A Study of the Traffic Safety at Roundabouts in Minnesota

Office of Traffic, Safety, and Technology
Minnesota Department of Transportation

DEPARTMENT OF TRANSPORTATION

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Executive Summary

The first Minnesota modern roundabout was constructed in 1995. Since then, roundabouts have been built across the state by the Minnesota Department of Transportation, counties, and cities. There is no definitive count across Minnesota, but it is likely nearing 200 roundabouts across the state on all roads. They have become an increasingly popular intersection type by traffic engineers, communities, and transportation officials. The purpose of this report is to examine the safety performance of roundabouts by comparing the before construction crash rates and the after construction crash rates and traffic volume data. Overall, roundabouts are performing well when looking at the crash reduction record. Roundabouts in Minnesota have had over an 80% reduction in fatal and serious injury crashes. At the time of this report, there still has not been a multi-vehicle fatality in a roundabout in Minnesota. Other highlights include:

- An 86% reduction in the fatal crash rate at intersections where roundabouts have been installed. This includes all roundabout types (Single Lane, Unbalanced, and full Dual Lane Roundabouts). See Pages 6-7 for more information on roundabout types.

- An 83% reduction in the serious injury crash rate at intersections where roundabouts have been installed.

- A 69% reduction in the Right Angle crash rate at intersections where Single Lane Roundabout have been installed.

- An 83% reduction in the Left Turning crash rate at intersections where Single Lane Roundabout have been installed.

- A 61% reduction in the injury crash rate at intersections where Single Lane Roundabout have been installed.

- A 42% reduction in the injury crash rate at intersections where Single Lane Roundabout have been installed.

- The average crash rates for roundabouts by type on all roads is below.

Type of Roundabouts	Number of Sites	Crash Rate (CR)	Fatal and Serious Injury Rate (FAR)
Single Lane	104	0.32	0.31
Unbalanced (2 lanes x 1 lane)	34	0.76	0.15
Full Multi-Lane	6	2.18	0.00
Total (All Roundabouts)	**144**	**0.600**	**0.24**

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Introduction: Roundabouts

Modern Roundabouts have been built in Minnesota and the United States over the past couple decades. The modern roundabout is a circular intersection form with specific design and traffic control features. These features – including yield control of entering traffic, channelized approaches, and other geometric elements designed to control travel speeds, facilitate efficient exchange of traffic flows, and minimize the number and severity of vehicle conflicts and crashes.

Modern roundabouts have shown to be viable intersection options in a wide variety of different locations and contexts. This includes urban, suburban, rural, higher volume locations, lower volume locations, and interchange ramp terminals.

In most cases, modern roundabouts compare favorably in safety and operational performance to conventional intersections with stop control or signalized operation. Additionally, roundabouts have comparable initial construction costs and lower life-cycle costs than a traffic signal with similar traffic capacity.

For these reasons and others, the Minnesota Department of Transportation (MnDOT) practice is that modern roundabouts are an intersection design choice equal to other traffic control methods in terms of the Department's acceptance and consideration. In general terms, any intersection – whether in an urban or rural environment – that meets the criteria for additional traffic control beyond a thru stop condition, also qualifies for evaluation as a modern roundabout.

In 1995, Minnesota had its first roundabout built in Brooklyn Park in a residential neighborhood at Selzer and Neddersen Parkway. Since then, over 150 roundabouts have been built across the state by the Minnesota Department of Transportation, counties, and cities.

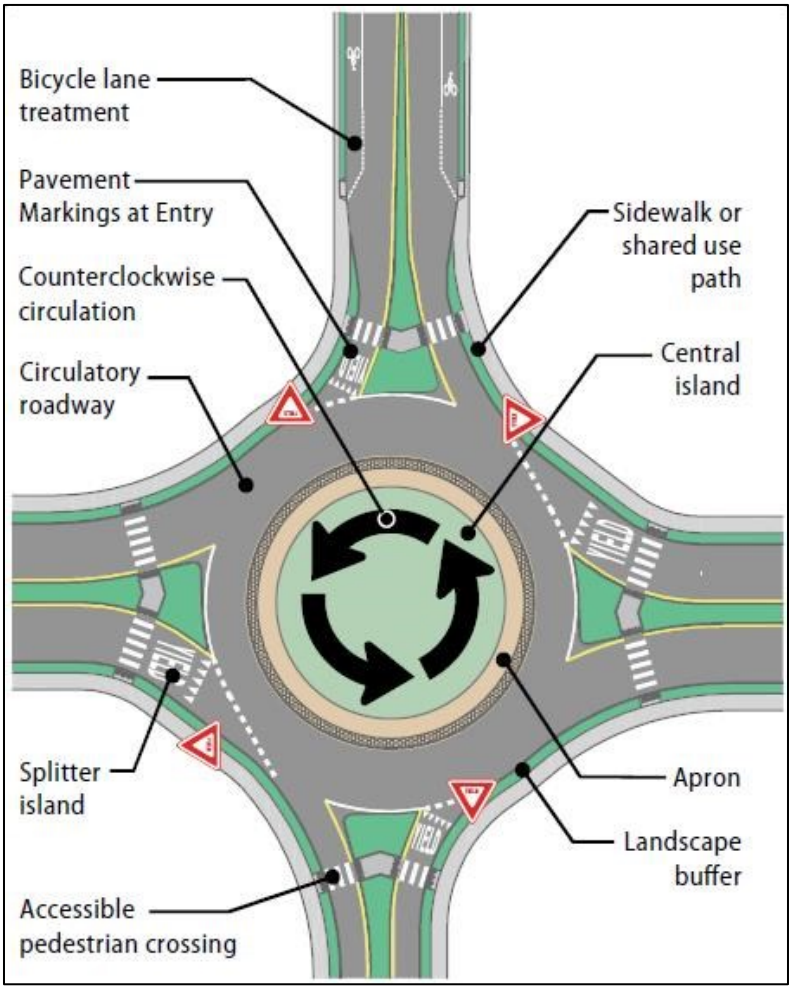


Figure 1: The layout and components of a Modern Roundabout
From FHWA (June, 2017)

For the purposes of this study, roundabouts were placed into one of three major categories.

Single Lane: Roundabouts with only one circulating lane around the center island.

Figure 2: A single lane roundabout. Located in Waconia, MN.
From Google Maps (September, 2017)

Unbalanced: Roundabouts that have two circulating lanes on at least one leg, and only one circulating lane on at least one leg.

Figure 3: An unbalanced roundabout. Located in Carver County, MN.
From Google Maps (September, 2017)

Dual Lane: Roundabouts that have two full circulating lanes on all legs around the center island.

Figure 4: A dual lane roundabout. Located in Richfield, MN.
From Google Maps (September, 2017)

How to Read This Report

Crash Records Data

These analyses used Minnesota crash data to assess crash frequency and severity before the construction of a roundabout and after construction. These analyses excluded data from the roundabout construction year.

A *site-year* is a way to quantify the amount of exposure to traffic by site. For example, a site with three years of data would have three site-years and another with four years would have four site-years. Combined, the two sites have seven site-years. This study examined 473 pre-construction site-years and 771 post construction site-years.

Vehicles Entering was another metric to adjust for exposure to traffic. Most sites used the Minnesota Traffic Mapping Application and associated Geographic Information System (GIS) layers to establish how much traffic had entered the intersection during the review years. When traffic volumes were missing or had gaps, traffic volume was either interpolated or extrapolated.

Injury Severity of Crash

Crash severity means the greatest level of injury sustained by all persons involved in a crash. One fatal crash may include one or more person killed and any number of persons who sustained other levels of injury, but it is a *K Injury Crash.*

K-Injury (Fatal) Crash: One or more person involved in the crash died due to injuries sustained in the crash

A - Injury Crash: One or more person involved in the crash sustained a serious life-altering injury due to the crash

B-Injury Crash: One or more person involved in the crash sustained moderate injury, e.g. broken bones in the crash

C- Injury Crash: One or more person involved in the crash sustained a minor injury in the crash

PDO-Injury Crash: No person involved in the crash sustained an injury and only vehicular or property damage occurred

Crash Type/Diagram

Crash type means the manner in which one or more vehicles collided with one another.

Right angle crash: When two vehicles collide perpendicular to each other, also known as a T-bone or broadside crash. This type of crash is among the highest risk of death and serious injury.

Rear-end crash: When two vehicles traveling the same direction collide with the front of the following vehicle colliding with the rear of the leading vehicle. This is the most common type of crash in Minnesota; however, it is typically of lower risk of death and serious injury.

Run-off-the-road crash: When a single vehicle departs the roadway surface and collides with a roadside object or rolls over. This includes both departing right and left from the roadway surface. This type of crash is among the highest risk of death and serious injury.

Head-On: Two vehicles collide directly into each other while heading in opposite directions striking at the front of both vehicles. This type of crash is among the highest risk of death and serious injury.

Sideswipe crash: Two vehicles collide off-center and scrape the sides of both vehicles. Sideswipe includes vehicles heading in the same direction or vehicles traveling in opposing directions. This type of crash is typically at lower risk of death and serious injury.

Left-Turn-Into-Traffic: A left turning vehicle, from either the major or the minor road collides with a vehicle crossing its intended path. This type of crash typically results in a right-angle crash or a sideswipe crash.

Other/Not Applicable/Unknown/Blank: These crash types were used when one of the above types or diagrams did not adequately address what had occurred. These four tended to be a catch-all for crashes that did not fit the above descriptions.

Multi-vehicle crash*: Involves two or more motor vehicles. This is mutually exclusive of the crash types/diagrams described above.

Pedestrian Crash*: A crash between a motor vehicle and a person walking or using a method of conveyance other than a vehicle or bicycle. This is mutually exclusive of the crash types/diagrams described above.

Bike Crash*: A crash between a motor vehicle and a person using a bicycle. This is mutually exclusive of the crash types/diagrams described above.

*Multi-Vehicle, Pedestrian, and Bike crashes are mutually exclusive from Right Angle, Rear-End, Run-off-the-Road, Head-On, Sideswipes, Left-Turn-Into-Traffic, Other/NA/Unknown, and Blank. As an example, a crash could be both a collision with a pedestrian and be coded as “Other” as well.

List of Acronyms and Terms

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
ADA	Americans with Disabilities Act (1990 Federal Law)
A Rate	Serious injury (A crash) crashes are totaled, multiplied by one hundred million, and divided by the total number of entering vehicles in the same time span
B Rate	Major Injury (B crash) crashes are totaled, multiplied by one million, and divided by the total number of entering vehicles in the same time span.
C Rate	Minor injury (C crash) crashes are totaled, multiplied by one million, and divided by the total number of entering vehicles in the same time span.
Crash Rate	Total number of crashes in a given time span, multiplied by one million, and divided by the total number of entering vehicles in the same time span
CSAH	County State Aid Highway
CTL	Channelized Turn Lanes
FA (K+A) Rate	Fatal(K crash) and Serious(A crash) injury crashes are added, multiplied by one hundred million, and divided by the total number of entering vehicles in the same time span
F(or K) Rate	Fatal(K crash) crashes are totaled, multiplied by one hundred million, and divided by the total number of entering vehicles in the same time span
FHWA	Federal Highway Administration
HAWK	High Intensity Activated Pedestrian Beacon/ Pedestrian activated flasher
MEV	Million Entering Vehicles (into an intersection)
MnDOT	Minnesota Department of Transportation
MUTCD	Manual of Uniform Traffic Control Devices
NCHRP	National Cooperative for Highway Research Program
O&M Specialist	Operation and Mobility Specialist
OCPPM	Office of Capital Programs and Performance Measures (MnDOT)
OTST	Office of Traffic, Safety, and Technology (MnDOT)
PDO Rate	Property Damage (PDO crash) crashes are totaled, multiplied by one million, and divided by the total number of entering vehicles in the same time span.
PROWAG	Public Right of Way Accessibility Guidelines
RRFB	Rectangular Rapid Flashing Beacon
TH	Trunk Highway
TWLTL	Two Way Left Turn Lane

Roundabout Study Locations

This roundabout study is the largest to date conducted in Minnesota on roundabouts. 144 individual sites were collected for this analysis.

Roundabout sites were selected from an initial list provided by the Minnesota Department of Transportation State Aid division. MnDOT State Aid has maintained a list of roundabouts constructed on the Trunk Highway Network and on local streets. The list also contained information such as the year of construction, specific and general location, prior traffic control, environment, and general geometric information. Sites with low traffic volumes, or no known traffic volume, were removed from the location site set as they were typically only servicing local traffic and businesses (residential neighborhoods, small office parks, etc). This left 142 locations for review. Two of the roundabouts have been modified since construction. The roundabouts in Forest Lake on TH 61 and Broadway Ave and at Radio Avenue and Bailey Avenue in Woodbury, were originally constructed as full dual multi-lane roundabouts. Due to the high number of crashes and complaints, the roundabouts were restriped to an unbalanced configuration (2 lanes on certain legs, 1 lane on the others). The new configurations were labeled as a separate "after" site with no before crash data.

The statistics on the sites breaks down as follows:

Table 1: Characteristics of the selected Roundabouts

Type of Roundabouts	Number of Sites	Sites with 3 years or more "Before" Data	Sites with 3 years or more "After" Data	Urban	Rural
Single Lane	104	47	83	81	23
Unbalanced (2 lanes x 1 lane)	34	25	16	33	1
Full Multi-Lane	6	4	5	6	0
Total	**144**	**69**	**104**	**120**	**24**

Table 2: Locations of the selected Roundabouts.

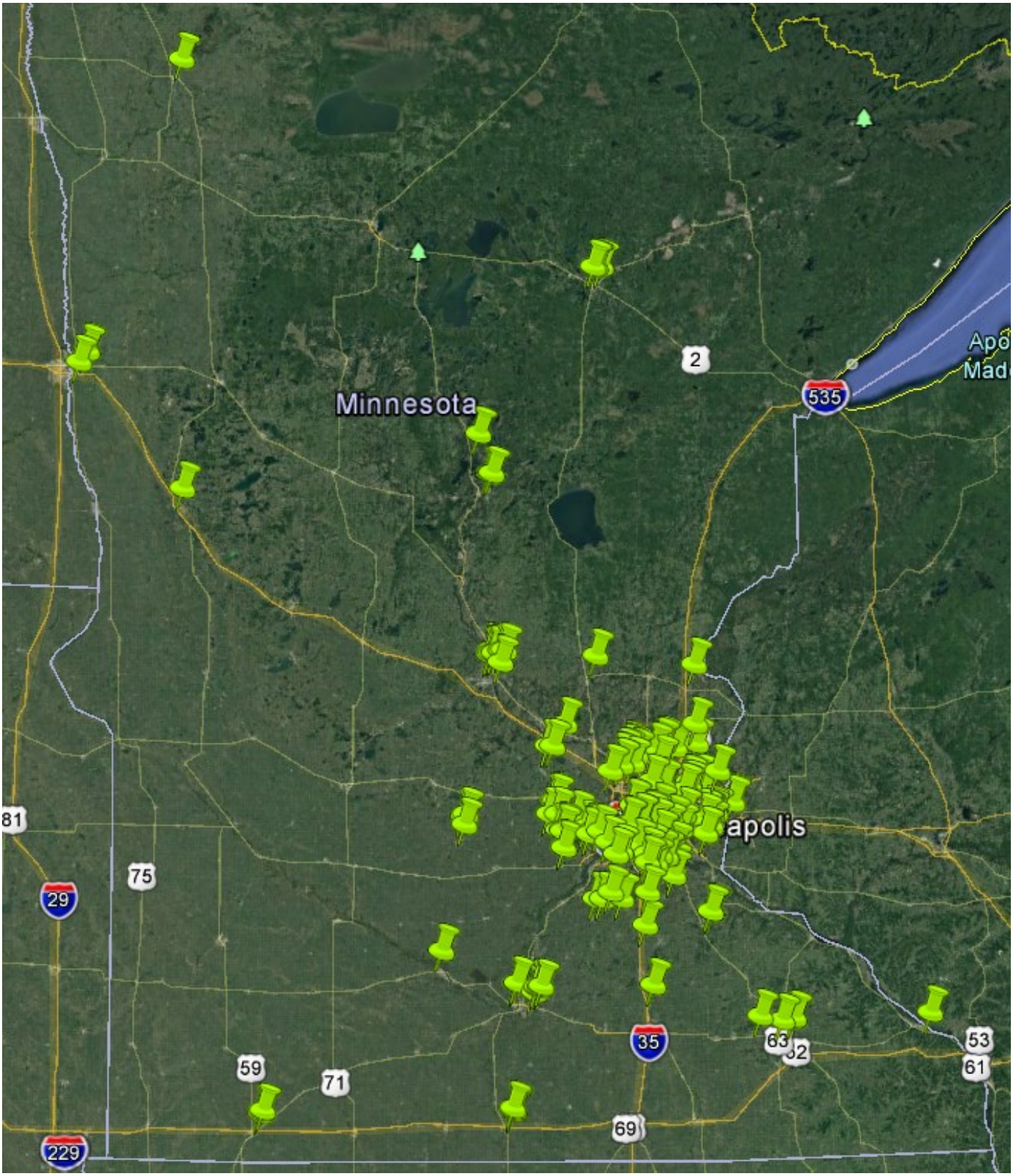
Roundabout ID	INTERSECTION	CITY	COUNTY
3.Dakota	153rd St. / Founders Lane	Apple Valley	Dakota
5.Anoka	Club West Parkway & 113th Avenue	Blaine	Anoka
6.Anoka	Lakes Parkway & Harpers Street	Blaine	Anoka
9.CrowWing	South 4th Street & College Drive	Brainerd	Crow Wing
10.CrowWing	SW 4th Street & College Drive	Brainerd	Crow Wing
11.CrowWing	Mississippi Parkway & College Drive	Brainerd	Crow Wing
13.Hennepin	Setzler Pkwy / Neddersen Pkwy / Founders Pkwy	Brooklyn Park	Hennepin
14.Wright	Pulaski Rd. and 16th St. NE	Buffalo	Wright
16.Dakota	Portland Avenue / Nicollet Blvd.	Burnsville	Dakota
17.Dakota	Burnhaven and 150th Street	Burnsville	Dakota
18.Olmsted	Frontage Road & 10th Ave NE	Byron	Olmsted
19.Scott	TH 13 (Langford Ave) at CSAH 2 (260th St E)	Cedar Lake Twp	Scott
20.Scott	Scott CSAH 23, TH 19, and Scott/Rice CSAH 86	Cedar Lake Twp	Scott
21.Hennepin	CSAH 14 (Douglas Dr. & 117th Ave	Champlin	Hennepin
22.Hennepin	117th Ave at Business Park Blvd	Champlin	Hennepin
23.Hennepin	Business Park Blvd and Emery Pkwy	Champlin	Hennepin

Roundabout ID	INTERSECTION	CITY	COUNTY
24.Carver	1/2 mile west of CSAH 17 on Bluff Creek Blvd	Chanhassen	Carver
25.Carver	Hundertmark Road and Clover Ridge Drive	Chaska	Carver
26.Carver	Pioneer Trail and Bavaria Road (N.)	Chaska	Carver
27.Carver	Pioneer Trail and Bavaria Road (S.)	Chaska	Carver
29.Carver	Village Pkwy and CR 53	Cologne	Carver
30.Anoka	39th Avenue / Jefferson St.	Columbia Heights	Anoka
31.Washington	CSAH 19 at CSAH 22	Cottage Grove	Washington
34.Dakota	Diffley Road (CSAH 30) / Rahn Road	Eagan	Dakota
35.Dakota	Northwood Prkwy / Denmark Ave	Eagan	Dakota
36.Hennepin	70th St. btwn France and York. (west)	Edina	Hennepin
37.Hennepin	70th St. btwn France and York. (middle)	Edina	Hennepin
38.Hennepin	70th St. btwn France and York. (east)	Edina	Hennepin
39.Hennepin	70th Street and Valley View Road	Edina	Hennepin
42.Dakota	TH 3 and CR 64 (190th St)	Farmington	Dakota
43.OtterTail	CSAH 1/15 S of Fergus Falls	Fergus Falls	Otter Tail
44.Washington	TH 61 at CSAH 2 (Broadway Ave)	Forest Lake	Washington
46.Rice	CSAH 1 & CSAH 46	Forest Township	Rice
47.Itasca	CSAH 23/CSAH 76	Grand Rapids	Itasca
48.Itasca	7th Avenue SE and 10th/8th Street SE	Grand Rapids	Itasca
49.Itasca	New @ Hospital Entrance	Grand Rapids	Itasca
50.Washington	TH 61 at CSAH 4 / CR 4A	Hugo	Washington
51.McLeod	Golf Course Rd. (W) & Montana St. (N & S) & 5th Ave	Hutchinson	McLeod
52.McLeod	CSAH 12 / TH 15	Hutchinson	McLeod
53.McLeod	TH 15 / CSAH 115	Hutchinson	McLeod
54.Dakota	TH 3 and Amana Trail	Inver Grove Heights	Dakota
55.Washington	TH 5 and CSAH 6 / Jamaca	Lake Elmo	Washington
56.Washington	CSAH 18 / 4th St.	Lakeland	Washington
57.Washington	CSAH 18 / Division St.	Lakeland	Washington
58.Washington	CSAH 18 / 5th St.	Lakeland	Washington
59.Dakota	CSAH 9 (Dodd Rd) at Highview Ave	Lakeville	Dakota
60.Dakota	169th and Eagleview	Lakeville	Dakota
61.Dakota	175th St and Kenrick Ave	Lakeville	Dakota
63.BlueEarth	CSAH 60 (Stadium Rd) and CSAH 82 (Victory Dr)	Mankato	Blue Earth
66.Hennepin	109th at Zachary Lane	Maple Grove	Hennepin
68.Hennepin	109th at Elm Creek Pkwy/Lancaster Ln	Maple Grove	Hennepin
74.Ramsey	Frost Ave / Parkway Dr / E Shore Dr	Maplewood	Ramsey
75.Ramsey	Frost Avenue / English St.	Maplewood	Ramsey
76.Ramsey	Kennard St. / Legacy Parkway	Maplewood	Ramsey
78.Ramsey	Castle Avenue/Van Dyke Street	Maplewood	Ramsey
80.Dakota	Mendota Heights Rd. and Visitation Drive	Mendota Heights	Dakota
81.Hennepin	Minnehaha Ave and Godfrey Pkwy	Minneapolis	Hennepin
82.Hennepin	TH 7 at Kings Point Road/CSAH 11	Minnetrista	Hennepin
83.Wright	CSAH 18 (Fenning Ave NE) and Meadow Oak Ave	Monticello	Wright
84.Clay	28th Ave S (MSAS #143) / 36th St S / 40th St S	Moorhead	Clay
85.Clay	24th Ave S (MSAS #140) and 40th St S (MSAS #141)	Moorhead	Clay
86.Clay	TH 75 & CSAH 12	Moorhead	Clay
87.Scott	TH 19 / Chalupsky	New Prague	Scott

Roundabout ID	INTERSECTION	CITY	COUNTY
88.Scott	TH 19 / Alton	New Prague	Scott
89.Scott	TH 19 / 11th Ave West	New Prague	Scott
90.Brown	TH 14 & Palmer Ave.	New Ulm	Brown
91.CrowWing	CSAH 18 & South Main Street	Nisswa	Crow Wing
92.Chisago	Fletcher Ave / N of 400th St.	North Branch	Chisago
95.Scott	Fountain Hills Dr at Jeffers	Prior Lake	Scott
96.Scott	Dakotah Parkway and Mystic Lake Blvd.	Prior Lake	Scott
97.MilleLacs	TH 95/CSAH 29 (Rum River Drive)	Princeton	Mille Lacs
98.Hennepin	66th St (CR 53) and Portland Ave (CR 35)	Richfield	Hennepin
99.Hennepin	66th St (CR 53) and Richfield Parkway	Richfield	Hennepin
100.Olmsted	North intersection - UCR Drive SE / UCR Parkway SE	Rochester	Olmsted
102.Olmsted	Fox Valley Dr / Fox Knoll Dr. SW	Rochester	Olmsted
104.Ramsey	Mount Ridge Road and Twin Lakes Parkway	Roseville	Ramsey
105.Stearns	University Dr. and 5th St	St. Cloud	Stearns
106.Stearns	Pinecone Rd and Glenview Lane	St. Cloud	Stearns
108.Stearns	CR 120 & Un-named Road 1	Sartell	Stearns
109.Stearns	CR 120 & Un-named Road 2	Sartell	Stearns
110.Stearns	CSAH 1 & CR 120	Sartell	Stearns
111.Stearns	Heritage Drive/50th Ave	Sartell	Stearns
112.Scott	CSAH 16 (McColl Drive) and Glendale Rd./Lynn Ave	Savage	Scott
115.Pennington	Greenwood St. & Pennington Ave.	Thief River Falls	Pennington
116.Carver	86th Street West and Kochia Lane	Victoria	Carver
117.Carver	TH 284 and 10th Street	Waconia	Carver
119.Carver	TH 284 and Sparrow Road/15th Street	Waconia	Carver
120.Carver	TH 284 & CSAH 10	Waconia	Carver
121.Carver	CSAH 10 & CSAH 20	Watertown	Carver
122.Carver	CSAH 20 & Paul Ave	Watertown	Carver
124.Winona	CSAH 17 / CSAH 15	Winona	Winona
125.Washington	CSAH 19 at CSAH 18 (Bailey)	Woodbury	Washington
126.Washington	CSAH 19 at Lake Rd	Woodbury	Washington
127.Washington	Lake Rd & Settler's Ridge	Woodbury	Washington
128.Washington	CSAH 13 (Radio) at CSAH 18 (Bailey)	Woodbury	Washington
129.Washington	Pioneer Drive / High School Drive 1	Woodbury	Washington
130.Washington	Pioneer Drive and Hargis Parkway	Woodbury	Washington
131.Washington	Hargis Parkway and High School Drive 1	Woodbury	Washington
132.Washington	Hargis Parkway and High School Drive 2	Woodbury	Washington
133.Washington	Hargis Parkway and High School Drive 3	Woodbury	Washington
134.Washington	Hargis Parkway and High School Drive 4	Woodbury	Washington
135.Nobles	US 59/ TH 60/ CSAH 35	Worthington	Nobles
136.Nobles	US 59/ TH 60/ Oxford St.	Worthington	Nobles
139.Carver	TH 7 and Carver CSAH 10		Carver
140.Carver	TH 7 and TH 25		Carver
141.Hennepin	28th Avenue and Lindau Lane	Bloomington	Hennepin
142.Hennepin	West River Road and Hayden Lake Road	Champlin	Hennepin
143.Hennepin	Hazelton Road East of France Avenue	Edina	Hennepin
144.Scott	CSAH 2 and CSAH 46	Elko/New Market	Scott
147.Benton	CSAH 3 at 10th Ave	Sauk Rapids	Benton

Roundabout ID	INTERSECTION	CITY	COUNTY
148.Benton	CSAH 3 at CSAH 1	Sauk Rapids	Benton
149.Scott	CR 79 and Vierling Drive	Shakopee	Scott
152.Hennepin	Louisiana Avenue and Walker Street	St. Louis Park	Hennepin
153.Washington	CSAH 13 (Radio) at CSAH 20 (Military)	Woodbury	Washington
154.Faribault	TH 169 & 7th Street/CSAH 16 East	Blue Earth	Faribault
155.Faribault	TH 169 & CSAH 16 West	Blue Earth	Faribault
156.Faribault	TH 169 & CSAH 44	Blue Earth	Faribault
158.BlueEarth	TH 22 and CSAH 17	Mankato	Blue Earth
159.BlueEarth	TH 22 and Adams	Mankato	Blue Earth
161.Stearns	Leander and 23rd	Sartell	Stearns
162.Stearns	CR 120 and CR 134	Sartell	Stearns
163.Stearns	CR 120 and CentraCare Street	Sartell	Stearns
164.Washington	Pioneer and Plymouth	Woodbury	Washington
165.Washington	Pioneer and Residential Street	Woodbury	Washington
128a.Washington	CSAH 13 (Radio) at CSAH 18 (Bailey)	Woodbury	Washington
44a.Washington	TH 61 at CSAH 2 (Broadway Ave)	Forest Lake	Washington
32.Washington	Jamaica Ave. and west ramps of TH 61	Cottage Grove	Washington
33.Washington	W. Pt. Douglas Rd, Jamaica Ave, E ramps of TH 61	Cottage Grove	Washington
64.BlueEarth	CSAH 12 and MNTH 14 EBL Ramp / Loop	Mankato	BlueEarth
65.BlueEarth	CSAH 12 and MNTH 14 WBL Ramp / Loop	Mankato	BlueEarth
69.Hennepin	Elm Creek Blvd at 99th Ave/Future TH 610 Off Ramp	Maple Grove	Hennepin
72.Hennepin	Zachary Lane (CR 202) at TH 610 North Ramp	Maple Grove	Hennepin
73.Hennepin	Zachary Lane (CR 202) at TH 610 South Ramp	Maple Grove	Hennepin
93.Washington	TH 36 EB Ramp at CSAH 29-36 Hilton Trail / Viking Dr	Pine Springs	Washington
94.Washington	TH 36 WB Ramp at CSAH 29-36 Hilton Trail / Viking Dr	Pine Springs	Washington
137.Nobles	TH 60 and I90 Off Ramp	Worthington	Nobles
145.Benton	TH 10 at CSAH 3/EB on& off ramps	Sauk Rapids	Benton
146.Benton	TH 10 at CSAH 3/WB on& off ramps	Sauk Rapids	Benton
150.Hennepin	Louisiana Avenue and Highway 7 (south ramps)	St. Louis Park	Hennepin
151.Hennepin	Louisiana Avenue and Highway 7 (north ramps)	St. Louis Park	Hennepin
79.Steele	I-35 and CSAH 12 (W)	Medford	Steele
113.Dakota	TH 52 at Wentworth / (CR 8)	South St. Paul	Dakota
123.Dakota	TH 52 at Wentworth / (CSAH 8)	West St. Paul	Dakota
160.Steele	I-35 and CSAH 12 (E)	Medford	Steele

Figure 5: A general depiction of the roundabout locations in this study



Methodology

Site Selection

The Minnesota Department of Transportation State Aid Division keeps an active inventory of known roundabouts within the State of Minnesota. This list was used as the original site selection criteria to begin selecting sites for this study.

Using Google Earth Pro, a pin was placed for each roundabout site. A total of 162 sites were initially identified and located within Google Earth Pro. Google Earth Pro was used to confirm the configuration and type of roundabout as well and to ensure the recorded construction year matched the aerial data within Google Earth. Roundabout sites that appeared to only service residential areas, small business parks, or private settings were identified for removal later. The file created, call a KMZ file, and was then brought into ArcGIS mapping software.

Crash Data

Using ArcMAP, Minnesota crash data from 2006-2015 was overlayed onto the map. A buffer of 300' was placed around each roundabout site, and used to select and extract the crash data. Based on a prior roundabout study, crashes from an additional 21 sites that had crash data back to 2004 were also added into the data set. Once this was complete, the sites that were identified as servicing residential areas, small business parks, or private settings were identified and had the site data and crash data removed from the data set. This left 142 unique sites. Two sites were identified as having changed configuration and were treated as separate sites. This yeilded a total of 144 roundabout locations to study. This extraction and cleanup gave a crash data set consisting of 4,176 crashes from 2004-2015. Each crash was tagged to the appropriate roundabout intersection.

To have a better understanding of the impacts of roundabouts, the following crash types were removed before the start of the analysis.

> Relation to Junction: Codes 00(Not Coded), 01(Not Intersection or Junction Related)
>
> Crash Type: 2(Collision with Parked Vehicle), 5 (Train), 8 (Deer), 9 (Other Animal)
>
> Year: Crashes that occurred during the construction year were removed. The exception to this were the two sites that were modified to an unbalanced roundabout in mid-2013.
>
> Crashes within interchanges were only included if the crash was coded to the the roundabout intersections. Crashes on the mainline, ramps, and outside the interchange terminals were not included.

After these crashes were removed from the data set, this left a total of 2,711 crashes to analyze.

Crashes were then assigned a descriptor of being "before" construction and "after" construction.

Traffic Data

Using the Traffic Mapping Application produced by MnDOT's Office of Traffic Forecasting and Analysis[1] and the corresponding GIS layers, ArcMAP was again used to assign traffic volume and entering traffic figures to each roundabout in this study. With traffic volumes going back to 1992, most sites had adequate data to create the amount of traffic entering before the construction of the roundabout, and after the construction as well. Most sites would only have data collected or calculated every other year. When data was missing for a year, the Average Daily Traffic was extrapolated or interpolated so each site would have a full before period and after period for vehicles entering.

Table 3: Site Years and Vehicles Entering for certain Roundabout Types

Type of Roundabouts	Number of Sites	Site-Years		Vehicles Entering the Intersection	
		Before Construction	After Construction	Before Construction	After Construction*
Single Lane	104	279	622	1,129 Million	1,605 Million
Unbalanced (2 lanes x 1 lane)	34	162	120	998.9 Million	664.9 Million
Full Multi-Lane	6	22	29	222.9 Million	216.2 Million
Total	**144**	**463**	**771**	**2,351 Million**	**2,486 Million**

***The after construction vehicles entering the intersection may give the appearance that some intersections are having a reduction in the amount of traffic entering the intersection. Though small fluctuations can occur at roundabouts after opening, this study did not notice any large decreases at any roundabout after construction. The perceived decreases have more to do with the larger before sample set then the after sample set, especially for unbalanced roundabouts.

[1] The Minnesota Department of Transportation Office of Traffic Forecasting and Analysis is responsible for thousands of traffic counts that are collected on Minnesota roadways each year. This information is used to produce volume, classification, speed and weight data as well as traffic forecasts, vehicle miles traveled (VMT) figures, reports, maps and analysis. Traffic data products are used in safety evaluation, pavement design, funding decisions, forecasting, modeling, and much more. From http://www.dot.state.mn.us/traffic/data/index.html

Before Construction Crash Data

Crash data listed in this section is attributed to crashes that occurred at a future roundabout site before the completion of the roundabout. Before crash data ranged from one year prior to construction to 8 years prior to construction. Crash data that occurred before construction, but during the construction year was excluded from any of the analysis. Before Crash data ranged from 2004 until 2013, was collected from 84 individual sites, and encompasses 463 site years from all sites.

Table 4: Crash data from before construction based on Severity

Roundabout Type	Total Crashes	K	A	B	C	PDO
Single Lane	499	7	17	61	140	274
Unbalanced (2 lanes x 1 lane)	524	0	7	42	124	351
Full Multi-Lane	197	0	3	15	46	133
Total Crashes	**1,220**	**7**	**27**	**118**	**310**	**758**

Table 5: Crash data from before construction based on Crash Type

Roundabout Type	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Right	Head On	Sideswipe Opposing
Single Lane	137	15	45	10	197	14	19	13
Unbalanced	221	28	43	5	158	10	19	6
Full Multi-Lane	95	7	26	0	46	0	2	2
Total	**453**	**50**	**114**	**15**	**401**	**24**	**40**	**21**

Table 6: Additional Crash data from before construction based on Crash Type

Roundabout Type	Other	Not Applicable	Unknown	Blank	Multi-Vehicle	Pedestrian Crash	Bike Crash
Single Lane	38	2	3	6	455	6	1
Unbalanced	20	6	1	7	491	4	4
Full Multi-Lane	14	4	0	1	181	0	4
Total	**72**	**12**	**4**	**14**	**1,127**	**10**	**9**

After Construction Crash Data

Crash data listed in this section is attributed to crashes that occurred at a built roundabout site after the completion of the roundabout. After crash data ranged from one year after completion to 10 years. Roundabouts built before 2006 only had data from 2006-2015 included in this data. Crash data that occurred after construction, but during the construction year was excluded from any of the analysis. After Crash data ranged from 2006 until 2015, was collected from 142 individual sites, and encompasses 771 site years from all sites.

Table 7: Crash data from after construction based on Severity

Roundabout Type	Total Crashes	K	A	B	C	PDO
Single Lane	518	1	4	35	87	391
Unbalanced (2 lanes x 1 lane)	502	0	1	18	74	409
Full Multi-Lane	471	0	0	15	53	403
Total Crashes	**1,491**	**1**	**5**	**68**	**214**	**1,203**

Table 8: Crash data from after construction based on Crash Type

Roundabout Type	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Right	Head On	Sideswipe Opposing
Single Lane	132	42	11	31	89	69	28	5
Unbalanced	112	163	5	20	79	40	13	6
Full Multi-Lane	64	209	19	8	104	11	2	5
Total	**308**	**414**	**35**	**59**	**272**	**120**	**43**	**16**

Table 9: Additional Crash data from after construction based on Crash Type

Roundabout Type	Other	Not Applicable	Unknown	Blank	Multi-Vehicle	Pedestrian Crash	Bike Crash
Single Lane	73	18	2	18	313	10	3
Unbalanced	33	15	1	15	399	3	0
Full Multi-Lane	26	3	0	20	435	5	2
Total	**132**	**36**	**3**	**53**	**1,147**	**18**	**5**

Two of the sites, at TH 61/CSAH 2 (Broadway) and at Radio(CSAH 13)/Bailey(CSAH 18), were converted from full dual lane roundabouts to unbalanced roundabouts in mid-2013. The roundabout types and crashes were adjusted accordingly. Both sites are represented as two distinct sites in the after period. Only the original, pre-roundabout condition is included in the before data.

Table 10: A comparison of two roundabouts that had traffic control changes from full dual lane to unbalanced.

Site Location	Prior Traffic Control	Year of Roundabout Construction	Before Roundabout Total Crashes	Full Dual Lane Total Crashes	Unbalanced Total Crashes
TH 61/ CSAH 2 (Broadway)	Traffic Signal	2010	50	42	21
Radio(CSAH 13) / Bailey(CSAH 18)	All-Way Stop	2007	3	81	17

Fatal and Serious Injury Crashes Exploratory Analysis

With the limited number of fatal and serious injury crashes, examining individual reports may offer insight into potential issues with roundabouts. A summary of the fatal and serious injury crashes is included in Table 11.

Table 11: Summary of the fatal and serious injury crashes that have occurred at roundabouts, 2006-2015.

Crash ID	Date	Location and Type	Crash Description
100740239	3/13/2010	MN Highway 7 and MN Highway 25 Carver County Single Lane Roundabout	Serious Injury Crash – Single Vehicle went through the roundabout raised center island at a high rate of speed. Report cited driver impairment as a contributing factor.
102950184	10/22/2010	Minnehaha and Godfrey Road, Minneapolis Single Lane Roundabout	Serious Injury Crash – Bicyclist was hit be vehicle exiting the roundabout
111310223	5/10/2011	MN Highway 19 and 11th Avenue, New Prague Single Lane Roundabout	Fatal Crash – Single Vehicle Motorcyclists entered the roundabout raised center island at a high rate of speed and hit a sign.
130670191	3/1/2013	MN Highway 3 and 190th Street, Dakota County Single Lane Roundabout	Serious Injury Crash – Driver went through the roundabout, over the median, and collided with vehicle head-on in opposing lane. Driver was cited for impaired driving.
143600104	12/26/2014	Radio Drive and Bailey Drive, Woodbury Unbalanced Roundabout	Serious Injury Crash – Motorcyclist entered the roundabout without yielding and was hit by a vehicle traveling through the intersection. Motorcyclist was found to be impaired upon testing.
152420096	8/30/2015	Radio Drive and Military Road, Woodbury Single Lane Roundabout	Serious Injury Crash – Motorcyclist was entering the roundabout, lost control, and flipped. Driver was considered impaired at the time of crash.

Analysis

The purpose of this analysis is to compare the before construction crash rates, based on severity, type, and diagram with the after crash rates. Crash rates are calculated with the formula:

Equation 1: The Crash Rate Equation used for comparisons through this report

$$Crash\ Rate\ = \frac{C\ x\ 1{,}000{,}000}{ADT\ x\ 365\ Days\ x\ Y}$$

$C = Number\ of\ Selected\ Crashes$

$ADT = Total\ Number\ of\ Vehicles\ Entering\ the\ Intersection$

$Y = Number\ of\ Years$

The crash rate is used as a way to normalize the crash data and to ensure that an equal comparison of sites with different traffic volumes can be made.

Single Lane Roundabouts

Single lane roundabouts were the first roundabouts built in Minnesota. They tend to be considered the basic roundabout and likely the default option for most engineers and transportation officials. Only as traffic volumes increase are more complex and multi-lane roundabouts considered.

Based on the before-after analysis shown here, single lane roundabouts are showing a remarkable performance and decrease in the number of fatal, serious, and injury-related crashes. In fact, the total crash reduction at single lane roundabouts comes completely from the reduction in injury crashes, as property damage crashes remain at the same rate.

Table 12: Crash data from Single Lane Roundabouts with before construction and after construction crash data based on Severity

Description	Vehicles Entering	Total Crashes	K	A	B	C	PDO
Before Crashes	1,129,275,675	499	7	17	61	140	274
Before Crash Rate	NA	0.442	0.0062	0.015	0.054	0.124	0.243
After Crashes	1,604,841,825	518	1	4	35	87	391
After Crash Rate	NA	0.323	0.001	0.0025	0.022	0.054	0.244
Percent Increase/Decrease (By Rate)	**+42.1%**	**-27.0%**	**-89.9%**	**-83.4%**	**-60.9%**	**-56.3%**	**+0.4%**

Table 13: Crash data from Single Lane Roundabouts with before construction and after construction crash data based on the crash diagram

Description	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Rt.	Head On	Sideswipe Opp
Before Crashes	137	15	45	10	197	14	19	13
Before Rate	0.121	0.013	0.040	0.009	0.174	0.012	0.017	0.012
After Crashes	132	42	11	31	89	69	28	5
After Rate	0.082	0.026	0.007	0.019	0.055	0.043	0.017	0.003
Percent Increase/Decr	**-32.2%**	**+97.0%**	**-82.8%**	**+118.1%**	**-68.2%**	**+246.8%**	**+3.7%**	**-72.9%**

Table 14: Crash data from Single Lane Roundabouts with before construction and after construction crash data based on the crash diagram/type

Description	Other	Not Applicable	Unknown	Blank/Right-Turn	Multi-Vehicle	Ped Crash	Bike Crash
Before Crashes	38	2	3	6	455	6	1
Before Crash Rate	0.034	0.002	0.003	0.005	0.403	0.005	0.001
After Crashes	73	18	2	18	313	10	3
After Crash Rate	0.045	0.011	0.001	0.011	0.195	0.006	0.002
Percent Increase/ Decrease	**+35.2%**	**+533.3%**	**-53.1%**	**+111.1%**	**-51.6%**	**+17.3%**	**+111.1%**

Some of the highlights from the single lane roundabout analysis include:

- An 89% reduction in Fatal Crashes
- An 83% reduction in Serious Injury Crashes
- The Fatal and Serious Injury Crash Rate, one of the Minnesota Department of Transportation's Statewide Performance Measures, decreased from 0.021 Severe Crashes per 1,000,000 Vehicles Entering to 0.003 Severe Crashes per 1,000,000 Vehicles Entering. This marks an 86% reduction in severe crashes.
- Fatal and Injury Crashes (K, A, B, and C injury) decreased from 0.20 injury crashes per 1,000,000 Vehicles Entering to 0.08 injury crashes per 1,000,000 Vehicles Entering. This marks a 60% reduction in injury crashes.
- Right Angle crashes, typically the most deadly type of crash in Minnesota, had a total reduction of 68% of all crash severities.
- Left Turn into Traffic crashes had an 83% reduction.
- Multi-vehicle crashes had a 51% reduction.

Unbalanced (2x1 Lane) Roundabouts

Unbalanced roundabouts, or those that have a different number of circulating lanes on different approaches, are typically used in locations where there is a significant traffic volume on the main road and a much smaller volume on the minor road. Typically with the traffic patterns at these locations, certain legs will only need one lane within the circulatory roadway, while other will need additional (typically two) lanes in the circulatory roadway.

Based on the before-after analysis, unbalanced roundabouts are not having the same success as the single lane roundabouts. Many of the sites have seen an *increase* in the frequency of crashes, and the overall total crash rates. However, unbalanced roundabouts are achieving a noticeable reduction in fatal, serious injury, and other injury crashes.

Table 15: Crash data from Unbalanced Roundabouts with before construction and after construction crash data based on Severity

Description	Vehicles Entering	Total Crashes	K	A	B	C	PDO
Before Crashes	998,943,195	524	0	7	42	124	351
Before Crash Rate	NA	0.525	0.000	0.007	0.042	0.124	0.351
After Crashes	664,905,712	502	0	1	18	74	409
After Crash Rate	NA	0.755	0.000	0.002	0.027	0.111	0.615
Percent Increase/ Decrease (By Rate)	**-33.4%**	**+43.9%**	**0.0%**	**-78.5%**	**-35.6%**	**-10.3%**	**+75.1%**

Table 16: Crash data from Unbalanced Roundabouts with before construction and after construction crash data based on the crash diagram

Description	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Rt.	Head On	Sideswipe Opp
Before Crashes	221	28	43	5	158	10	19	6
Before Rate	0.221	0.028	0.043	0.005	0.158	0.010	0.019	0.006
After Crashes	112	163	5	20	79	40	13	6
After Rate	0.168	0.245	0.008	0.030	0.119	0.060	0.020	0.009
Percent Increase/Decr	**-23.9%**	**+774.6%**	**-82.5%**	**+501.0%**	**-24.9%**	**+501.0%**	**+2.8%**	**+50.2%**

Table 17: Crash data from Unbalanced Roundabouts with before construction and after construction crash data based on the crash diagram/type

Description	Other	Not Applicable	Unknown	Blank/Right-Turn	Multi-Vehicle	Ped Crash	Bike Crash
Before Crashes	20	6	1	7	491	4	4
Before Crash Rate	0.020	0.006	0.001	0.007	0.492	0.004	0.004
After Crashes	33	15	1	15	399	3	0
After Crash Rate	0.050	0.023	0.002	0.023	0.600	0.005	0.000
Percent Increase/ Decrease	**+147.9%**	**+275.6%**	**0.0%**	**+221.9%**	**+22.1%**	**+12.7%**	**-100.0%**

Some of the highlights from the unbalanced roundabout analysis include:

- No reported fatal crashes at any of the sites.
- A 78% reduction in Serious Injury Crashes
- The Fatal and Serious Injury Crash Rate, one of the Minnesota Department of Transportation's Statewide Performance Measures, decreased from 0.007 Severe Crashes per 1,000,000 Vehicles Entering to 0.002 Severe Crashes per 1,000,000 Vehicles Entering. This marks a 78% reduction in severe crashes.
- Fatal and Injury Crashes (K, A, B, and C injury) decreased from 0.17 injury crashes per 1,000,000 Vehicles Entering to 0.14 injury crashes per 1,000,000 Vehicles Entering. This marks an18% reduction in injury crashes.
- Right Angle crashes, typically the most deadly type of crash in Minnesota, had a total reduction of 25% of all crash severities.
- Left Turn into Traffic crashes had an 83% reduction.

Some of the results to notice for future considerations of unbalanced roundabouts include:

- The total crashes rate is up about 44%
- Sideswipe Same Direction crash rate is up 774%
- Multi-vehicle crashes had a 22% increase.

Dual Lane Roundabouts

Full Dual roundabouts, or those that have a 2 circulating lanes on each approach, are typically used in locations where there is a significant traffic volume on the main road and on the minor road. Since all of the legs have significant traffic volumes, two circulating lanes are needed on all legs.

Based on the before-after analysis, dual roundabouts are not having the same success as the single lane roundabouts, and have even higher crash rates then unbalanced roundabouts. Many of the sites have seen an *increase* in the frequency of crashes, and the overall total crash rates. However, dual lane roundabouts are achieving a reduction in serious injury crashes.

Table 18: Crash data from Dual Lane Roundabouts with before construction and after construction crash data based on Severity

Description	Vehicles Entering	Total Crashes	K	A	B	C	PDO
Before Crashes	222,961,345	197	0	3	15	46	133
Before Crash Rate	NA	0.884	0.000	0.013	0.067	0.206	0.597
After Crashes	216,209,639	471	0	0	15	53	403
After Crash Rate	NA	2.178	0.000	0.000	0.069	0.245	1.864
Percent Increase/ Decrease (By Rate)	**-3.0%**	**+146.6%**	**0.0%**	**-100.0%**	**+3.1%**	**+18.8%**	**+212.5%**

Table 19: Crash data from Dual Lane Roundabouts with before construction and after construction crash data based on the crash diagram

Description	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Rt.	Head On	Sideswipe Opp
Before Crashes	95	7	26	0	46	0	2	2
Before Rate	0.426	0.031	0.117	0.000	0.206	0.000	0.009	0.009
After Crashes	64	209	19	8	104	11	2	5
After Rate	0.296	0.967	0.088	0.037	0.481	0.051	0.009	0.023
Percent Increase/Decr	**-30.5%**	**+2,979%**	**-24.6%**	**+800%**	**+133.1%**	**+1,100**	**+3.1%**	**+157.8%**

Table 20: Crash data from Dual Lane Roundabouts with before construction and after construction crash data based on the crash diagram/type

Description	Other	Not Applicable	Unknown	Blank/Right-Turn	Multi-Vehicle	Ped Crash	Bike Crash
Before Crashes	14	4	0	1	181	0	4
Before Crash Rate	0.063	0.018	0.000	0.004	0.812	0.000	0.018
After Crashes	26	3	0	20	435	5	2
After Crash Rate	0.120	0.014	0.000	0.093	2.012	0.023	0.009
Percent Increase/ Decrease	**91.5%**	**-22.7%**	**0.0%**	**1962.5%**	**147.8%**	**+500%**	**-48.4%**

Some of the highlights from the dual lane roundabout analysis include:

- No reported fatal crashes at any of the sites.
- A 100% reduction in Serious Injury Crashes
- The Fatal and Serious Injury Crash Rate, one of the Minnesota Department of Transportation's Statewide Performance Measures, decreased from 0.013 Severe Crashes per 1,000,000 Vehicles Entering to 0.00 Severe Crashes per 1,000,000 Vehicles Entering. This marks a 100% reduction in severe crashes.
- Left Turn into Traffic crashes had a 25% reduction.

Some of the results to notice for future considerations of dual lane roundabouts include:

- The total crash rate is up about 146%
- Sideswipe Same Direction crash rate is up 2,979%
- Right Angle crashes are up 133%
- Multi-vehicle crashes had a 148% increase.

All Roundabouts

Though each type of roundabout has different safety performance records, the tables below are the aggregated data from all 144 roundabout sites within this study.

Table 21: Crash data from all Roundabouts with before construction and after construction crash data based on Severity

Description	Vehicles Entering	Total Crashes	K	A	B	C	PDO
Before Crashes	2,351,180,215	1,220	7	27	118	310	758
Before Crash Rate	NA	0.519	0.003	0.011	0.050	0.132	0.322
After Crashes	2,485,957,176	1,491	1	5	68	214	1,203
After Crash Rate	NA	0.600	0.000	0.002	0.027	0.086	0.484
Percent Increase/ Decrease (By Rate)	**+5.7%**	**+15.6%**	**-86.5%**	**-82.5%**	**-45.5%**	**-34.7%**	**+50.1%**

Table 22: Crash data from all Roundabouts with before construction and after construction crash data based on the crash diagram

Description	Rear End	Sideswipe Same Dir	Left Turn	Ran-off-Road Left	Right Angle	Ran-off-Road Rt.	Head On	Sideswipe Opp
Before Crashes	453	50	114	15	401	24	40	21
Before Rate	0.193	0.021	0.048	0.006	0.171	0.010	0.017	0.009
After Crashes	308	414	35	59	272	120	43	16
After Rate	0.124	0.167	0.014	0.024	0.109	0.048	0.017	0.006
Percent Increase/Decr	**-35.7%**	**+683.1%**	**-71.2%**	**+272.0%**	**-35.8%**	**+372.9%**	**+1.7%**	**-27.9%**

Table 23: Crash data from all Roundabouts with before construction and after construction crash data based on the crash diagram/type

Description	Other	Not Applicable	Unknown	Blank/Right-Turn	Multi-Vehicle	Ped Crash	Bike Crash
Before Crashes	72	12	4	14	1,127	10	9
Before Crash Rate	0.031	0.005	0.002	0.006	0.479	0.004	0.004
After Crashes	132	36	3	53	1,147	18	5
After Crash Rate	0.053	0.014	0.001	0.021	0.461	0.007	0.002
Percent Increase/ Decrease	**+73.4%**	**+183.7%**	**+0.0%**	**+258.0%**	**-3.7%**	**+70.2%**	**-47.5%**

Some of the highlights from the total roundabout analysis include:

- An 87% reduction in Fatal Crashes
- An 83% reduction in Serious Injury Crashes
- The Fatal and Serious Injury Crash Rate, one of the Minnesota Department of Transportation's Statewide Performance Measures, decreased from 0.0144 Severe Crashes per 1,000,000 Vehicles Entering to 0.002 Severe Crashes per 1,000,000 Vehicles Entering. This marks an 84% reduction in severe crashes.
- Fatal and Injury Crashes (K, A, B, and C injury) decreased from 0.20 injury crashes per 1,000,000 Vehicles Entering to 0.12 injury crashes per 1,000,000 Vehicles Entering. This marks a 40% reduction in injury crashes.
- Right Angle crashes, typically the most deadly type of crash in Minnesota, had a total reduction of 36% of all crash severities.
- Left Turn into Traffic crashes had a 71% reduction.

Comparing to Other Traffic Control Devices

The type of traffic control at any intersection is usually based on several factors, and is typically selected by an engineer after going through an engineering evaluation process. Since roundabouts are typically a large investment, how they perform compared to other intersection types should always be evaluated. Safety and crash performance is only one aspect of that selection. Engineers should always weigh the known safety benefits (and disadvantages) with other aspects such as user delay, right-of-way impacts, environmental context, costs, political, demographic and other factors.

Table 24: Crash Rates and Fatal and Serious Injury Crash Rates comparing various Traffic Control Devices to Roundabouts. and

Figure 6: A graphical representation of crash rates, by traffic control device highlight the crash performance (by crash rate and fatal/serious injury crash rate) against other common types of traffic control used in Minnesota. The rates are from the 2015 Minnesota Intersection Toolkit, and based on 5 years of crash data from 2011-2015.

Table 24: Crash Rates and Fatal and Serious Injury Crash Rates comparing various Traffic Control Devices to Roundabouts.

Traffic Control Device	**Crash Rate**	**Fatal and Serious Injury Crash Rate**
Urban Thru-Stop	0.18	0.33
Rural Thru-Stop	0.25	1.05
Signal - Low Volume/Low Speed	0.52	0.42
All-Way Stop	0.35	0.57
Single Lane Roundabout	*0.32*	*0.31*
Signal - High Volume/Low Speed	0.70	0.76
Signal - High Volume/High Speed	0.45	0.48
Unbalanced Roundabout	*0.76*	*0.15*
Dual Lane Roundabout	*2.18*	*0.00*
All Roundabouts	*0.51*	*0.24*

Definitions of the intersection control types above are as follows:

Urban Thru-Stop – Minor Road is controlled by a stop sign or amber flashers; general environment is listed as urban or suburban

Rural Thru-Stop– Minor Road is controlled by a stop sign or amber flashers; general environment is listed as rural

Signal - Low Volume/Low Speed – Traffic control device is a traffic signal; speed limit is 45 mph or lower; the no leg has a volume more than 15,000 vehicles per day

All-Way Stop – All approaches are stop controlled

Signal - High Volume/Low Speed – Traffic control device is a traffic signal; speed limit is 45 mph or lower; the highest volume leg is more than 15,000 vehicles per day

Signal - High Volume/High Speed– Traffic control device is a traffic signal; speed limit is greater than 45 mph; the highest volume leg is more than 15,000 vehicles per day

Figure 6: A graphical representation of crash rates, by traffic control device

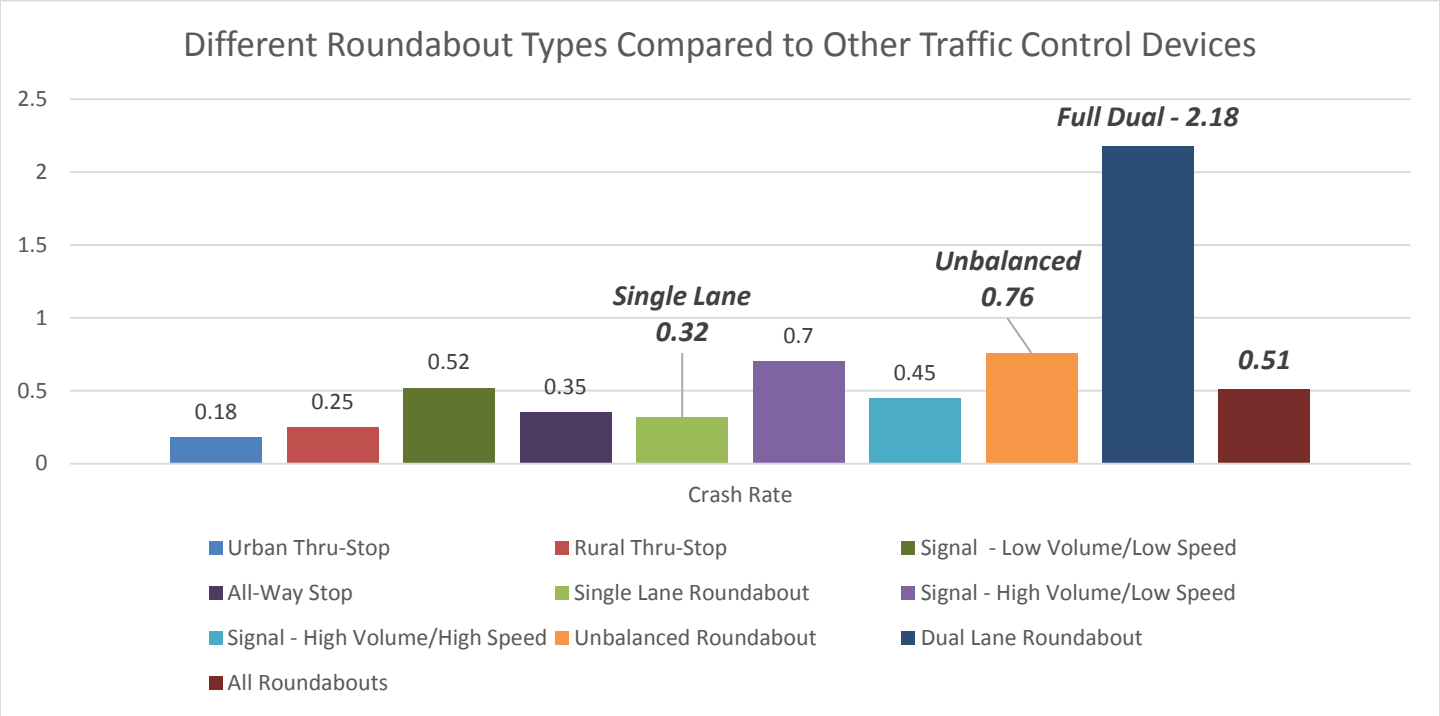
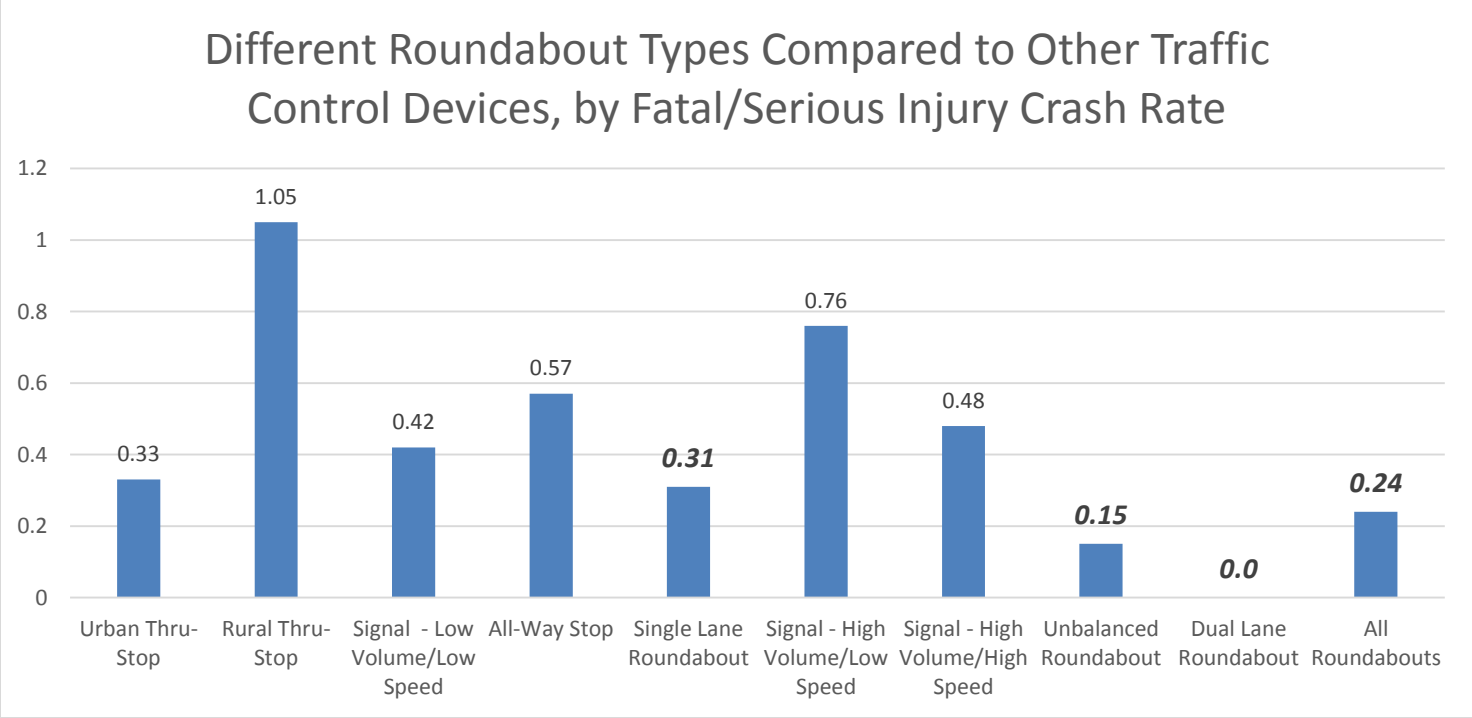


Figure 7: A graphical representation of fatal/serious injury crash rates, by traffic control device



Conclusion

Roundabouts in Minnesota have experienced over an 80% reduction in fatal and serious injury crashes. At the time of this report, there still has not been a multi-vehicle fatality in a roundabout in Minnesota. Other important highlights highlights include:

- An 86% reduction in the fatal crash rate at all roundabout types (Single Lane, Unbalanced, and full Dual Lane Roundabouts)
- An 83% reduction in the serious injury crash rate at all roundabout types (Single Lane, Unbalanced, and full Dual Lane Roundabouts)
- A 69% reduction in the Right Angle crash rate at Single Lane Roundabouts.
- An 83% reduction in the Left Turning crash rate at Single Lane Roundabouts.
- A 61% reduction in the injury crash rate at Single Lane Roundabouts
- A 42% reduction in the injury crash rate at all roundabout types (Single Lane, Unbalanced and full Dual Lane Roundabouts)
- The average crash rates for roundabouts by type is shown below.

Type of Roundabouts	Number of Sites	Crash Rate (CR)	Fatal and Serious Injury Rate (FAR)
Single Lane	104	0.32	0.31
Unbalanced (2 lanes x 1 lane)	34	0.76	0.15
Full Multi-Lane	6	2.18	0.0
Total (All Roundabouts)	**144**	**0.60**	**0.24**

Bibliography

"Minnesota Department of Transportation." *SALT Home*. N.p., n.d. Web. October2 2016. http://www.dot.state.mn.us/stateaid/roundabout/RaListOct2016.xlsx

Federal Highway Administration. *Roundabouts: An Informational Guide*. Tech. no. FHWA-RD-00-067. McLean, VA: Bared, Joe, June 2ooo. Web. 11 Oct. 2016. http://www.fhwa.dot.gov/publications/research/safety/00068/

National Cooperative Highway Research Program. *Modern Roundabout Practice in the United States*. Rep. Http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_264.pdf , 1998. Web. 18 Oct. 2016.

Federal Highway Administration, Highway Safety Information System (HSIS). *Data Request.* Submitted and Responded. September 18, 2013 & November 18, 2016. Available online at: http://www.hsisinfo.org/index.cfm

Google. Google Maps. Accessed continuously from Accessed continuously from October 1 – July 2017. < https://maps.google.com/

Minnesota Department of Transportation, State Aid for Local Transportation. *Crash Mapping Analysis Tool.* Accessed continuously from October 1 - July, 2017. http://www.dot.state.mn.us/stateaid/crashmapping.html

Minnesota Department of Transportation. *Interactive Basemap*. Accessed continuously from Accessed continuously from October 1 - July, 2017. http://gisservices.dot.state.mn.us/geocortex/essentials/web/viewer.aspx?site=mndot_basemap

Minnesota Department of Transportation. *2006-2015 Crash Data.* Accessed continuously from Accessed continuously from October 1 - July, 2017.

Minnesota Department of Transportation, Traffic Forecasting and Analysis. *AADT GIS Shapefile.* Accessed continuously from October 1 - July, 2017. http://www.dot.state.mn.us/traffic/data/data-products.html#volume

Appendix A – Roundabout Data Sheets

Appendix Page Number	CITY	COUNTY	INTERSECTION
A.1	Apple Valley	Dakota	153rd St. / Founders Lane
A.2	Blaine	Anoka	Club West Parkway & 113th Avenue
A.3	Blaine	Anoka	Lakes Parkway & Harpers Street
A.4	Bloomington	Hennepin	28th Avenue and Lindau Lane
A.5	Blue Earth	Faribault	TH 169 & 7th Street/CSAH 16 East
A.6	Blue Earth	Faribault	TH 169 & CSAH 16 West
A.7	Blue Earth	Faribault	TH 169 & CSAH 44
A.8	Brainerd	Crow Wing	SW 4th Street & College Drive
A.9	Brainerd	Crow Wing	Mississippi Parkway & College Drive
A.10	Brainerd	Crow Wing	South 4th Street & College Drive
A.11	Brooklyn Park	Hennepin	Setzler Pkwy / Neddersen Pkwy / Founders Pkwy
A.12	Buffalo	Wright	Pulaski Rd. and 16th St. NE
A.13	Burnsville	Dakota	Portland Avenue / Nicollet Blvd.
A.14	Burnsville	Dakota	Burnhaven and 150th Street
A.15	Byron	Olmsted	Frontage Road & 10th Ave NE
A.16	Cedar Lake Twp	Scott	Scott CSAH 23, TH 19, and Scott/Rice CSAH 86
A.17	Cedar Lake Twp	Scott	TH 13 (Langford Ave) at CSAH 2 (260th St E)
A.18	Champlin	Hennepin	West River Road and Hayden Lake Road
A.19	Champlin	Hennepin	CSAH 14 (Douglas Dr. & 117th Ave
A.20	Champlin	Hennepin	117th Ave at Business Park Blvd
A.21	Champlin	Hennepin	Business Park Blvd and Emery Pkwy
A.22	Chanhassen	Carver	1/2 mile west of CSAH 17 on Bluff Creek Blvd
A.23	Chaska	Carver	Hundertmark Road and Clover Ridge Drive
A.24	Chaska	Carver	Pioneer Trail and Bavaria Road (N.)
A.25	Chaska	Carver	Pioneer Trail and Bavaria Road (S.)
A.26	Cologne	Carver	Village Pkwy and CR 53
A.27	Columbia Heights	Anoka	39th Avenue / Jefferson St.
A.28	Cottage Grove	Washington	CSAH 19 at CSAH 22
A.29	Cottage Grove	Washington	Jamaica Ave. and west ramps of TH 61
A.30	Cottage Grove	Washington	W. Pt. Douglas Rd, Jamaica Ave, E ramps of TH 61
A.31	Eagan	Dakota	Diffley Road (CSAH 30) / Rahn Road
A.32	Eagan	Dakota	Northwood Prkwy / Denmark Ave
A.33	Edina	Hennepin	Hazelton Road East of France Avenue
A.34	Edina	Hennepin	70th St. btwn France and York (West)
A.35	Edina	Hennepin	70th St. btwn France and York (Middle)
A.36	Edina	Hennepin	70th St. btwn France and York (East)
A.37	Edina	Hennepin	70th Street and Valley View Road
A.38	Elko/New Market	Scott	CSAH 2 and CSAH 46
A.39	Farmington	Dakota	TH 3 and CR 64 (190th St)
A.40	Fergus Falls	Otter Tail	CSAH 1/15 S of Fergus Falls
A.41	Forest Lake	Washington	TH 61 at CSAH 2 (Broadway Ave)
A.42	Forest Lake	Washington	TH 61 at CSAH 2 (Broadway Ave)
A.43	Forest Township	Rice	CSAH 1 & CSAH 46
A.44	Grand Rapids	Itasca	CSAH 23/CSAH 76
A.45	Grand Rapids	Itasca	7th Avenue SE and 10th/8th Street SE
A.46	Grand Rapids	Itasca	New @ Hospital Entrance
A.47	Hugo	Washington	TH 61 at CSAH 4 / CR 4A
A.48	Hutchinson	McLeod	Golf Course Rd. (W) & Montana St.
A.49	Hutchinson	McLeod	CSAH 12 / TH 15
A.50	Hutchinson	McLeod	TH 15 / CSAH 115
A.51	Inver Grove Heights	Dakota	TH 3 and Amana Trail
A.52	Lake Elmo	Washington	TH 5 and CSAH 6 / Jamaca
A.53	Lakeland	Washington	CSAH 18 / 4th St.
A.54	Lakeland	Washington	CSAH 18 / Division St.
A.55	Lakeland	Washington	CSAH 18 / 5th St.
A.56	Lakeville	Dakota	CSAH 9 (Dodd Rd) at Highview Ave
A.57	Lakeville	Dakota	169th and Eagleview

Appendix Page Number	CITY	COUNTY	INTERSECTION
A.58	Lakeville	Dakota	175th St and Kenrick Ave
A.59	Mankato	BlueEarth	TH 22 and CSAH 17
A.60	Mankato	Blue Earth	TH 22 and Adams
A.61	Mankato	Blue Earth	CSAH 60 (Stadium Rd) and CSAH 82 (Victory Dr)
A.62	Mankato	Blue Earth	CSAH 12 and MNTH 14 EBL Ramp / Loop
A.63	Mankato	Blue Earth	CSAH 12 and MNTH 14 WBL Ramp / Loop
A.64	Maple Grove	Hennepin	109th at Zachary Lane
A.65	Maple Grove	Hennepin	109th at Elm Creek Pkwy/Lancaster Ln
A.66	Maple Grove	Hennepin	Elm Creek Blvd at 99th Ave/Future TH 610 Off Ramp
A.67	Maple Grove	Hennepin	Zachary Lane (CR 202) at TH 610 North Ramp
A.68	Maple Grove	Hennepin	Zachary Lane (CR 202) at TH 610 South Ramp
A.69	Maplewood	Ramsey	Frost Ave / Parkway Dr / E Shore Dr
A.70	Maplewood	Ramsey	Frost Avenue / English St.
A.71	Maplewood	Ramsey	Kennard St. / Legacy Parkway
A.72	Maplewood	Ramsey	Castle Avenue/Van Dyke Street
A.73	Medford	Steele	I-35 and CSAH 12 (E)
A.74	Medford	Steele	I-35 and CSAH 12 (W)
A.75	Mendota Heights	Dakota	Mendota Heights Rd. and Visitation Drive
A.76	Minneapolis	Hennepin	Minnehaha Ave and Godfrey Pkwy
A.77	Minnetrista	Hennepin	TH 7 at Kings Point Road/CSAH 11
A.78	Monticello	Wright	CSAH 18 (Fenning Ave NE) and Meadow Oak Ave
A.79	Moorhead	Clay	28th Ave S/ 36th St S / 40th St S
A.80	Moorhead	Clay	24th Ave S (MSAS #140) and 40th St S (MSAS #141)
A.81	Moorhead	Clay	TH 75 & CSAH 12
A.82	New Prague	Scott	TH 19 / Chalupsky
A.83	New Prague	Scott	TH 19 / Alton
A.84	New Prague	Scott	TH 19 / 11th Ave West
A.85	New Ulm	Brown	TH 14 & Palmer Ave.
A.86	Nisswa	Crow Wing	CSAH 18 & South Main Street
A.87	North Branch	Chisago	Fletcher Ave / N of 400th St.
A.88	Pine Springs	Washington	TH 36 EB Ramp at CSAH 29-36 Hilton Trail / Viking Dr
A.89	Pine Springs	Washington	TH 36 WB Ramp at CSAH 29-36 Hilton Trail / Viking Dr
A.90	Princeton	Mille Lacs	TH 95/CSAH 29 (Rum River Drive)
A.91	Prior Lake	Scott	Fountain Hills Dr at Jeffers
A.92	Prior Lake	Scott	Dakotah Parkway and Mystic Lake Blvd.
A.93	Richfield	Hennepin	66th St (CR 53) and Portland Ave (CR 35)
A.94	Richfield	Hennepin	66th St (CR 53) and Richfield Parkway
A.95	Rochester	Olmsted	North intersection - UCR Drive SE / UCR Parkway SE
A.96	Rochester	Olmsted	Fox Valley Dr / Fox Knoll Dr. SW
A.97	Roseville	Ramsey	Mount Ridge Road and Twin Lakes Parkway
A.98	Sartell	Stearns	CR 120 & Un-named Road 1
A.99	Sartell	Stearns	CR 120 & Un-named Road 2
A.100	Sartell	Stearns	CSAH 1 & CR 120
A.101	Sartell	Stearns	Heritage Drive/50th Ave
A.102	Sartell	Stearns	Leander and 23rd
A.103	Sartell	Stearns	CR 120 and CR 134
A.104	Sartell	Stearns	CR 120 and CentraCare Street
A.105	Sauk Rapids	Benton	TH 10 at CSAH 3/EB on& off ramps
A.106	Sauk Rapids	Benton	TH 10 at CSAH 3/WB on& off ramps
A.107	Sauk Rapids	Benton	CSAH 3 at 10th Ave
A.108	Sauk Rapids	Benton	CSAH 3 at CSAH 1
A.109	Savage	Scott	CSAH 16 (McColl Drive) and Glendale Rd./Lynn Ave
A.110	Shakopee	Scott	CR 79 and Vierling Drive
A.111	South St. Paul	Dakota	TH 52 at Wentworth (CR 8)
A.112	St. Cloud	Stearns	University Dr. and 5th St
A.113	St. Cloud	Stearns	Pinecone Rd and Glenview Lane
A.114	St. Louis Park	Hennepin	Louisiana Avenue and Highway 7 (south ramps)
A.115	St. Louis Park	Hennepin	Louisiana Avenue and Highway 7 (north ramps)
A.116	St. Louis Park	Hennepin	Louisiana Avenue and Walker Street
A.117	Thief River Falls	Pennington	Greenwood St. & Pennington Ave.

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A.118	Victoria	Carver	86th Street West and Kochia Lane
A.119	Waconia	Carver	TH 284 and 10th Street
A.120	Waconia	Carver	TH 284 and Sparrow Road/15th Street
A.121	Waconia	Carver	TH 284 & CSAH 10
A.122	Watertown	Carver	CSAH 10 & CSAH 20
A.123	Watertown	Carver	CSAH 20 & Paul Ave
A.124	Watertown Twp	Carver	TH 7 and Carver CSAH 10
A.125	Watertown Twp	Carver	TH 7 and TH 25
A.126	West St. Paul	Dakota	TH 52 at Wentworth (CSAH 8)
A.127	Winona	Winona	CSAH 17 / CSAH 15
A.128	Woodbury	Washington	CSAH 19 at CSAH 18 (Bailey)
A.129	Woodbury	Washington	CSAH 19 at Lake Rd
A.130	Woodbury	Washington	Lake Rd & Settler's Ridge
A.131	Woodbury	Washington	CSAH 13 (Radio) at CSAH 18 (Bailey)
A.132	Woodbury	Washington	CSAH 13 (Radio) at CSAH 18 (Bailey)
A.133	Woodbury	Washington	Pioneer Drive / High School Drive 1
A.134	Woodbury	Washington	Pioneer Drive and Hargis Parkway
A.135	Woodbury	Washington	Hargis Parkway and High School Drive 1
A.136	Woodbury	Washington	Hargis Parkway and High School Drive 2
A.137	Woodbury	Washington	Hargis Parkway and High School Drive 3
A.138	Woodbury	Washington	Hargis Parkway and High School Drive 4
A.139	Woodbury	Washington	CSAH 13 (Radio) at CSAH 20 (Military)
A.140	Woodbury	Washington	Pioneer and Plymouth
A.141	Woodbury	Washington	Pioneer and Residential Street
A.142	Worthington	Nobles	US 59/ TH 60/ CSAH 35
A.143	Worthington	Nobles	US 59/ TH 60/ Oxford St.
A.144	Worthington	Nobles	TH 60 and I90 Off Ramp