Development of a Crash Modification Factor for Conversion of a Conventional Signalized Intersection to a CFI

NCDOT RNS 2020-29

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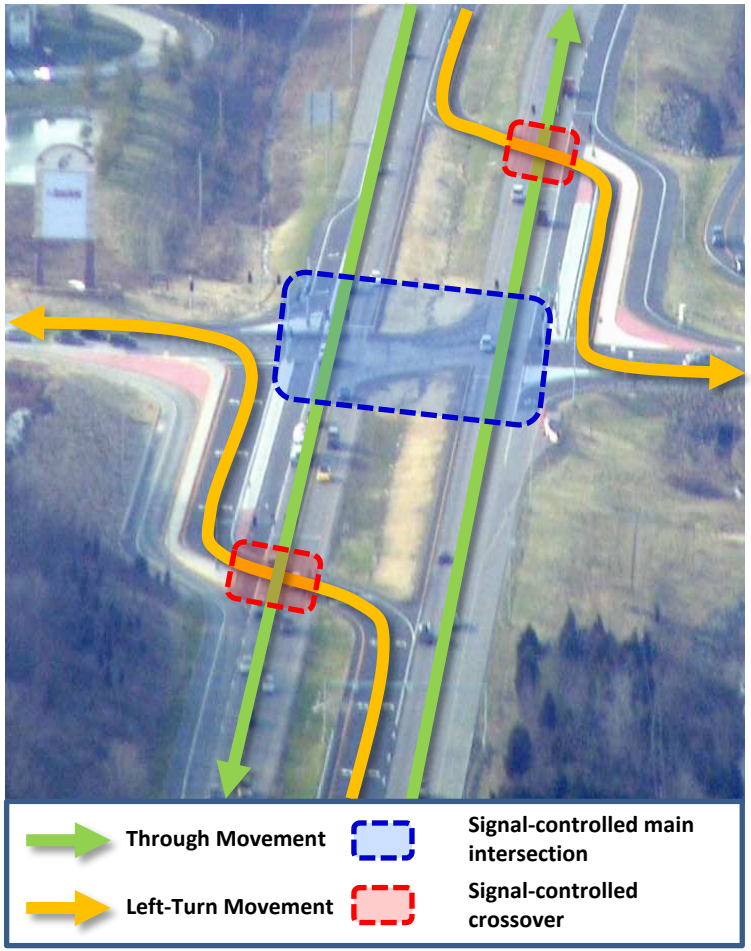
Outline

- Overview
- Literature Review
- Site Selection
- Data Collection
- Methodology
- Analysis
- Conclusions

CFI Description

- Relocates the left-turn movement on an approach upstream of the main intersection by directing it to the other side of the opposing roadway via a left-over.
- Reduced phases increases overall efficiency
- Often used to extend the life of existing intersections



A Partial CFI at the intersection of US Route 30 and Summit Drive in Frenton, MO

Overview

Objective

To investigate the safety impacts of conversion of a conventional signalized intersection to a CFI to determine potential use of the treatment in NC

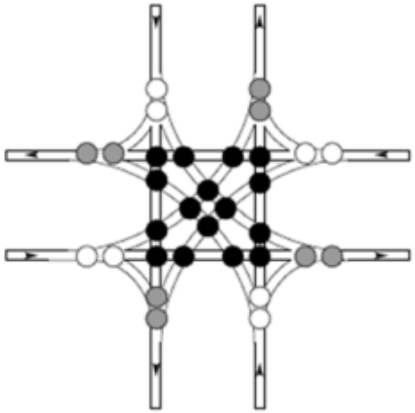
1) Jagannathan, R., & Bared, J. G. (2004). Design and operational performance of crossover displaced left-turn intersections. Transportation research record, 1881(1), 1-10.
2) Reid, J. D., & Hummer, J. E. (2001). Travel time comparisons between seven unconventional arterial intersection designs. Transportation Research Record, 1751(1), 56-66.

Research Questions

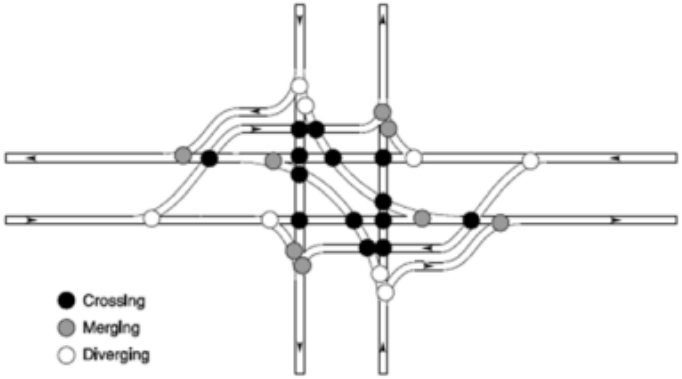
1) What is the anticipated overall safety impact of installing a CFI?
2) Are there any geometric features of the CFI seem to be crash hotspots?
3) Are there certain crash types that are more likely to increase or decrease in CFI?
4) Are there any changes in crash severity in the CFIs over time?

Literature Review

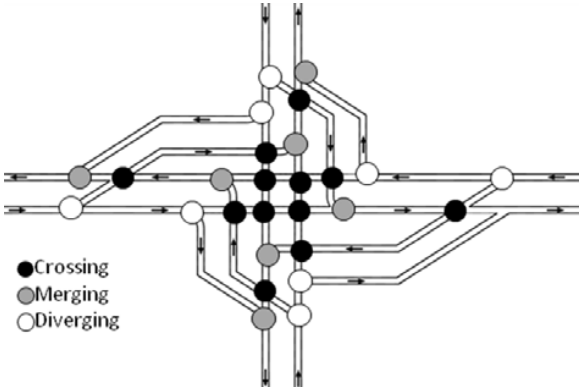
Conflicts



(a) Conventional Intersection



(b) Partial CFI (4 legs)



(c) Full CFI

CFI Type	Num of Legs	Num of Crossovers on CFI	Conflict Points	
			Conventional	CFI
Partial	3	1	9	9
Partial	4	2	32	30
Full	4	4	32	28

Comparison of Conflict Point Totals for different number of legs and crossovers

Literature Review

Previous Studies

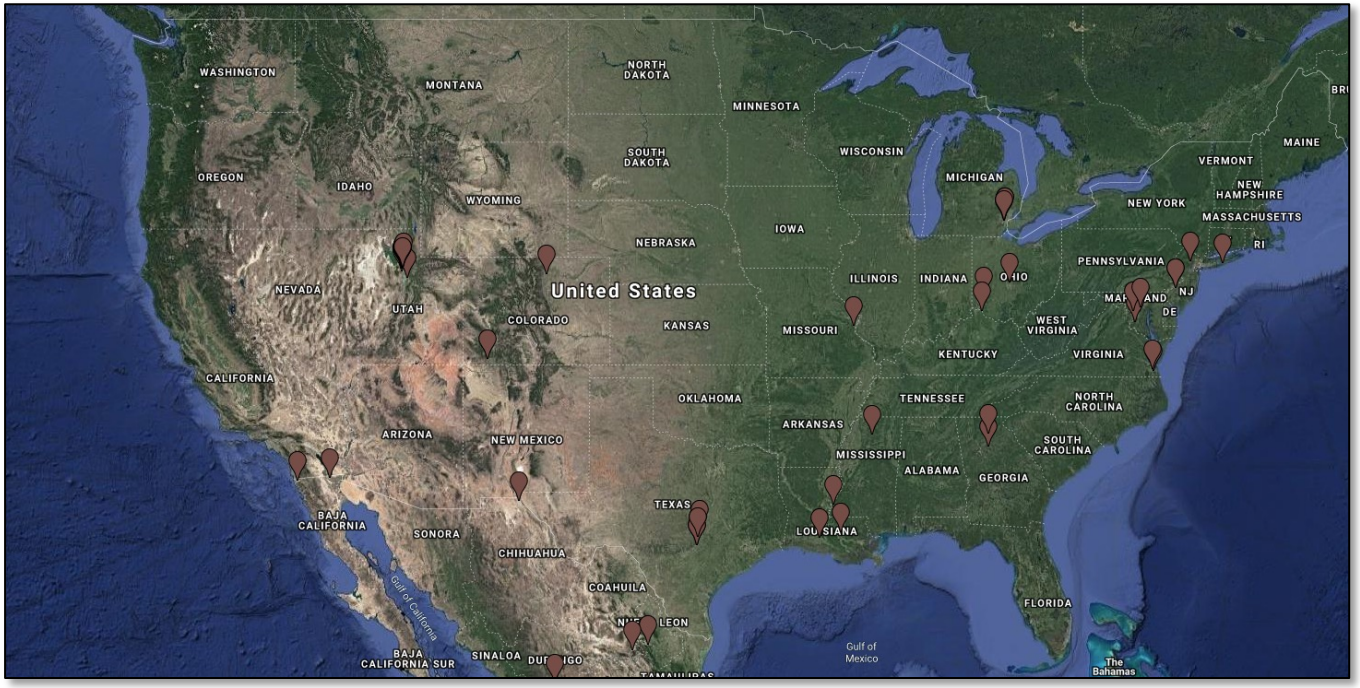
- Yahl et al. (2013)
  - C-G method
  - CMF of 1.239
  - Low sample sizes, several “non-typical” geometric designs (3 of 5)
- Zlatovic (2015)
  - C-G method
  - CMF of 0.877
  - Low sample sizes and minimal comparison sites. Utah specific (n=8). Recommended updating later.
- Abdelrahman (2020)
  - C-G and C-S Methods
  - CMF of 1.112 (CG)
  - CMF and CS methods had conflicting results for several crash types

Site Selection

CFIs in United States

- According to the alternative intersections and interchanges list of ITRE, there are 45 CFIs across 13 states in the US prior to NC's 1st CFI.

State	Num of Listed Sites
Total	45
MS	2
LA	2
CO	2
UT	13
MO	1
TX	5
MD	4
NY	1
OH	3
NJ	3
GA	2
MI	5
VA	2



Locations of CFIs in the AIIs list of ITRE

Site Selection

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CFIs in United States

CFIs in the AIIs list of ITRE	Number of Sites
Total	45
Typical CFI	27
- Full CFI	1
- Partial CFI	26
Non-Typical CFI	*10*
- Partial Unconventional CFI	*5*
- Partial CFI on Interchange	*5*
Intersection is not a CFI	*8*

Number of CFIs for Different Compositions

Number of CFIs (27 Typical CFIs)		CFI Legs (48 Legs in Total)			
		1	2	3	4
Intersection Total Legs	3	8	0	0	0
	4	2	16	0	1

Number of CFIs for Intersection Total Legs and CFI Legs

Site Selection

Reference Sites

1) Located in the same region (city or county) of the CFI
2) Standard 3-leg or 4-leg signalized intersections with two-way approaches
3) No major geometric changes between 'before' and 'after' periods
4) Should be at least 150ft away from any component of other intersections (e.g. a 150ft away from left-turn cross over points of CFI)
5) Should have available AADT data for both major and minor roads.

A Partial CFI on Interchange (I-35 & TX 80, San Marcos, TX)

Data Collection

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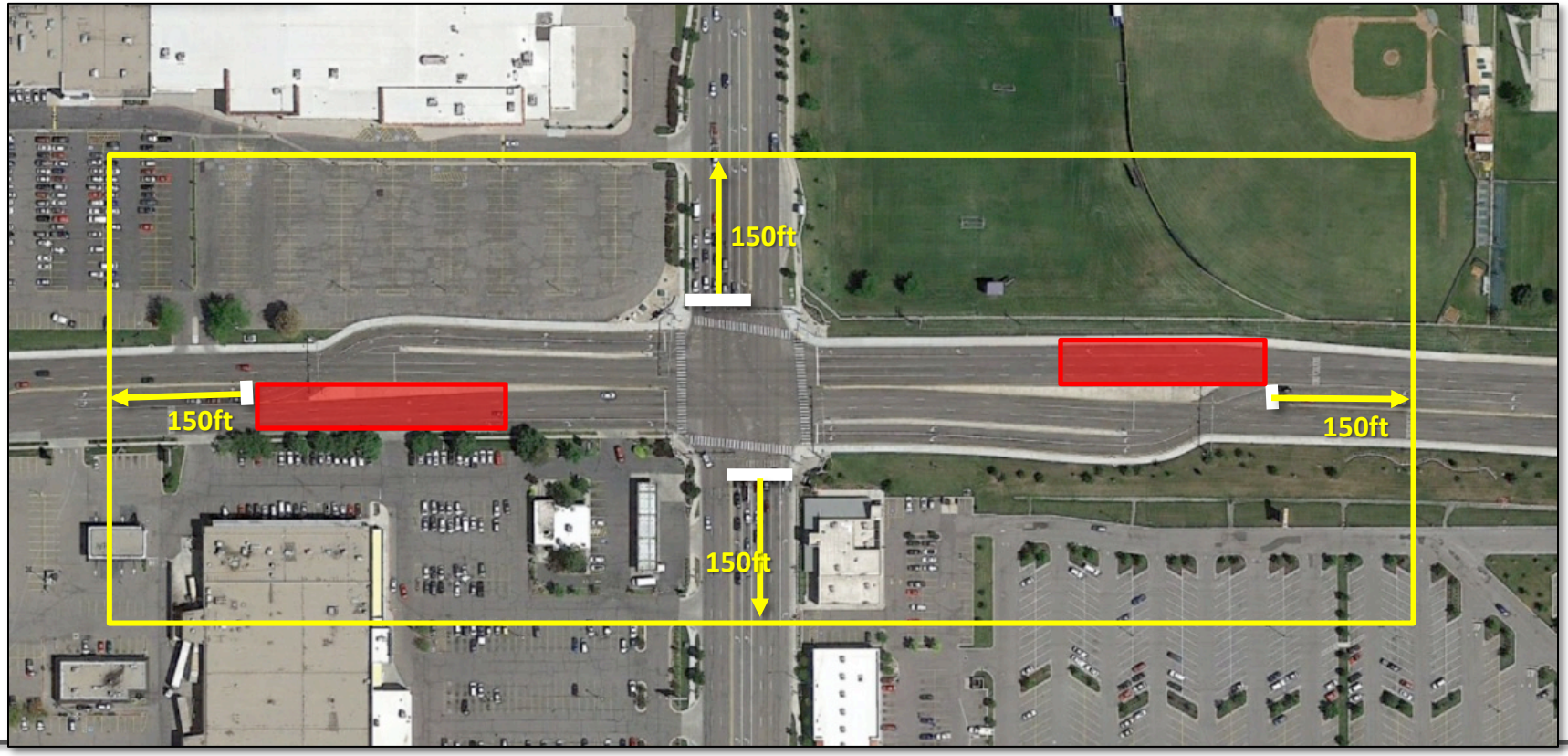
- 27 “Typical” CFIs considered
- Only 19 possible based on states willingness to provide data
- 3 eliminated
  - Late removal due to unusual design (T5)
  - Lack of AADT Data (T6)
  - No available crash data available prior to 2006/database change (T17)
- 16 total “typical” CFI sites studied

Site Code	City	State	Name	Num of Leg	Area Type
T1	Durango	CO	US 550 & US 160	3-leg	Rural
T2	Loveland	CO	US 34 & Madison Ave	4-leg	Urban
T3	Dawsonville	GA	US-19 & Hwy 53	4-leg	Rural
T4	Snellville	GA	Scenic Hwy S & Main St W	4-leg	Suburban
~~T5~~	~~Baton Rouge~~	~~LA~~	US 61 & Sherwood Forest Blvd / Siegen Ln	~~4-leg~~	~~Urban~~
~~T6~~	~~Accokeek~~	~~MD~~	~~MD 210 & MD 228~~	~~3-leg~~	~~Suburban~~
T7	Oxford	MS	US 278 & Jackson Ave	3-leg	Suburban
T8	Cincinnati	OH	Beechmont Ave & Five Mile Rd	4-leg	Suburban
T9	Austin	TX	US 290 & W William Cannon Dr	4-leg	Suburban
T10	Austin	TX	US 290 & TX 71	3-leg	Suburban
T11	Cedar Park	TX	Whitestone Blvd & Ronald Reagan Blvd	4-leg	Suburban
T12	Taylorsville	UT	5400 S & Redwood Rd	4-leg	Urban
T13	Riverton	UT	SR 154 & 13400 S	4-leg	Suburban
T14	Taylorsville	UT	SR 154 / Bennion Blvd & 6200 S	4-leg	Suburban
T15	Taylorsville	UT	SR 154 & 4700 S	4-leg	Urban
T16	Taylorsville	UT	SR 154 & 4100 S	4-leg	Urban
~~T17~~	~~West Valley City~~	~~UT~~	~~SR 154 & SR 171~~	~~4-leg~~	~~Urban~~
T18	West Valley City	UT	SR 154 & 3100 S	4-leg	Urban
T19	Salt Lake City	UT	Redwood Rd & Bennion Blvd	4-leg	Urban

Data Collection

Data Collection

- 150ft back from the stop bar of the outermost signalized movement
- Most conservative method – should not overestimate any safety effects!



Methodology

- C-G and Empirical Bayes (EB) methods considered
  - C-G best utilized when sites are not chosen for safety improvements
  - RTM could still be possible (and likely) if additional vehicles take advantage of improved operations, therefore increasing exposure.
- EB method ultimately chosen
- Naïve results provided for reference

Analysis_Categorical Data

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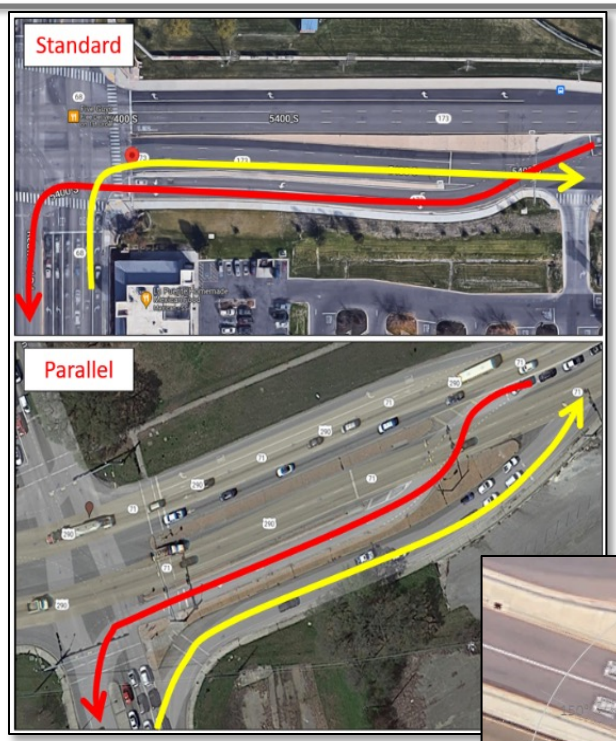
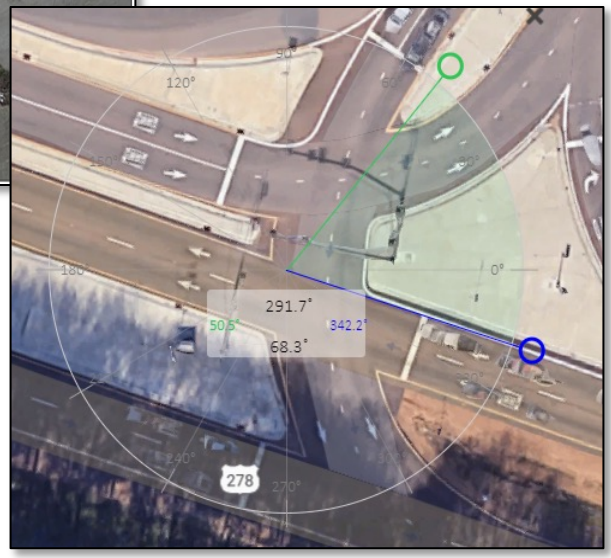
Crash Data Categories

- Aggregate vs. Disaggregate
- Crash Categories
  - Severity: Fatal & Injury (KABC) and PDO
  - Type: Total, Angle, Rear End
- Disaggregate
  - Area Type
  - Number of Approaches
  - Number of Crossover Lanes
  - Intersection Skew
  - Right Turn Treatment





Analysis_Aggregated

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Crash Type	Crashes in the After Period	Expected Crashes in the After Period without Treatment	CMF (Naïve)	CMF (EB)	Std. Error of CMF	Range of CMFs (95% CI)
Total	2365	2688.85	0.958	**0.879***	**0.027**	0.826 - 0.932
Fatal & Injury (KABC)	662	766.67	0.916	**0.862***	**0.050**	0.764 - 0.960
Property Damage Only (PDO)	1703	1928.39	0.975	**0.882***	**0.032**	0.819 - 0.945
Angle Crashes	486	686.55	0.747	**0.706***	**0.046**	0.616 - 0.796
Rear End Crashes	1243	1426.55	0.981	**0.871***	**0.036**	0.800 - 0.942

** Statistically Significant at the 95-percent Confidence Level*

Analysis_Area Type

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Area Type	Crash Type	Crashes in the After Period	Expected Crashes in the After Period w/o Treatment	CMF (Naïve)	CMF (EB)	Std. Error of CMF	Range of CMFs (95% CI)
Rural (n = 2)	Total	238	397.01	0.758	**0.598***	**0.048**	0.504 - 0.692
	Fatal & Injury (KABC)	61	89.93	0.854	**0.672***	**0.106**	0.464 - 0.880
	Property Damage Only (PDO)	177	308.27	0.730	**0.573***	**0.052**	0.471 - 0.675
	Angle Crashes	50	70.03	0.890	**0.706***	**0.124**	0.463 - 0.949
	Rear End Crashes	132	285.92	0.646	**0.460***	**0.047**	0.368 - 0.552
Urban / Suburban (n = 14)	Total	2127	2291.84	0.987	**0.927***	**0.031**	0.866 - 0.988
	Fatal & Injury (KABC)	601	676.74	0.922	**0.886***	**0.055**	0.778 - 0.994
	Property Damage Only (PDO)	1526	1620.12	1.014	**0.941*****	**0.038**	0.867 - 1.015
	Angle Crashes	436	616.52	0.734	**0.705***	**0.049**	0.609 - 0.801
	Rear End Crashes	1111	1140.62	1.046	**0.973**	**0.045**	0.885 - 1.061

** Statistically Significant at the 95-percent Confidence Level*

**** Statistically Significant at the 85-percent Confidence Level*

Analysis_Number of Approaches

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No. of Legs	Crash Type	Crashes in the After Period	Expected Crashes in the After Period w/o Treatment	CMF (Naïve)	CMF (EB)	Std. Error of CMF	Range of CMFs (95% CI)
3 (n = 3)	Total	231	267.35	1	**0.860****	**0.083**	0.697 - 1.023
	Fatal & Injury (KABC)	60	73.59	0.945	**0.800**	**0.149**	0.508 - 1.092
	Property Damage Only (PDO)	171	195.13	1.021	**0.871**	**0.096**	0.683 - 1.059
	Angle Crashes	27	23.80	1.350	**1.072**	**0.312**	0.460 - 1.684
	Rear End Crashes	123	161.10	0.939	**0.758***	**0.094**	0.574 - 0.942
4 (n = 13)	Total	2134	2421.50	0.953	**0.881***	**0.029**	0.824 - 0.938
	Fatal & Injury (KABC)	602	693.08	0.913	**0.867***	**0.053**	0.763 - 0.971
	Property Damage Only (PDO)	1532	1733.26	0.970	**0.883***	**0.034**	0.816 - 0.950
	Angle Crashes	459	662.75	0.728	**0.691***	**0.046**	0.601 - 0.781
	Rear End Crashes	1120	1265.45	0.986	**0.884***	**0.039**	0.808 - 0.960

** Statistically Significant at the 95-percent Confidence Level*

*** Statistically Significant at the 90-percent Confidence Level*

Analysis_Crossover Lanes

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Max. # of Crossover Lanes at Site	Crash Type	Crashes in the After Period	Expected Crashes in the After Period w/o Treatment	CMF (Naïve)	CMF (EB)	Std. Error of CMF	Range of CMFs (95% CI)
1 (n = 6)	Total	657	597.21	1.086	**1.097**	**0.070**	0.960 - 1.234
	Fatal & Injury (KABC)	210	225.94	0.913	**0.923**	**0.100**	0.727 - 1.119
	Property Damage Only (PDO)	447	373.68	1.191	**1.191***	**0.094**	1.007 - 1.375
	Angle Crashes	132	147.12	0.885	**0.888**	**0.116**	0.661 - 1.115
	Rear End Crashes	298	256.29	1.106	**1.157*****	**0.106**	0.949 - 1.365
2 (n = 10)	Total	1708	2091.63	0.916	**0.816***	**0.029**	0.759 - 0.873
	Fatal & Injury (KABC)	452	540.73	0.917	**0.834***	**0.057**	0.722 - 0.946
	Property Damage Only (PDO)	1256	1554.71	0.916	**0.807***	**0.033**	0.742 - 0.872
	Angle Crashes	354	539.43	0.706	**0.654***	**0.049**	0.558 - 0.750
	Rear End Crashes	945	1170.26	0.948	**0.807***	**0.038**	0.733 - 0.881

** Statistically Significant at the 95-percent Confidence Level*

**** Statistically Significant at the 85-percent Confidence Level*

Analysis_Intx. Skew & Right Turn

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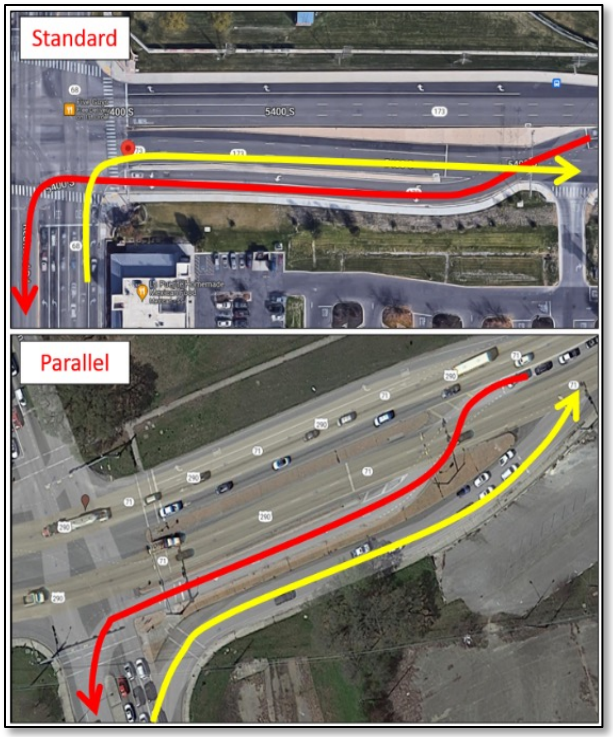
Skew	Right Turn Type	Crash Type	Crashes in the After Period	Expected Crashes in the After Period w/o Treatment	CMF (Naïve)	CMF (EB)	Std. Error of CMF	Range of CMFs (95% CI)
Not Present	Parallel Right Turn (n = 8)	Total	790	1115.94	0.838	**0.707***	**0.036**	0.636 - 0.778
		Fatal & Injury (KABC)	219	322.39	0.792	**0.676***	**0.065**	0.549 - 0.803
		Property Damage Only (PDO)	571	795.11	0.857	**0.717***	**0.043**	0.633 - 0.801
		Angle Crashes	163	340.81	0.557	**0.476***	**0.049**	0.380 - 0.572
		Rear End Crashes	337	507.24	0.866	**0.663***	**0.049**	0.567 - 0.759
	Standard Right Turn (n = 5)	Total	1195	1031.92	1.067	**1.156***	**0.054**	1.050 - 1.262
		Fatal & Injury (KABC)	338	327.48	0.958	**1.028**	**0.087**	0.857 - 1.199
		Property Damage Only (PDO)	857	704.42	1.117	**1.214***	**0.068**	1.081 - 1.347
		Angle Crashes	257	287.45	0.827	**0.890**	**0.083**	0.727 - 1.053
		Rear End Crashes	686	552.59	1.125	**1.238***	**0.078**	1.085 - 1.391
Present	Parallel Right Turn (n = 3)	Total	380	540.98	0.933	**0.701***	**0.050**	0.677 - 0.877
		Fatal & Injury (KABC)	105	116.80	1.119	**0.890**	**0.123**	0.751 - 1.237
		Property Damage Only (PDO)	275	428.86	0.877	**0.639***	**0.052**	0.589 - 0.801
		Angle Crashes	66	58.30	1.404	**1.112**	**0.200**	0.668 - 1.354
		Rear End Crashes	220	366.72	0.823	**0.598***	**0.054**	0.513 - 0.737
	Standard Right Turn (n = 0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a

** Statistically Significant at the 95-percent Confidence Level*



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Conclusions

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- Overall
  - Total Crashes reduced -12.1%*
  - All crash types and severity reduced significantly
- Categorically
  - Rural sites (-24.2%)* much safer than urban/suburban (-7.3%)*
  - 4 approach (-11.9%*) sites safer than 3 approach (-14.0%*)
  - 2 crossover (-18.4%)* lanes much safety than 1 crossover (+9.7%)
  - Parallel right turns much safer than standard right turns
    - Parallel/No-Skew (-29.3%)* vs. Standard/No-Skew (+15.6%)*
  - Skewed intersections with parallel right turns
    - Parallel/No-Skew (-29.3%)* vs. Parallel/Skew (-29.9%)*

** Findings were statistically significant with 95% confidence*

Future Research

- There are still several states not responsive to our request for data that could be included
  - 24 possible “typical” sites (27 – 3 late removals)
- Narratives and crash diagrams would be helpful for looking at specific features. Most states do not provide this detail.
- Cleaned data could be used for future national conflict-based efforts such as MBSPFs.

Discussion

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