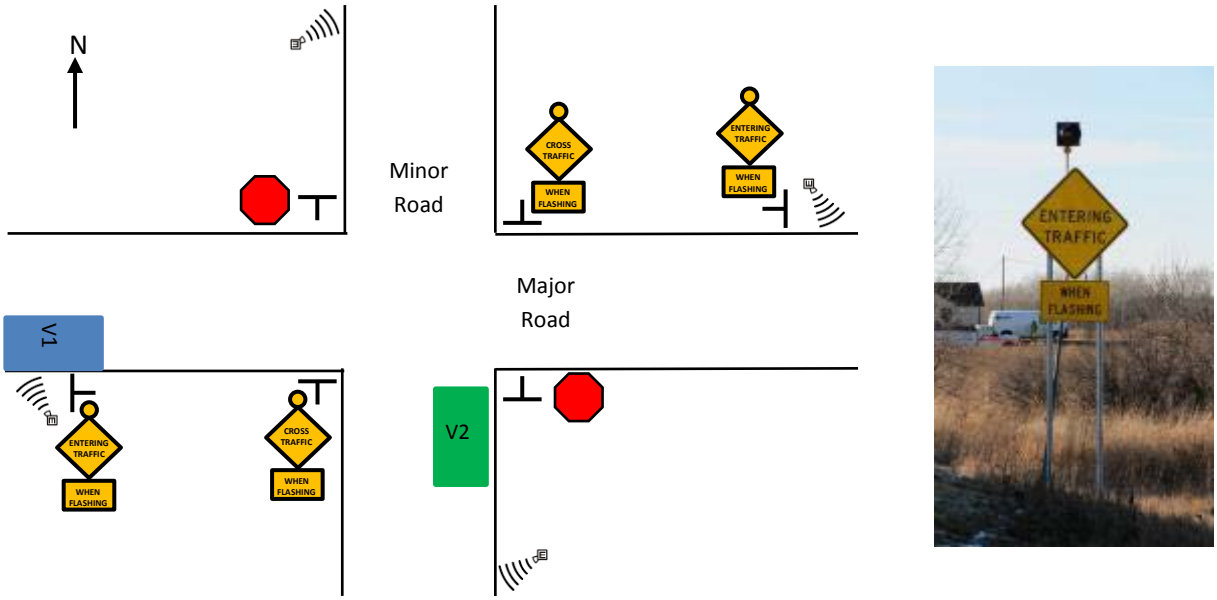
Introduction

The Minnesota Department of Transportation (MnDOT) has developed the Rural Intersection Conflict Warning Systems Deployment project to reduce crashes at stop-controlled intersections. It is a statewide, Intelligent Transportation Systems project that will deploy intersection conflict warning systems (ICWS) at up to 150 rural, stop-controlled intersections. These systems will address crashes at stop-controlled intersections by providing drivers – on both the major and minor road – with a dynamic warning of other vehicles approaching the intersection. ICWS typically consist of static signing, detection and dynamic elements as illustrated in Figure 1.

Figure 1 Intersection Conflict Warning System Concept



Candidate intersections were initially identified by counties and MnDOT district traffic staff through the systematic development of localized road safety plans, which outline specific safety investment priorities and projects based on crash data. From the road safety plans, intersections were further selected for this project if poor sight distance or gap acceptance were believed to be strong contributing factors and if there was local support for the project.

The primary goal of this project is to reduce crashes at stop-controlled intersections by deploying intersection conflict warning systems throughout Minnesota. The project will also allow MnDOT and its partners to more conclusively evaluate the effectiveness these systems at reducing crashes under certain conditions (i.e., road types, traffic volumes, etc.), as well as their longer term operational and maintenance needs. A Concept of Operations was prepared for this project to identify fundamental stakeholder needs. Needs were then translated into high-level and detailed requirements in the System Requirements document. **This Test Plan presents test phases and a corresponding log which will be used to verify that the ICWS meets parameters specified in the System Requirements.**

Test Plan

Testing is necessary to ensure that requirements, as specified in the System Requirements document and subsequent design documents, are met. For this project, testing will be done on two levels. First, validation testing will be conducted on system components as they are identified for procurement. Validation will confirm that a product meets its specified requirements and it will be performed primarily through inspection before the system is deployed. Once validated, the Contractor may proceed with system integration and installation. Acceptance testing is the second level of review for this project and it will take place after the first ICWS is installed at an installation site chosen by MnDOT. System acceptance will confirm that the products fulfill their intended use and it will be completed when the system is in its operational environment to allow for demonstration. Once accepted at the initial site, the Contractor may complete installation at the remaining sites.

Under MnDOT supervision, the Contractor will initiate the validation and acceptance test cases presented in the next sections of this document. Five test cases are required for this project: Product Specification Review, Integration Demonstration (30-day), Plan Set Review, Functional Demonstration (1-Day) and Reliability Demonstration (30-day). For each test case, the accepted test environment is noted. Test processes and verification instructions then describe which ICWS features will be inspected or demonstrated to verify the correspondingly noted system requirements. The test processes also indicate who shall participate in the verification process. Some ICWS features will be verified at both phases of testing and are noted as such in the verification instructions. Test log details are also included to use during testing as formal documentation of whether the system passed or failed to meet requirements. Comments about each verification step should be entered in the log with enough detail for the Contractor to make product, design or installation modifications as needed.

Test Phases – Validation Testing

There are six primary components that when combined form an intersection conflict warning system – detection, warning, system communication, data management, system monitoring and power. These components will be procured off-the-shelf by the Contractor according to the System Requirements and final design specifications accepted by MnDOT. Validation testing will occur as the components are identified for procurement by the Contractor to ensure requirements are met. Any items failed during validation testing will be corrected by the Contractor and then presented again to MnDOT for final acceptance. Once this stage of testing is completed and accepted by MnDOT, the Contractor may proceed with procurement and each product should also be accompanied by manufacturer documentation of successful Factory Acceptance Testing prior to shipping. Table 1 below presents the three test cases, environment, processes, verification instructions, relevant system requirements and log that will be used for validation testing.

Table 1 Validation Test Cases

Test Case 1: Product Specification Review **Environment:** Office or Factory / Warehouse **Process:** As Contractor selects ICWS components for procurement, the Contractor will provide MnDOT product specifications for requirements verification and accepted. Once accepted, the Contractor may complete procurement and proceed with integration of the first ICWS that will be tested prior to installation and integration of remaining ICWS. *Several steps described in the verification instructions below will be repeated during Test Case 5. The test log has been separated to reflect both instances of testing.* **Participants:** Shall include the MnDOT Project Manager, Contractor and Oversight Consultant.			
Verification Instructions	**System Requirement**	**Test Log**	
		Pass/ Fail	**Comments**
1a. Verify that ICWS **detection, warning, system communication, data management, system monitoring and power** product specifications conform to NEMA TS 2-2003 environmental requirements.	2.2.1.3		
1b. Verify that ICWS **alert product specifications conform** to NEMA TS 4-2005 standards for the hardware and functional characteristics of electronically controlled dynamic message signs, if used.	2.2.1.4		
1c. Verify that ICWS **system communication component product specifications comply** with FCC emission requirements.	2.2.1.7		
1d. Verify that **ICWS Control Cabinet** meet the requirements of UL 508 “Standard for Industrial Control Equipment”, January 28th 1999 Edition.	2.2.1.8		
1e. Verify that ICWS **detection, warning, system communication, data management, system monitoring and power** product specifications conform to MN MUTCD and AASHTO requirements for crashworthiness.	2.5.1		

1f. Verify that **ICWS detection** product specification states capability to continuously detect presence of multiple vehicles in multiple lanes. *Verify again during reliability demonstration in Test Case 5.*	1.1.1.1, 1.3.1.1, 1.3.1.2	**Test Case 1 Results**	
		Test Case 4 Results	
1g. Verify that **ICWS detection** product specification states less than 0.05% error rate. *Verify again during reliability demonstration in Test Case 5.*	1.1.1.2, 1.3.1.3	**Test Case 1 Results**	
		Test Case 4 Results	
1h. Verify that **ICWS alert** product specification states lag time is user-configurable without hardware or software changes. *Verify again during reliability demonstration in Test Case 5.*	1.1.2.3, 1.1.2.4, 1.3.2.3, 1.3.2.4	**Test Case 1 Results**	
		Test Case 4 Results	
1i. Verify that **ICWS alert** product specification states sign sheeting and lighting are within ranges specified by MN MUTCD Section 2A.7 Retroreflectivity and Illumination, MN MUTCD 2L.4 Design Characteristics of Changeable Message Signs, and TEM 6-4.05.05 Retroreflective Sheeting Policy.	1.8.1.1		

Test Case 2: Integration Demonstration

Environment: MnDOT Fort Snelling Office

Process: Once the Contractor has procured and integrated a complete set of ICWS components, the system integration will be demonstrated prior to installation at the first intersection site. The demonstration will take place at MnDOT's Fort Snelling Office to simulate the installation environment. All ICWS features (e.g., detection, alert, etc.) shall be integrated, constructed (intrusive detection shall be present however will not be installed in the pavement), activated and observed for requirements verification and acceptance during the demonstration. The entire system will remain at the MnDOT Fort Snelling Office for the 30-day environmental testing and other requirement testing. Once accepted, the Contractor will proceed with preparation of materials for the test plan review prior to the functional demonstration. The integration test system will remain at MnDOT's Fort Snelling Office through the end of the functional demonstration. *Many of the steps described in the verification instructions below will be repeated in Test Case 4. The test log has been separated to reflect both instances of testing.*

Participants: Shall include, at a minimum, the MnDOT Project Manager, MnDOT Electrical Services personnel, Contractor and Oversight Consultant. Additional participants may include MnDOT Safety Unit, State Aid for Local Transportation, District Traffic Engineer, County Engineer (if relevant), or FHWA Division Safety Engineer.

Verification Instructions	System Requirement	Test Log	
		Pass/ Fail	Comments
2a. Verify that **ICWS alert is active on minor road whenever any vehicle** a. is approaching less than the user-configured lag time away from, and b. has not yet entered the intersection on the major road.	1.3.2.1	**Test Case 2 Results**	
		Test Case 4 Results	
2b. Verify that ICWS **alert is inactive on the minor road** whenever no major road vehicle a. is approaching less than a user-configurable lag time away from, and b. has not yet passed the intersection on the major road	1.3.2.2	**Test Case 2 Results**	
		Test Case 4 Results	
2c. Verify that **ICWS alert is active on the major road** whenever any minor road vehicle is a. approaching less than time "t" away from the stop sign, or b. waiting at the stop sign on the minor road.	1.1.2.1	**Test Case 2 Results**	
		Test Case 4 Results	
2d. Verify that **ICWS alert is inactive**	1.1.2.2	**Test Case 2 Results**	

on the major road whenever NO minor road vehicle is a. approaching less than time "t" away from the stop sign, or b. waiting at the stop sign on the minor road. Time "t" is the major road vehicle lag time from 100 feet in advance of the major road warning sign to the intersection at the posted speed limit.			
		Test Case 4 Results	

Test Case 3: Plan Set Review

Environment: Office

Process: After detailed design is complete, Contractor will present a completed plan set for the first ICWS installation site to MnDOT for requirements verification and acceptance. Once accepted, the Contractor may proceed with installation at the first intersection site. *Several steps described in the verification instructions below will be repeated in Test Case 4. The test log has been separated to reflect both instances of testing.*

Participants: Shall include, at a minimum, the MnDOT Project Manager, District Traffic Engineer, Contractor and Oversight Consultant. Additional participants may include MnDOT Safety Unit, State Aid for Local Transportation, State Sign Engineer, County Engineer (if relevant), or FHWA Division Safety Engineer.

Verification Instructions	**System Requirement**	**Test Log**	
		Pass/ Fail	**Comments**
3a. Verify that ICWS **alert is visible from any approach lane and placed along major road** according to MN MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs for the posted speed and distance from the intersection. *Verify again during functional demonstration in Test Case 4.*	1.2.1.1, 1.2.1.2	**Test Case 3 Results**	
		Test Case 4 Results	
3b. Verify that ICWS **detection is placed on major road** to detect vehicles in all approach lanes and from both directions. *Verify again during functional demonstration in Test Case 4.*	1.3.1.1, 1.3.1.2	**Test Case 3 Results**	
		Test Case 4 Results	
3c. Verify that ICWS **alert is placed**	1.4.1.1	**Test Case 3 Results**	

along minor road on the far right corner of intersection, across from the stop sign, where intersection geometry permits. If geometry is restricted, ICWS alert should be on far left corner of intersection. *Verify again during functional demonstration in Test Case 4.*			
		Test Case 4 Results	
3d. Verify that ICWS **alert reflects** the placement, sign combinations and messages described for ICWS4: Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection.	1.6.2.1		
3e. Verify that **all ICWS designs** use standard static or blank out sign design for minor road alert and standard static for major road alert as specified in Book 2.	1.7.1.1		
3f. Verify that ICWS **alert functions as warning sign** defined in MN MUTCD Sections 2C.1-2C.2 and does not replace or conflict with any regulatory signs.	2.1.1		
3g. Verify that ICWS **utility power source is identified and adequate** for continuous operations 24x7, 365 days per year. *Verify again during functional demonstration in Test Case 4.*	2.2.1.5	**Test Case 3 Results**	
		Test Case 4 Results	
3h. Verify that **ICWS component placement** will not obstruct any drivers' view of the road, other vehicles or regulatory signs. *Verify again during functional demonstration in Test Case 4.*	2.4.1	**Test Case 3 Results**	
		Test Case 4 Results	
3i. Verify that all **ICWS materials** conform to Section 2564 Traffic Signs and Devices and 2565 Traffic Control Signals of the MnDOT Standards Specifications for Construction.	2.5.2		

3j. Verify that **ICWS indication on the major road alert** consists of continuous activation of the flashing beacon, excluding utility power service failure. If utility power service fails, it is acceptable for beacon to just be off.	2.3.2.1		
3k. Verify that ICWS **indication on the minor road alert** has a 72 hour minimum power backup or an indication different than any other active or inactive state.	2.3.2.2		

Test Phases – System Acceptance Part 1

This stage of testing will include a functional (1-day) test and a reliability (30-day) test to be conducted at the first ICWS installation site. For the purposes of warranty, the functional test of the installed ICWS will serve as an acceptance test. The Contractor will create a test plan and conduct the functional test to demonstrate that all system requirements are adequately met. The oversight Consultant will verify reliability test results every 96 hours for a minimum of 30 Days. The reliability test must be passed to proceed to system installation at all remaining sites. For all the remaining sites, the oversight Consultant will observe the Turn-on Tests to verify that the systems are properly installed and function as required. For the initial 30-day reliability test, the Contractor will continue operation of the ICWS at the first installation site, with the system covered and unavailable for driver interaction until MnDOT accepts the system for full operation. Table 2 below presents further detail for the test cases, environment, processes, verification instructions, relevant system requirements and log that will be used for system acceptance testing.

Table 2 System Acceptance Part 1 Test Cases

Test Case 4: Functional Demonstration (1-Day)

Environment: First ICWS Installation Site

Process: Once the Contractor has installed an ICWS at the first installation site, the 1-day functional demonstration will be scheduled to allow for observation under dawn/dusk lighting and peak/off-peak traffic conditions. The demonstration will require two vehicles (provided by the Oversight Consultant) to drive through the intersection while ICWS features (e.g., alert activation) are activated and observed for requirements verification and acceptance. The Oversight Consultant will also provide a laptop in order to download and observe data recorded by the ICWS. *In addition to the verification instructions listed below, there are several verification steps in Test Case 1, Test Case 2 and Test Case 3 above that need to be repeated in this test case.*

Participants: Shall include, at a minimum, the MnDOT Project Manager, Contractor and Oversight Consultant. Additional participants may include MnDOT Safety Unit, State Aid for Local Transportation, State Sign Engineer, District Traffic Engineer, County Engineer (if relevant), or FHWA Division Safety Engineer.

Verification Instructions	System Requirement	Test Log	
		Pass/ Fail	Comments
4a. Verify that **ICWS minor road warning is active** within the user-configured lag time between 4 and 9 seconds, in increments of 0.1 seconds, for vehicles approaching the intersection on the major road.	1.3.2.3		
4b. Verify that **ICWS is active within the user-configured lag time whenever** vehicle speeds are ±10 MPH of the posted speed.	1.3.2.5		
4c. Verify that **ICWS detection malfunction** is detected and indicated within 1 minute of the onset of the malfunction. This will require a force malfunction not related to power supply.	2.2.1.6, 2.3.1.1		
4d. Verify that **ICWS malfunction** is recorded and categorized in data management according to the malfunctioning component and time/date stamped according to when failure began/ended.	3.3.1.1		

4e. Verify that ICWS automatically returns to a fully operational state when power is restored after a power outage	2.2.1.9		
4f. Verify that **ICWS operates without dependence on external systems.**	2.2.2		
4g. Verify that **ICWS components** are physically accessible for maintenance within the right of way with one Transportation Agency vehicle and a 1-2 person crew.	2.9.2		

Test Case 5: Reliability Demonstration (30-Day)

Environment: First ICWS Installation Site

Process: Following completion of Test Case 4, the Contractor will continue operation of the first ICWS site for another 30 days to demonstrate reliability and verify the associated requirements. During this period, the ICWS should be covered and unavailable for driver interaction. Because most requirements being reviewed in this test case revolve around data storage, the Contractor shall visit the site to confirm operation and download data once every 96 hours.

The State, through a separate contract with the University of Minnesota, will deploy a portable IDS/CICAS system which shall be used to collect data, analyze data and compare results to that of the intersection warning system data provided by the Contractor. The University will write a summary report after each 96 hour interval and a final evaluation report after the test period.

Participants: Shall include, at a minimum, the Contractor, the Oversight Consultant and the University of Minnesota. Additional participants may include MnDOT Project Manager, District Traffic Engineer or County Engineer (if relevant) and FHWA Division Safety Engineer.

Verification Instructions	System Requirement	Test Log	
		Pass/ Fail	Comments
5a. Verify that **ICWS operated continuously**, with no service interruptions during 30-day test, excluding utility power service failure.	2.2.1.1		
5b. Verify that **ICWS service interruption,** if one occurs, does not last longer than 72 hours, excluding utility power service failure.	2.2.1.2		
5c. Verify that **ICWS shall respond** with an activation, to approaching vehicles on with less than 0.05% error.	1.1.1.2 1.3.1.3		

5d. Verify that **ICWS data management** records individual system and vehicle detection activations with time/date stamped over a 96-hour period.	3.3.1.2, 3.3.1.3		

Test Case 6: Turn on test (1-Day)

Environment: All remaining ICWS Installation Sites

Process: After the first installation passes the Reliability Demonstration, all subsequent installations shall be subject to the following Turn On Test.

- One hour observation of Major Road operation.
- One hour observation of Minor Road operation.
- The Contractor shall provide MnDOT with as-built plan with GPS coordinates.

Participants: Shall include, at a minimum, the Contractor and Oversight Consultant. Additional participants may include MnDOT Project Manager, District Traffic Engineer or County Engineer (if relevant), or FHWA Division Safety Engineer. .

Verification Instructions	System Requirement	Test Log	
		Pass/ Fail	Comments
6a. Verify that **ICWS minor road warning is active** within the user-configured lag time between 4 and 9 seconds, in increments of 0.1 seconds, for vehicles approaching the intersection on the major road.	1.3.2.3		
6b. Verify that **ICWS is active within the user-configured lag time whenever** vehicle speeds are ±10 MPH of the posted speed.	1.3.2.5		
6c. Verify that **ICWS detection malfunction** is detected and indicated within 1 minute of the onset of the malfunction. This will require a force malfunction not related to power supply.	2.2.1.6, 2.3.1.1		
6d. Verify that **ICWS malfunction** is recorded and categorized in data management according to the malfunctioning component and time/date stamped according to when failure began/ended.	3.3.1.1		

6e. Verify that ICWS automatically returns to a fully operational state when power is restored after a power outage	2.2.1.9		
6f. Verify that **ICWS operates without dependence on external systems.**	2.2.2		
6g. Verify that **ICWS components** are physically accessible for maintenance within the right of way with one Transportation Agency vehicle and a 1-2 person crew.	2.9.2		

Test Phases – System Acceptance Part 2

MnDOT or the Oversight Consultant will observe the Turnover testing for all of the systems installed prior to concluding warranty work of the ICWS Systems. Table 3 below presents further detail for the test cases, environment, processes, verification instructions, relevant system requirements and log that will be used for system acceptance testing.

Table 3 System Acceptance Part 2 Test Cases

Test Case 7: Turn over test at all intersections

Environment: All ICWS Installation Sites.

Process: Prior to the conclusion of the warranty period, the Contractor shall conduct a 1-day turn over test. This testing shall confirm that the detection, warning, system communication, data management, system monitoring and power are all in working order.

Participants: Should include, at a minimum, the Contractor and Oversight Consultant. Additional participants may include MnDOT Project Manager, District Traffic Engineer or County Engineer (if relevant), or FHWA Division Safety Engineer.

Verification Instructions	System Requirement	Test Log	
		Pass/ Fail	Comments
7a. Verify that **ICWS is active within the user-configured lag time whenever** vehicle speeds are ±10 MPH of the posted speed.	1.3.2.5		
7b. Verify that **ICWS detection malfunction** is detected and indicated within 1 minute of the onset of the malfunction. This will require a force malfunction not related to power supply.	2.2.1.6, 2.3.1.1		

7c. Verify that **ICWS malfunction** is recorded and categorized in data management according to the malfunctioning component and time/date stamped according to when failure began/ended.	3.3.1.1		
7d. Verify that **ICWS operates without dependence on external systems.**	2.2.2		
7e. Verify that **ICWS components** are physically accessible for maintenance within the right of way with one Transportation Agency vehicle and a 1-2 person crew.	2.9.2		