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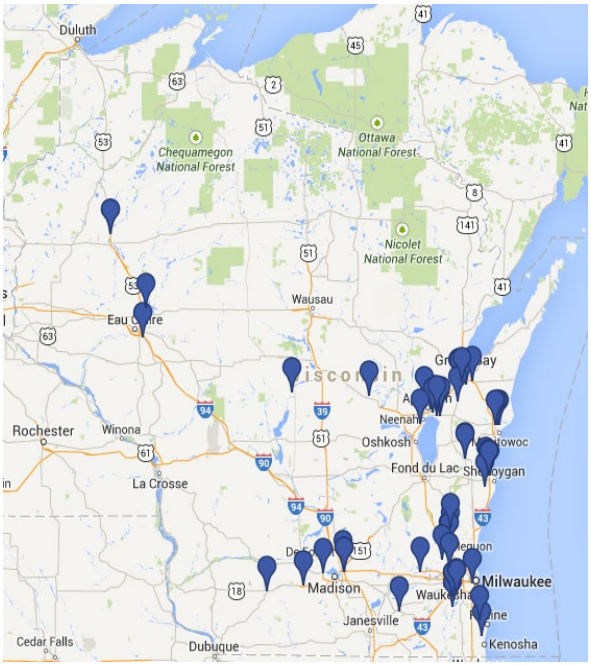
Safety Evaluation of Wisconsin Roundabouts: Phase 3

Executive Summary

Roundabouts (RABs) can have significant safety benefits, as well as provide significant operational benefits in terms of continuous traffic flow. RABs have become an equally popular choice for effectively reducing congestion, including at intersections that don't necessarily have a previous crash history.

As of February 2015, Wisconsin has approximately 331 RABs along the state trunk highway system and local system. Roundabouts are found at less than one percent of the intersections on the state highway system.

Although roundabouts have been shown to generally reduce both frequency and severity of crashes, in some cases, roundabouts may offer safety tradeoffs similar to other traffic control strategies, i.e., reduce severity of crashes while property damage only (PDO) crashes increase. Such cases are not dissimilar to increases in rear-end crashes after installation of a traffic signal or increase in PDO crashes after installation of a cable median barrier. Therefore, it is important to view safety evaluation of roundabouts in this respect as well.



This document provides an Executive Summary of the key findings from a safety study of existing Wisconsin RABs. A safety study was performed that compared the roundabout to a 'no build' (aka previous) condition, which assumes the roundabout had not been installed and the prior intersection treatment remained. This is known as a 'with and without treatment' analysis methodology, which was used to determine the safety benefits gained with Wisconsin RABs. However, in cases where RABs were installed for reasons other than safety (e.g., congestion relief) the roundabout treatment may not have a positive impact on safety, but the 'no build' option would not have addressed the needs of the intersection. The key findings indicate that RABs continue to provide the intended objective of significantly reducing severe (fatal and injury) crashes at intersections. An important next step is further investigation of the increase in low severity (PDO) crashes to identify

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potential design improvements and assess the need for additional public outreach on navigational information.

Study Design

- 66 RABs were built with WisDOT oversight in 2008 or before. 56 of the 66 RABs were selected for this analysis
- 10 RABs were omitted due to either a lack of post-construction data or unique geometry, specifically:
  - 8 RABs were new intersections
  - 2 RABs combined several closely spaced intersections
- Crash data was collected for 5 years before and either 3, 4, or 5 years after the RAB installation
- Traffic volume data were collected before and after the RAB installation
- Crash data obtained during the construction year were omitted
- Statistical methods were applied to make inferences about the safety data, namely the Empirical Bayes and Simple Before/After Crash Analysis methods

Empirical Bayes Crash Analysis

Key Findings

- Change in Fatal and Injury Crashes (KABC)
  - Roughly two-third (37) RAB sites experienced a decrease in fatal and injury crashes
  - Seven locations experienced one fatal crash each before RAB installation. By comparison, there were zero fatal crashes at these seven locations after RAB installation. One location experienced 2 fatal crashes before RAB installation, compared to 1 fatal crash after the RAB installation
  - 19 of 56 locations had an increase in injury crashes after RAB installation
    - The average annual increase was 0.4 crashes per year, equating to 2 additional injury crashes every 5 years
    - The minimum annual increase was 0.01 crashes per year, the maximum annual increase was 4.6 crashes per year.
  - Single lane roundabouts experienced a 41% decrease in fatal and injury crashes, and multi-lane roundabouts experienced a 26% decrease in fatal and injury crashes.
  - At the aggregate level (all types, all locations), the results revealed a 30% decrease in fatal and injury crashes.
    - For each of the fatal and injury severities (KABC**), the results show consistent decreases from before RAB installation to after.
    - RABs nationwide have also experienced a significant decrease in fatal and injury crashes.

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**K= Fatal Injury Crash, A= Incapacitating Injury Crash, B= Non-incapacitating Injury Crash, C= Possible Injury Crash, O= Property Damage Only Crash

- Change in Total Crash Frequency (KABCO)
  - About one-third (19) RAB sites experienced an overall decrease in total crashes.
  - Roughly two-third (37) RAB sites experienced an increase in total crashes, with most being PDO crashes.
    - Overall, the aggregate results revealed a 31% increase in total crashes across 37 locations.
    - 12 locations observed increases that equated to less than 1 crash per year.
    - 25 locations observed increases equal to approximately 8 crashes per year.
  - Single lane roundabouts experienced a 4% increase in total crashes, and multi-lane roundabouts experienced a 37% increase in total crashes.
  - Out of the 56 locations included in this analysis, 3 locations experienced disproportionately large increases in total crashes in the after condition.
    - These sites accounted for more than 50% of the aggregate increase.
      - 1 site accounted for roughly a quarter of the increase.
    - These sites were retained in the final analysis to be consistent with earlier phases of the study.
      - Omitting these sites as outliers would likely produce more favorable results, such as smaller crash increases or larger crash reductions at the aggregate levels.

Table 1 Roundabout (RAB) Safety Performance by Number of Lanes

		Single-lane	Multi-lane
	Number of RABs Analyzed	21	35
Total Crashes	**RABs with Increased Crashes[a]**	14	23
	RABs with Decreased Crashes[a]	7	12
	Total Expected RAB Crashes[b]	226	531
	Total Observed RAB Crashes[c]	335	728
	% of Changes[d]	4% Increase	37% Increase
Fatal and Injury (KABC) Crashes	**RABs with Increased Crashes[a]**	7	11
	RABs with Decreased Crashes[a]	14	24
	Total Expected RAB Crashes[b]	78	189
	Total Observed RAB Crashes[c]	46	140

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	% of Changes[d]	41% Decrease	26% Decrease

[a]In comparison to the 'no-build' condition

[b] Total Expected Crashes refers to the number of crashes expected if the RAB had not been installed given the future traffic volumes.

[c]Actual number of RAB crashes

[d]% Change = (Total Expected Crashes – Total Observed Crashes)/Total Expected Crashes*100

Note: % Changes represent the reduction in crashes and can be used as a Crash Modification Factor (CMF)

- For total crashes, a conversion to a RAB increases the frequency of crashes.
  - Conversion from a two-way stop-controlled traffic control to a RAB showed a crash increase of 20%.
  - Conversion from an all-way stop controlled intersection to a RAB had a 30% increase in total crashes.
  - Signalized traffic control converted to a RAB has a 29% increase in traffic crashes.
  - Due to the small sample size of sites with no control or yield in the before period, the total crash frequency is not recommended for comparison purposes.
- While RABs compared to the other traffic control alternatives showed an increase in total crashes, for fatal and injury crashes, RABs demonstrated a decrease in crashes over all the traffic control alternatives.
  - Conversion from a two-way stop-controlled traffic control to a RAB showed a crash decrease of 46%.
  - Conversion from an all-way stop controlled intersection to a RAB had a 23% decrease in total crashes.
  - Signalized traffic control converted to a RAB has a 15% decrease in traffic crashes.
  - Due to the small sample size of sites with no control or yield in the before period, the injury crash frequency is not recommended for comparison purposes.

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Table 2 Roundabout (RAB) Safety Performance by Traffic Control Type

		'No-Build' Traffic Control Type			
		No Control/ Yield[a]	TWSC[b]	AWSC[c]	Signalized
	Number of RABs	2	28	14	12
Total Crashes	RABs with Increased Crashes[d]	-	16	10	8
	RABs with Decreased Crashes[d]	-	12	4	4
	Total Expected RAB Crashes[e]	-	266	168	313
	Total Observed RAB Crashes[f]	-	319	219	403
	% of Changes[g]	-	20% Increase	30% Increase	29% Increase
Fatal and Injury (KABC) Crashes	RABs with Increased Crashes	-	6	7	6
	RABs with Decreased Crashes	-	22	7	6
	Total Expected RAB Crashes[a]	-	108	62	92
	Total Observed RAB Crashes	-	58	48	78
	% of Changes[b]	-	46% Decrease	23% Decrease	15% Decrease

[a] Due to the small sample size "No Control/Yield" is not recommended for comparison purposes.

[b] Two-way stop control

[c] All-way stop control

[d] In comparison to the 'no-build' condition

[e] Total Expected Crashes refers to the number of crashes expected if the RAB had not been installed given the future traffic volumes.

[f] Actual number of RAB crashes

[g] % Change = (Total Expected Crashes – Total Observed Crashes)/Total Expected Crashes*100

Note: % Changes represent the reduction in crashes and can be used as a CMF

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- When examining by region, please note that NC and NW have limited roundabouts so the sample size is small and should not be used to for comparisons.

Table 3 Roundabout (RAB) Safety Performance by Region

		NC[a]	NE	NW[a]	SE	SW
	Number of RABs	2	26	4	18	6
Total Crashes	RABs with Increased Crashes[b]	-	16	-	13	3
	RABs with Decreased Crashes[b]	-	10	-	5	3
	Total Expected RAB Crashes[c]	-	441	-	155	104
	Total Observed RAB Crashes[d]	-	534	-	228	125
	% of Changes[e]	-	21% Increase	-	47% Increase	20% Increase
Fatal and Injury (KABC) Crashes	RABs with Increased Crashes[b]	-	8	-	5	3
	RABs with Decreased Crashes[b]	-	18	-	13	3
	Total Expected RAB Crashes[c]	-	146	-	60	41
	Total Observed RAB Crashes[d]	-	108	-	30	32
	% of Changes[e]	-	26% Decrease	-	50% Decrease	22% Decrease

[a]Due to the small sample size the NC and NW regions are not recommended for comparison purposes
[b]In comparison to the 'no-build' condition
[c]Total Expected Crashes refers to the number of crashes expected if the RAB had not been installed given the future traffic volumes.
[d]Actual number of RAB crashes
[e]% Change = (Total Expected Crashes – Total Observed Crashes)/Total Expected Crashes*100
Note: % Changes represent the reduction in crashes and can be used as a Crash Modification Factor (CMF)

- For total crashes, RABs in rural locations showed a crash reduction of 9%, while urban locations showed an increase of 48%. For fatal and injury crashes, urban locations showed a decrease of 18% and rural locations displayed a decrease in crashes of 49%.

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Table 4 Roundabout (RAB) Safety Performance by Urban/Rural Location

		Rural	Urban
	Number of RABs	17	39
Total Crashes	**RABs with Increased Crashes[a]**	8	29
	RABs with Decreased Crashes[a]	9	10
	Total Expected RAB Crashes[b]	276	481
	Total Observed RAB Crashes[c]	250	713
	% of Changes[d]	9% Decrease	48% Increase
Fatal and Injury (KABC) Crashes	**RABs with Increased Crashes[a]**	4	15
	RABs with Decreased Crashes[a]	13	24
	Total Expected RAB Crashes[b]	106	161
	Total Observed RAB Crashes[c]	54	132
	% of Changes[d]	49% Decrease	18% Decrease

[a]In comparison to the 'no-build' condition

[b] Total Expected Crashes refers to the number of crashes expected if the RAB had not been installed given the future traffic volumes.

[c]Actual number of RAB crashes

[d]% Change = (Total Expected Crashes – Total Observed Crashes)/Total Expected Crashes*100

Note: % Changes represent the reduction in crashes and can be used as a Crash Modification Factor (CMF)

Multi-State KABCO Expected Before and Observed After Comparison

Before and after crash data available for roundabouts in Michigan, Minnesota, North Carolina, and Wisconsin was examined. The crashes were summarized and categorized according to severity. The relative proportion of each crash severity category was compared for before and after conditions, and is shown in Figures 1 and 2. This information reveals a consistent shift in crash severity distributions in all four states. The roundabout after condition produces smaller proportions of fatal and injury crashes (KABC) and larger proportions of PDO crashes. While this severity distribution shift was observed for both single and multi-lane roundabouts, the data does show that the shift is less pronounced for multi-lane roundabouts. There is no multi-lane roundabout data from North Carolina.

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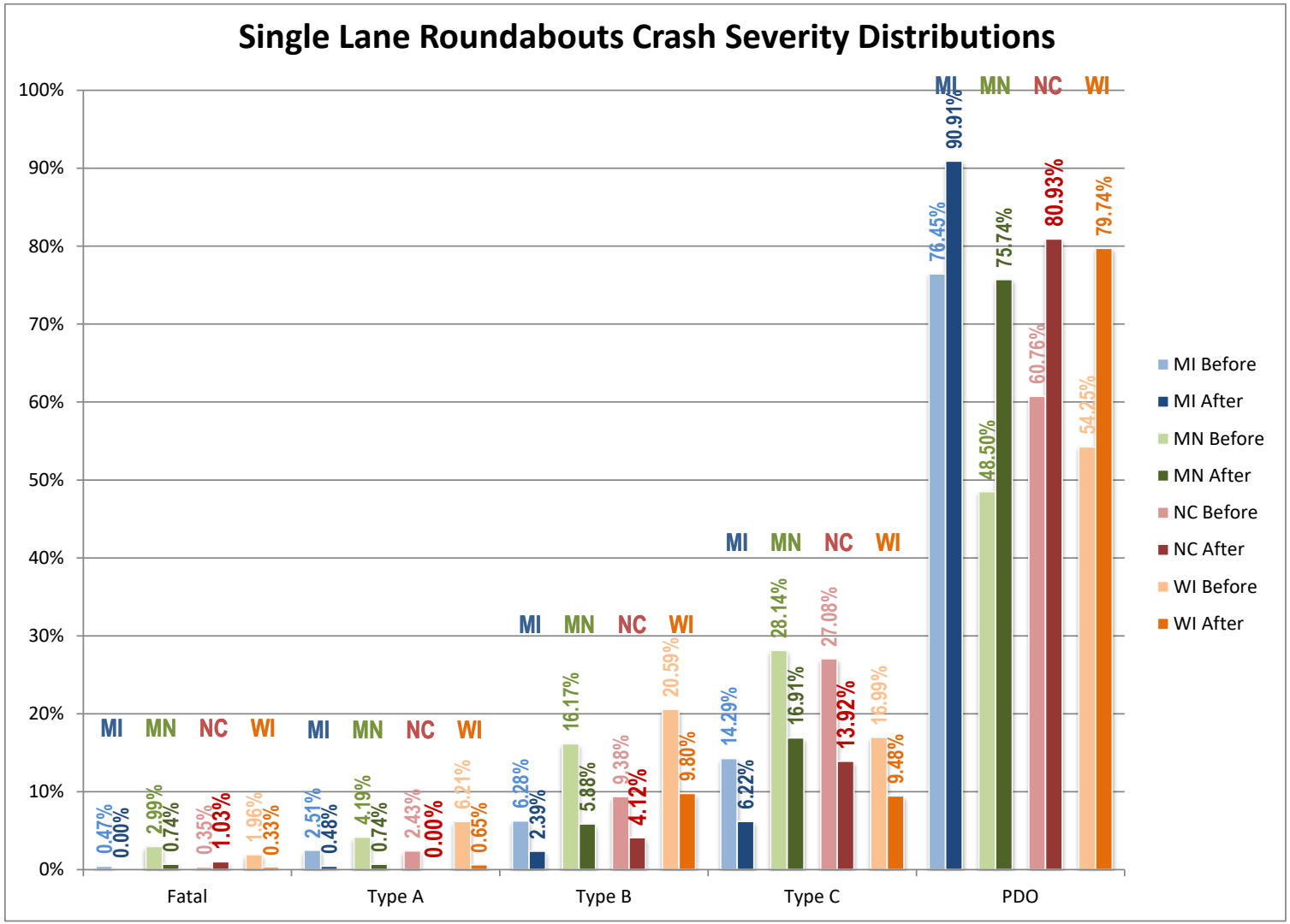

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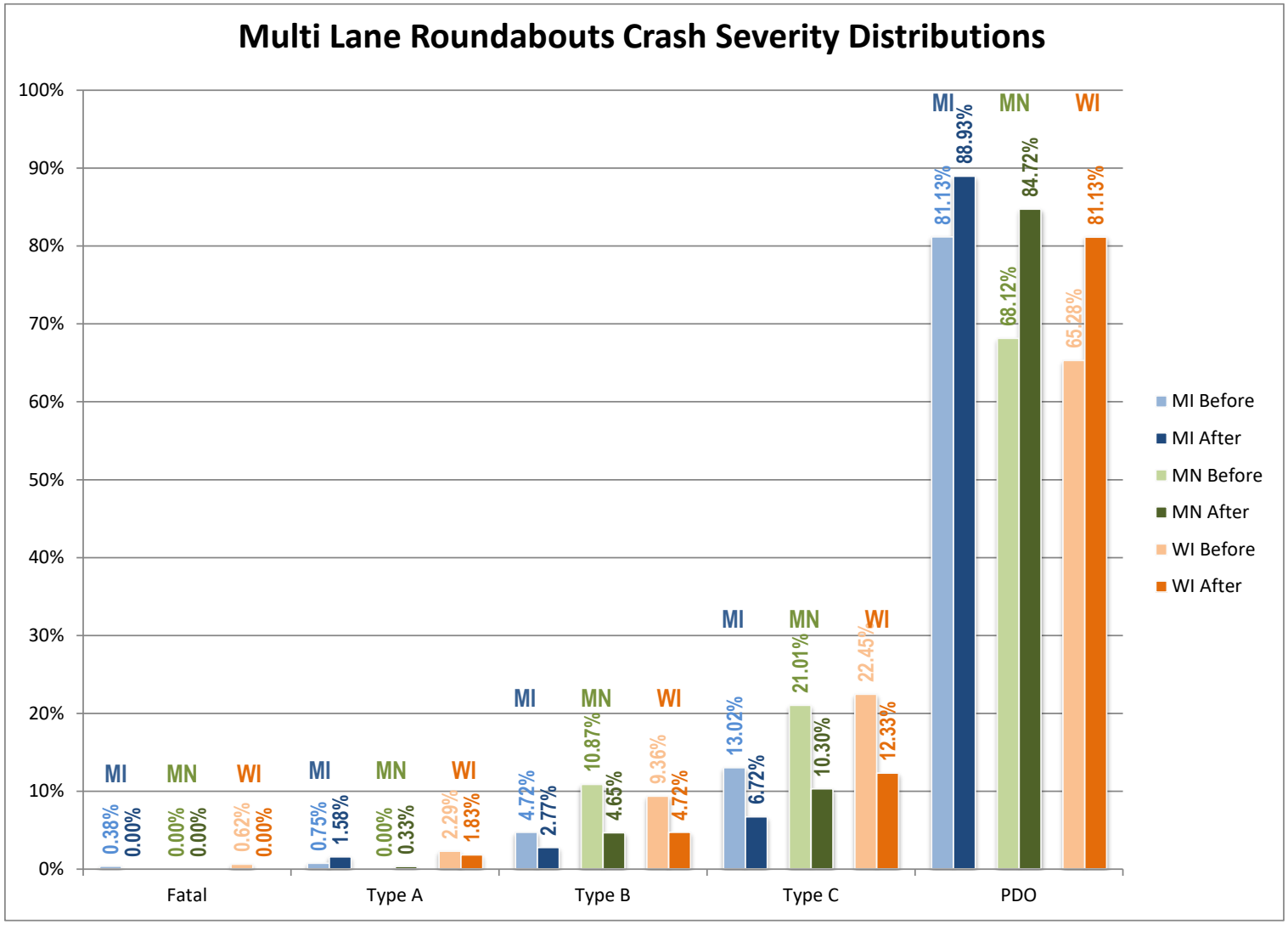

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An average of the four state's crash severity distribution was taken from before the roundabouts were installed. From the four states the proportion of KABCO crashes is as follows:

- K – 0.8%
- A – 2.5%
- B – 9.5%
- C – 18.7%
- O – 68.6%

These proportions were then applied to the expected after condition in Wisconsin acquired from the EB analysis. This would give the expected crashes for each severity level that would be expected at the intersection if the roundabout treatment were not installed. The expected number of crashes for each crash severity level at the intersection was then compared to the number of observed crashes after the installation of the roundabout. This analysis gives a way to compare the change in crashes for each severity level.

Table 5 Percent Change of Crash Severities at Wisconsin Roundabouts

Crash Severity	K	A	B	C	O
% Change*	83.1% Decrease	26.0% Decrease	17.5% Decrease	22.0% Decrease	53.3% Increase

*% Change = (Total Expected Crashes – Total Observed Crashes)/Total Expected Crashes*100

The crash reduction when comparing the intersection before the installation of a roundabout and after follows a similar pattern to the EB analysis. The number of fatal and injury crashes is reduced by a large amount, particularly for "K" (83.1% reduction from the before period). Fatal and serious injury crashes (K and A) were reduced approximately 40%. However, the number of PDO crashes increased by 53.3%. Examining the crash reductions in this way allows for a comparison between each crash severity before and after the installation of a roundabout, as opposed to looking at injury crashes and PDO crashes only.

Simple Before and After Analysis

The crash frequency is classified by crash outcome (K, A, B, C, and PDO). Using a simple before-and-after crash analysis, researchers found that seven sites in which fatal crashes were found in the before condition experienced no fatal crashes after the installation of a roundabout. One site experienced two fatal crashes in the before condition and experience one fatal crash after a roundabout was installed. For all injury (A, B, and C) crashes, the number of locations with a reduction in these crash types was greater than the number of locations with increases in these crash types. Similarly, the magnitude of decrease in injury crashes is higher than the magnitude of increase.

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Table 6 Before and After Crash Data for Wisconsin Roundabouts Built in 2009 or Before

Roundabout	Wis DOT Region	Before (five years)						After (five years)					
		K	A	B	C	PDO	Total	K	A	B	C	PDO	Total
STH 54/Gaynor St/17th St	NC	0	0	2	5	6	13	0	1	3	0	17	21
CTH F/S. Ninth St.	NE	0	0	1	0	1	2	0	0	0	0	6	6
CTH F/Suburban Dr.	NE	0	0	0	0	3	3	0	0	0	1	3	4
STH 32/57 and STH 96	NE	1	0	2	0	9	12	0	0	1	1	10	12
STH 14 /Allouez Ave	NE	0	0	1	2	6	9	0	0	1	2	17	20
STH 32/STH 57 Broadway	NE	0	1	3	11	35	50	0	2	7	21	142	172
STH 55/CTH KK (high speed)	NE	0	2	8	5	12	27	0	0	0	0	3	3
Lake Park/Plank Rd (CTH LP/CTH P)	NE	0	0	1	1	3	5	0	0	0	0	10	10
CTH N/Emons Road	NE	0	0	1	4	4	9	0	0	6	6	28	40
STH 28/32 (high speed)	NE	0	0	0	0	4	4	0	0	2	1	19	22
STH 42/I-43, Interchange Ramps (West)	NE	0	1	2	3	16	22	0	0	3	5	18	26
STH 42/I-43, Interchange Ramps (East)	NE	0	0	0	2	19	21	0	1	1	2	24	28
STH 42/Vanguard, Wal-Mart entrance	NE	0	0	0	1	1	2	0	0	1	3	13	17
Breezewood In/Tullar Td	NE	0	0	1	1	4	6	0	0	0	2	13	15
US 53 ramps and CTH O(West)	NW	0	0	0	1	8	9	0	0	1	2	7	10
US 53 ramps and CTH O(East)	NW	0	0	0	1	5	6	0	0	0	1	10	11
STH 124/CTH S	NW	0	1	3	9	13	26	0	0	2	1	6	9
Canal St/25 Ave	SE	0	0	0	0	0	0	0	1	1	1	12	15
STH 38/CTH K	SE	0	0	5	9	28	42	0	2	1	2	36	41
Elkhorn Rd (Bus 12)/Bluff Rd/Clay St	SE	0	1	1	0	1	3	0	0	0	0	7	7
STH 78/STH 92, 8th St, Springdale, CTH ID	SW	0	0	2	0	26	28	0	0	2	4	23	29
Thompson and Commercial (North)	SW	1	1	3	12	13	30	0	1	2	16	45	64
Thompson and STH 30 (South)	SW	0	0	1	7	12	20	0	1	1	0	8	10
Old STH 12/Parmenter	SW	0	0	0	0	0	0	0	0	0	1	9	10
Roundabout	Wis DOT Region	Before (five years)						After (four years)					
		K	A	B	C	PDO	Total	K	A	B	C	PDO	Total
STH EE (Grant St.) & Lawrence Dr.	NE	0	0	2	2	9	13	0	0	3	1	6	10
USH 10 & CTH N	NE	2	3	12	6	15	38	1	0	3	0	14	18
CTH A (N. Lynndale Dr.) & CTH JJ (W.Edgewood Dr.)	NE	0	0	0	2	8	10	0	1	1	1	8	11
STH 16 (Wisconsin Ave.) & Walnut. St	SE	0	0	1	7	21	29	0	0	0	5	17	22
STH 74(Main St.)/McLaughlin Rd. & CTH V(Townline Rd.)	SE	0	0	0	0	6	6	0	0	0	1	12	13
USH 18 & Bennett Rd.	SW	1	1	4	5	2	13	0	0	1	3	7	11
STH22 & Royalton	NC	0	0	0	0	0	0	0	0	0	0	4	4
I-43 & CTH O NorthRAB	SE	0	0	0	5	8	13	0	0	0	0	4	4
I-43 & CTH O SouthRAB	SE	0	0	0	2	2	4	0	1	1	2	17	21
Hanson Rd & Portage	SW	0	0	0	1	0	1	0	0	0	0	1	1
STH53 & Old Town Hall Rd	NW	0	0	0	0	0	0	0	0	3	2	16	21

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Table 6 continued

Roundabout	Wis DOT Region	Before (five years)						After (three years)					
		K	A	B	C	PDO	Total	K	A	B	C	PDO	Total
CTH G (DICKINSON) & CTH GV (MONROE)	NE	0	0	0	2	9	11	0	0	1	0	9	10
USH 10 & STH 55	NE	0	5	4	1	8	18	0	0	1	1	21	23
STH 310 & CTH B	NE	0	0	2	0	3	5	0	0	0	0	10	10
STH 310 & CTH Q	NE	0	1	3	2	7	13	0	0	0	2	4	6
STH 67 & CTH AA	NE	0	0	0	0	8	8	0	0	4	0	5	9
STH 67 & STH 32 STH 57	NE	0	0	1	1	13	15	0	0	1	0	10	11
STH 310 & CTH R	NE	1	3	3	3	7	17	0	1	3	3	2	9
CTH CE & E JOHN ST/S WALTER AVE	NE	0	0	4	15	44	63	0	0	2	6	22	30
STH 42 & CTH JJ	NE	0	0	3	2	3	8	0	0	0	0	1	1
STH 42 & CTH Y	NE	1	1	4	5	5	16	0	1	1	1	8	11
CTH G (WOOD RD) & PARKSIDE BLVD	SE	0	0	0	0	0	0	0	0	0	2	4	6
CTH P & CTH PV	SE	1	2	5	3	11	22	0	0	1	1	19	21
USH 41 & STH 145 NB	SE	0	0	1	1	3	5	0	0	0	0	0	0
USH 41 & STH 145 SB	SE	0	0	1	0	4	5	0	0	0	0	1	1
USH 45 & STH 145 NB	SE	0	1	3	3	3	10	0	0	0	0	5	5
USH 45 & STH 145 SB	SE	0	0	1	1	6	8	0	0	0	0	0	0
VETERANS AVE & WATER ST	SE	0	0	0	0	1	1	0	0	0	0	3	3
CTH Y (RACINE AVE) & KELSEY DR	SE	1	1	7	3	6	18	0	0	1	1	10	12
I43 & CTH Y (S RACINE AVE) NB	SE	0	1	2	3	15	21	0	0	0	1	21	22
I43 & CTH Y (S RACINE AVE) SB	SE	0	0	4	5	23	32	0	1	0	4	16	21
STH 164 & CTH Q	SE	0	4	5	10	15	34	0	0	0	3	48	51
Grand Total		9	30	109	164	494	806	1	14	59	110	795	979