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Minnesota Department of Transportation Rural Intersection Conflict Warning System (RICWS) Reliability Evaluation

Final Report

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The Minnesota Department of Transportation (MnDOT) developed the Rural Intersection Conflict Warning System (RICWS) Deployment project to reduce crashes at stop-controlled intersections. It is a statewide, Intelligent Transportation Systems project that will deploy intersection conflict warning systems at up to 50 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. The first RICWS site, Trunk Highway 7 and Carver County CSAH 33, was evaluated for a period of 34 days to demonstrate the reliability of the system. During this period, the RICWS signs, beacons, and any other displays were covered and unavailable for driver interaction. The University of Minnesota installed a portable Intersection Surveillance System (ISS) and collected data from the RICWS as well as from the ISS. The data collected from the RICWS was validated against data recorded by the ISS in order to determine the accuracy and reliability of the RICWS. The RICWS was determined to have an activation rate of 99.98%, and meets the MnDOT specification of 99.95% sign activation rate. Sign activations were also validated using video captured at the site and a sample of times for valid activations and valid periods when the sign was inactive were recorded.

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Executive Summary

The Minnesota Department of Transportation (MnDOT) developed the Rural Intersection Conflict Warning System (RICWS) Deployment project to reduce crashes at stop-controlled intersections. It is a statewide, Intelligent Transportation Systems project that will deploy intersection conflict warning systems at up to 50 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.

The first RICWS site, Trunk Highway 7 and Carver County CSAH 33, was evaluated for a period of 34 days to demonstrate the reliability of the system. During this period, the RICWS signs, beacons, and any other displays were covered and unavailable for driver interaction. The University of Minnesota installed a portable Intersection Surveillance System (ISS) and collected data from the RICWS as well as from the ISS. The data collected from the RICWS was validated against data recorded by the ISS in order to determine the accuracy and reliability of the RICWS.

A successful evaluation of the installed RICWS technology would ensure that the system reliably detects approaching vehicles (to 99.95% accuracy), enhancing driver confidence in the system.

The Intersection Surveillance System (ISS) used for the evaluation consisted of four radar stations and four video cameras. The radar stations contain Delphi ESR radar units that have been documented to have over 99.995% detection accuracy. Four video cameras were also installed at the NW corner of the intersection. Each camera was pointed at one of the four approaches to the intersection. The goal of the evaluation was to determine the accuracy and reliability of the RICWS. This was done by comparing the sign activation data collected by the radar-based ISS with those from the RICWS. To ensure the reliability of the system, it was required that the RICWS perform accurately for a period of 30 days.

The data collected by the RICWS and the ISS was extracted and analyzed every 96 hours and a summary of valid and missed activations was determined. The RICWS was determined to have an activation rate of 99.98%, and thus meets the MnDOT specification of 99.95% sign activation rate. Sign activations were also validated using video captured at the site and a sample of times for valid activations and valid periods when the sign was inactive were recorded.

Introduction

The Minnesota Department of Transportation (MnDOT) developed the Rural Intersection Conflict Warning System (RICWS) Deployment project to reduce crashes at stop-controlled intersections. It is a statewide, Intelligent Transportation Systems project that will deploy intersection conflict warning systems at up to 50 rural, stop-controlled intersections. More may be deployed as new District/County Safety Plans come out in the future. 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. The RICWS typically consist of static signing, detection and dynamic elements.

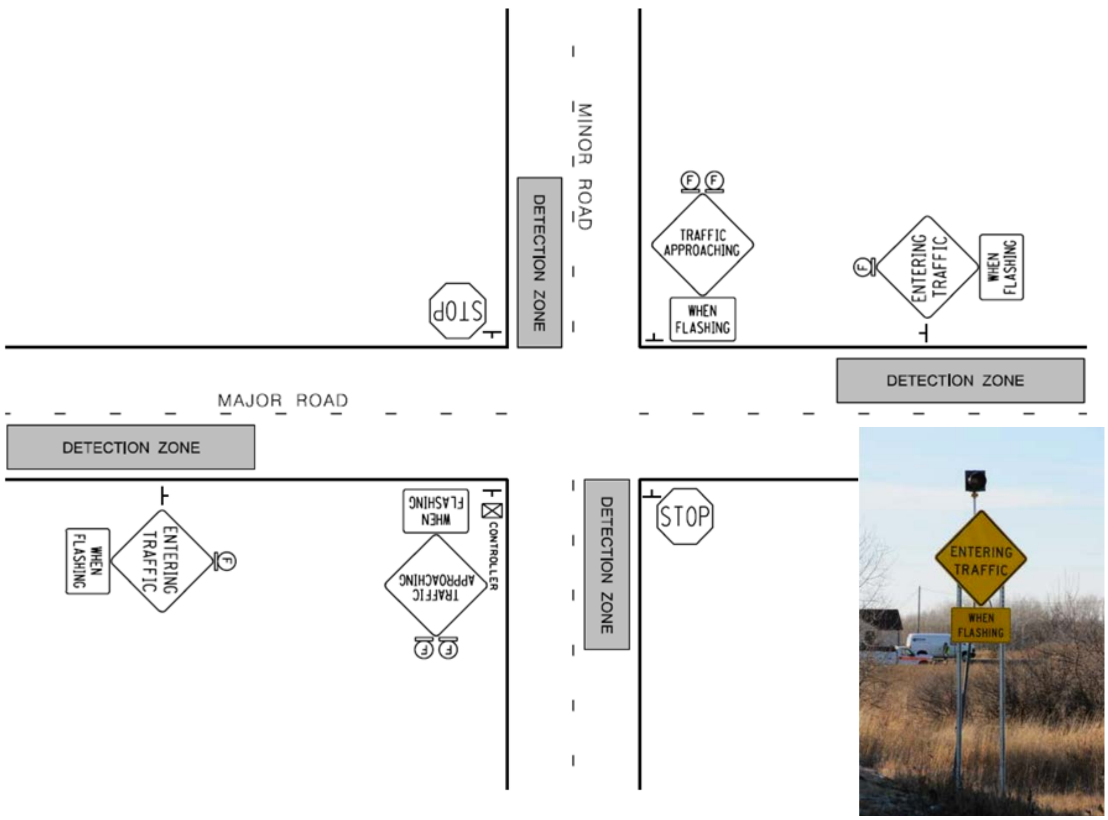

Figure 1. Typical layout for the RICWS (From Exhibit A [1])

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 the RICWS 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 of 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. As they are currently conceived, RICWS fit within Minnesota's ITS architecture under the Advanced Vehicle Safety Systems market packages AVSS05-Intersection Safety Warning and AVSS10-Intersection Collision Avoidance.

The first RICWS site, Trunk Highway 7 and Carver County CSAH 33, was evaluated for a period of 34 days to demonstrate the reliability of the system. During this period, the RICWS signs, beacons, and any other displays were covered and unavailable for driver interaction. The University of Minnesota (University) installed a portable Intersection Surveillance System (ISS) and collected data from the RICWS as well as from the ISS. The data collected from the RICWS was validated against data recorded by the ISS in order to determine the accuracy and reliability of the RICWS.

Figure 2. A view of the TH7 and Carver County CSAH 33 intersection. Vehicles waiting at the STOP sign on CSAH33 (minor road) are alerted about vehicles on the mainline with flashing beacons (shown above).

Objective

A successful evaluation of the installed RICWS technology will ensure that the system reliably detects approaching vehicles (to 99.95% accuracy), enhancing driver confidence in the system. If the RICWS is determined to work reliably, it will be installed at up to 50 locations across Minnesota to help improve safety at those intersections.

System Description

The Intersection Surveillance System (ISS) used for the evaluation consists of four radar stations and four video cameras.

The radar stations contain Delphi ESR radar units that have been documented to have over 99.995% detection accuracy [2] [3]. This radar sensor operates in the 77 GHz spectrum and provides two radar beams; a long range beam of 20 (+/- 10) degrees and a medium range beam of 90 (+/- 45) degrees. It can detect up to 64 objects in each scan and provides the range, range rate, azimuth angle and acceleration at 20Hz. The sensor has an approximate range of 180m.

The raw radar data captured from this sensor is wirelessly transmitted via 802.11g radios to a data acquisition (DAQ) station located on the NW corner of the intersection.

Four video cameras were also installed at the NW corner of the intersection. Each camera points at each of the four approaches to the intersection; this video is also stored at the DAQ station and can be used to visually validate discrepancies between the ISS and RICWS systems. The DAQ station also contained a cellular modem that allowed for it to be monitored remotely. The Internet connection provided by this modem allowed for the station to also synchronize time with a network time protocol (NTP) server.

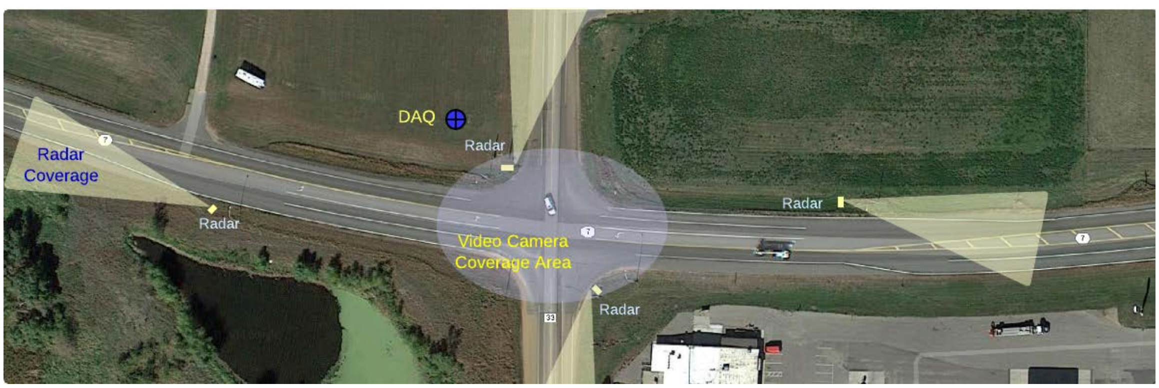

Figure 3. Layout of the four radar stations, video cameras and DAQ station

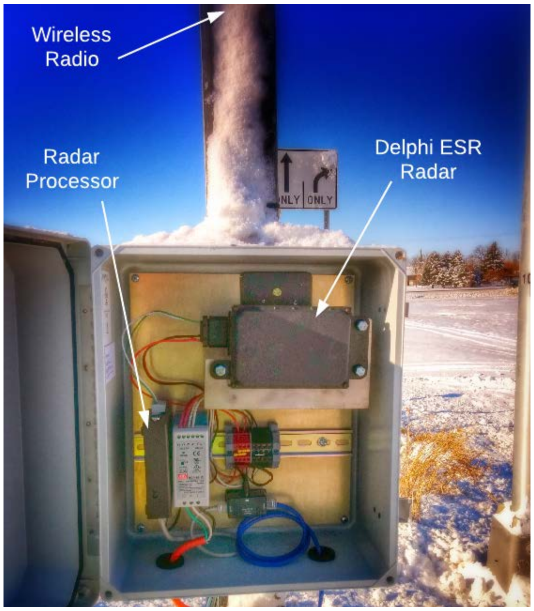

Figure 4. A typical radar station. The station consists of an ESR Delphi radar aimed to detect approaching vehicles. The radar processor reads this data, which then transmits this to the DAQ station through a wireless radio. During normal operation, the door of this station is closed to ensure weatherproofing. The door is transparent to the radar beams.

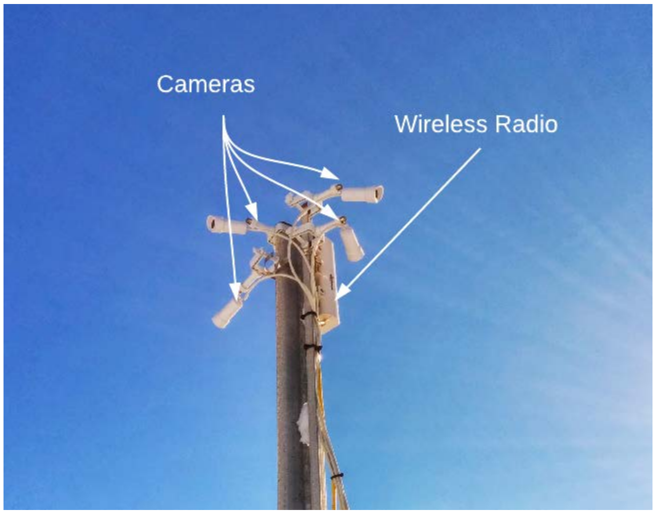

Figure 5. Four cameras point at each of the intersection approaches. Video from these cameras was recorded at the DAQ station. Also seen is the wireless radio that receives data from the 4 remote radar stations.

The RICWS uses a combination of Canoga micro loops and loop detectors installed in the pavement to detect vehicles on both the mainline and the minor road. Two microloops were installed on the major road approaches to detect the speed of approaching vehicles in order to provide a consistent warning time. Loop detectors were installed on the minor road, both in advance of the intersection and at the stop bar.

Evaluation Methodology

The goal of the evaluation is to determine the accuracy and reliability of the RICWS. This was done by comparing sign activation data collected by the radar -based Intersection Surveillance System and from the RICWS. To ensure the reliability of the system, it was required that the RICWS perform accurately for a period of 30 days.

The raw data from the ISS was processed to determine valid sign activation times for the signs on both the mainline and minor road. This data was time-stamped before being stored on the Data Acquisition (DAQ) station. The DAQ computer’s clocked was synced to the GPS timeserver.

A record of all the mainline and minor road sign activations determined by the RICWS were collected by the RICWS. This data was also time-stamped and recorded. However, the clock on the RICWS data loggers was not synchronized to network or GPS time; this resulted in inaccuracies in the timestamps for this data. The accuracy of these timestamps varied throughout the data collection period and was usually within a few seconds. MnDOT was aware of this inaccuracy, and it was decided that a tolerance of 3 seconds would be used to compare sign activations detected by the RICWS with those determined by the ISS.

In the case of a missed sign activation – a sign activation that was detected by the ISS and not by the RICWS, the videos from the four cameras were used to validate that the RICWS missed a sign activation. This provided visual proof of all missed sign activations.

Results

The data collected by the RICWS and the ISS was extracted and analyzed every 96 hours and a summary of valid and missed activations was determined.

Table 1 shows the results of this analysis aggregated by day. The table indicates that on most days, the RICWS did not miss any mainline or minor road activations.

Table 1. Summary of mainline and minor road sign activations

Evaluation Period	Date	Mainline Sign Activations			Minor Road Sign Activations		
		Recorded Activations	Missed Activations	Total Activation Rate (%)	Recorded Activations	Missed Activations	Total Activation Rate (%)
1	10/18/2013	3127	2	99.936%	1498	0	100.000%
	10/19/2013	2829	1	99.965%	1617	1	99.938%
	10/20/2013	2487	0	100.000%	1353	0	100.000%
	10/21/2013	2961	0	100.000%	1473	0	100.000%
2	10/22/2013	3025	0	100.000%	1476	0	100.000%
	10/23/2013	2938	1	99.966%	1430	0	100.000%
	10/24/2013	2952	1	99.966%	1397	0	100.000%
	10/25/2013	3075	0	100.000%	1464	0	100.000%
3	10/26/2013	2912	1	99.966%	1536	0	100.000%
	10/27/2013	2544	1	99.961%	1372	0	100.000%
	10/28/2013	2905	0	100.000%	1349	0	100.000%
	10/29/2013	2811	0	100.000%	1394	0	100.000%
4	10/30/2013	2791	1	99.964%	1283	0	100.000%
	10/31/2013	2888	0	100.000%	1301	0	100.000%
	11/01/13	3065	0	100.000%	1426	0	100.000%
	11/02/13	2890	0	100.000%	1419	0	100.000%
5	11/03/13	2560	0	100.000%	1314	0	100.000%
	11/04/13	2913	0	100.000%	1366	0	100.000%
	11/05/13	1205	1722*		1403	0	100.000%
	11/06/13	67	2715*		1279	0	100.000%
6	11/07/13	67	2639*		1315	0	100.000%
	11/08/13	1926	938*		1327	0	100.000%
	11/09/13	2725	0	100.000%	1381	0	100.000%
	11/10/13	2421	0	100.000%	1200	0	100.000%
7	11/11/13	2804	0	100.000%	1339	0	100.000%
	11/12/13	2917	0	100.000%	1383	0	100.000%
	11/13/2013	2917	0	100.000%	1331	0	100.000%
	11/14/2013	3104	1	99.968%	1361	0	100.000%
8	11/15/2013	3082	0	100.000%	1369	0	100.000%
	11/16/2013	2777	0	100.000%	1473	0	100.000%
	11/17/2013	2448	1	99.959%	1201	0	100.000%
	11/18/2013	2884	0	100.000%	1316	0	100.000%
9	11/19/2013	2886	1	99.965%	1324	0	100.000%
	11/20/2013	3007	0	100.000%	1333	0	100.000%
Total		**85645**	**11**	**99.987%**	**41479**	**1**	**99.998%**

*Between 11/5/2013 and 11/8/2013, some of the data loggers used by the RICWS had failed. This resulted in a large missed activation rate for these dates. MnDOT was notified about this data collection problem, and it was determined that data from those days would be excluded.

Excluding the dates during which the data loggers were faulty, the RICWS missed 1 sign activation out of 41,479 activations on the minor road and 11 sign activations out of 85,645 activations on the mainline. This results in a sign activation rate of greater than 99.98%.

Video that was recorded was also viewed at random times to verify sign activations that both the ISS and RICWS detected. Table 2 depicts this sample. Video samples were observed at times when no sign activations were detected to validate that vehicle detections were not missed and these are shown in Table 3.

Table 2. Sample sign activation times that were corroborated by watching the recorded video

Date	Corroborated with Video	Not Corroborated with Video	Total Sampled
11/20/2013	5	0	5
11/19/2013	5	0	5
11/18/2013	5	0	5
11/17/2013	5	0	5
11/16/2013	5	0	5
Total	**25**	**0**	**25**

Table 3. Sample times when the sign was not active and was corroborated by watching the recorded video

Date	Corroborated with Video	Not Corroborated with Video	Total Sampled
11/20/2013	5	0	5
11/19/2013	5	0	5
11/18/2013	5	0	5
11/17/2013	5	0	5
11/16/2013	5	0	5
Total	**25**	**0**	**25**

Due to the inadequate performance of the logger unit's timing protocols, a statistically relevant comparison of the sign activation times of the RICWS and ISS was not possible. This is due to the disparity between the clock on the RICWS data collection system and that of the ISS data collection system.

Conclusion

An evaluation of the RICWS was performed by comparing the system's performance with the University of Minnesota's Intersection Surveillance System. The RICWS was determined to have an activation rate of 99.98%, and meets the MnDOT specification of 99.95% sign activation rate. Sign activations were also validated using video captured at the site and a sample of times for valid activations and valid periods when the sign was inactive were recorded.

References

[1] Minnesota Department of Transportation, "Rural Intersection Crash Warning System (RICWS) Contract," Book 2, Section 1.

[2] A. Gorjestani, C. Shankwitz and M. Donath A. Menon, "Roadside range sensors for intersection decision support," in *Intelligent Transportation Systems*, Washington D.C, 2004, pp. 210-215.

[3] A. Menon, A. Gorjestani, C. Shankwitz, and M. Donath J. Fischer, "Range sensor evaluation for use in Cooperative Intersection Collision Avoidance Systems," in *Vehicular Networking Conference (VNC)*, vol. 1, Tokyo, 2009, pp. 29-36.