An Addendum to "A Study of the Rural Intersection Conflict Warning System (RICWS)"

Prepared by:

Ian Saari
Mark Wagner
Office of Traffic Engineering
Minnesota Department of Transportation

February 2021

Introduction

The problem of rural road fatalities has been a large and persistent issue in the state of Minnesota, just as it has throughout the United States. Traditionally, past information about the locations of severe crashes would tend to drive the selection traffic safety improvements. And while effective up to a point, transportation professionals will also acknowledge that proactively planning how and where to install new safety improvements can be difficult as the locations of fatal crashes can be highly variable.

To support the safety of all those travelling on Minnesota roads, engineers and transportation researchers are committed to a systemic approach to traffic safety. Working to improve safety with a systemic approach acknowledges the value of responding where severe crashes occur, but it also recognizes that gathering additional information about crash characteristics and characteristics of the surrounding area locations are key to identifying risk factors for how and where crashes occur across the entire road network. Using this approach, the goal is to prevent future crashes from occurring by finding areas of improvement, selecting safety infrastructure with the potential to address identified needs, and conducting evaluations of crash countermeasures based on their real-world performance. In Minnesota, this is the approach used in development of District Safety Plans and County Roadway Safety Plans.

Since the problem of rural road fatalities has been a persistent one, the multi-year development and deployment of MnDOT's Rural Intersection Conflict Warning Systems (RICWS) to 66 intersections around the state has undoubtedly been an important investment. With the information gathered from the previous study, and with about two years of additional information available for every RICWS and Control site, the goal with this supplemental report is to extend analyses from the previous study and to further inform planning related to Minnesota's RICWS deployments. In our office's 2019 report, the number of crashes based on crash severity and crash diagrams were reviewed; and the frequencies in which crashes occurred at the report sites were discussed in terms of their crash <u>rates</u>. The rationale for using the calculated crash rates for the study's comparisons was important, because it served as a standardized metric for measuring site differences in two important areas: 1) differences in site traffic volumes (both between any pair or group of sites, and for *within-site* variation from year to year), and 2) differences in the available period of time for the Before-After crash analysis, based on each study site's "Turn-On" date. These crash rates provided an overview of the crash distributions before and after installation for both RICWS and control sites and were necessary for later statistical testing. Ultimately, using crash rates as a metric in the previous report made it possible for our office to account for the potential moderating effects of traffic volumes and the availability of crash information.

Observed data based on intersection crash trends and the lack of consistency between Minnesota's findings and other states which have published clear safety impacts with Intersection Conflict Warning Systems (ICWS) are also discussed.

Data Methodology

Crash Density, Explained

In the previous study, traffic volumes did not appear to have a very strong relationship with the frequency of crashes. Therefore, the decision was made for this report to specifically focus on the amount of time and the average number of crashes at each location during the "Before" and "After" sample periods. To accomplish this, observations based on before and after "crash densities" were calculated for both RICWS and control sites, using this formula:

$$Crash\ Density_{site_{Before}} = \frac{\sum(x_1 + x_2 + \ldots + x_n)}{Y_B}$$

$Crash\ Density_{site_{Before}}$	=	The average number of "Before" crashes, per year, for an individual site
x_n	=	Number of crashes (x) that occurred in year (n)
Y_B	=	Total number of years of available crash data before RICWS turn-on

Put another way, the calculated crash density for an individual test site is equal to *the average number of crashes observed at a specific site in one year*. When extending that formula to our Before-After analysis and the review of the two site groups, the calculated values for the crash densities can be read as *the average number of crashes observed per site, per year* (of the "Before" or "After" sample). Once these crash densities computed for the target crash types and severities, the degree to which these crash densities changed from the "Before" to the "After" sample period was also reviewed for both site groups. Percent (%) differences for the crash densities are reported as a standardized measure for each crash type. For example, a negative (-) percent difference would indicate that the crash density decreased after the corresponding "RICWS turn-on" date. Conversely, a positive value would denote that the crash density increased.

Overview of Crash Data

Crashes at RICWS and Control Sites, Based on Severity

For context that illustrates some of the general trends in the crash data, Figure 1 shows the total number of crashes which had been reported each year across the two site groups from 2009 through early 2020. An overview of the number and density of crashes at RICWS sites is presented in *Table* 1. Similar summary information about the number and density of crashes at control sites is shown in Table 2**Error! Reference source not found.**.

From *Table* 1*,* it can be seen that the number of 'K', 'C', and 'PDO' severity crashes decreased, as did the 'Total' count of crashes, after implementation at RICWS sites. Compared to the control site crashes detailed in Table 2, the number of 'B', 'C', 'PDO', and 'Total' crashes decreased at control sites, after their respective "RICWS turn-on" dates. All other analyzed pairs of "site group" and "crash severity" exhibited crash increases in the "After" testing period.

Before and after crash densities were calculated based on crash severity for both RICWS and control sites. Average site crash densities for RICWS sites are shown in **Error! Reference source not found.** and the crash densities for control sites are shown in Table 2**Error! Reference source not found.**. In **Error! Reference source not found.**, it can be seen that the average site crash densities for 'K' and 'C' crashes decreased after implementation at RICWS sites. This observation differs from to the "After" period crash densities for control locations, which can be found in Table 2. At control sites, where there had been smaller 'B' and 'C' average crash densities in the years following the control sites "RICWS turn-on" dates. It is worth noting that, although previously published literature suggested that, given time, 'A' crash densities should diverge and the overall rate 'A' crashes would decrease for RICWS, this trend was not what the data indicated. Instead of a widening gap between the predicted 'A' crash reductions at RICWS sites and more steady trends (or even increases) in crashes at control sites, the density and frequency of 'A' crashes increased substantially for both sites groups, defying expectations and raising several important questions.

Table 1. Summary of RICWS Site Crash Statistics

Time Period	Metric	K	A	B	C	PDO	Total
Before	Num. of Crashes	**17**	**12**	**86**	**133**	**301**	**549**
	Average Site Crash Density	**.042**	**.027**	**.204**	**.317**	**.714**	**1.304**
After	Num. of Crashes	**12**	**23**	**96**	**77**	**290**	**498**
	Average Site Crash Density	**.037**	**.069**	**.307**	**.239**	**.892**	**1.544**
	% Change in Avg. Site Crash Density	**- 13%**	**+ 152%**	**+ 51%**	**- 25%**	**+ 25%**	**+ 18%**

Table 2. Summary of Control Site Crash Statistics

Time Period	Metric	K	A	B	C	PDO	Total
Before	Num. of Crashes	**7**	**9**	**77**	**93**	**227**	**413**
	Average Site Crash Density	**.015**	**.020**	**.164**	**.205**	**.514**	**.919**
After	Num. of Crashes	**11**	**14**	**60**	**72**	**219**	**376**
	Average Site Crash Density	**.027**	**.040**	**.159**	**.182**	**.588**	**.997**
	% Change in Avg. Site Crash Density	**+ 84%**	**+ 98%**	**- 3%**	**-11%**	**+ 14%**	**+ 9%**

Given the observed crash trends ran counter to our expectations at the project outset, the next step for the analysis was to determine the significance of any these observed differences between the two site groups. It would also important to ascertain whether any new patterns could be observed in the crash data collected since the initial report's analysis period concluded; the authors agreed that any new information that could be gleaned from the observed crashes at the two site groups would likely be invaluable for formulating guidance moving forward.

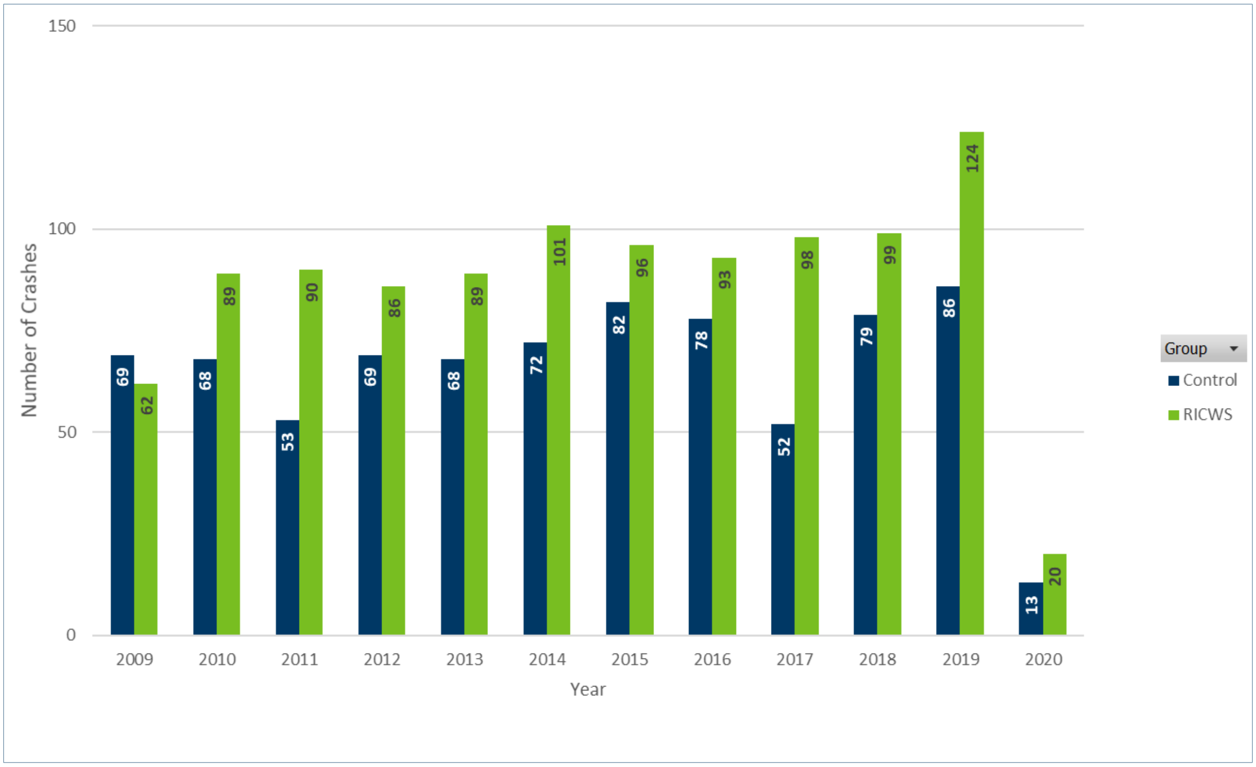

Figure 1. RICWS and Control Site Crashes (2009 to Early 2020)

Crashes at RICWS and Control Sites, Based on Manner of Collision

After reviewing how the two groups performed in each crash severity category, the RICWS and control sites were assessed based on crashes involving multiple vehicles. Distinguishing the different types of crashes that occurred at the two test groups of intersections is key to understanding if the RICWS has been effective, as these systems were designed to address specific types of collisions (primarily, right-angle crashes). With this analysis, our goal is to determine whether there are real reductions in these types of crashes even if there are impacts to others such as rear-end or head-on crashes. Please note that prior to the MNCrash system upgrade in 2016, the way in which two or more vehicles collided had been assigned the label “Crash Diagram.” Since the upgrade, this is now referred to as “Manner of Collision.”

In the previous RICWS report, crash rates for six target crash types (Angle, K+A Only; Angle, All Severities; Read-End; Side-Swipe, Same Direction; Head-On; and Side-Swipe, Opposite Direction) were compared between RICWS and control sites. To evaluate performance across the same target crash categories for this study, both groups’ target crashes were counted, and then corresponding crash densities were calculated. Summaries of the six target crashes types can be found in Table 3 and Table 4.

Table 3. Before and After Crash Densities for RICWS Sites, Based on Manner of Collision

Time Period	Metric	Angle *K+A only*	Angle *All Severities*	Rear-end	Sideswipe *Same Dir.*	Head-on	Sideswipe *Opp. Dir.*	Other
Before	Num. of Crashes	**23**	**294**	**81**	**22**	**19**	**14**	**109**
	Average Site Crash Density	**.057**	**.698**	**.192**	**.051**	**.027**	**.034**	**.257**
After	Num. of Crashes	**27**	**233**	**85**	**21**	**28**	**19**	**27**
	Average Site Crash Density	**.079**	**.710**	**.260**	**.066**	**.089**	**.060**	**.081**
% Increase/Decrease Change in Crash Density		**+ 39%**	**+ 2%**	**+ 35%**	**+ 29%**	**+ 86%**	**+ 75%**	**- 68%**

Table 4. Before and After Crash Densities for Control Sites, Based on Manner of Collision

Time Period	Metric	Angle *K+A only*	Angle *All Severities*	Rear-end	Sideswipe *Same Dir.*	Head-on	Sideswipe *Opp. Dir.*	Other
Before	Num. of Crashes	**12**	**177**	**65**	**25**	**12**	**20**	**97**
	Average Site Crash Density	**.027**	**.400**	**.143**	**.055**	**.025**	**.046**	**.214**
After	Num. of Crashes	**19**	**177**	**62**	**25**	**18**	**11**	**21**
	Average Site Crash Density	**.052**	**.460**	**.166**	**.038**	**.047**	**.029**	**.057**
% Increase/Decrease Change in Crash Density		**+ 93%**	**+ 15%**	**+ 16%**	**- 30%**	**+ 86%**	**- 37%**	**- 74%**

Before and After RICWS Installation

Like in the original report, RICWS installation sites were analyzed in order to determine the differences in crash frequency before and after the device was turned on. Previously, when the RICWS and control sites were analyzed, the average amount of time from the sites' "RICWS turn on date" to the end of data collection was about 2 years, 10 months. This review consisted of all crashes available after the turn on date until April 20, 2020. Additionally, the before and after periods for the control sites were analyzed. Since each control site is matched with a RICWS site, the before and after period for each control site are the same as those of its RICWS counterpart.

From the initial report, a few rural intersections underwent major changes either before or after the installation of a RICWS system, which led to alterations to the data:

- The intersection of TH 55 and CSAH 3/CR 136 in Wright County became signalized on Nov. 15, 2016. Without an exact turn-off date, it was estimated that the RICWS system was removed on Oct. 15, 2016, one month before the new signal was turned on.
- The intersection of CSAH 2 and Minnesota Street in Saint Joseph was completely reconfigured starting in Fall 2012. January 1, 2013 was defined as the first day that the new road was open and the beginning of the before period.
- The intersection of US 53 and Landfill Drive near Virginia, MN underwent major road reconstruction in 2017. The project dedication was held on Sept. 15, 2017 and will be used as the beginning of the before period. The RICWS was turned on a month later, starting the "After" period on Oct. 23, 2017.

Wilcoxon Signed Rank Test

In order to give an accurate analysis of the before and after data, a Wilcoxon Signed Rank test was used. This test assumes two dependent samples with independent observations. There is also the assumption of symmetry among the data; however, it does not assume normality in the data. Not assuming normality allows for more freedom when working with the data.

A Wilcoxon Signed Rank Test operates under the assumption of a null hypothesis. In this case, the null hypothesis is that the median differences between the distribution of before and after crash rates is equal to zero (i.e. the two distributions are the same). The alternative hypothesis is that the median difference between the before and after crash distributions is not equal to zero (i.e. the two distributions are different). When run, the Wilcoxon Signed Rank Test will provide a p-value which will be compared to a threshold significance level of $p = .05$. If the installation of RICWS produces little safety benefit, only slight differences would be observed when comparing the Before and After crash densities. However, if RICWS installations demonstrate a positive effect on intersection crashes, the expected result would be fewer target crashes in the "After" sample period.

The results from the Wilcoxon Signed Rank Test are shown in Table 5.

Table 5. Within-group Differences in Target Crashes, Comparing Before and After Crash Density

Intersection Type	Crash Density Type	*p*-value	Significant
RICWS	Total Crash	.024	Yes; Crash density increased
	K+A Right-angle Crash	.246	No
	K+A Crash	.097	No
	K Crash	.700	No
	A Crash	.030	Yes; Crash density increased
	Right-angle Crash	.886	No
Control	Total Crash	.348	No
	K+A Right-angle Crash	.084	No
	K+A Crash	.041	Yes; Crash density increased
	K Crash	.188	No
	A Crash	.115	Yes; Crash density increased
	Right-angle Crash	.283	No

Note: Test compares target crashes within the same site group during the same time period (e.g. RICWS "Before" to RICWS "After")

Discussion

From Table 5, none of the provided *p*-values are less than 0.05. This analysis indicates that based on before and after crash rates, no statistically significant reductions in target crash rates occurred in either RICWS or control groups after their respective “RICWS Turn-on dates.” The lack of significant difference between the before and after crash rates for the control sites is to be expected because no treatment was applied to those intersections. Since the results between the RICWS and control sites are similar, the change in crash reporting discussed earlier in this report is neither decreasing nor enhancing the effect of RICWS. These results indicate that RICWS installation has neither reduced nor increased crash rates.

Cross-Sectional Study

After the separate Before-After analyses, the next step in the review was to compare the differences observed between the site groups. Following the analytical format used in the previous report, the performance observed at the RICWS sites for each of the six target crash types was tested against the changes seen at the control sites.

Independent Two-sample *t*-Test

The independent two-sample *t*-test is used in this report to test for significant group differences between the two sample groups.

In this study, the test is specifically used to measure and compare the degree to which the two groups had differed in the earlier Before-After analysis. The results of the test indicate the densities for the target crash types by comparing the “average” RICWS site to the “average” control site. A significant t-test result would indicate that the size of the differences observed, when compared for each of the two site groups, is too great to be due to random chance alone. As with the previous analysis, a statistically significant test here would strongly suggest the RICWS systems are making a real-world impact at intersections where they are installed.

The results of the independent samples *t*-test are shown in Table 6. Similar outcomes to the Mann-Whitney U-Test from the first report were obtained in this analysis, where differences between the two site groups were not determined to be statistically significant. Again, the provided p-values will be compared to a significance level of $\alpha = 0.05$. If the p-value is greater than 0.05, RICWS and control sites have similar crash outcomes.

Table 6. Between-group Differences in Target Crashes, Comparing RICWS and Control Sites (Before-After)

Target Crash Type	RICWS % Δ	Control % Δ	*p*-value	Significant
Total Crash	+ 18%	+ 9%	.651	No
K + A Right-angle Crash	+ 39%	+ 93%	.893	No
K + A Crash	+ 52%	+ 92%	.780	No
K Crash	- 13%	+ 84%	.585	No
A Crash	+ 152%	+ 98%	.977	No
Right-angle Crash	+ 1%	+ 15%	.575	No

Note: Test compares the average percentage change (decrease or increase) in crashes over time, between the study groups (i.e. comparing average percent change observed for RICWS sites with the average change for Control sites)

Discussion

Since 2003, fatal and serious injury crashes across the state have trended down. As a result, the expected outcome for control sites would be small decreases. If the installation of RICWS has no effect, the treatment sites should be operating the same as the control sites. If RICWS installation had an effect, the expected result would be a decrease that significantly exceeds the control sites.

From Table 6, the average change in frequency of the observed target crashes was not found to be significantly different for the two groups. Several nominally lower crash rates for the RICWS sites may still suggest that RICWS could hold some potential for reducing certain types of crashes, but a distinct or consistent effect on crash rates remains to be seen. That said, it is worth noting that when evaluated using the less stringent 90% confidence interval ($p = 0.10$), the difference between the groups' average 'A' rates would be great enough to be considered statistically significant. This would also, unfortunately, indicate that RICWS are potentially increasing 'A' crashes after installation, which is counter to one of the most common reasons these systems are installed (i.e., reducing 'A' crashes).

Summary

Both a before and after study and a site comparison study were completed to assess the effectiveness that RICWS systems have on rural roadway safety. To accomplish this, the safety benefits of RICWS were analyzed by comparing before and after crash densities at RICWS and control locations. Comparing the average change in the frequency of crashes at RICWS and control sites before and after RICWS deployment for the six target crash types, no significant differences were identified between RICWS and control sites. As had been the case in the previous RICWS report, the before and after study of the sites' crash densities yielded no indication that densities decreased for the target crash types. Comparing the Before and After study period observations at the control sites, the occurrence of "K+A crashes" increased significantly and the increase in "A crashes" was also found to be statistically significant for both site groups.

Put another way, the amount that the 'A' crash densities changed at both RICWS and control sites makes it harder to attribute the changes to chance alone. While this difference in the groups' 'A' crash densities may be an apparent one, it is difficult to interpret the practical significance of this difference within the context of the data reporting change for 'A' crashes in 2016 that is mentioned earlier in this report and an overall lack of distinction between the select RICWS and control sites.

This second analysis of the RICWS installations shows little to no change from the results of our previous report: implementation of these systems has not been found to be the cost-effective safety countermeasure it was expected to be. Even so, the authors do not advocate for active removal of in-place systems and instead recommend following the *DRAFT RICWS Decision Guidance* on the MnDOT Traffic Engineering website[1] when determining whether to remove or replace them. MnDOT will continue to monitor the performance of the system for those remaining in service.

[1] mndot.gov/trafficeng