Crash Modification Factors for the Application of Auxiliary Buffer Lanes for Interchanges with Consecutive Loops

A Report Submitted to the

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Executive Summary

This study aims to better understand the potential crash reduction of Auxiliary Buffer Lanes (ABL) at consecutive loop interchanges. An Auxiliary Buffer Lane is an additional lane within the weaving section between the two clover-leaf loops (see **Figure 1** and **Figure 2**). The traditional cloverleaf (see **Figure 3**) offers no additional lane between the on ramp and exit loops. The auxiliary buffer lane provides an additional lane for drivers to safely maneuver from the on-ramp to travel lanes and from travel lanes to the off-ramp and separates the higher speed through traffic from entrance and exit maneuvers.

Though auxiliary buffer lanes are not being systemically constructed or added to the system, the use of this is often discussed in early project development, with the impacts and benefits largely unknown regarding traffic safety. This study is an attempt to quantify the safety benefits of auxiliary buffer lanes.

The basic concepts of the 2010 Highway Capacity Manual suggest that auxiliary buffer lanes reduce delays, increase the Level of Service (LOS – a qualitative assessment for the speed and density of traffic), and reduce the number of conflict points in an interchange. The findings from this analysis show that ***auxiliary buffer lanes appear to reduce target crashes by 37%-60%*** versus their non-ABL comparable sites***.*** This study examined 13 sections with an auxiliary buffer lane sections and 20 sections without an auxiliary buffer lane. The analyses included all crashes from 2009 through 2013: these data included 3,063 crashes for review.

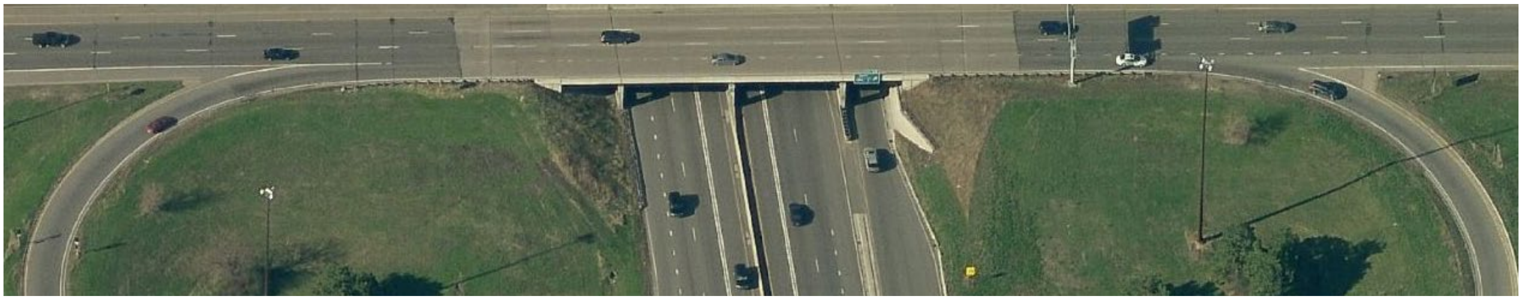
Figure 1: An interchange section that contains an auxiliary buffer lane (I-494 and MN 100)

Source: Bing Maps, 2015

Figure 2: This figure highlights where and what the auxiliary buffer lane is (I-494 and MN 100)

Source: Bing Maps, 2015

Figure 3: This figure highlights where there is no auxiliary buffer lane (I-494 and I-35W)



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Introduction

This study aims to measure the magnitude of crash reduction associated with the presence of Auxiliary Buffer Lanes (ABL) on continuous loop interchanges. Though not a common strategy, nor done solely as a retrofit, the use of ABL is often discussed in early project development for congested interchanges. However, justifying costs can be difficult since the benefits are not clearly known (capacity or safety). This report was written to provide context to decision makers.

Methodology

To measure the traffic safety impact of ABL, this study includes two site groups: a treatment group with ABL and a control group without ABL. The study period included 2009 through 2013. The control sites were selected with similar volumes and congestion levels to the treatment sites. All sites fall within the Minnesota Department of Transportation, Metro District[1]. This study includes 13 ABL treatment sites (see **Table 1: Auxiliary Buffer Lane Treatment Sites)** and 20 non-treatment control sites (see **Table 2: Non-treatment Control Sites**). Since each direction of a grade separated divided freeway can operate as a separate entity, some locations include a treatment site with an ABL in one direction and non-treatment control site in the opposite direction.

Table 1: Auxiliary Buffer Lane Treatment Sites

Mainline Highway	Mainline Direction	Crossing Highway	Number of Thru Lanes	Mainline Traffic Volume (ADT)	Crossing Highway Traffic Volume (ADT)
I-494	Eastbound	MN-100	3	138,000	51,750
I-494	Westbound	MN-100	3	160,000	51,750
MN-100	Northbound	I-494	2	38,500	149,000
MN-100	Southbound	I-494	2	65,000	149,000
I-694	Eastbound	US-169	3	121,000	64,000
I-694	Westbound	US-169	3	106,000	64,000
I-494	Southbound	MN-7	3	105,000	37,500
I-494	Northbound	MN-7	3	105,000	37,500
MN-7	Westbound	I-494	2	29,000	105,000
MN-212	Westbound	I-494	2	92,000	94,000
MN-610	Westbound	US-169	2	35,000	58,000
US-169	Southbound	MN-610	2	58,000	35,000
US-169	Northbound	MN-610	2	58,000	35,000

[1] The Minnesota Department of Transportation, Metro District includes Anoka County, Carver County, Dakota County, Hennepin County, Ramsey County, Scott County, and Washington County.

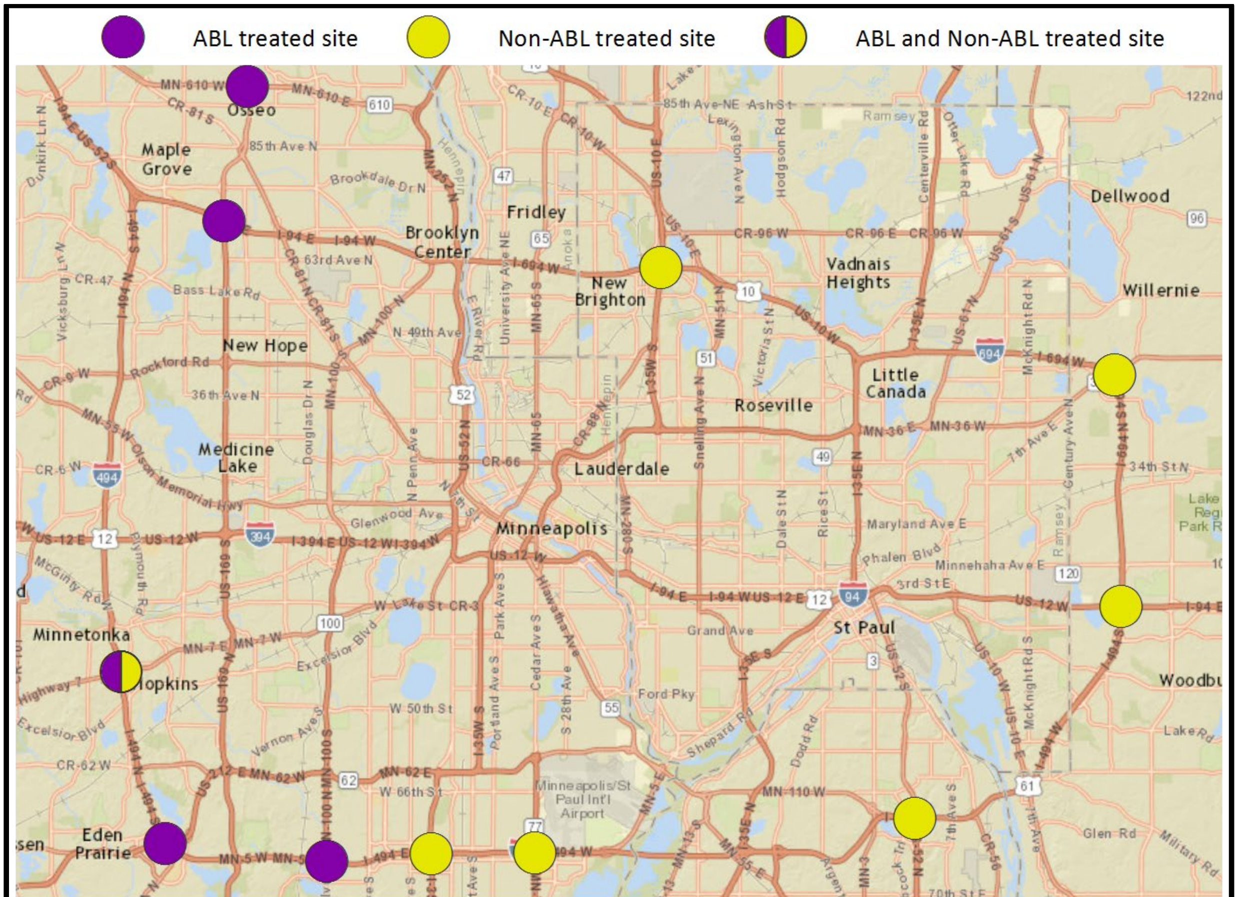
Table 2: Non-treatment Control Sites

Mainline Highway	Mainline Direction	Crossing Highway	Number of Thru Lanes	Mainline Traffic Volume (ADT)	Crossing Highway Traffic Volume (ADT)
I-494	Eastbound	I-35W	3	157,000	105,500
I-494	Westbound	I-35W	3	142,000	105,500
I-35W	Northbound	I-494	3	113,000	149,500
I-494	Eastbound	MN-77	3	125,000	65,000
I-494	Westbound	MN-77	3	144,000	65,000
MN-77	Northbound	I-494	2	65,000	134,500
US-52	Northbound	I-494	2	59,000	106,000
US-52	Southbound	I-494	2	55,000	106,000
I-494	Northbound	I-94	2	74,000	84,000
I-694	Southbound	I-94	2	85,000	84,000
MN-36	Westbound	I-694	2	45,000	58,500
MN-36	Eastbound	I-694	2	28,000	58,500
I-694	Northbound	MN-36	2	56,000	36,500
I-694	Southbound	MN-36	2	61,000	36,500
I-35W	Southbound	I-694	2	121,000	93,000
I-35W	Northbound	I-694	2	113,000	93,000
I-694	Eastbound	I-35W	2	107,000	117,000
I-694	Westbound	I-35W	2	79,000	117,000
MN-7	Eastbound	I-494	2	46,000	105,000
MN-7	Westbound	I-494	2	29,000	105,000

Crash records for these sites were extracted from the Minnesota Crash Database owned by the Minnesota Department of Public Safety. These data include all crashes from 2009 through 2013.

Most frequent types of crashes involve “Sideswipe Same Direction” and “Rear End” collisions. These target crash types are often associated with freeways, congestion, and vehicle maneuvering. Theoretically, Auxilary Buffer Lands should offer drivers additional space to maneuver. For this reason, “Sideswipe Same Direction” and “Rear End” have been designated as the target crashes within the element and will be focused on for this report.

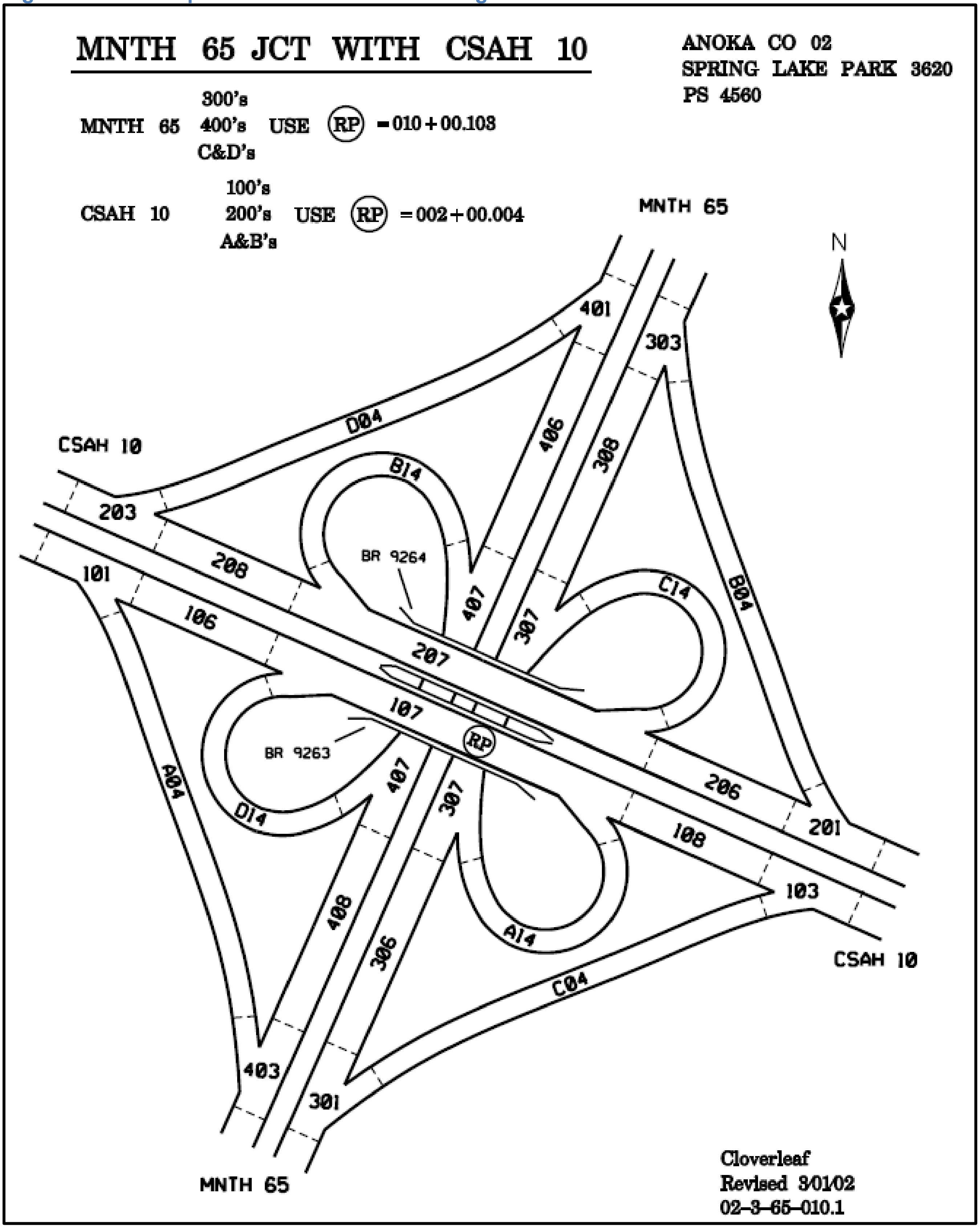
Figure 4: Locations of the sites selected.



SOURCE: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

When crashes occur in an interchange, law enforcement officers document the location of a crash using 'element codes'. Each section of an interchange has an assigned element code. **Figure 5** shows an example of an interchange with corresponding element codes. The specific sections of interest for these analyses crashes that occurred in "Element Codes" sections: 107, 207, 307, and 407. At the time of final publication, Element Codes have been retired from the Minnesota Crash Database Reporting System.

Figure 5: An example of a Minnesota Interchange Element Sketch



Data Sources

This study leveraged three data sources: crash data, roadway data, and specific site observation data. Crash data used for these analyses originated from the Minnesota Department of Public Safety crash records system. Crash record data are recorded by the responding officer. All data collected at the crash scene are based on officer observation. Site specific observations were conducted using the Minnesota Department of Transportation Video log augmented with observations using Google Maps/ Street View, and Bing Maps. For the 33 listed sites, a total of 3,063 crashes from 2009 through 2013 were used in this analysis.

Findings

The crashes were disaggregated into the following categories:

1. ABL treatment vs. non-ABL treatment
2. Directionality of the Vehicles in the Crash
3. Crashes within the selected element code
4. Crashes within the selected element code and had the field for “diagram” coded as “Rear End” or “Sideswipe – Same Direction”.
5. Crashes within the selected element code and had a K(fatal) or A(serious injury) severity

To gain an understanding of the impact of ABL treatments, the directionality (typically Cardinal Directions; North, East, South, West) of the vehicle(s) was examined. This was done by looking at the number of vehicles traveling in each direction. Since the target crash types were “Rear End” and “Sideswipe Same Direction”, looking at directionality of the vehicles intended path could show if the ABL treatment is having an impact at reducing total crashes and target crashes. As an example, when looking at the ABL treatment site of I-494 Eastbound and MN 100, the total number of crashes that were heading “eastbound” was noted. See **Table 3.**

Table 3: Crashes at I-494 and MN 100. Directional Crashes are those that were heading eastbound.

Year	Interchange Crashes	Directional Crashes
2009	59	24
2010	54	25
2011	50	20
2012	42	20
2013	64	31
Total	**269**	**120**

This was done for each ABL treated and non-treated site. These were then aggregated into each category. The results for treated versus non-treated ABL can be seen in **Table 4.**

Table 4: Crash Data and Exposure (vehicles entering traffic) of ABL treated sites versus non-treated ABL sites.

Description	Number of Sites	Total Number of Crashes (2009-2013)	Total Entering Vehicles (EV) (2009-2013)	Crash Rate (Crashes*1M/EV)
ABL Treated Sites	13	877	1,011,233,000	0.87
Non-ABL Treated Sites	20	2,186	1,545,273,000	1.42
Total	**33**	**3,063**	**2,556,506,000**	**1.20**
Difference of Non-ABL (%)	+54%	+149%	+53%	+63.2%

Comparing the total number of all crashes at each interchange and adjusting for volume, **Table 4** shows that sites with no ABL treatment have a crash rate that is 63% higher than those with ABL treatments.

Figure 6: Crash Rates for individual sites and individual years.

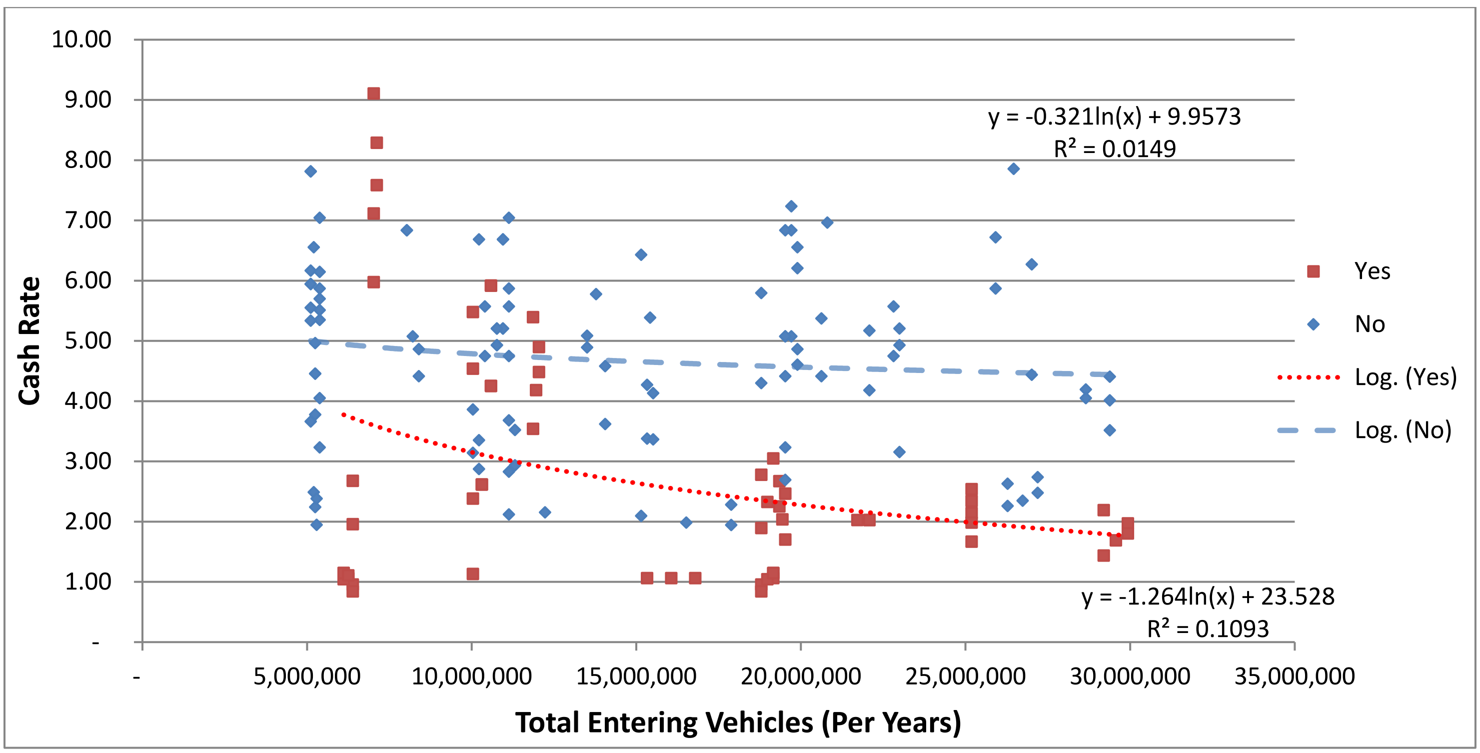


Figure 6 graphs the crash rate (each dot represents one year and one site) of the sites with ABL treatment (Yes) and sites without (No) ABL treatment. This shows that the typical ABL treated site would likely have fewer crashes then a similar site without ABL.

Crashes were disaggregated into the direction and treatment status. See **Table 5.** Comparing treatment (with ABL) to those of the non-treatment sites, the non-ABL had crash frequency that was 144% higher than at the treatment sites. When adjust for the volume, this equates to a crash rate that is nearly 60% higher at non-ABL treatment sites versus the ABL-treatment sites.

Table 5: Crashes that occurred in the vehicle direction of each site

Description	Number of Sites	Total Directional Crashes (2009-2013)	Total Entering Vehicles (EV) (2009-2013)	Crash Rate (Crashes*1M/ EV)
ABL Treated Sites	13	629	1,011,233,000	0.62
Non-ABL Treated Sites	20	1,533	1,545,273,000	0.99
Total	**33**	**2,162**	**2,556,506,000**	**0.85**
Difference of Non-ABL (%)	+54%	+144%	+53%	+59.7%

Since each interchange has been created as an Element Sketch, each interchange and the zone where the ABL-treatment exists (or does not exist) was reviewed. Crashes were examined and aggregated for each coded ABL zone. Using the example of I-494 and MN-100, the crashes were collected that had been coded to Element 207. See **Table 6** for a breakdown of the crashes and types that were collected for each site. These were then aggregated, and the results are shown in **Table 7.**

Table 6: A sample of the crash data that was collected at each ABL and non-ABL treated site.

Year	Total Crashes	Directional Crashes	Element Code Crashes	Element Code Target Crashes	Element Code K+A Crashes
2009	59	24	7	6	0
2010	54	25	11	10	0
2011	50	20	8	5	0
2012	42	20	2	1	0
2013	64	31	9	7	0
Total	**269**	**130**	**37**	**29**	**0**

Table 7: Aggregated Crash Data of all crashes at ABL and non-ABL treated sites.

Description	Element Code Crashes	Element Code Rear End Crashes	Element Code Sideswipe Crashes	Element Code K+A Crashes
ABL Treated Sites	142	65	37	0
ABL non-Treated Sites	498	219	166	4
Difference of Non-ABL (%)	**+251%**	**+237%**	**+348%**	**NA**

Table 7, shows the ABL treated sites have a lower crash frequency than non-treated locations. Crash rates are computed by the total number of each crash category divided by the total entering volume of each site. Crash Modification Factors (CMF) are computed comparing the ABL Treated Site Rates compared to the Non-Treated Site Rates. See **Table 8.**

Table 8: Crash Modification Factors for ABL treated sites.

Description	Total Interchange Crash Rate	Directional Crash Rate	Element Code Crash Rate	Element Code Target Crash Rate
ABL Treated Sites	0.87	0.62	0.14	0.10
ABL non-Treated Sites	1.41	0.99	0.32	0.25
All Sites Combined	1.20	0.85	0.25	0.19
Crash Modification Factor (CMF) for sites with ABL	**0.61**	**0.63**	**0.44**	**0.40**

The data shown in **Table 8** demonstrates that the number of crashes and target crashes within the ABL zone/ element code is reduced by a large portion compared to sites without the ABL-Treatment.

Recommendations

From this small analysis, it appears Auxiliary Buffer Lanes reduce the number of crashes at an interchange and provide positive safety impacts.

However, the need to add ABL treatments should be reviewed on a case-by-case basis. Due to the limited number of full system interchanges within Metro and the State of Minnesota, this will likely be a limited application. However, in situations where the full system interchange is experiencing significant operational delays or crashes, the addition of an ABL may be a cost-effective solution versus construction of full collector-distributor roads and fly-over bridges. The ABL may be a permanent solution that can be included when construction or reconstruction is occurring. At lower volumes (fewer than 35,000 vehicles entering the interchange per day) the benefits of the ABL may not be sufficient to offset the additional cost needed to build the extra bridge width required to accommodate the ABL.

Given the future financial limitations projected for road construction within Minnesota (and nationally), the ABL treatment should be reserved for when the benefits will clearly outweigh the additional costs required for construction, retrofit, and/or continuing maintenance and operations.

Appendices

Appendices A:

Significance level at alpha=0.10

Independent Sample T-Test	Number	Sig.	Natural Log Transformation					CRF		
			Directional CR		Difference	90% Conf. Int.				
	N	*p*	Mean	Std. Error	Mean	Lower	Upper	Mean	Lower	Upper
Buffer Lanes	13	**.043**	.471	.053	.184	.036	.331	**28%**	6%	51%
NO Buffer Lanes	20		.655	.069						

Independent Sample T-Test	Number	Sig.	Crash Rate (no transformation)					CRF		
			Total CR		Difference	90% Conf. Int.				
	N	*p*	Mean	Std. Error	Mean	Lower	Upper	Mean	Lower	Upper
Buffer Lanes	5	**.005**	2.407	.354	2.013	1.020	3.005	**46%**	23%	68%
NO Buffer Lanes	6		4.419	.396						

Descriptive Statistics	Directional CR			Natural Log Directional CR			Total CR		
	ALL	Buffer	No Buffer	ALL	Buffer	No Buffer	ALL	Buffer	No Buffer
Sample Size (N)	33	13	20	33	13	20	11	5	6
Mean	.862	.628	1.013	.582	.471	.655	3.504	2.407	4.419
Std. Error Mean	.096	.087	.140	.049	.053	.069	.407	.354	.396
Skewness	1.022	.341	.625	.424	.068	.082	.089	.296	-.385
Std. Error Skewness	.409	.616	.512	.409	.616	.512	.661	.913	.845
Kurtosis	.772	-.926	-.268	-.414	-1.064	-.798	-1.038	-1.434	-.358
Std. Error Kurtosis	.798	1.191	.992	.798	1.191	.992	1.279	2.000	1.741

Sources

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