

Overview and Objectives

Since the first DDI opened in Springfield, MO in 2009, approximately ninety DDI's are operational with many others under construction or in planning stages. Figure 1 provides the location of the ninety know DDI's in operation at this time. In the last six years, several studies have documented the operational benefits of DDI's. The FHWA



Figure 1. DDI's constructed (green) or under construction (yellow) in the continental United States.

DDI Informational Guide was even recently updated to include detailed recommendations for signal timing of the DDI and system-wide considerations. However, at the time of this effort, there existed very little solid nationally recognized guidance on the safety benefits or geometric considerations outside of this guide. The primary means for answers skeptics safety concerns was a comparison of expected conflict types, or small studies done on individual DDI sites. In response to this need for guidance, the FHWA sponsored this research project to develop a nationally recognized crash modification factor (CMF) based on data from the first seven DDI's to be constructed in the U.S.

Methodology

An observational before and after study was employed as part of this research effort. Typically empirical bayes (EB) analysis is employed to account for all types of safety bias including time period, historical effects, seasonality, and especially regression-to-the mean. However, our team hypothesized that EB analysis was not necessary because sites were not chosen based on a safety concern, but instead operational concerns. A survey of DDI roadway designers confirmed this hypothesis. In addition, a study published by Edara et al. in Missouri conducted EB and comparison group studies and found no difference in the findings, further validating this hypothesis (Edara, 2015). Therefore, **the team used the comparison group methodology** outlined by Hauer in his seminal text "Observational Before and After Studies in Road Safety" **because regression-to-the-mean was not present in the study of DDI's (Hauer, 1997).**

Comparison Site Considerations

The research team utilized a comparison group to account for time, historical effects, and seasonality. Three to five comparison sites were selected in close proximity for each treatment location. Comparison site types included diamond interchanges and nearby signalized intersections. Based on Hauer's text, the odd's ratio was utilized to

determine if comparison sites behave similarly to treatment sites prior to construction of the DDI. All possible combinations of comparison sites were tested and compared for each DDI, and the best group was paired with each treatment DDI site for analysis.

Data Collection

Five years of before crash data were collected for all sites unless there was reason not to collect it. In total, the team analyzed 29 site-years of before data and 19 site-years of after data providing a sufficient sample size for analysis. In total, 929 crashes were utilized for treatment sites across seven sites.

Key Findings and Recommendations

Four separate analyses were completed as part of this study: Site-by-site, all sites, KY/NY/TN versus MO sites to see if state specific designs or drivers vary across states, and all sites except I-270 in Maryland Heights, MO which also redirected a frontage road to an adjacent upstream signal. The results from each are found in Table 1.

Site	Before		After		CMF	Std. dev. of CMF
	Treatment Crashes	Comparison Crashes	Treatment Crashes	Comparison Crashes		
KY	621	658	261	531	0.52	0.05
NY	182	282	38	74	0.78	0.17
TN	76	115	69	100	1.02	0.21
I-44	229	175	145	171	0.64	0.10
US-60	170	639	136	466	1.09	0.14
I-270	430	976	217	844	0.58	0.06
I-435	273	257	63	110	0.51	0.13
All	1981	3102	929	2296	0.63	0.06
KY, NY, TN	879	1055	368	705	0.62	0.05
All MO	1102	2047	561	1591	0.64	0.12
All except I-270	1551	2126	712	1452	0.67	0.04

Table 1. Comparison Group Analysis Results for Total Collisions

Five of the seven sites showed statistically significant reductions in crashes. The remaining two sites were within one standard deviation, showing no significant change. State specific differences did not seem to be present and the I-270 site was in the expected CMF range of other sites. **Using total collisions, the recommended CMF for all sites is 0.63, or an expected reduction of crashes by 47%.**

An analysis of fatal and injury crashes indicates that DDI's were very promising. At six of the seven sites, the CMF was less than one, ranging as low as 0.27, and was more than four standard deviations from one at four of the sites. **Using fatal and injury collisions, the recommended CMF for all sites is 0.45, or an expected reduction of crashes by 55%.**

Acknowledgments

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References

- Edara, P. S. (2015). *Safety Evaluation of Diverging Diamond Interchanges in Missouri*. Jefferson City: Missouri Department of Transportation.
- Hauer, E. (1997), *Observational Before-After Studies in Road Safety*, Pergamon Press.