TECHBRIEF

Field Evaluation of Diverging Diamond Interchanges

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Field Evaluation of Double Crossover Diamond Interchanges (DTFH61-10-C-00029)

Overview

This TechBrief provides results from an evaluation of the safety effects of converting a standard diamond interchange to a double crossover diamond, also referred to as a diverging diamond interchange (DDI). This work was performed as part of a broader research project for Federal Highway Administration (FHWA) which is evaluating the operational and safety impacts of converting an existing diamond interchange into a DDI and investigating how accurately field-observed traffic conditions at DDIs can be replicated in the microscopic simulation model VISSIM.

Theory and previous literature suggest that DDIs should be safer than comparable standard diamonds. However, the only previously published paper on DDI crash data with rigorous analysis methods was performed in only one state. Therefore, during this project a before-and-after safety analysis was performed for seven of the earliest DDI interchanges opened in the US (opening date shown in parenthesis):

- Bessemer Street at US 129, Alcoa, TN (opened December 14, 2010)
- MO 13 at I-44, Springfield, MO (opened June 21, 2009)
- National Avenue at US 60, Springfield, MO (opened July 12, 2010)
- Dorsett Road at I-270, Maryland Heights, MO (opened October 17, 2010)
- Harrodsburg Road at KY 4, Lexington, KY (opened August 14, 2011, see Figure 1)
- Front Street at I-435, Kansas City, MO (opened November 6, 2011)
- Winton Road at I-590, Rochester, NY (September 11, 2012)

Figure 1. Harrodsburg Road at KY 4 DCD Interchange, Lexington, KY

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Safety Evaluation Approach

The objective of a safety effectiveness evaluation is to determine how a particular treatment or group of treatments has affected the crash frequency and severity. The goal is to estimate a crash modification factor (CMF), and the standard deviation of this CMF. A CMF indicates the relative change that a treatment is expected to have on crashes.

Crash data for the before-after evaluation were gathered for the seven study DDIs. Five years of crash data before the implementation of the DDI were obtained where feasible.

The team analyzed crash data for an area extending 800 feet along the arterial street and 1500 feet along the ramps in each direction from the center of the interchange so that crashes at the back of queues were included.

Additional evaluation was conducted beyond the estimation of the CMF described above, including:

- Analysis of crash diagrams and spatial distributions of crashes
- Crash frequency in years when the DDIs were under construction
- Analysis of variables such as light and weather conditions.

Where possible, the team examined the changes in crashes at signalized intersections near to the DDI that could have been affected by new traffic patterns.

DDI Sites Selected for Crash Analysis

Table 1 summarizes the crash data analyzed by year. Overall the team analyzed 29 site-years of before data and 19 site-years of after data, or 48 site-years of data between them. The sample size of crashes was more than sufficient for analysis by site.

Reference Site Analysis

The primary analysis method employed by the research team as part of the safety evaluation was to use reference sites to adjust for the possibility of changes during the study period, such as land development patterns, major weather events, driver behavior, vehicle fleets, and crash reporting tendencies. Empirical Bayes analysis to account for regression to the mean was not necessary in this case because DDIs are usually installed for congestion relief rather than as a countermeasure at a high-crash site.

The key to a successful reference site analysis is to match the crash patterns of the treatment sites year-by-year in the before period with the respective reference sites. The theory is that any year-by-year change in the reference site would have happened at the treatment sites if the treatment had not been installed. The team employed the odds ratio test, as described by Hauer (1997), to determine the best reference site or sites for each treatment site or group of treatment sites.

Table 1 Crash Data Analyzed by Year

State	Treatment site	Before period	Year(s) DDI constructed	After period
KY	US-68 at KY-4	2006-2010 (5 years)	2011	2012-2014 (3 years)
NY	South Winton Road at I-590	2006-2010 (5 years)	2011 - 2012	2013 (1 year)
TN	Bessemer Street at US-129	2005-2009 (5 years)	2010	2011-2013 (3 years)
MO	MO-13 at I-44	06/2004 - 08/2008 (4.2 years)	2009	6/21/09 - 8/31/13 (4.2 years)
	National Avenue at US-60	07/2006 to 08/2009 (3.1 years)	2010	7/12/10 to 8/31/13 (3.1 years)
	Dorsett Road at I-270	10/2006 to 08/2009 (2.9 years)	2010	10/17/10 to 8/31/13 (2.9 years)
	Front Street at I-435	11/2006 to 08/2008 ; 11/2008 to 08/2010 (3.6 years)	2011	11/6/11 to 8/31/13 (1.8 years)

Table 2 provides perhaps the most important results from the safety study—the results for all crashes using reference sites to adjust for potential simultaneous event biases. The safety effect or CMF in Table 2 is represented as the number of after period crashes divided by the number of before period crashes, adjusted for several aspects including the change in crashes at the reference sites from the before to the after period

Table 2 shows that five treatment sites had reductions in crashes, with CMF values ranging from 0.51 to 0.78, and all of those CMF values were at least one standard deviation away from a value of one. The two sites that showed crash increases had CMF values that were within one standard deviation of a neutral value, meaning that this value was not statistically significant. The results for all combinations of sites tested were very uniform, with CMF values from 0.62 to 0.67 and relatively small standard deviations.

Analysis of Injury Crashes

An analysis of injury crashes indicates that DDIs very likely reduced the frequency of injury crashes. Using reference sites, CMF was less than one at six of the seven sites, ranging as low as 0.27, and was more than four standard deviations from one at four of the sites. At the site where the CMF was greater than one, NY, the CMF value was not more than one standard deviation away from one, in part because there was only one year of after period data. The CMF for all sites was 0.45 and the CMF for all groups of sites was well below one.

Table 2 Results From Reference Site Analysis of Each Site and Groups of Sites

	Before		After			
Site	Treatment Crashes	Reference Crashes	Treatment Crashes	Reference Crashes	CMF	Std. dev. of CMF
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

Conclusions

This study collected and analyzed collision data before and after conversion of seven diamond interchanges into DDIs. The researchers had access to over 3000 crash reports at the treatment sites including over 600 injury crashes. The researchers also collected data at over 20 potential reference sites for use in adjusting for history and maturation biases.

For most individual sites and groups of sites examined, odds ratio tests showed that there were high quality reference sites available, so it is the reference site analyses that should provide readers with the most confidence. Results from the I-270 site proved problematic because DDI installation also involved the shift of a signalized frontage road away from the interchange, so the most trusted results were those that did not include this site.

Based on the reference site results that do not include the I-270 site, the researchers recommend the following as the best general estimates of crash modification factors (CMFs) for conversion of a diamond to a DDI interchange:

- For overall crashes, CMF = 0.67 (CRF = 33%)
- For injury crashes, CMF = 0.59 (CRF = 41%)

Because the samples were large, the standard deviations around the CMFs above were relatively small at 0.04 and 0.07, respectively, which should boost confidence.

The research team examined crashes at signalized intersections near the DDI at the KY and I-435 sites. In KY, there were nearby signals on each side of the DDI. Both of those signals showed substantial overall and injury crash reductions after DDI installation. At the I-435 site, there was one nearby signal and crash data showed little change from before to after DDI installation. Altogether, it appears that DDI installation may have a beneficial effect on safety at nearby signalized intersections, likely due to reduction in queuing and spillback.

Examining crash types, it is clear that DDI installation should mean a substantial reduction of angle and turning crashes and a reduction in rear end crashes. Meanwhile the number of sideswipe same-direction crashes may stay steady or increase somewhat with DDI installation. These changes in crash patterns are consistent with expectations. Other crash variables did not reveal large changes over multiple sites with DDI installation. At a DDI, rear end crashes will likely remain the dominant crash type, with sideswipe crashes a distant second.

References

Hauer, E. (1997), *Observational Before-After Studies in Road Safety*, Pergamon Press.

Researchers – This study was performed under direction of Principal Investigators Nagui M. Rouphail and Joseph E. Hummer. For more information about this research, contact Dr.Wei Zhang, FHWA Project Manager, HRDA-10, at (202) 493-3317, Wei.Zhang@dot.gov.

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