DEPARTMENT OF TRANSPORTATION

Strategies for Effective Roundabout Speed Reduction

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Stonebrooke Engineering, Inc.

DECEMBER 2022

Research Project
Final Report 2022RIC03

LRRB
LOCAL ROAD RESEARCH BOARD

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Appropriate deceleration on approaches to roundabouts is primarily accomplished through the use of applicable geometric design principles. However, traffic control devices (specifically signing and makings on approach) also serve a vital role in communicating to the approaching driver what speed profile should be anticipated. This report provides a resource for engineers to identify and select appropriate speed-reduction treatments for high-speed approaches to roundabouts. The research examines best practices and techniques that are the most effective at lowering approach speed.

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Strategies for Effective Roundabout Speed Reduction

FINAL REPORT

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EXECUTIVE SUMMARY

This project was initially identified and supported by local agencies in Minnesota out of a desire to improve consistency of the methods that design professionals use to reduce speeds at roundabout approaches. It is widely known and accepted that deceleration on approaches is best accomplished using applicable geometric design principles. However, traffic control devices (specifically signing and pavement makings) also serve a vital role in communicating to the approaching driver what speed profile should be anticipated.

This report was intended to provide a resource for engineers to identify and select appropriate speed-reduction treatments. This effort included a literature review, a local agency survey, and development of a quick reference guide. A case study review of various roundabout intersections was also performed.

The literature review included evaluating 7 technical documents to evaluate the effectiveness of various speed reduction techniques including:

- *Impacts of S-Curve on Speed in a Modern Roundabout* [1]
- *Effect of Signing and Lane Markings on the Safety of a Two-Lane Roundabout* [2]
- *Evaluation of Safety and Mobility of Two-Lane Roundabouts* [3]
- *Review of Fastest Path Procedures for Single-Lane Roundabout* [4]
- *Capacity-Related Driver Behavior on Roundabouts Built on High-Speed* Roads [5]
- *Strategies for Effective Roundabout Approach Speed Reduction* [6]
- *Design Guidance for High-speed to Low-speed Transition Zones for Rural Highways* [7]

A survey of Minnesota cities and counties was completed using Survey Monkey, an online survey development software. The survey was used to inform local agencies about the project and to solicit information regarding their agency's practices for roundabout approaches. The survey was distributed by MnDOT to Minnesota cities and counties and 23 responses were obtained.

A draft Quick Reference Guide was created that primarily focused on how certain countermeasures can lower approach speeds and when they should be applied. The guide largely followed MnDOT's *Strategies for Effective Roundabout Approach Speed Reduction* [6] report. The guide was intended to be used by agencies for use in determining when to employ different countermeasures based on roadway type, location, and posted speed limits. Fact sheets for different countermeasures were also developed. As the project progressed, however, it became clear that the current practices being employed by roundabout designers were effective. The quick reference guide development was stopped as it was simply re-stating information that was already commonly being employed by roundabout designers. Furthermore, advancement in local and national technical documentation has effectively standardized approach designs. The most applicable technical documents include:

- *MnDOT Facility Design Guide* Chapter 6: Intersections
- NCHRP Report 672 (*Roundabouts an Informational Guide*)
- *Minnesota Manual on Uniform Traffic Control Devices*

To avoid restating information that is readily available to designers in a different format, it was decided instead to examine various roundabout intersections with known crash issues. The case study used locations that were identified in the local agencies survey. Agencies that identified problem intersections were interviewed to determine whether approach speeds were thought to be a contributing factor. Crash data was also obtained and reviewed for each of the locations, a summary of this effort is included with this report.

The case study reviewed 10 existing roundabout intersections with known crash issues. However, it was determined that approach speed was a contributing factor at only 1 location. The TH 7/CSAH 10 roundabout experienced 4 semi-truck rollovers. Two of these were likely due to speed, while the third reported having struck the curb and had an improperly secured load, while the fourth involved an impaired driver. Two passenger vehicles also left the road due to speed at this location; however, one of these was a driver speeding to evade the police.

The following information represents the data obtained and information presented through the development of this project.

CHAPTER 1: LITERATURE REVIEW

1.1 IMPACTS OF S-CURVE ON SPEED IN A MODERN ROUNDABOUT (SAFER-SIM) [1]

This research used traffic modeling to test the effects an S-curve approach has on entrance speeds of roundabouts. Other factors were evaluated such as the effect of various central angles including 30, 45, and 60 degrees.

Using an existing roundabout on the campus of the University of Massachusetts, a model was built matching the dimensions and traffic volumes, the model was then adjusted to create three more alternatives with a variety of S-curves using AIMSUN.

The results demonstrated a significant reduction of approach speeds when S-curves were introduced. The reduction in approach speed increased as the central angle increased. These results show that even a minimal amount of curvature can lead to significant reductions in speed.

1.2 EFFECT OF SIGNING AND LANE MARKINGS ON THE SAFETY OF A TWO-LANE ROUNDABOUT (MNDOT 2014-04) [2]

This report focuses on a roundabout located in Richfield; Minnesota constructed in 2005. For nearly 3 years after the construction, the roundabout continued to experience an abnormally high number of crashes.

The report examines the impact lane markings and signing have on driving behavior. In this study, engineers experimented with changes in the roundabout's signs and lane markings. An observational study was conducted that examined over 200 hours of before and after video and examined crash records. The data demonstrated that improper turns and failing to properly yield account for most crashes.

The research then implemented changes to the intersection signing and striping that resulted in a nearly 50% reduction of both improper turns, and drivers choosing the incorrect lane. This study identified that signs and lane markings are critical in helping improving motorists understanding of roundabout driving rules.

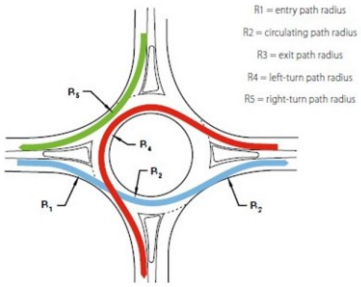
1.3 EVALUATION OF SAFETY AND MOBILITY OF TWO-LANE ROUNDABOUTS (MNDOT 2017-30) [3]

This study examines why multilane roundabouts fail to provide the same safety performance as single lane roundabouts when compared to signalized intersections. Four roundabout intersections were examined. Two intersections were full 2x2 roundabouts and the other two were 2x1. The locations studied included:

- University Dr. S and 5th Ave. S in St. Cloud (2x1)
- 185th St. W and Kenwood Trail in Lakeville (2x2)
- TH-22 and Adams St. in Mankato (2x1)
- TH-22 and Madison Ave. in Mankato (2x2).

Traffic control changes were implemented to reduce failure-to-yield crashes, and the study compared the driver behavior before and after the interventions. It was concluded that turn violation rates are affected on the single or multilane geometry of the links approaching the roundabout. Single-lane roads result in fewer lane violations. Also, it was discovered that overhead lane designation signs also result in reduced turn violations. No successful design or intervention was discovered regarding yield violations.

1.4 REVIEW OF FASTEST PATH PROCEDURES FOR SINGLE-LANE ROUNDABOUT [4]



This article examines the importance of a well-designed roundabout around the premise of the fastest path. Designing a roundabout with special care to the fastest path allows for a higher standard of safety and capacity. To achieve this goal, many different techniques are described to calculate the fastest paths and they all vary from region to region. A key point of this article is that fastest path speeds should not be altered too far from approach speeds. This should be done to prevent vehicles from losing control as well as to improve the visibility to traffic already in the roundabout. Balancing geometric design and proper signage with the fastest path leads to safer roundabouts.

1.5 CAPACITY-RELATED DRIVER BEHAVIOR ON ROUNDABOUTS BUILT ON HIGH-SPEED ROADS [5]

This report examines systems such as the UK Empirical Capacity Model, SIDRA INTERSECTION Model, and the HCM 2010 Capacity Model used to calculate the capacity of roundabouts. These methods are heavily reliant on the behavior of drivers. This article discusses the impact high-speed roads have on driver behaviors at roundabouts. The study identifies that at dual-lane roundabouts, passenger vehicles accepted a 0.6 second longer critical headway to conflicting cars while heavy trucks accepted a 1.1 second longer critical headway than drivers at a single lane roundabout. It was also found that the entrance lane width at a dual lane roundabout did not have a significant impact on determining critical headway entering a roundabout.

1.6 STRATEGIES FOR EFFECTIVE ROUNDABOUT APPROACH SPEED REDUCTION (MNDOT 2017-14) [6]

This report attempts to provide a resource for engineers to identify and select appropriate speed-reduction treatments for high-speed approaches to roundabouts. The research examines best practices and research literature on various speed reduction techniques for all intersection types, as well as treatments for work zones and horizontal curves.
The report also summarizes a selection of treatments. Information on the effectiveness of these treatments, as well as potential costs of installation and maintenance, is also provided.

The study identifies various research needs specific to treatments as well as the general need for field research of the recommended countermeasures specifically on approaches to high-speed rural roundabouts.

1.7 DESIGN GUIDANCE FOR HIGH-SPEED TO LOW-SPEED TRANSITION ZONES FOR RURAL HIGHWAYS [7]

This research study examines the effectiveness of high speed to low-speed transition zones on rural highways. Information was collected through a two-stage process that began with a literature review to obtain a large-scale scope of knowledge of best implementation and practices. The second phase included conducting field studies to evaluate effectiveness in the field. Field research was conducted at six different locations along different approaches of four towns. Data was collected along different locations within a transition zone such as the settled area, transition zone, approach zones, and the rural area giving an in-depth look at each zone. The study found that transitions zones followed by roundabouts increase the rate of compliance of vehicles at or below the speed limit at the end of the transition zones by 15 and 20 percent respectively. Findings also suggest that after transition zones additional measures most likely are needed to keep vehicles traveling at lower speeds.

CHAPTER 2: LOCAL AGENCY SURVEY RESULTS

A survey of Minnesota cities and counties was completed to inform local agencies about the project, and to solicit information regarding their agency's practices for roundabout approaches. The survey was distributed by MnDOT to Minnesota cities and counties.

There was a total of 23 responses to the survey but only 10 responders provided their name and contact information. The survey questions and a summary of the results in included below.

2.1 QUESTION 1: HOW MANY HIGH-SPEED APPROACH (≥45MPH) ROUNDABOUTS ARE WITHIN YOUR AREA (COUNTY/CITY)?

- 23/23 answered

Results:

- Answers ranged from 0-23 high-speed approach (≥45MPH) roundabouts
- 12 answered they have 0 high-speed approach (≥45MPH) roundabouts
- Average number of high-speed approach (≥45MPH) roundabouts: 3

2.2 QUESTION 2: DO ANY OF THESE ROUNDABOUTS HAVE APPROACHES THAT HAVE HAD A RECURRING PROBLEM ATTRIBUTED TO EXCESSIVE APPROACH SPEED BY DRIVERS? IF YES, WOULD YOU SHARE THE LOCATION AND APPROACH DIRECTION(S)?

- 23/23 answered

Results:

- 4 answered "No, we have high speed roundabouts but none that experience approach speed issues"
- 13 answered "No, we do not have any high-speed roundabouts"
- 6 answered "Yes (please specify location and approach directions)"
    - CSAH 4 (Valley High Drive NW) and 50th Ave NW - Approach from the west
    - Hudson Road/Spring Hill Drive (Eastbound)
    - Radio Drive/Bailey Road (Southbound)
    - Woodbury Drive/Lake Road (Southbound & Northbound)
    - TH 61 at CSAH 4 (170th St N) in Forest Lake
    - TH 7 at TH 25 (E-W)

2.3 QUESTION 3: WHAT TECHNIQUE(S) HAVE YOU IMPLEMENTED TO ATTEMPT TO SLOW DRIVERS UPON APPROACH AT HIGH SPEED (≥45MPH?) ROUNDABOUTS THAT WOULD DIFFER FROM LOW SPEED (<45MPH?) ROUNDABOUTS? RESPONDERS WERE ASKED TO SELECT ALL THAT APPLIED.

- 17/ 23 answered

Results:

- 8 responses for “Splitter Islands/Curb”
- 7 responses for “Mounded Center”
- 7 responses for “Illumination”
- 6 responses for “Chicane/ S- Approach”
- 6 responses for “Clear and Concise Signage”
- 6 responses for “Landscaping”
- 6 responses for “We do not have any high-speed roundabouts”
- 4 responses for “Chevrons (located on island)”
- 4 responses for “Lane Narrowing”
- 4 responses for “Suggested Approach Speed”
- 3 responses for “Advanced Warning Signs without Beacon”
- 2 responses for “Lower Speed Fastest Path Design”
- 2 responses for “Increase Size of ICD (Inscribed Circle Diameter)
- 1 response for “Hatched areas in Place of Splitter Islands”
- 1 response for “Transitional Speed Zones”
- 1 response for “Transitional Pavement Markings”
- 2 responses for “Other (please specify)”
    - “We have used many of these strategies but we have also used the same strategies at our lower speed roundabouts so I can't say that it differs.”
    - “No Roundabouts”
- Techniques that got no response were
    - Gateway Approach
    - Turbo Roundabout
    - Speed Tables
    - Chevrons (located outside of island)
    - Optical Speed Bars
    - Advanced Warning Signs with Beacon
    - Speed Feedback Signs
    - Rumble Strips

2.4 QUESTION 4: HOW HAVE YOU DECIDED WHAT STRATEGIES TO USE IN THE PAST? RESPONDERS WERE ASKED TO SELECT ALL THAT APPLIED.

- 23/23 answered

Results:

- 12 responses for "Have not had to decide (no high-speed roundabouts)"
- 8 responses for "Guide/Manual"
- 7 responses for "Experience"
- 7 responses for "Recommendations"
- 5 responses for "Cost"
- 2 responses for "Other (please specify)
    - "Crash records"
    - "Collaboration with the engineering consultant."
- 1 response for "Location"

2.5 QUESTION 5: ARE THERE ANY STRATEGIES YOU DEEM TO BE STANDARD PRACTICE? RESPONDERS WERE ASKED TO SELECT ALL THAT APPLIED.

- 19/23 responded

Results:

- 10 responses for "Mounded Center Island"
- 10 responses for "Splitter Islands/Curbs"
- 9 responses for "We do not have any high-speed roundabouts"
- 8 responses for "Illumination"
- 8 responses for "Clear and Concise Signage"
- 6 responses for "Chicane/S-Approach"
- 6 responses for "Chevrons (located on island)"
- 5 responses for "Lower Speed Fastest Path Design"
- 4 responses for "Lane Narrowing"
- 4 responses for "Suggested Approach Speed"
- 4 responses for "Advanced Warning Signs without Beacon"
- 4 responses for "Landscaping"
- 1 response for "Increased Size of ICD (Inscribed Circle Diameter)"
- 1 response for "Chevrons (located outside of island)"
- Techniques that got no response were
    - Hatched Areas in Place of Splitter Islands
    - Gateways Approach
    - Turbo Roundabout
    - Speed Bumps
    - Speed Tables
    - Transitional Speed Zones
    - Optical Speed Bars

- Transverse Pavement Markings
- Advanced Warning Signs with Beacon
- Speed Feedback Signs
- Rumble Strips
- Other (please specify)

2.6 QUESTION 6: WHAT STRATEGIES HAVE YOU FOUND TO BE EFFECTIVE? RESPONDERS WERE ASKED TO SELECT ALL THAT APPLIED.

- 19/23 responded

Results:

- 9 responses for “We do not have any high-speed roundabouts”
- 7 responses for “Splitter Islands/Curbs”
- 6 responses for “Chicane/S-Approach”
- 5 responses for “Lower Speed Fastest Path Design”
- 5 responses for “Illumination”
- 5 responses for “Clear and Concise Signage”
- 4 responses for “Chevrons (located on island)”
- 3 responses for “Lane Narrowing”
- 2 responses for “Increased Size of ICD (Inscribed Circle Diameter)”
- 2 responses for “Suggested Approach Speed”
- 2 responses for “Advanced Warning Signs without Beacon”
- 2 responses for “Other (please specify)”
  - “Use of tube delineators on left side of approach, used to help ensure that a driver does not expect to go left of the yield sign.”
  - “It is difficult to answer this question. We've used many strategies, so it is difficult to understand the effect of any one of those strategies.”
- 1 response for “Chevrons (located outside of island)”
- 1 response for “Landscaping”
- Techniques that got no response were
  - Hatched Areas in Place of Splitter Islands
  - Gateways Approach
  - Turbo Roundabout
  - Speed Bumps
  - Speed Tables
  - Transitional Speed Zones
  - Optical Speed Bars
  - Transverse Pavement Markings
  - Advanced Warning Signs with Beacon
  - Speed Feedback Signs
  - Rumble Strips

2.7 QUESTION 7: WHAT STRATEGIES HAVE YOU FOUND TO BE INEFFECTIVE?

- 14/23 responded

Results:

- 10 responses for We do not have any high-speed roundabouts
- 3 responses for Suggested Approach Speed
- 1 response for Mounded Center Island
- 1 response for Hatched Areas in Place of Splitter Islands
- 1 response for Lane Narrowing
- 1 response for Optical Speed Bars
- 1 response for "Other (please specify)"
    - "It is difficult to answer this question. We've used many strategies, so it is difficult to understand the effect of any one of those strategies."
- Techniques that got no response were:
    - Lower Speed Fastest Path Design
    - Splitter Islands/Curbs
    - Illumination
    - Gateways Approach
    - Chicane/S-Approach
    - Increased Size of ICD (Inscribed Circle Diameter)
    - Turbo Roundabout
    - Speed Bumps
    - Speed Tables
    - Clear and Concise Signage
    - Chevrons (located on island)
    - Chevrons (located outside of island)
    - Transitional Speed Zones
    - Transverse Pavement Markings
    - Advanced Warning Signs with Beacon
    - Advanced Warning Signs without Beacon
    - Speed Feedback Signs
    - Rumble Strips
    - Landscaping

2.8 QUESTION 8: WHAT LESSONS HAVE YOU LEARNED ABOUT STRATEGIES FOR REDUCING ROUNDABOUT APPROACH SPEED?

- 9/23 responded

Results:

- "We are fortunate that many of our drivers are familiar to the area and also familiar with roundabouts. The conversation might be different in an area with lots of drivers who are not familiar with the location or with roundabouts in general."
- "The practice and conventions are not standardized. Most including MnDOT Design Review Committee is inconsistent and not as knowledgeable or consistent with effective high-speed design."
- "Provide multiple conspicuous elements to provide the best chance to acquire drivers' attention."
- "Quite making it so fun to see how fast you can go around them, testing out the suspension setup on your car. "
- "We do not have any speed issues with our Roundabouts "
- "Keep light poles as far away from the road as possible without affecting illumination"
- Advisory speed plaques for roundabouts are not recommended by FHWA. Check the roundabout guide second edition page 7-22. They were recommended in the first edition, but the second edition says they are no longer recommended. We have removed all of our advisory speed plaques from all of our roundabouts.
- "Do not overdesign roundabouts to accommodate future traffic projections/needs. Expand roundabouts to achieve future capacity when traffic volumes reach that level."
- "Narrow the approach lane and decrease the entrance radii."

2.9 QUESTION 9: ARE THERE TECHNIQUES OR OTHER IDEAS THAT YOU ARE SEEKING MORE INFORMATION ABOUT?

- 5/23 responded

Results:

- "I'd be curious to know if anyone had used a radar speed sign on an approach and if that showed any positive results. I would also be curious to know the effect of reflective posts for the yield signs, and the effect of improved delineation of the central island (e.g., chevrons all the way around, or a clearance marker on the right-most edge of the central island). We used a clearance marker at one location (40 mph) but I don't have before/after data on if it was effective."
- "Chicane S-Approach and other non roundabout Speed Management Techniques that currently aren't used in the Roundabout field."
- "No"
- "Improved stopping compliance for pedestrian crossings at roundabouts"
- "Why are roundabouts being what I see as over designed for truck traffic? The approach lanes are too wide along with the ICD lane."

2.10 QUESTION 10: PLEASE PROVIDE YOUR NAME AND CONTACT INFORMATION IF YOU ARE INTERESTED IN SHARING YOUR ROUNDABOUT POLICY OR EXPERIENCE WITH THE TAP.

- 10/23 responded

The responding agencies included:

- Washington County
- Blue Earth County
- St. Louis County
- City of Eagan
- Olmsted County
- Dodge County Hwy Dept
- City of Detroit Lakes
- City of Albert Lea
- City of Plymouth
- Itasca County

The survey responses indicated that most agencies are following generally accepted design practices.

CHAPTER 3: CASE STUDIES

As part of this effort, 11 intersections were identified by the TAP as well as agencies that responded to the survey. Crash reports were obtained for each location and a summary of the results are included below. Approach speed did not appear to be a contributing factor in most instances. Most crashes appeared to be the result of drivers failing to yield when entering the circulatory roadway.

Locations included:

1. CSAH 4 (Valley High Drive NW) and 50th Ave NW
2. Hudson Road/Spring Hill Drive (eastbound)
3. Radio Drive/Bailey Road (southbound)
4. Woodbury Drive/Lake Road (southbound & northbound)
5. TH 61 at CSAH 4 (170th St N) in Forest Lake
6. TH 7 at TH 25 (E-W)
7. TH 7 at CSAH 10 (E-W)
8. TH 7 at CSAH 11 / Kings Pt (E-W)
9. Hwy 11 at Hwy 61 (Former TH 101 / US 212) (NB Direction)
10. St. Croix Trail N and Division St
11. TH 61 at CSAH 4 (170th St N) in Forest Lake

3.1 CSAH 4 (VALLEY HIGH DRIVE NW) & 50TH AVE NW

- 20 total crashes
  - 3 Rear End
  - 5 Sideswipe Same Direction
  - 3 Angle
  - 6 Single Vehicle Run Off Road
  - 3 Other
    - Deer
    - 2 Pedestrian (poor conditions, tried to stop but couldn't due to ice)

Of the 20 crashes at this roundabout 14 of them were rear end, side swipes and angle crashes. None of which were due to approach speed.

Six of the 20 crashes were single vehicle run off the road, 5 of those were due to ice and the other crash was due to driver error.

3.2 HUDSON ROAD & SPRING HILL DRIVE

- 10 Total Crashes
  - 4 Angle
  - 3 Sideswipe Same Direction
  - 2 Vehicle Run Off Road
  - 1 Rear End

None of the crashes appear to be due to approach speed.

3.3 RADIO DRIVE & BAILEY ROAD

- Total of 25 crashes
  - 9 Rear End
  - 9 Sideswipe Same Direction
  - 1 Sideswipe Opposing
  - 5 Ran off the Road
  - 14 Angle
  - 3 Other

None of the crashes appear to be due to approach speed. Several drivers did accuse the other of speeding/driving carelessly. One rear end crash involving a motorcycle and the report cites speeding as a contributing factor, but description implies it was careless driving and that accident occurred because the motorcycle lost control.

3.4 WOODBURY DRIVE/LAKE ROAD (SOUTHBOUND & NORTHBOUND)

- 21 Total Crashes
  - 1 Rear End
  - 5 Ran off the Road
  - 14 Angle
  - 3 Other

None of the crashes appear to be due to approach speed.

3.5 TH 61 AT CSAH 4 (170TH ST N) IN FOREST LAKE

- 41 total crashes
    - 1 Sideswipe Opposing
    - 14 Single Vehicle Run Off Road
    - 6 Sideswipe Same Direction
    - 6 Angle
    - 10 Rear End
    - Single Vehicle Other
    - 3 Other

None of which appear to be due to approach speed. Of the 14 single vehicle off the road crashes, one was failure to keep proper lane, one a driver had health issue, 3 were poor conditions, one driver didn't like roundabouts and just drove over the roundabout, 2 of the drivers were under the influence, and one driver swerved to avoid a crash and crashed into another vehicle.

One report mentions speed was a contributing factor due to road conditions (ICE), two other reports mention one driver accusing the other of speeding, but no citations were given.

3.6 TH 7 AT TH 25

- 16 total crashes
    - 4 Sideswipe -Same Direction
    - 2 Single Vehicle Run Off Road
    - 6 Rear End
    - 4 angle crashes

None of the crashes appear to be due to approach speed.

3.7 TH 7 AT CSAH 10

- 31 Total Crashes
    - 17 Vehicle Run Off Road
        - 4 were semis rolling over from shifting load through roundabout
            - 1 of the drivers was impaired
        - 1 passenger vehicle also left the road due to speed.
    - 10 Rear End Crashes
    - 1 Angle Crash
    - 1 Side Swipe
    - 2 Other
        - Deer

        - Vehicle Fire

Of the 31 crashes at this roundabout 12 were rear end, side swipes and angle crashes none of which were due to approach speed. Of the remaining 19, four (4) involved semi-trucks rolling over. Three (3) of these were likely due to speed, while the 4th involved an impaired driver. Two passenger vehicles also left the road due to speed, one of these was a driver speeding to evade the police.

3.8 TH 7 AT CSAH 11/KINGS PT ROAD

- 22 Total Crashes
    - 3 Sideswipe Same Direction
    - 5 Angle (Two were identified as other but description appears to be angle)
    - 8 Rear End (one was identified as other, but description appears to be rear end)
    - 5 Single Vehicle Run Off Road
    - 1 Deer

There was a total of 22 crashes, 15 of those were rear ends, side swipes and angle crashes, none of which were due to approach speed. One driver did not notice the roundabout and 1 driver failed to slow.

3.9 HWY 11 AT HWY 61 (FORMER TH 101 / US 212)

- 22 Total Crashes
    - 9 Vehicle Off Road
        - Semi Rollover due to load Shift (improperly secured)
    - 7 Sideswipe – Same Direction
    - 5 Rear End
    - 1 Other (Motorcycle Crash due to speed)

Of the 22 total crashes only two mentioned speeds as a contributing factor. One was a motorcycle; the driver claimed his “tire wasn’t warmed up yet”. The other was attempting to commit suicide.

3.10 ST. CROIX TRAIL N AND DIVISION ST

- 22 Total Crashes
    - 1 rear end
    - 1 run off road
    - 1 fell off motorcycle in roundabout

This roundabout only had 3 crashes, 1 was a rear end, 1 was a motorcycle slipped on gravel in the roundabout, and one was a driver ran off the road due to a health issue. None of which appear to be related to approach speed.

CHAPTER 4: CONCLUSIONS

Roundabout approach speeds are a topic of interest across the spectrum of city and county agencies in Minnesota because of appropriate use of speed reduction techniques to have the most impact on speed. However, through the course of this project and the subsequent additional research completed, it became evident that existing speed reduction techniques are being properly employed and that speed reduction on roundabout approaches does not appear to be a significant contributing factor in roundabout crashes. The most widely used documents for determining appropriate roundabout design include:

- *MnDOT Facility Design Guide,* Chapter 6: Intersections
- *Roundabouts an Informational Guide* (NCHRP Report 672)
- *Minnesota Manual on Uniform Traffic Control Devices* (MMUTCD)

The *MnDOT Facility Deign Guide* provides detailed information on appropriate design features, while the MMUTCD provides guidance on signing and pavement markings. For agencies less familiar with roundabouts, NCHRP Report 672 also provides useful information regarding roundabout designs and operations.

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APPENDIX A:
QUICK REFERENCE GUIDE

Advanced Roundabout Warning Sign with beacon

A Roundabout Ahead sign that has flashing lights or messages to inform drivers that they are approaching a roundabout.

Advanced Roundabout Warning Sign without beacon

A Roundabout Ahead sign is used to convey to a driver that they are approaching an intersection with the form of a roundabout.

Source: FHWA: Roundabouts: An Informational Guide

Source: Lompoc Record

Benefits:

- Allows drivers to slow down before roundabout approach
- Gives drivers knowledge that there is a roundabout

Design Considerations:

- Sign installation location
- Beacon maintenance
- Power source

Where to use:

- Works best in rural areas or on the outer edge of urban areas

Effectiveness:

- Research showed a decrease in speed of 1.8 mph at point of curves on rural roadways

  – *Source: Toolbox of Countermeasures for Rural Two-Lane Curves*

Chevrons

Directional Arrows used to convey the presence of a Roundabout circulatory roadway.

Benefits:

- Increase awareness of roundabout

Design Considerations:

- Due to weather, striping can be covered for many months by snow and ice

Where to use:

- All locations

Effectiveness:

- Studies show the effectiveness of converging chevron pavement marking patterns show the potential to reduce 85th percentile speeds by 11 to 24 percent. An FHWA study reported a 3 mph reduction in 85th percentile speeds.

Illumination

Lighting on approach and circulatory roadway as well as pedestrian crossings.
For a roundabout to operate satisfactorily, all users—drivers, pedestrians, and cyclists— must be able to enter, navigate around, and exit the roundabout in a safe and efficient manner and pedestrians must be able to safely use crosswalks, during the day and at night. A typical lighting layout is shown below.
Source: Roundabouts: An informational Guide Second Edition (2010)

Source: Stonebrooke Engineering

Design Considerations:

- Maintenance cost
- Operating cost
- Light placement

Where to use:

- All locations (Should be standard practice at all roundabouts)

Benefits:

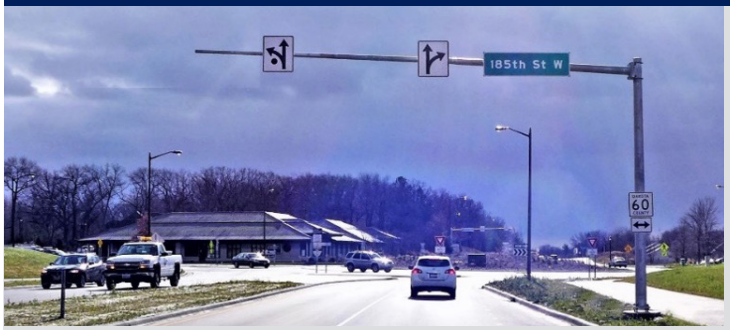
- Improved visibility of the intersection allowing drivers to properly prepare for and successfully navigate the roundabout
- Makes the intersection more visible both day and night
- Improve pedestrian safety by illuminating crossing locations

Effectiveness:

- Increased lighting reduces crashes at all intersection types.

Overhead Signage

Signs mounted above roadway to provide better direction. Used to provide clear and concise direction to minimize driver confusion while alerting drivers they are approaching a Roundabout.



Design Considerations:

- Space for the signs

Where to use:

- Multi-lane roundabouts

Benefits:

- Can be added after roundabout is already in place
- Gives drivers advanced warning of upcoming roundabout

Effectiveness:

- Provides better direction finding

Speed Feedback Signs

LED or other digital signs used to detect and display motorists actual speed.

Design Considerations:

- Maintenance
- Power source

Where to use:

- All locations

Benefits:

- Provides visual cue of driver speed

Effectiveness:

- A study found that speed display signs reduce the free flow speed by 6 mph

  - *Source: Evaluating Effective of Dynamic Speed Display Signs in Transition Zones of Two-lane, Rural Highways in Pennsylvania*

Suggested Approach Speed

High-speed approaches may utilize advance signing in addition to pavement markings and channelization to encourage drivers to adjust their speeds, slow on approach, and navigate the roundabout safely.

Design Considerations:

- Due to the weather, there are many months that the striping is covered by snow and ice

Where to use:

- All locations

Benefits:

- Drivers will slow to a safe approach speed

Effectiveness:

- Research studies report speed reductions between 3 and 8 mph

Transition Speed Limit Zones

Transition zones incrementally reduce speeds.

Source: Fed Highway Admin

Benefits:

- Drivers may have slowed down by time they have reached the roundabout
- Provides advanced warning to roundabout approach

Design Considerations:

- Relies on drivers to follow the posted speed limit
- Requires Speed Study
- Sign location

Where to use:

- All locations

Effectiveness:

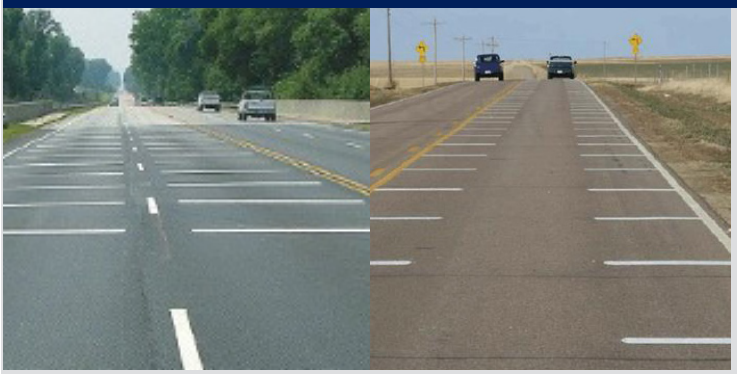
- Research reported speed reduction between 1 and 13 mph and compliance rates in school buffer zones of 82 to 88 percent

  - Source: Transition Zone Design Final Report

Transverse Pavement Markings

Pavement markings, usually bars or chevrons, spaced to create an illusion that vehicles are speeding up. These design modifications are intended to slow drivers in advance of the intersection.

Source: Roundabouts: An informational Guide Second Edition (2010)



Left Image: NCHRP Report 613 (Guidelines for selection of Speed Reduction Treatments at High Speed Intersections

Benefits:

- The illusion on the road surface leads drivers to slow their vehicles to a more appropriate approach speed

Design Considerations:

- Due to weather, striping can be covered for many months by snow and ice

Where to use:

- All locations

Effectiveness:

- Research has reported all transverse pavement markings cause a reduction of 0 to 9 mph on roadway segments

  – Source: Transportation Research Record Journal of the Transportation Research Board

Chicane/S-Approach

A chicane or "S curve" approach is a series of turns in opposite directions to create entry deflection and increase driver awareness.

Image: Stonebrooke Engineering

Design Considerations:

- Radius of approach curve
- Length of splitter Island
- Roadway width
- Approach speed
- Visibility of median

Where to use:

- At aproaches of 45mph or higher

Benefits:

- The S shape of the approach forces drivers to slow down

Effectiveness:

- The higher the angle, the higher the reduction in approach speed

– *Source: WSDOT Design Manual for Roundabouts*

Gateway Approach

Creating community focal points with landscaping or other features.

Source: Washington County

Design Considerations:

- Cost of installation
- Ongoing maintenance

Where to use:

- Urban or rural settings for both single-lane and multi-lane locations, generally located near a city limit or urban center

Benefits:

- Alerts drivers to the intersection using visual cues
- Reduces speed by increasing visibility of the intersection
- Provides streetscape opportunities for communities
- Alerts drivers they are approaching a community

Effectiveness:

- Research studies have reported a decrease of 5% to 7% in the 85th percentile of speed at locations with Gateway approach

– *Source: Speed Management Toolkit FHWA Safety Program*

Size of Inscribed Circle Diameter (ICD)

The basic parameter used to define the size of a roundabout, measured between the outer edges of the circulatory roadway. It is the diameter of the largest circle that can be inscribed within the outline of the intersection.

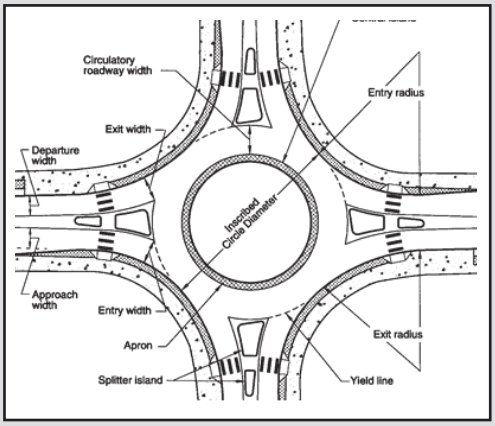


Image: FHWA Geometric Design

Benefits:

- Longer path for drivers to travel causing them to slow down
- Provides better approach geometry and deflection

Design Considerations:

- This countermeasure is in the initial design of the roundabout, can't be add later

Where to use:

- Essential part of all RAB designs

Effectiveness:

- No studies

Landscaping

The landscaping of the central island can enhance the safety of the intersection by making the intersection a focal point, by promoting lower speeds, and by breaking the headlight glare of oncoming vehicles.

Source: Roundabouts: An informational Guide Second Edition (2010)

Benefits:

- Simple solution
- Reduces site distance to a minimum and reduces speeds
- Breaks head light glare from oncoming vehicles

Design Considerations:

- On-going maintenance

Where to use:

- All locations

Effectiveness:

- Layered landscape yielded a mean speed reduction of 1 to 3 mph, and 85th percentile speed reduction of around 4 mph

  - *Source: Speed Management: A Manual for Local Rural Road Owners*

Lane Narrowing

Lane Narrowing can be used to create a psychological effect to reduce approach speeds.

Design Considerations:

- Restriping must occur

Where to use:

- Single Lane Roundabouts, generally located near a city limit or urban center

Benefits:

- As the lane narrows drivers begin to slow down
- Easily implemented on existing roundabouts

Effectiveness:

- Rural road speeds may decrease by as much as 3 mph for each foot that the roadway is narrowed down to 10 ft

Raised (Mounded) Center Island

The central island of a roundabout is the raised, mainly non-traversable area surrounded by the circulatory roadway. It may also include a traversable truck apron. The island is typically landscaped for aesthetic reasons and to enhance driver recognition of the roundabout upon approach.

Design Considerations:

- On going maintance
- Design vehicle
- Approach speed for how high to have center island

Where to use:

- All locations

Benefits:

- It allows the driver to see the roundabout from further away, allowing them to slow down sooner
- Common roundabout design practice

Effectiveness:

- Should be part of all RAB except minis

Rumble Strips

A safety feature designed to alert inattentive drivers by creating vibration and rumbling noise.
A rumble strip is typically installed along the edge-line or centerline, to narrow an approach or be installed across the direction of travel, to alert drivers to stop or slow down.

Source: Surface Preparation Technologies

Benefits:

- Indicates to the driver to slow down before roundabout

Design Considerations:

- Installed along edge-line or centerline

Where to use:

- All locations but best in rural areas

Effectiveness:

- Some studies have found that the treatment can reduce injury crashes by 14 percent, severe crashes by 18 percent, fatal and serious crashes by 67 percent, and overall crashes by 20 percent
  – *Source: FHWA*
- Studies found that when a roundabout has rumble strips warning of its presence the mean speed lowered 4.3 and 3.3 mph at 100 and 250ft from the yield line
  – *Source: FHWA*

Splitter Island/Curb

A splitter island is a raised (or painted) area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing that intersection approach in two stages. Also known as a median island or a separator island.

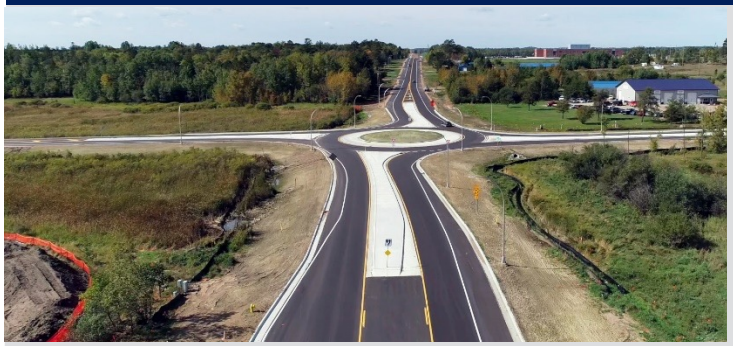


Image: Beltrami County

Benefits:

- Creates a channeling effect that causes drivers to slow down

Design Considerations:

- Increase in maintenance if landscaping is added

Where to use:

- >200' For approaches of 45mph or higher

Effectiveness:

- Research shows that introducing curbs to road segments is associated with 1.2 mph speed reduction when compared to sections with no curbs