DEPARTMENT OF TRANSPORTATION

Traffic Safety Evaluation of Lane Constrictor Intersections in Minnesota

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Minnesota Department of Transportation

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Between 2018 and 2019, MnDOT installed a lane constrictor design at 66 side-street, stop-controlled intersections in Minnesota. The lane constrictor design narrows the lane width for mainline approaches via a striped median with centerline rumble strips. By narrowing the mainline lane, the goal of this design is to encourage mainline traffic to slow down as it approaches the intersection. The striped median also provides greater separation between mainline directions and draws more attention to the location of the intersection. Following the installation of lane constrictors at MnDOT intersections, overall crash rates have seen little change but there have been decreases in fatal and serious injury (KA) as well as fatal and all injury (KABC) crash rates. These results indicate the addition of lane constrictors have a positive impact on crashes by reducing the severity of crashes, swapping injury crashes for property damage only crashes.

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TRAFFIC SAFETY EVALUATION OF LANE CONSTRICTOR INTERSECTIONS IN MINNESOTA

FINAL REPORT

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LIST OF ABBREVIATIONS & DEFINITIONS OF TERMS

Acronym	**Meaning**
KA	Fatal and serious injury crash
KAB	Fatal, serious injury, and minor injury crashes
KABC	Fatal and all injury crashes
MEV	Million entering vehicles
MnDOT	Minnesota Department of Transportation

Crash Severities

- K Crash: Fatal crash. At least one person involved in the crash died as a result of injuries sustained in the crash.
- A Crash: Suspected serious injury crash. The crash resulted in a suspected serious injury for at least one person involved in the crash.
- B Crash: Suspected minor injury crash. The crash resulted in a suspected minor injury for at least one person involved in the crash.
- C Crash: Possible injury crash. The crash resulted in a possible injury for at least one person involved in the crash.
- PDO Crash: Property damage only crash. The crash resulted in property damage with no injuries for anyone involved in the crash.

Other Definitions:

- Site-Year: One year of data at a site.

EXECUTIVE SUMMARY

Between 2018 and 2019, MnDOT installed a lane constrictor design at 66 side-street, stop-controlled intersections in Minnesota. The lane constrictor design narrows the lane width for mainline approaches via a striped median with centerline rumble strips. By narrowing the mainline lane, the goal of this design is to encourage mainline traffic to slow down as it approaches the intersection. The striped median also provides greater separation between mainline directions and draws more attention to the location of the intersection.

The purpose of this evaluation is to review the crash history at lane constrictor intersections in Minnesota to determine the crash impact of installing lane constrictors. This report includes the results of a before-after crash analysis at intersections with lane constrictors and compares those results against similar intersections without lane constrictors.

Following the installation of lane constrictors at MnDOT intersections, overall crash rates saw little change, but the following decreases were found:

- 10% decrease in fatal and serious injury crash rates (KA)
- 22% decrease in fatal and all injury crash rates (KABC)

These decreases were compared to increases in KA and KABC crash rates at comparison sites without lane constrictors. These results indicated the addition of lane constrictors had a positive impact on crashes by reducing the severity of crashes, swapping injury crashes for property damage only crashes.

It should be noted that this evaluation did not create a policy, practice, or care within the Minnesota Department of Transportation. The purpose of this evaluation was purely exploratory.

CHAPTER 1: INTRODUCTION

Lane constrictor intersections are an intersection design for rural, high-speed intersections with side-street, stop control that narrows the lane width for mainline approaches via a striped median with centerline rumble strips. By narrowing the mainline lane, the goal of this design is to encourage mainline traffic to slow down as it approaches the intersection. The striped median also provides greater separation between mainline directions and draws more attention to the location of the intersection.

Figure 1.1 shows the layout of a lane constrictor intersection with mainline right turn lanes. This figure indicates where the striped median is as well as the location of rumble strips. The lane constrictor design can be used at intersections with or without mainline right- or left-turn lanes as well as on intersections with only one side-street approach. MnDOT installed the lane constrictor design at two intersections in 2018 and 64 intersections in 2019.

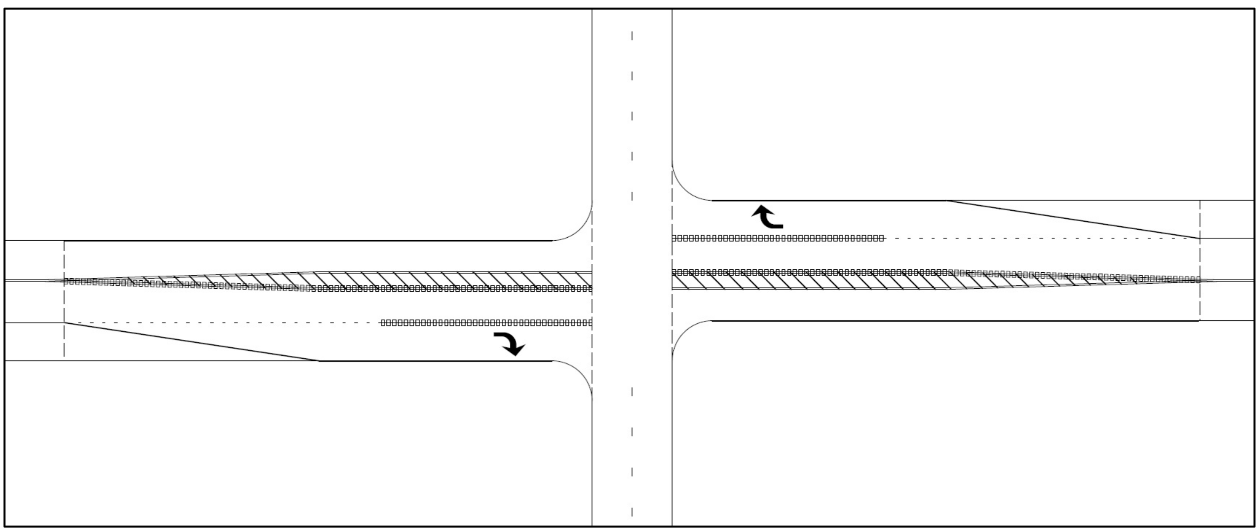

Figure 1.1 – Example Lane Constrictor Layout

CHAPTER 2: METHODOLOGY

2.1 LOCATIONS

As mentioned, there are 66 intersections on MnDOT roadways with the lane constrictor layout that were installed in 2018 and 2019. Those locations are shown in Figure 2.1.

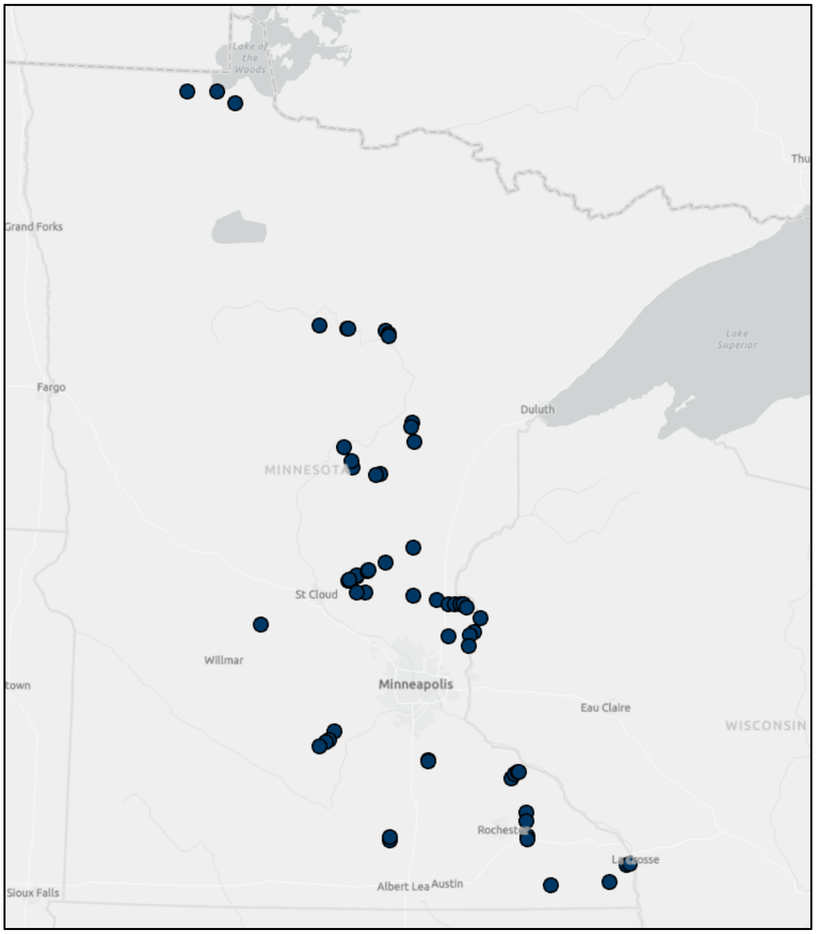

Figure 2.1 – Locations of Lane Constrictor Intersections

The analysis includes a comparison between the lane constrictor intersections and similar intersections without lane constrictors. A comparison intersection was identified for each intersection with the lane constrictor layout. These comparison intersections were identified by having the same side-street stop control and being in a similar context with similar entering volumes. All comparison intersections are also on the MnDOT roadway network. Those locations are shown in Figure 2.2.

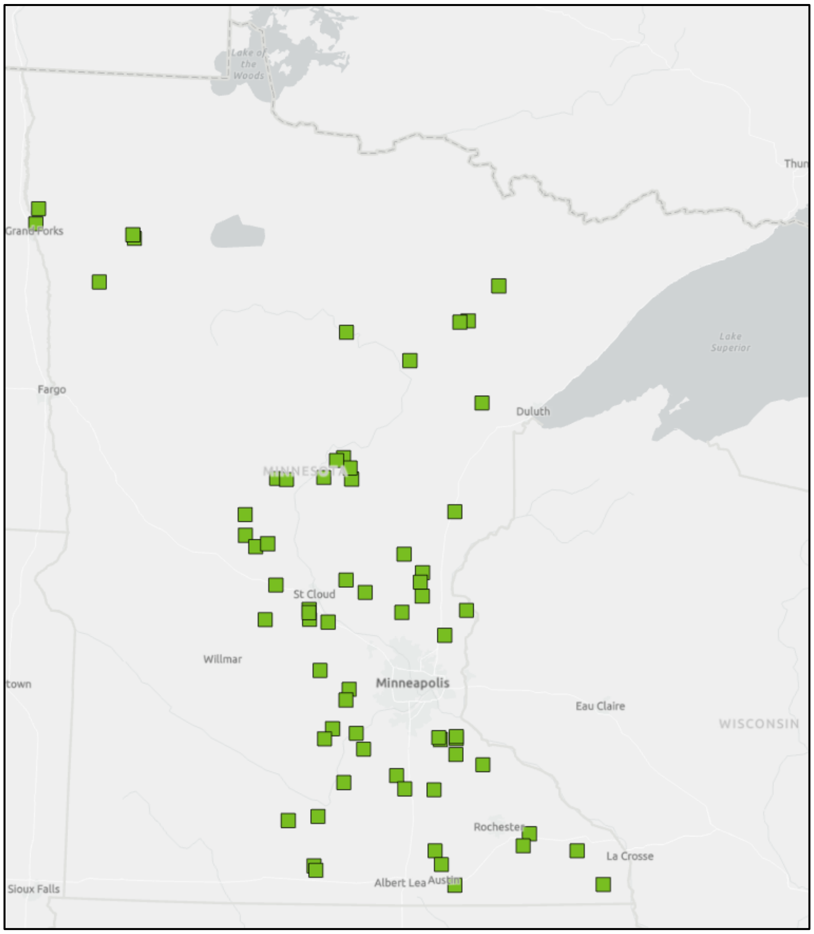

Figure 2.2 – Locations of Comparison Intersections for Evaluation

2.2 CRASH DATA

For comparison purposes, all crash data in this evaluation is analyzed by site-year. Crashes that occurred during the year of installation of the lane constrictor at each location are not included in the analysis due to varying installation dates. The analysis in this evaluation was conducted in 2023, so the most recent year of data analyzed was from 2022 as there was not a complete year of data for 2023 at the time of analysis.

Crash data for the applicable years was collected spatially at each intersection. Crashes that were located within the bounds of the turn lanes of the intersection and/or associated with the intersection were included.

Appendix A highlights all fatal and suspected serious injury crashes that occurred at intersections with lane constrictors, including in the year of installation.

2.3 ANALYSIS OVERVIEW

Two different types of analyses were conducted as part of this evaluation. Those analyses are:

A before-after analysis
This analysis focuses on comparing the crashes in a period before the lane constrictors were installed to a period after the lane constrictors were installed at the same locations. The before and after periods for each site include the same number of site-years.

A cross-sectional analysis
This analysis compares before-after crash data at locations with lane constrictors to similar locations without lane constrictors.

CHAPTER 3: RESULTS

3.1 BEFORE-AFTER ANALYSIS

The before-after analysis compares crash data at intersections before the lane constrictors were installed and after the lane constrictors were installed.

3.1.1 Question Addressed

How do crashes change after lane constrictors are installed at an intersection?

3.1.2 Locations

The analysis for this evaluation was conducted in the year 2023. Without having a full year of crash data for 2023, only crash data through 2022 was used. The 66 locations with lane constrictors discussed in section 2.1 were utilized for the analysis.

3.1.3 Crash Data

The before-after crash data at the 66 intersections with lane constrictors was collected and compiled. The year of installation was not included in the crash analysis, and the number of years used in the before period was set to match the number of years in the after period, with 2022 being the most recent year of data. Table 3.1 shows that compiled crash data. The total entering volumes (sum of daily volumes at each site) were 383,659,478 vehicles in the before scenarios and 371,155,689 vehicles in the after scenarios. Crash rates, in units of crashes per million entering vehicles (MEV), for the before-after scenarios are also included in Table 3.1.

Table 3.1 - Before-After Crash Data at Intersections with Lane Constrictors

Crash Severity/Type	Before # of Crashes	After # of Crashes	Before Crash Rate	After Crash Rate
Total Crashes	126	130	0.328	0.350
KA Crashes	8	7	0.021	0.019
KABC Crashes	62	47	0.162	0.127
Head-On Crashes	7	9	0.018	0.024
Sideswipe Opposing Crashes	3	1	0.008	0.003
Head-on + Sideswipe Opposing Crashes	10	10	0.026	0.027
Angle Crashes	40	43	0.104	0.116
Property Damage only Crash	64	83	0.167	0.224

3.1.4 Crash Analysis

To compare the before-after crash data samples, a Wilcoxon signed-rank test was used. This test is used to compare two related (or dependent) samples with independent observations. However, the Wilcoxon signed-rank test does not require normality in the data which was needed given the unique distribution of the sample data. The Wilcoxon signed-rank test tests the assumptions of a null hypothesis, although this test will not be comparing averages by relying on differences in group means. Since this test converts all of the observed values into two ordinal sets of ranks, the measure we are using for each group's average will be its median (or middle) value. For this analysis, the null hypothesis being tested is that the median difference between paired observations at the lane constrictor sites is equal to zero (i.e., the two distributions are the same). The alternative hypothesis being tested is that the median difference between pairs of the sample observations is not equal to zero (i.e., the two distributions are different).

The analysis and testing focused on eight crash severities/types which are listed below:

- Total crashes
- Fatal (K) and suspected serious injury (A) crashes
- Fatal and all injury crashes (severities KABC)
- Head-on crashes. These crashes may be impacted by a lane constrictor since there is added separation between mainline due to the painted median.
- Sideswipe opposing crashes. Similar to head-on crashes, these crashes may be impacted by a lane constrictor since there is added separation between mainline due to the painted median.
- Combined head-on and sideswipe opposing crashes.
- Angle crashes. A common crash type at intersections that often results in severe crashes.
- Property damage only crashes.

The Wilcoxon signed-rank test results in a p-value which is compared to a predetermined threshold significance level of 0.05 in this case. When the p-value is below the significance level, the null hypothesis is rejected in favor of the alternative hypothesis suggesting there is a significant difference in the before-after results. The results are shown in Table 4.2.

Table 3.2 - Results of Wilcoxon Signed-Rank Test for Before-After Analysis at Lane Constrictor Intersections (Treatment Intersections)

Category	Change in Crash Rate	p-value	Significant?
Total Crashes	+6.7%	0.301	No
KA Crashes	-9.6%	0.721	No
KABC Crashes	-21.6%	0.288	No
Head-On Crashes	+32.9%	0.875	No
Sideswipe Opposing Crashes	-65.5%	0.715	No
Head-on + Sideswipe Opposing Crashes	+3.4%	1.000	No
Angle Crashes	+11.1%	0.537	No
Property Damage only Crash	+34.1%	0.099	Yes*

*Statistically significant at 0.10

As seen in Table 3.2, the addition of lane constrictors did not have statistically significant impacts on any of the crash types at a significance level of 0.05. At a significance level of 0.10, an increase in property damage only crashes could be seen. That goes along with a decrease in KABC crashes, though that decrease on its own was not statistically significant. There was also a small decrease in KA crashes seen with the installation of lane constrictors, but not enough to be statistically significant. However, it should be noted that the after period for these crash rates was 2020 through 2022 which saw increases in fatal and serious injury crash rates statewide. Therefore, the cross-sectional analysis will be a more telling analysis of the crash impacts on these intersections by utilizing a control group.

As seen in Table 3.2, the lane constrictor intersections saw an over 20% decrease in KABC crash rates. To give a sense of the types of crashes that saw changes in severity, Figure 3.1 categories crashes into several different groups and shows the number of KABC crashes from the before period and the after period.

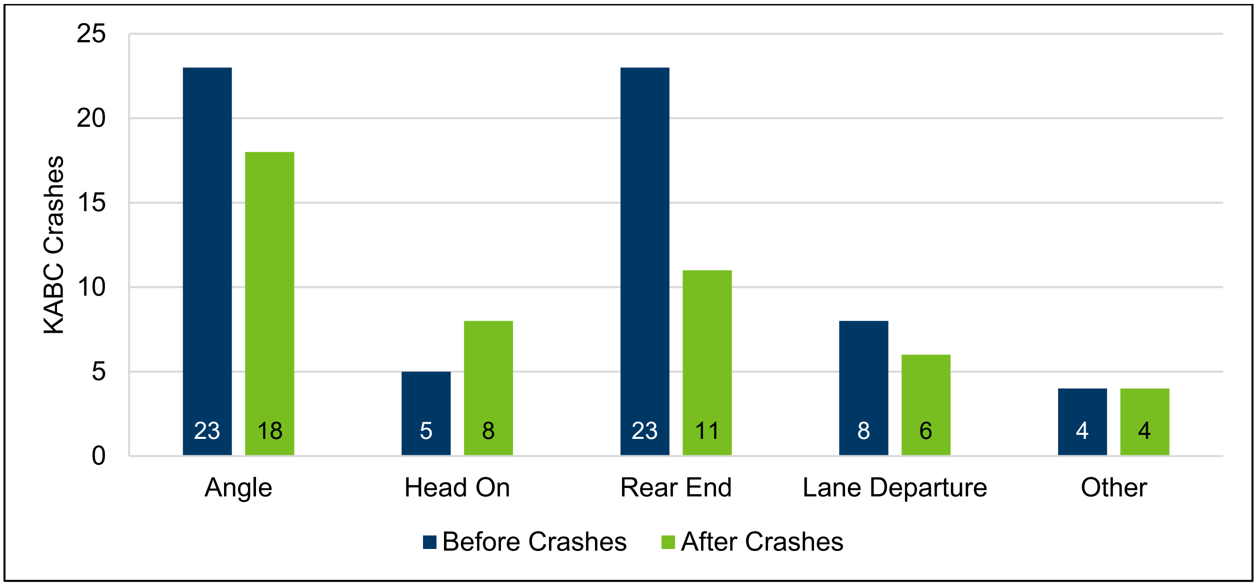

Figure 3.1 – Before and After KABC Crash Counts by Type at Lane Constrictor Intersections

As can be seen in Figure 3.1, with the installation of lane constrictors the biggest change is a decrease in KABC rear end crashes followed by a decrease in KABC angle crashes. Though angle crash rates went up, a decrease in KABC angle crashes indicates a severity shift occurs with the installation of lane constrictors.

3.2 CROSS-SECTIONAL ANALYSIS

The cross-sectional analysis takes the group of intersections that have lane constrictors at them (treatment sites) and compares the before-after crash data there against the before-after crash data at a group of similar intersections without lane constrictors (control sites).

3.2.1 Question Addressed

How much of the crash impacts at intersections can be attributed to the lane constrictors?

3.2.2 Locations

For this comparison, the 66 MnDOT intersections with lane constrictors were each matched to a similar MnDOT intersection without lane constrictors. These 66 control locations had layouts and traffic volumes that were similar to the treatment locations. Figures 2.1 and 2.2 shown earlier in this report show the locations of the treatment and control sites used in the analysis.

3.2.3 Crash Data

The cross-sectional analysis involved a before period and an after period at the treatment and control sites. At the treatment sites, the same data from the before-after analysis was utilized. At the control sites, the before and after periods were set to match those of the matching treatment sites. Table 3.3 shows the entering volumes for each scenario that were used in the analysis. The treatment sites saw a 3% decrease in entering volumes from the before to after period while the control sites saw a 5% decrease. Table 3.4 shows the compiled crash data. Crash rates, in units of crashes per million entering vehicles (MEV), for the before and after scenarios are shown in Table 3.5.

Table 3.3 - Cross-Sectional Analysis Entering Volumes

	Treatment Before	Treatment After	Control Before	Control After
Total Entering Volume (sum of daily volumes at each site)	383,659,478	371,155,689	372,030,028	354,698,359

Table 3.4 - Cross-Sectional Crash Counts

Crash Severity/Type	Treatment Before # of Crashes	Treatment After # of Crashes	Control Before # of Crashes	Control After # of Crashes
Total Crashes	126	130	58	60
KA Crashes	8	7	3	3
KABC Crashes	62	47	22	23
Head-On Crashes	7	9	2	4
Sideswipe Opposing Crashes	3	1	3	1
Head-on + Sideswipe Opposing Crashes	10	10	5	5
Angle Crashes	40	43	10	12
Property Damage only Crash	64	83	36	37

Table 3.5 - Cross-Sectional Crash Rates

Crash Severity/Type	Treatment Before Crash Rate	Treatment After Crash Rate	Control Before Crash Rate	Control After Crash Rate
Total Crashes	0.328	0.350	0.156	0.169
KA Crashes	0.021	0.019	0.008	0.008
KABC Crashes	0.162	0.127	0.059	0.065
Head-On Crashes	0.018	0.024	0.005	0.011
Sideswipe Opposing Crashes	0.008	0.003	0.008	0.003
Head-on + Sideswipe Opposing Crashes	0.026	0.027	0.013	0.014
Angle Crashes	0.104	0.116	0.027	0.034
Property Damage only Crash	0.167	0.224	0.097	0.104

3.2.4 Crash Analysis

Before conducting the cross-sectional analysis, a before-after analysis was conducted on the crash data for the control sites. The method used for this matched the method used in the before-after analysis of the treatment sites. Table 3.6 shows the results of that analysis.

Table 3.6 - Results of Wilcoxon Signed-Rank Test for Before-After Analysis at Intersections without Lane Constrictors (Control Intersections)

Category	Change in Crash Rate	p-value	Significant?
Total Crashes	+8.5%	0.388	No
KA Crashes	+4.9%	0.273	No
KABC Crashes	+9.7%	0.319	No
Head-On Crashes	+109.8%	0.138	No
Sideswipe Opposing Crashes	-65.0%	0.273	No
Head-on + Sideswipe Opposing Crashes	+4.9%	1.000	No
Angle Crashes	+25.9%	0.407	No
Property Damage only Crash	+7.8%	0.726	No

As can be seen in Table 3.6, the control sites did not have statistically significant changes in crash rates in the before and after periods. Though with the exception of sideswipe opposing crashes, crash rates at the control intersections increased for all other crash types analyzed. Figure 3.2 categories crashes into several different groups and shows the number of KABC crashes from the before period and the after period.

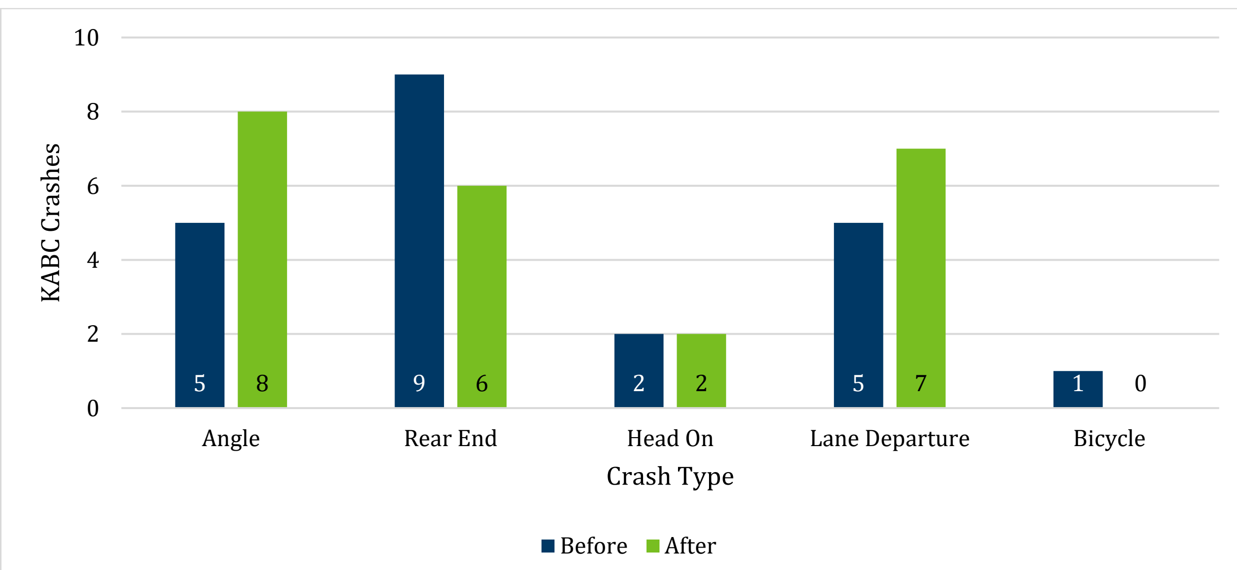

Figure 3.1 – Before and After KABC Crash Counts by Type at Control Intersections

For the cross-sectional crash data analysis, a Mann-Whitney U-Test was used. Like with the previous analysis, it is necessary to use a nonparametric test because the sampled crash rates are not normally distributed. Also like the previous test, a Mann-Whitney U-Test tests the assumptions of a null hypothesis, although this test will not be comparing averages by relying on differences in group means. Since this test converts all of the observed values into two ordinal sets of ranks, the measure we are using for each group's average will be its median (or middle) value.

For this analysis, the null hypothesis being tested is that the median difference between pairs of observations from the two groups (treatment and control) is equal to zero. The alternative hypothesis being tested is that the median difference between pairs of observations from the two groups is not equal to zero. Here, the observations being compared are the sites' crash reduction factors, or the observed percentage decrease in crashes at the treatment and control sites.

The Mann-Whitney U-Test produces a test statistic with a corresponding p-value, which is then compared to a predetermined alpha level (in this case, alpha = 0.05) to evaluate the null hypothesis. If the test produces a result with a p-value that is less that the threshold significance level, the null hypothesis is rejected in favor of the alternative hypothesis. The results are shown in Table 3.7.

Table 3.7 - Results of Mann-Whitney U-Test for Cross-Sectional Analysis

Category	Treatment % Change	Control % Change	p-value	Significant?
Total Crashes	+6.7%	+8.5%	0.431	No
KA Crashes	**-9.6%**	**+4.9%**	**0.085**	**Yes***
KABC Crashes	**-21.6%**	**+9.7%**	**0.030**	**Yes**
Head-On Crashes	**+32.9%**	**+109.8%**	**0.079**	**Yes***
Sideswipe Opposing Crashes	-65.5%	-65.0%	0.985	No
Head-on + Sideswipe Opposing Crashes	+3.4%	+4.9%	0.455	No
Angle Crashes	+11.1%	+25.9%	0.723	No
Property Damage only Crash	+34.1%	+7.8%	0.652	No

*Statistically significant at 0.10

As seen in Table 3.7, there was a statistically significant difference in the crash rate change between the treatment and control groups for KABC crashes at a significance level of 0.05. The locations with lane constrictors saw a decrease in KABC crash rates while the control locations saw an increase. There is a similar finding for KA crashes, though at a significance level of 0.10. Though the total number of crashes did not decrease, these results indicate the addition of lane constrictors have an impact on reducing the severity of crashes by swapping injury crashes for property damage only crashes. Whether that severity shift is caused by reducing speeds of mainline traffic or making drivers more aware of the intersection or other reasons is not known from these results, but it does appear the lane constrictors are having a positive impact.

Table 3.7 also shows that the control intersections saw a statistically significantly larger increase in head-on crash rates than the treatment sites at a significance level of 0.10, even though the treatment sites had an increase as well. The changes in crash rates between the two groups for the other crash types were not statistically significantly different from one another.

CHAPTER 4: CONCLUSIONS

The results of the analyses conducted show the addition of lane constrictors on MnDOT rural, undivided, side-street, stop-controlled intersections does not have an impact on overall crash rates, but it does result in a decrease in KA and KABC crash rates. These results indicate the addition of lane constrictors have an impact on reducing the severity of crashes by swapping injury crashes for property damage only crashes. Whether that severity shift is caused by reducing speeds of mainline traffic or making drivers more aware of the intersection or other reasons is not known from these results, but it does appear the lane constrictors are having a positive impact.

This analysis is based on only a few years of after data, so future analysis when more site-years are available would be beneficial in confirming the role of lane constrictors on crash impacts.