Evaluation of Wider Edge Lines on Minnesota Roads

Minnesota Department of Transportation
Office of Traffic, Safety, and Technology

Katie Fleming, MA

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Introduction

From 2008-2012, lane departure crashes accounted for 46% of all severe crashes, 45% of all fatal and serious lane departure crashes occurred on a 2-lane, 2-way road, and 45% of all fatal and serious injury lane departure crashes occurred on county roads. (Minnesota Department of Transportation, 2014). In an effort to reduce roadway departure crashes, MnDOT funded the installation of six-inch edge lines on over 3,000 miles of county and township roads.

Wider edge lines offer clear delineation of the roadway edge. Standard roadway edge lines measure four-inches wide. The six-inch edge lines provide additional guidance and help drivers avoid leaving the roadway to the right. In a three state evaluation of wider edge lines, Park, et al. found wider edge lines significantly reduced total crashes, fatal and injury crashes in Kansas and Illinois, and single vehicle night crashes (Park, Carlson, Porter, & Andersen, 2012). The results for each state varied; total crash reductions ranged from 17.5 to 30.1% reduction, fatal and injury crash reduction ranged 36.5 to 37.7% reduction, and single vehicle, night crash reductions ranged from 18.0 to 29.5% (Park, Carlson, Porter, & Andersen, 2012).

This study includes two phases of installation – 2010 and 2011. In 2010, MnDOT funded six-inch edge lines installations on 1,501 miles of road; in 2010, MnDOT funded six-inch edge line installations on 1,658 miles of road. This evaluation covers 3,159 miles of Minnesota county and township roads with six-inch edges.

Figure 1: Minnesota's Six Inch Edge Lines on a Rural 2-lane/2-way Road

Total miles for comparison group 1,727. In order to ensure that comparison segments were similar to the treatment segments, the following selection criteria were used: undivided, rural, 2-lane/2-way roadways in a non-metro county that was not part of the six-inch edge line project in 2010 or 2011.

Hypotheses

For these analyses, we explored four levels of crash reduction: total crash reduction fatal and serious injury crash reduction, run-off-road crashes to the right and fatal or serious run off road crashes to the right.

The following hypotheses aim to identify impact of six-inch edge lines on Minnesota roads.

H_1: Six-inch edge lines will reduce crashes.
$H0_1$: Six-inch edge lines will not change crashes.

H_2: Six-inch edge lines will reduce fatal and serious injury crashes (severe).
$H0_2$: Six-inch edge lines will not change fatal and serious injury crashes (severe).

H_3: Six-inch edge lines will reduce target, run-off-road right crashes.
$H0_3$: Six-inch edge lines will not change target, run-off-road right crashes.

H_4: Six-inch edge lines will reduce severe, target, run-off-road right crashes.
$H0_4$: Six-inch edge lines will not change severe, target, run-off-road right crashes.

Method

These analyses compare two time points – two years before six-inch edge lines installation and a two years following six-inch edgeline installation. Six-inch edgeline installations occurred at two time points – 2010 and 2011. Phase 1 of these analyses represents comparisons for segments installed in 2010. Phase II of these analyses represent comparison for segments installed in 2011. The final analyses combine the pre and post-treatment data for Phase I and Phase II.

- ***Pre-treatment**:* Phase I: 2008-2009; Phase II: 2009-2010; Combined Phase I and Phase II
- ***Post-treatment:*** Phase I: 2011-2012; Phase II: 2012-2013; Combined Phase I and Phase II

In order to control for regression to the mean, crash data for treatment segments we compared to the similar, randomly selected segments.

- ***Treatment segments*:** indicates locations with six-inch edge lines
- ***Comparison segments*:** indicates locations with-out six-inch edge lines

In order to test our hypotheses, the research team used 2x2 crosstabulation with a Chi-square test. A crosstab analysis is a relatively simple analysis suitable for comparison of four groups, as is the case here; the Chi-square yields the linear-by-linear association test. For these analyses our alpha is set at .10; p values of 0.10 or lower are statistically significant. This means that changes from pre and post condition of the treatment group compared to the non-treatment group is consistent and profound enough to rule out random fluctuations in crashes (regression to the mean).

Findings

The following three tables show the total number of crashes for the treatment and comparison group before and after treatment. These comparisons include all crash types and crash severities. For each analysis phase, crashes reductions for the treatment segments are dramatically greater than crash reductions observed on the comparison segments.

Table 1 shows the analysis of the Phase I installations. On treatment segments, total crashes decreased by 23%. On comparison segments total crashes decreased by 14%. While the treatment locations show noticeably greater crash reduction, this change is not statistically significant. Crash reductions are promising.

Table 1: Crosstab Comparison of Total Crashes Phase I

	Pre-Treatment (2008-09)	Post Treatment (2011-12)	Total
Comparison Segments	402	344	746
Treatment Segments	622	477	1,099
Total	1,024	821	1,845

X^2=1.32, *p*=0.25.

Table 2 shows the analysis of the Phase II installations. On treatment segments, total crashes decreased by 39%. On comparison segments total crashes decreased by 1%. The treatment locations show noticeably greater crash reduction, this change is not statistically significant. Crash reductions are promising.

Table 2: Crosstab Comparison of Total Crashes Phase II

	Pre-Treatment (2009-10)	Post Treatment (2021-13)	Total
Comparison Segments	357	352	709
Treatment Segments	28	17	45
Total	385	369	754

X^2=2.386, *p*=0.12.

Table 3 shows the analysis of the combined Phase I and II installations. On treatment segments, total crashes decreased by 24%. On comparison segments total crashes decreased by 8%. Treatment locations show statistically significant (*p*=.02) crash reduction. Crash reductions on treatment locations are statistically different from those reductions of comparison segments.

Table 3: Crosstab Comparison of Total Crashes Phase I and II

	Pre-Treatment	Post Treatment	Total
Comparison Segments	759	696	1,455
Treatment Segments	650	494	1,144
Total	1,409	1,190	2,599

X^2=5.587, *p*=0.02.
Odds Ratio = 0.83

Total crashes at locations with six-inch edge lines dropped by 24%; whereas, crashes at the comparison segments dropped by 8%. Our statistical test indicates that a portion of the crash reduction in the treatment locations were not attributable to chance or random fluctuations. The odds ratio calculated for table three, indicates roads with wider edge lines are 18 times less likely to have a crash than roads with standard edge lines.

The combined Phase I and II analyses support hypothesis one:
H_1: Six-inch edge lines will reduce crashes.

We reject the null hypothesis:
$H0_1$: Six-inch edge lines will not change crashes.

Severe Crashes

A severe crash includes crashes in which one or more fatalities and or serious injuries occurred. The following three tables show the total number of fatal and serious injury, severe, crashes for the treatment and comparison group before and after treatment. These comparisons include all crash types. For each analysis phase, crashes reductions for the treatment segments severe crashes reduced; however, these reductions are not dramatic. Small sample size fettered these analyses.

Table 4 shows the Phase I analysis of severe crashes. The comparison segments showed greater reductions in the number of severe crashes in the post treatment period; however, the comparison and treatment segments are statistically similar.

Table 4: Crosstab Comparison of Severe Crashes Phase I

	Pre-Treatment (2008-09)	Post Treatment (2011-12)	Total
Comparison Segments	38	28	66
Treatment Segments	42	41	83
Total	80	69	149

X^2=0.72, p=0.40.

Table 5 shows the Phase II analysis of severe crashes. On comparison segments, severe crashes increased by 92%. On treatment segments, severe crashes decreased by 100%. While these differences appear notable, due to small sample size, the differences are not statistically significant.

Table 5: Crosstab Comparison of Severe Crashes Phase II

	Pre-Treatment (2009-10)	Post Treatment (2021-13)	Total
Comparison Segments	14	27	41
Treatment Segments	1	0	1
Total	15	27	42

X^2=1.84, p=0.17.

Table 6 shows the Phase I and Phase II analysis of severe crashes. On comparison segments, severe crashes increased by 6%. On treatment segments, severe crashes decreased by 5%. The differences are not statistically significant. Comparison and treatment segments are statistically similar.

Table 6: Crosstab Comparison of severe Crashes Phase I and II

	Pre-Treatment	Post Treatment	Total
Comparison Segments	52	55	107
Treatment Segments	43	41	84
Total	95	96	191

X^2=0.13, p=0.72.

The reduction of severe crashes on treatment segments was not statistically significant; the slight reduction of fatal and serious injury crashes at these locations was not robust enough to attribute to wider edge lines.

The preceding analyses do not support hypothesis two.

H_2: Six-inch edge lines will reduce fatal and serious injury crashes (severe).

We fail to reject the null hypothesis.

$H0_2$: Six-inch edge lines will not change fatal and serious injury crashes (severe).

Run-off-Road Crashes

In order to prevent run-off-road to the right crashes, six-inch edge lines provide high visibility delineation to drivers. The following three tables show the total number of run-off-road-right crashes for treatment and comparison group before and after treatment. These comparisons include run-off-road to the right crashes of all severities. For each analysis phase, crashes reductions for the treatment segments are dramatically greater than crash reductions observed on the comparison segments.

Table 7 shows the total number of run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, run-off-road right crashes increased by 2%. On treatment segments, run-off-road right crashes decreased by 30%. The difference between the pre and post, installation treatment segments is statistically significant (p=0.057).

Table 7: Crosstab Comparison of Total Run-Off-Road Right Crashes Phase I

	Pre-Treatment (2008-09)	Post Treatment (2011-12)	Total
Comparison Segments	96	98	194
Treatment Segments	130	91	221
Total	226	189	415

X^2=3.633, p=0.06.

Table 8 shows the total number of run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, run-off-road right crashes increased by 3%. On treatment segments, run-off-road right crashes decreased by 67%. The difference between the pre and post, installation treatment segments is not statistically significant (p=0.15), but the change is promising.

Table 8: Crosstab Comparison of Total Run-Off-Road Right Crashes Phase II

	Pre-Treatment (2009-10)	Post Treatment (2012-13)	Total
Comparison Segments	100	103	203
Treatment Segments	6	2	8
Total	106	105	211

X^2=2.04, p=0.15.

Table 9 shows the total number of run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, run-off-road right crashes increased by 3%. On treatment segments, run-off-road right crashes decreased by 32%. The difference between the pre and post, installation treatment segments is statistically significant (p=0.02).

Table 9: Crosstab Comparison of Total Run-Off-Road Right Crashes Phase I and II

	Pre-Treatment	Post Treatment	Total
Comparison Segments	196	201	397
Treatment Segments	136	93	229
Total	332	294	626

X^2=5.85, p=0.02.
Odds ratio = 0.67

Total run-off-road right crashes at locations with six-inch edge lines dropped by 32%; whereas, crashes at the comparison segments dropped by 3%. Our statistical test indicates that a portion of the crash reduction in the treatment locations were not attributable to chance or random fluctuations. The odds ratio calculated for table three, indicates roads with wider edge lines are 33 times less likely to have a run-off-road right crash than roads with standard edge lines.

The Phase II and combined Phase I and II analyses support hypothesis three.

H_3: Six-inch edge lines will reduce target, run-off-road right crashes.

We reject the null hypothesis:

$H0_3$: Six-inch edge lines will not change target, run-off-road right crashes.

Severe Run-off-Road Crashes

The following three tables show the total number of fatal and serious injury (severe), run-off-road-right crashes for treatment and comparison group before and after treatment. For each analysis phase, crashes reductions for the treatment segments are greater than crash reductions observed on the comparison segments.

Table 10 shows the total number of severe run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, severe run-off-road right crashes remained constant. On treatment segments, severe run-off-road right crashes decreased by 36%. The difference between the pre and post, installation treatment segments is not statistically significant.

Table 10: Crosstab Comparison of Severe Run-Off-Road Right Crashes Phase I

	Pre-Treatment (2008-09)	Post Treatment (2011-12)	Total
Comparison Segments	9	9	18
Treatment Segments	14	9	23
Total	23	18	41

X^2=0.48, *p*=0.486.

Table 11 shows the total number of severe run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, severe run-off-road right crashes increased 200%. On treatment segments, severe run-off-road right crashes remained the same. The difference between the pre and post, installation treatment segments is not statistically significant.

Table 11: Crosstab Comparison of Severe Run-Off-Road Right Crashes Phase II

	Pre-Treatment (2009-10)	Post Treatment (2012-13)	Total
Comparison Segments	3	9	12
Treatment Segments	0	0	0
Total	3	9	12

Unable to calculate X^2.

Table 12 shows the total number of severe run-off-road right crashes for the treatment and comparison segments before and after the six-inch edge lines installation. On comparison segments, severe run-off-road right crashes increased 50%. On treatment segments, severe run-off-road right crashes decreased 35%. The difference between the pre and post, installation treatment segments is not statistically significant (*p*=0.13), but the difference is promising.

Table 12: Crosstab Comparison of Severe Run-Off-Road Right Crashes Phase I and II

	Pre-Treatment	Post Treatment	Total
Comparison Segments	12	18	30
Treatment Segments	14	9	23
Total	26	27	53

X^2=2.27, *p*=0.13.

Small sample size fettered the rigor of these analyses. The analyses do not support the hypothesis, but the direction of change is promising. Severe run-off-road right crashes at locations with six-inch edge lines dropped by 36%; whereas, crashes at the comparison segments increased by 50%.

The preceding analyses do not support hypothesis four.

H_4: Six-inch edge lines will reduce severe, target, run-off-road right crashes.

We fail to reject the null hypothesis.

$H0_4$: Six-inch edge lines will not change severe, target, run-off-road right crashes.

Discussion

On roads with six-inch edge lines, total crashes, severe crashes, run-off-road right, and severe run-off-road right crashes decreased. On locations with six-inch edge lines:

- Adjusting for overall crash reductions within the analyses periods, total crashes decreased by 15.7%.
- Total crash reductions are statistically significant.
- Adjusting for the overall crash fluctuation of crashes within the analyses periods, severe crashes decreased 10.4%.
- Severe crash reduction is not statistically significant, but is promising.
- Adjusting for the overall fluctuations of crashes within the analyses periods, run-off-road right crashes decreased 34.2%.
- Total run-off-road right crash reductions are statistically significant.
- Adjusting for overall crash fluctuation of crashes within the analysis period, severe run-off-road crash decreased 85.7%.
- Severe, run-off-road right crash reduction is not statistically significant, but is promising.

Conclusion

Six-inch edge lines are an effective countermeasure for overall crash reduction and run-off-road right crash reduction. Other studies have found significant changes in fatal and injury crashes and run-off-road fatal and injury crashes. This study included four hypotheses. Each hypothesis revealed crash reductions; however, statistically significant changes were not evident for severe crashes or severe run-off-road right crashes. Larger sample sizes may reveal conclusive findings for severe crashes.

These analyses do not account for driver adaptation to six-inch edge lines. Future research should consider possible driver adaptation to well delineated roads – such as increased travel speeds.

Works Cited

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Appendix A: Algorithm for statistical tests.

Crosstab Algorithm Notes

X_i Distinct values of row variable arranged in ascending order:

$$X_1 < X_2 < \cdots < X_R$$

Y_j Distinct values of column variables arranged in ascending order:

$$Y_1 < Y_2 < \cdots < Y_C$$

f_{ij} Sum of cell weights for cases in cell (*i,j*)

C_j The j^{th} column subtotal

$$\sum_{i=1}^{R} f_{ij}$$

r_i The i^{th} Column subtotal

$$\sum_{j=1}^{C} f_{ij}$$

W The Grand Total

$$\sum_{j=1}^{C} c_i = \sum_{i=1}^{R} r_i$$

Crosstab Algorithm

Count

$$\text{Count} = \mathrm{f_{ij}}$$

Expected Count

$$Expected\ Count\ = \frac{r_{\ i}c_j}{W}$$

Row Percent

$$Row\ percent\ = \ 100\left(f_{ij}/r_j\right)$$

Column Percent

$$Column\ percent\ = \ 100\left(\frac{f_{\ ij}}{C_j}\right)$$

Total Percent

$$Total\ percent\ = \ 100\left(f_{\ ij}/W\right)$$

Residual

$$\mathrm{R}_{ij} = f_{ij} - E_{ij}$$

Standardized Residual

$$SR_{ij} = \frac{R_{ij}}{\sqrt{E_{ij}}}$$

Adjusted Residual

$$AR_{ij} = \frac{R_{Ij}}{\sqrt{E_{ij}\ \left(1 - \frac{r_i}{W}\right)}\left(1 - \frac{c_j}{j}\right)}$$

Pearson’s Chi-Square

$$X_{\mathrm{p}}^2 = \sum\nolimits_{ij} \frac{(f_{ij} - E_{ij})^2}{E_{ij}}$$

Degrees of freedom

$$(R-1)(C-1)$$