FDM 11-26-1 General

November 15, 2022

1.1 General

This section and its sub-sections are comprised of roundabout design and operations guidelines developed through research and experience. Much of the prescribed guidance has been proven through application, evaluation and refinement.

The Department has updated previous versions of this guide to account for changes in national roundabout guidelines made possible through research, namely NCHRP 572 - Roundabouts in the United States, 2006 and NCHRP 672, Roundabouts: An Informational Guide, Second Edition. The NCHRP guidelines and research are heavily relied upon in this chapter. Where appropriate and justified by local experience, exceptions for use by the Wisconsin Department of Transportation are noted. Where both references are cited but differences exist, the Facilities Development Manual guidance shall govern.

Roundabouts may be considered for a wide range of intersection types including but not limited to freeway interchange ramp terminals, state route intersections, and state route/local route intersections. Roundabouts generally process high volume left turns more efficiently than all-way stop-controlled or signalized intersections and will process a wide range of side road volumes. Roundabouts can improve safety by reducing vehicle speeds and eliminating crossing conflicts that are present at conventional intersection. The required intersection sight distance is greatly reduced from what is required for a signalized intersection due to the reduced intersection travel speeds.

A roundabout is defined by three basic principles:

1. Yield-at-Entry - Vehicles approaching the roundabout must wait for a gap in the circulating flow, or yield, before entering the circle.
2. Deflection - Traffic entering the roundabout is directed or channeled to the right with a curved entry path into the circulating roadway.
3. Geometric Curvature - The radius of the circular road and the angles of entry are designed to slow the speed of vehicles.

FHWA, AASHTO, and WisDOT have made intersection safety a high priority. The objective is to improve the safety and operation of intersections. Studies conducted over the last two decades, including studies by WisDOT, have continuously shown that roundabouts provide a safety advantage over other intersection types, particularly with regards to fatal and injury type crashes.

Critical to the acceptance of the roundabout intersection is overcoming the internal and external skepticism of its advantages and value compared to stop controlled or signalized intersections. Meet with local officials and adjoining property owners early in the process to address potential political or economic impacts. Designers and traffic engineers should also coordinate presentation materials with region staff as well as the Bureau of Project Development to present a consistent unified approach for roundabout implementation throughout the State.

1.2 Advantages and Disadvantages

Table 1.1 lists advantages and disadvantages of roundabouts versus other intersection alternatives.

***Table 1.1** Advantages and Disadvantages of Roundabouts*

Category	Advantages	Disadvantages
Safety	Reduced number of conflict points compared to other non-circular intersections. Left-turn and right angle conflicts are removed. Elimination of high angles of conflict and high operational speeds; reduces severe crashes. Reduction in conflicting speeds passing through the intersection. Reduced decision making at point of entry. Splitter islands and other geometric features provide advanced warning of the intersection. Raised level of consciousness for drivers. Facilitate U-turns that can substitute for more difficult midblock left-turns.	Total crashes may increase due to more property damage crashes. Lack preemptive control for first responders. May reduce the number of available gaps for midblock unsignalized intersections and driveways.
Operations	Traffic yields, nonstop, continuous traffic flow. Can reduce the number of lanes required between intersections, including bridges between interchange ramp terminals. Can reduce side-street delay during off-peak hours.	As queues develop, drivers accept smaller gaps, which may increase crashes. Equal priority for all approaches can reduce the progression for high volume approaches. Cannot provide explicit priority to specific users (e.g., trains, emergency vehicles, transit, pedestrians) unless supplemental traffic control devices are provided.
Pedestrians & Bicyclists	Splitter islands can provide pedestrian refuge and shorter one-directional traffic crossing. Pedestrians only need to consider one direction of traffic at a time. Low speed conditions improve bicycle and pedestrian safety.	Pedestrians, especially children, elderly, and handicapped may experience increased delay and reduced safety in securing acceptable gaps to cross. Pedestrians with vision impairments may have the most trouble establishing safe opportunities to cross due to challenges in detecting gaps and determining that vehicles have yielded at crosswalks. Longer travel path. Bicycle ramps could be confused for pedestrian ramps.
Environmental	Reduced starts and stops; reduced air pollution.	Possible impacts to natural and cultural resources due to potentially greater spatial requirements at the intersection.
Oversized-Overweight Truck Route (OSOW-TR)	Reduction of potential obstacles at intersections (traffic signals, signing, median islands).	The geometric design may be challenging to allow the navigation of OSOW vehicles. Additional right of way and paved areas may be needed to accommodate OSOW vehicles.
Aesthetics	Provide attractive entries or centerpieces to communities. Provide opportunity for landscaping or gateway to enhance the community.	May create a safety hazard if fixed objects are placed in the central island.

1.3 Roundabout Categories

Roundabouts are categorized by size and environment. The following is a list of basic categories and their characteristics.

1.3.1 Single-Lane Roundabouts

There are three types of single-lane roundabouts: standard (includes urban and rural), compact, and mini. WisDOT defines mini-roundabouts as those with an inscribed diameter (ICD) less than 80 feet. The Department is not currently constructing mini-roundabouts as they generally are not suitable for intersections on the State Highway system. Table 1.2 gives some general features of the single-lane roundabout types. Standard and compact roundabouts are described further in the following sections.

Table 1.2 Single-Lane Roundabout Types

Single-lane Roundabout Type	Inscribed Circle Diameter (ICD)	Central Island	Suitable for STH system	Suitable for local roads
Standard Roundabout	> 120 feet	Non-traversable	Y	Y
Compact Roundabout	80 feet to 120 feet	Traversable/Non-traversable	Y	Y
Mini Roundabout	< 80 feet	Traversable/Non-traversable	N	Y

1.3.1.1 Compact Roundabouts

A compact roundabout is an intersection design form that can be used in place of stop control or signalization at physically constrained intersections to help improve safety and reduce delays. They are typically characterized by:

- small diameter – the inscribed diameter of a compact roundabout ranges from 80 feet to 120 feet
- may have a completely traversable central island; splitter islands may also be traversable
- low speeds – compact roundabouts should only be used at locations where the posted speed limit is 40 mph or lower
- constrained right of way that may not accommodate a traditional roundabout

Smaller vehicles circulate around the roundabout in the circulatory roadway as they would at larger roundabouts, but larger vehicles may need to drive directly over the central island or the splitter islands to make certain movements. See Figure 1.1.

Some agencies refer to smaller roundabouts as mini-roundabouts. WisDOT defines compact roundabouts as described above, and mini-roundabouts as those with an inscribed diameter less than 80 feet. The Department is not currently constructing mini-roundabouts as they generally are not suitable for intersections on the State Highway system.

Compact roundabouts can be considered and may be favorable in the following locations:

- Congested intersections where the AADT is less than 15,000 vehicles per day
- Locations where traffic calming by reducing vehicle speeds is desired
- Existing all-way stop-controlled intersections
- Locations where intersection control is expected and visible to approaching drivers

Compact roundabouts may not be favorable at the following locations:

- As a replacement for two-way stop-controlled intersections
- Four-lane roadways
- Locations where truck percentages are expected to be higher than 5%
- Locations where U-turn truck traffic is expected
- Locations where WB-65's are expected to make a lot of turns

A compact roundabout will not operate as efficiently as a larger standard roundabout due to the smaller size and proximity of adjacent legs to one another. The WisDOT procedure for performing operational analysis for compact roundabouts can be found in FDM 11-26-20.4.5 and TEOpS 16-15-20.

There is no current available research on the safety of compact or mini roundabouts in the US, but trends show that fatal and severe injury crashes are similar to larger roundabouts while the minor injury crashes may be 30-50% higher than at a traditional roundabout.

A compact roundabout is often considered as an alternative to a larger single-lane roundabout due to a desire to minimize impacts outside of the existing intersection footprint. Therefore, the existing intersection curb lines are a typical starting point for establishing the compact roundabout inscribed circle diameter.

1.3.1.2 Urban Single-lane Roundabouts

Urban single-lane roundabouts are roundabouts in urban areas where posted speed limits are 40 mph or less. This type of roundabout is characterized as having a single-lane entry at all legs and one circulatory lane. The roundabout design is focused on achieving consistent entering and circulating vehicle speeds. The geometric design includes raised splitter islands, a non-traversable central island, and may include an apron surrounding the non-traversable part of the central island to accommodate long trucks. The minimum inscribed diameter to accommodate a WB-65 is 120 feet. Where long trucks are anticipated, verify that the circulating roadway width and the truck apron can accommodate off-tracking of a WB-65 design vehicle. A truck apron is included to allow the semi-tractor to stay in the circulating roadway while the trailer off-tracks onto the apron. If the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.3.1.3 Rural Single-lane Roundabouts

Rural single-lane roundabouts generally have high speeds on the roadway approaches in the range of 45 to 55 mph. They require supplementary geometric and traffic control device treatments on the approaches to encourage drivers to slow to an appropriate speed before entering the roundabout. Such treatments include raised and extended splitter islands, a non-traversable central island, and adequate horizontal deflection.

Rural roundabouts which may one day become part of an urbanized area should be designed as urban roundabouts, with slower speeds and pedestrian accommodations. In the interim, design them with supplementary approach and entry features to achieve speed reduction. If the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.3.2 Multi-lane Roundabouts

1.3.2.1 Urban Multi-lane Roundabouts

Urban multi-lane roundabouts are roundabouts in urban areas where posted speed limits are 40 mph or less and at least one approach leg has two or more entry lanes. These require wider circulatory roadways to accommodate more than one vehicle traveling side by side. Again, it is important that the vehicular speeds be consistent throughout the roundabout. The geometric design includes raised splitter islands, a non-traversable central island, and appropriate horizontal deflection, and may include an apron surrounding the non-traversable part of the central island to accommodate long trucks. A truck apron should be included to allow the semi-tractor to stay in the inner lane and the trailer to off-track onto the apron. When long trucks are anticipated, or if the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.3.2.2 Rural Multi-lane Roundabouts

Rural multi-lane roundabouts have speed characteristics similar to rural single-lane roundabouts with approach speeds in the range of 45 to 55 mph. They differ in having two or more entry lanes, or entries flared from one or more lanes, on one or more approaches. Consequently, many of the characteristics and design features of rural multi-lane roundabouts mirror those of their urban counterparts. The main design differences are designs with higher entry speeds, larger diameters, and recommended supplementary approach treatments. Design rural roundabouts that may one day become part of an urbanized area for slower speeds, with design details that fully accommodate pedestrians and bicyclists. In the interim, design them with approach and entry features to achieve speed reduction. A truck apron should be included to allow the semi-tractor to stay in the inner lane and the trailer to off-track onto the apron. When long trucks are anticipated, or if the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.4 Defining Physical Features

The defining features of a roundabout are shown in Figure 1.1, Figure 1.2, and Figure 1.3, and described in Table 1.2. These figures are for illustrative purposes only and the features shown may not be required on all roundabouts.

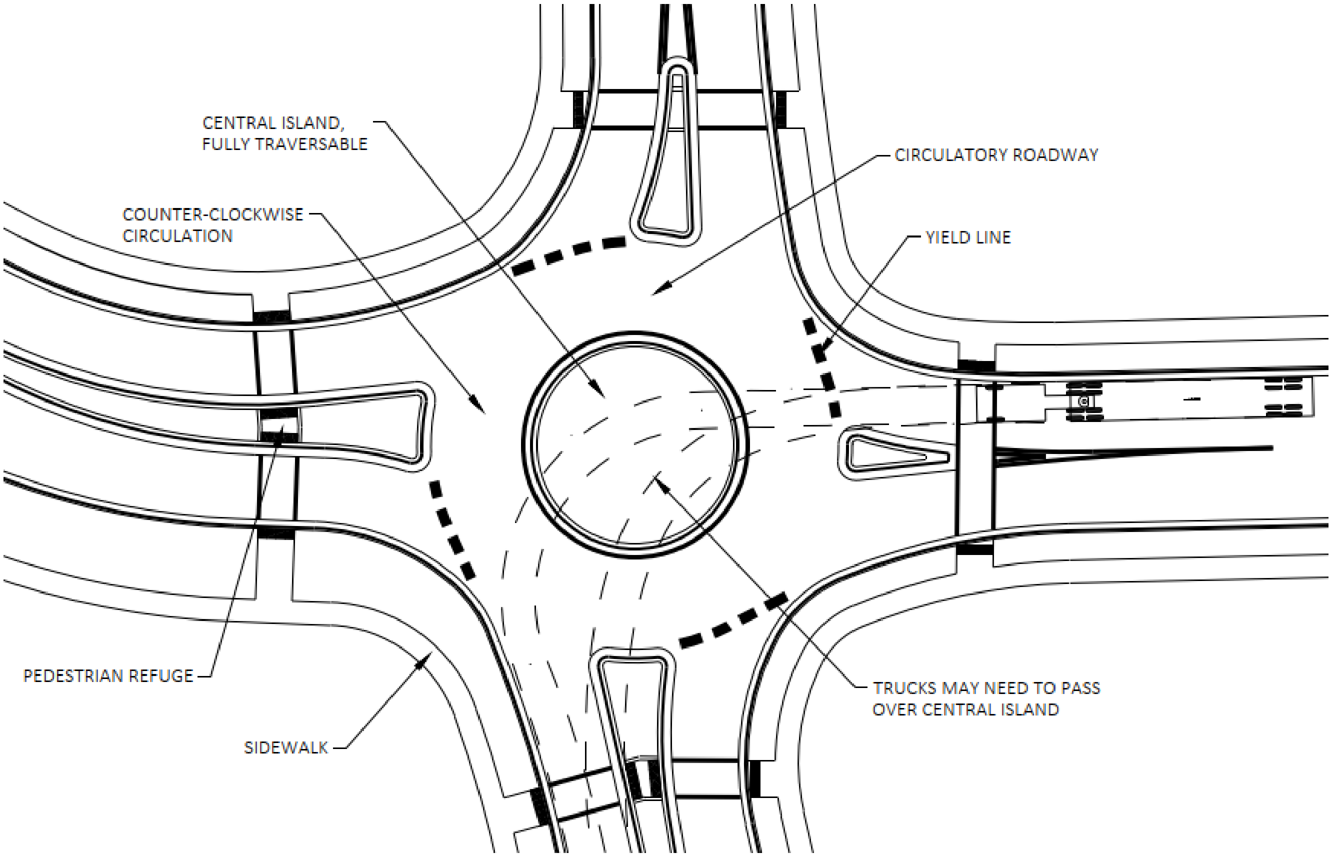


Figure 1.1 Physical Features of a Compact Roundabout

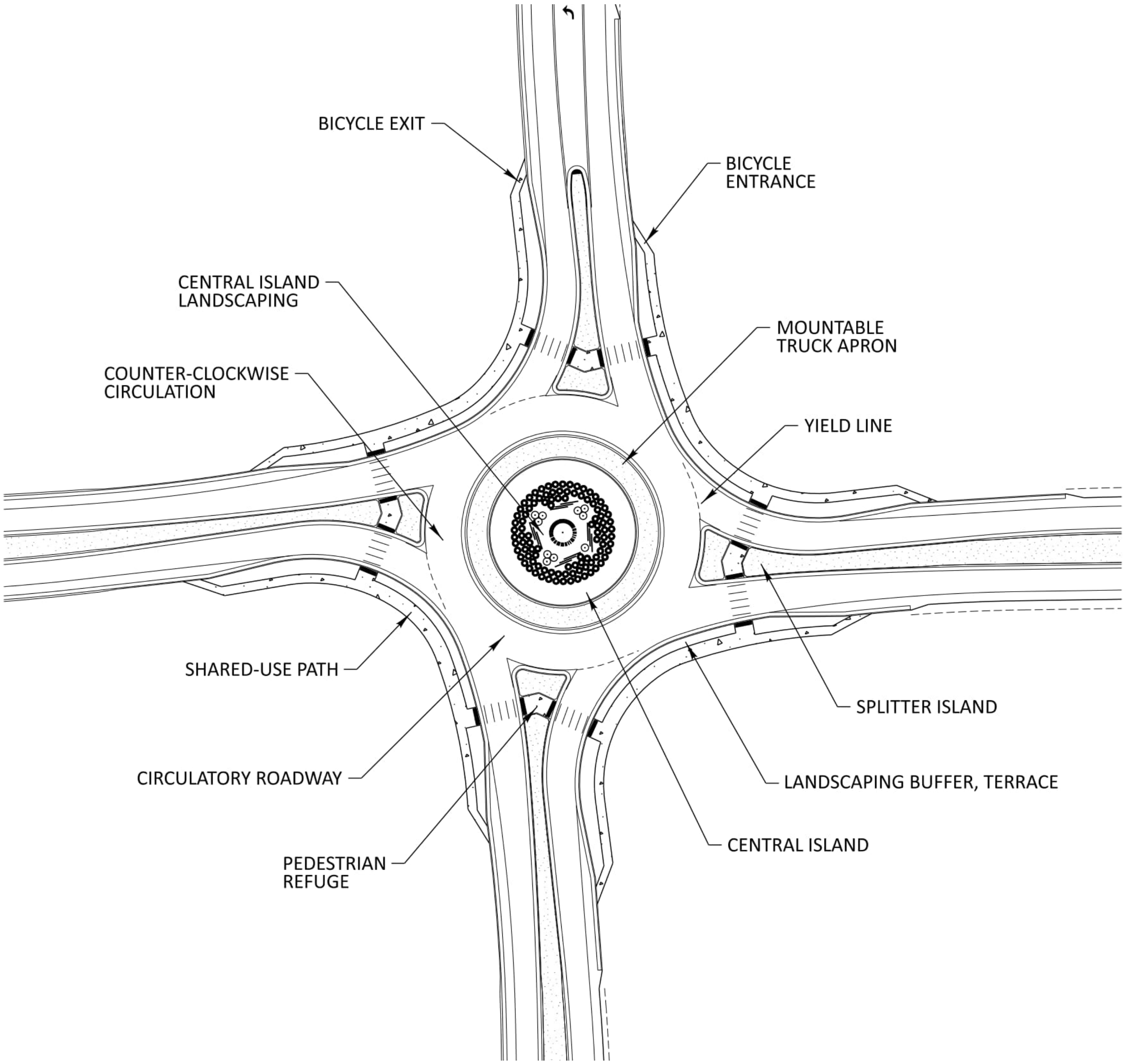


Figure 1.2 Physical Features of a Single-lane Roundabout

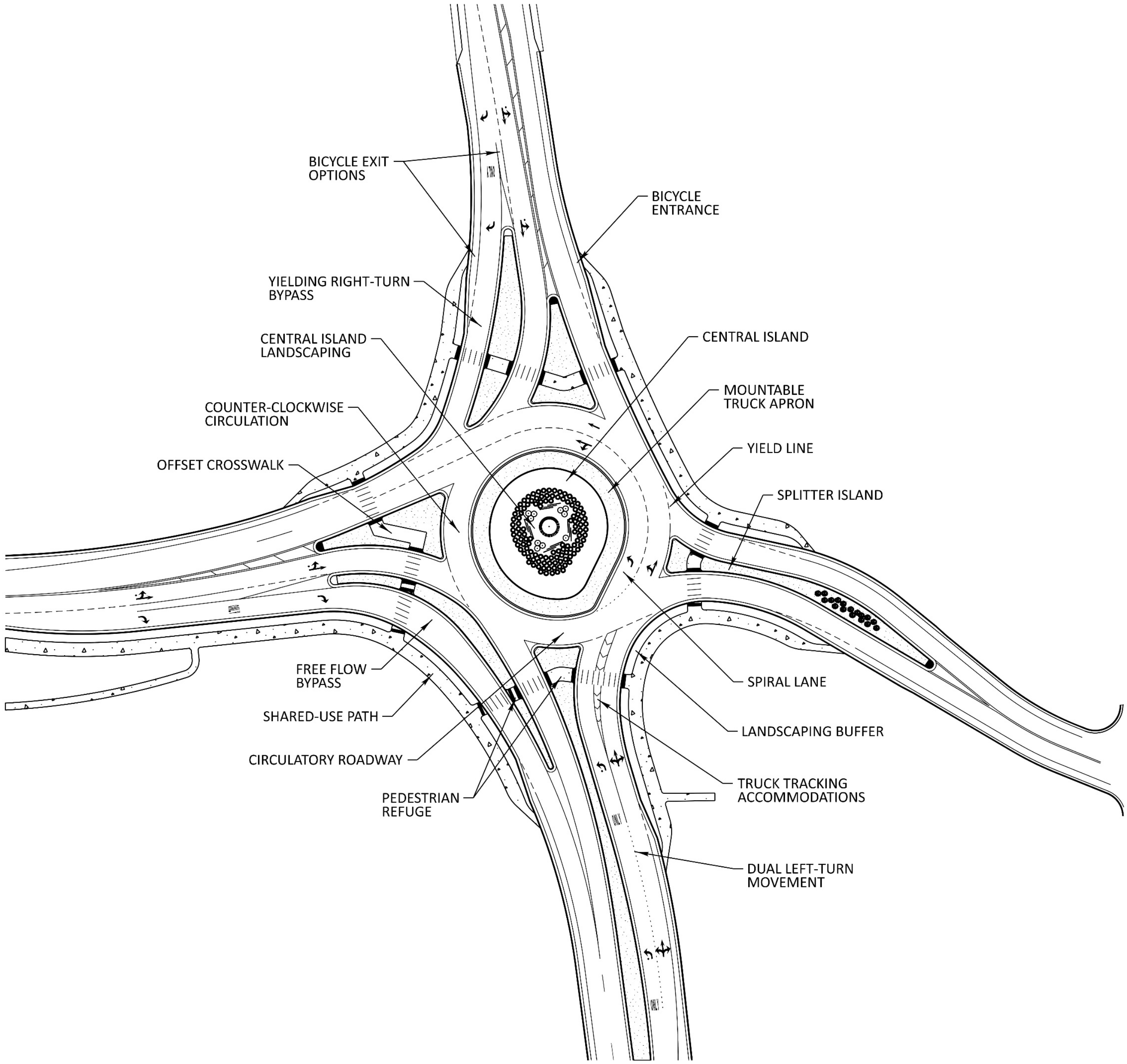


Figure 1.3 Physical Features of a Multi-lane Roundabout

Table 1.2 Roundabout Features

Feature	Description
Central island	The raised area in the center of a roundabout around which traffic circulates. The central island does not necessarily need to be circular in shape.
Splitter island	A raised curb island (special situations may be painted) area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and to provide refuge for pedestrians crossing the road in two stages.
Circulatory roadway	The curved path used by vehicles to travel in a counterclockwise fashion around the central island.
Truck apron	The traversable portion of the central island adjacent to the circulatory roadway and widened pavement area adjacent to outside curbs. It is required to accommodate snowplows and the wheel off-tracking of large trucks, and OSOW vehicles. It is paved with a contrasting color (usually red) to delineate the apron from the normal vehicle path.
Yield line	A point of demarcation separating traffic approaching the roundabout from the traffic already in the circulating roadway. The yield point is usually defined by a thick, (typically 18-inch wide), dotted edge line pavement marking.
Pedestrian crossings	Pedestrian crossings can be provided on all legs of a roundabout. The crossing location is set back from the yield line. The splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.
Bicycle treatments	Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either by riding in the travel lane as a vehicle, or by exiting the roadway and using the crosswalk as a pedestrian, or as a cyclist using the shared-use path, depending on the bicyclist's level of comfort. The entrance and exit ramps should be located approximately 50-150 feet from the circulating traffic to allow the bicyclist an opportunity to transition onto a path away from the circulatory roadway.
Landscaping buffer	Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection as long as they are placed outside the required sight limits.
Shared-use path	Pathway for non-motorized users (pedestrians, bicyclists, skaters, etc.). In the urban environment, it is common to provide a shared-use path around the perimeter of the roundabout.

1.99 References

[1] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, December 2010, http://www.trb.org/Publications/Blurbs/164470.aspx

FDM 11-26-5 Design Process and Qualifications — *May 17, 2022*

5.1 Roundabout Design Process and Qualifications

Due to the complexity of a roundabout's geometric and operational aspects, WisDOT has developed a roundabout design process which requires a Qualified Roundabout Designer (QRD) to participate in each roundabout design. A QRD must be involved with each stage of the roundabout design process.

FDM 11-26-5.2 describes the required proficiencies for each QRD level and the various roles the QRD may take in completing a roundabout design. FDM 11-26-5.3 defines the roundabout design process and the critical design elements.

5.2 Roundabout Designer Requirements

A qualified designer must meet the skills, knowledge and experience level determined appropriate by the Wisconsin Department of Transportation for roundabout design. A list of QRDs for each of the following 3 levels of roundabout complexity is available on the WisDOT Consultant Resources Roundabout Design webpage.

The region will determine the appropriate QRD Level (1, 2, or 3) based on the requirements shown in Table 5.1.

Table 5.1 QRD Level Requirements

QRD Level	Roundabout Design Complexity	QRD Proficiencies

Level 1	• Single-lane entries
	• Up to four legs
		• Assess the basic capacity requirements of single-lane roundabouts using the approved analysis software per FDM 11-26-20
		• Have the skills, knowledge, and experience to review the critical elements of design (FDM 11-26-5.3) pertinent to the roundabout(s) in question
		• Accommodate design and check vehicles (including evaluation of vertical clearance for OSOW vehicles) using software-based vehicle swept path analysis
		• Develop data for Roundabout Critical Design Parameters Document (Attachment 5.1)
		  o Design parameters (widths, angles, inscribed circle diameter)
		  o Fastest speed paths
		  o Minimum sight parameters
		• Inform the region when the roundabout design exceeds the complexity stated above for a Level 1.

Level 2	• Same as Level 1, plus… • Two-lane entries • Bypass lanes • Compact roundabouts	• Same as Level 1, plus… • Properly run the approved capacity analysis software (see FDM 11-26-20) and evaluate alternative lane configurations and output from the software program • Develop special signing and pavement marking needs for two-lane roundabouts • Inform the region when the roundabout design exceeds the complexity stated for a Level 2
Level 3	• All roundabout designs, including but not limited to… • Three or four-lane entries • Five or more legs • Closely spaced roundabouts where the operations of one may have an impact on the operations, signing, or marking of another • There are other multi-lane roundabouts in close proximity • Lane assignment or lane continuity is difficult to achieve without adding another lane • Reduction in weaving between roundabouts is desired • Queue backup into an adjacent multi-lane roundabout is possible • Other special needs that have been identified	• A Level 3 QRD must have the skills knowledge and experience to complete all tasks required for the most complex roundabout designs

WisDOT regions, consultants, local agencies such as a counties, townships, municipalities, and developers, etc. shall have a QRD on staff, or contract with a firm with a QRD, to provide the required sign-off on the Critical Design Parameters document for roundabout designs, as described below, for both WisDOT and WisDOT oversight projects.

QRDs may participate in different ways in order to provide the required sign-off on the Critical Design Parameters document.

1. Independently complete the roundabout design. When a WisDOT region, consultant, local agency such as a county, township, municipality etc. or a developer has a roundabout on a project they must have a QRD to oversee or complete all aspects of the plans, specifications and estimate (PS & E)

package for the roundabout according to the 3-Stage Design Process described below.

2. Assist and mentor the project team in their completion of the roundabout design. A WisDOT region, consultant or local agency such as a county, township, municipality etc. or developer that has a roundabout on the project may prefer to contract for assistance or mentoring from a QRD in the plans preparation process. The QRD must directly assist the project team addressing the critical design elements in the 3-Stage Design Process described below.
3. Independently review the roundabout design prepared by a project team. When a WisDOT region, consultant, local agency such as a county, township, municipality etc. or developer has a roundabout on the project and the design is prepared without any assistance from a QRD, the roundabout designer is responsible to contract with one of the QRDs to review the critical elements of the design at each stage of the Roundabout Design Process described below. The information to be provided to the QRD at each stage of plans complete is provided below.

Coordinate the proposed roundabout design with a QRD early in the design process. It is better to allow the QRD to be proactive and in a position to suggest modifications rather than to be reactive and lose design options because the design or commitments on the project are too far along.

The QRD's review comments shall be submitted to the project team and the WisDOT region at each Stage. The critical design recommendations from the QRD should be identified clearly so the roundabout design team knows what to modify on the plans. Less critical comments will likely improve the design more toward optimal and should not be taken lightly. A discussion between the QRD, design team, and region may be needed to properly address recommendations in the plans or document the dismissal of the comment(s).

The QRD in consultation with WisDOT will determine which elements of the design are critical in the situation where a dispute may take place. Department personnel are responsible to ensure that the QRD recommendations and comments are properly addressed by the design team.

5.3 The Roundabout Design Process

The following information, including Figure 5.1, describes each of the stages of development where it is critical to have a qualified designer involved in the roundabout design. There may be a project schedule delay or adverse cost ramifications associated with a roundabout design if each stage of the evaluation is not followed in sequence.

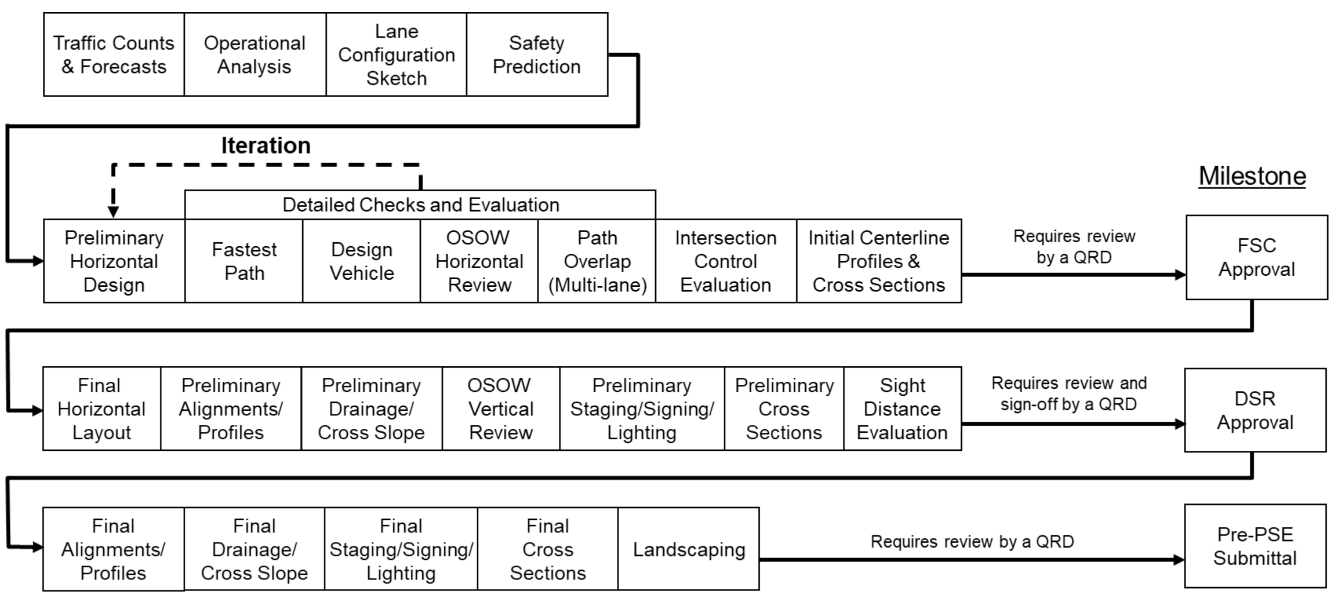


Figure 5.1 Roundabout Design Process

5.3.1 Final Scope Certification (FSC) Approval

The roundabout design process begins with an analysis of the forecasted traffic volumes, determination of the lane configuration, and development of a Phase I and/or Phase II Intersection Control Evaluation (ICE). A public involvement meeting (PIM) is also typically held prior to Final Scope Certification (FSC) approval to present the intersection alternatives. The roundabout design should be developed enough for the ICE and PIM to have an idea of right of way needs, raised median locations, access accommodations, OSOW horizontal impacts, major utilities and other potential impacts. A cursory review of centerline profiles for the roadway approaches and circulatory roadway, along with initial cross sections, is also recommended prior to FSC approval to help further evaluate impacts. This initial vertical review could take place after the PIM and before FSC approval.

Review of the roundabout design components by a QRD is required prior to ICE submittals and prior to the PIM. A QRD should also be consulted in the PIM planning process, and it is advisable to have a QRD present at the PIM. Reviewer comments and concept plans should be included as part of the Final Scope Certification document. These requirements for QRD review also apply to local program projects that may not have a FSC milestone.

The critical elements of design that the QRD needs to review prior to FSC approval include:

1. Optimum location and size of circle.
2. Lane configurations and operational analysis.
4. Lane markings and pavement arrows for multi-lane roundabouts only.
5. Highly developed design that shows face of curb locations, crosswalks, splitter islands, shared-use path, bike ramps, truck apron, etc. with appropriate widths.
6. Accommodation of design vehicles and required check vehicles.
7. Fast paths with speed calculations for R1 thru R5.
8. Initial centerline profiles of the circulatory and approach roadways, and initial cross sections.

5.3.2 Design Study Report (DSR) Approval

Prior to DSR approval, complete design revisions recommended by the QRD from the previous FSC design. At this stage, a QRD is required to review the critical design elements identified below. Review comments and design adjustments shall be incorporated in the plans prior to DSR approval. The QRD shall sign the Critical Design Parameters document (Attachment 5.1) for attachment to the DSR. One of the primary critical elements of design at this stage is the vertical control with each leg having vertical profiles, circulating roadway profile, crown location, slope intercepts, central island grading, drainage consideration with inlet locations, and spot elevations.

The critical elements of design that the QRD needs to review prior to DSR approval include:

1. Horizontal design changes implemented.
2. Roadway profiles on each leg.
3. Circulating roadway profile.
4. Crown location, cross slopes, spot elevations.
5. Crosswalks, sidewalks, and curb ramps for ADA compliance.
6. Vertical OSOW analysis.
7. Central island grading design.
8. Drainage design/inlet locations.
9. Preliminary light standard locations.
10. Preliminary stopping sight distance for - approach, circulatory roadway, crosswalk and exit, and the intersection sight distance.
11. Signing plan, and identify the need for large green and white guide signs, overhead guide signs, or other non-typical installations.
12. Pavement marking plan for multi-lane roundabouts.
13. Identify major utility conflicts (i.e. utility conflicts that may result in relocating the circle).
14. Preliminary typical sections.
15. Consider preliminary construction staging layout and identify potential staging conflicts, such as access control, large grade differences between stages, etc. that may impact the design.

5.3.3 Pre-PS&E Submittal

Prior to Pre-PS&E submittal, finalize the vertical, drainage, pavement marking, signing, lighting, landscaping plans, and construction staging. At this stage, a QRD is required to review the critical design elements identified below. Review comments and design adjustments shall be incorporated in the plans prior to Pre-PS&E submittal.

The critical elements of design that the QRD needs to review prior to the Pre-PS&E submittal include:

1. Final plan and profile with any vertical and horizontal control details included for field layout.
2. Final signing and pavement marking plan.
3. Final landscaping and lighting plan.
4. Final construction staging plan.

LIST OF ATTACHMENTS

Attachment 5.1 Roundabout Critical Design Parameters Document

FDM 11-26-10 User Considerations May 17, 2022

10.1 Pedestrian and Bicyclist Accommodations

Accommodating pedestrians and bicycles is a Department priority. Therefore, the project context is important in the design of these facilities at roundabouts. For example, consider the adjacent land use and destinations in the corridor (e.g., schools, hospitals, commercial, residential), area demographics (populations of non-drivers such as people with disabilities), network connectivity and continuity of sidewalks, and regional shared-use paths. If available, information on pedestrian and bicycle volumes, risk exposure, or crash data should also be considered, as well as evaluating roadway characteristics (e.g., speed, number of travel lanes) that people walking, and biking will need to navigate at a roundabout. Designers should contact the region or state bicycle and pedestrian coordinator for their guidance.

10.1.1 Pedestrians

Research report NCHRP 672 [1] indicates pedestrian crash severity is generally lower at roundabout intersections when compared to signalized and unsignalized intersections with comparable volumes. Design principles need to be applied that provide for slow entries and exits for pedestrian safety.

Due to relatively low operating speeds of 15 to 20 mph, pedestrian safety can be better with a roundabout design than with other intersection types. Table 10.1 lists the advantages and disadvantages of roundabouts as related to pedestrians.

***Table 10.1* Roundabout Advantages and Disadvantages for Pedestrians**

Advantages	Disadvantages
Vehicle speed is reduced as compared to other intersections.	Vehicle traffic is yield controlled so traffic does not necessarily come to a full stop.
The splitter island may assist pedestrians in crossing to reduce conflicts with entering and exiting vehicles separately, having to only look for vehicles in one direction. The crossings can also be offset in the splitter island, improving sightlines for people crossing and making them more visible to drivers.	May be difficult for people crossing to judge gaps in traffic, particularly for people with visual impairments, which may lead to increased pedestrian delay. Additional cues to locate the crosswalk may be needed, as crosswalk placement is typically behind the first stopped vehicle. May be a longer travel path as compared to other intersections.

Proper design of the crosswalks is important for pedestrian safety and function as well as for the overall operation of the roundabout. Crosswalk placement should minimize crossing distance to reduce exposure to pedestrian-vehicle conflicts.

Pedestrian facilities, including crossings at roundabouts, are to be designed and constructed to comply with Americans with Disabilities Act (ADA) and follow Public Rights of Way Accessibility Guidelines (PROWAG) for new and altered facilities to ensure meeting ADA requirements. Information from other guides and research includes and may be referenced:

- NCHRP 672, Chapter 6, §8.1 and Chapter 7, §5.3;
- NCHRP 834, Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities – A Guidebook
- AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, 2nd Edition
- MUTCD, §3B.18 and
- Wisconsin MUTCD (WMUTCD), 3B.18.

NCHRP 834 discusses traffic control devices at roundabouts which may be useful crossing solutions in limiting risks for pedestrians with visual impairments and facilitating pedestrian crossings. It may be appropriate to consider Rectangular Rapid Flashing Beacons (RRFBs) at locations where pedestrians may have challenges in finding a gap for crossing, in high-noise environments, at multi-lane facilities, or if there are other accessibility concerns. Pedestrian hybrid beacons (PHB) are another type of traffic control for pedestrian crossings, and, if considered for installation at roundabouts on the STH system, must be approved by BTO and BPD. Refer to TEOpS 4-5 for guidance and contact the regional traffic operations unit, regional bicycle and pedestrian coordinator, and BTO if considering installing any of these traffic control devices at roundabouts. See FDM 11-26-30.5.13.5 for placement of RRFBs if applicable.

10.1.2 Bicyclists

The Insurance Institute for Highway Safety reports that roundabouts provide a 10 percent reduction in bicycle crashes at 24 signalized intersections that were converted to roundabouts in the U.S. Multi-lane entry roundabouts may be more problematic than single-lane entries.

The complexity of vehicle interactions within a roundabout could leave a cyclist vulnerable, and for this reason, designated bike lane markings within the circulatory roadway shall not be used (WMUTCD, 9C.04). Effective designs that constrain motorized vehicles to speeds more compatible with bicycle speeds are much safer for bicyclists.

The operation of a bicycle through a roundabout presents challenges to the bicyclist similar to that of traditional signalized intersections especially for turning movements. As with pedestrians, one of the difficulties in accommodating bicyclists is their wide range of skills and comfort levels. While experienced bicyclists may have no difficulty maneuvering through a roundabout, less experienced bicyclists may have difficulty and discomfort mixing with vehicles and may feel safer on a roundabout sidepath.

Design features such as proper entry curvature and entry width help slow traffic entering the roundabout. Providing a ramp from the roadway to a roundabout sidepath or shared-use path prior to the intersection allows a bicyclist to exit the roadway and proceed around the intersection safely through the use of crosswalks.

Bicyclists are often less visible and therefore more vulnerable when merging into and diverging from multi-lane roundabouts. Therefore, it is recommended that a wider shared-use pedestrian-bicycle path be built where bicycle use is expected. While this will likely be more comfortable for the casual bicyclist, the experienced commuter bicyclist will be slowed down by having to cross as a pedestrian at the cross walk and may choose to continue to traverse a multi-lane roundabout as a vehicle. Refer to FDM 11-26-30.5.13 for design guidance.

Information from other guides and research includes and may be referenced:

- NCHRP 672, Chapter 6, §8.1
- AASHTO Guide for the Development of Bicycle Facilities

10.2 Transit, Large Vehicle, Oversized Vehicles and Emergency Vehicle Considerations

10.2.1 Transit

Transit considerations at roundabouts are similar to those for any other intersection configuration. A properly designed roundabout will readily accommodate buses. For rider comfort, transit vehicles should not have to use the truck apron.

Bus stops on the far side are preferred and should be constructed with pull-outs. They should be located beyond the pedestrian crossing to improve visibility of pedestrians to other exiting vehicles. Far-side stops result in the crosswalk being behind the bus, which provides for better sight lines for vehicles exiting the roundabout to pedestrians and keeps bus patrons from blocking the progress of the bus when they cross the street.

The use of bus pull-outs has some trade-offs to consider. A positive feature of a bus pullout is that it reduces the likelihood of queuing behind the bus into the roundabout. A possible negative feature is that a bus pullout may create sight line challenges for the bus driver to see vehicles approaching from behind when attempting to merge into traffic. It may also be possible at multi-lane roundabouts in slow-speed urban environments to include a bus stop without a bus pullout immediately after the crosswalk, as exiting traffic has an opportunity to pass the waiting bus. In a traffic-calmed environment, or close to a school, it may be appropriate to locate the bus stop at a position that prevents other vehicles from passing the bus while it is stopped.

If a bus stop must be located upstream of the roundabout (near side), it should be placed far enough away from the splitter island, such that a vehicle overtaking the stationary bus has adequate space. If the approach is a single-lane and capacity is not an issue, the bus stop could be placed at the pedestrian crossing. Nearside stops provide the advantage of having a potentially slower speed environment where vehicles are slowing down, compared to a far-side location where vehicles may be accelerating upon exiting the roundabout. Nearside stops are not recommended for entries with more than one lane because vehicles in the lane next to the bus may not see pedestrians.

The decisions in regard to transit stop location must be coordinated with the local transit authority.

10.2.2 Large Vehicles

Design roundabouts for the largest vehicle that is anticipated to use the roundabout on a regular basis. All roundabouts on the State Highway system must accommodate a WB-65 design vehicle, which is the largest vehicle allowed on the State Highway system without a permit. Refer to FDM 11-25 Table 2.1 for required intersection design vehicles and check vehicles for various trucking route scenarios. Designing a roundabout for a large vehicle to stay in-lane at entry and within the roundabout presents challenges such as the possibility of:

- A larger diameter
- Wider entries

- Wider circulating lanes
- Increased right of way needs
- Increases in certain types of crashes
- Other unique design features

Several of the items listed above including a larger diameter, wider entries, and wider circulating lanes are contradictory when looking at compact roundabouts. Compact roundabouts are especially difficult to design when WB-65 or larger vehicles are required to make right or left turning movements at the intersection. See FDM 11-26-30.5 for design guidance on accommodating large trucks.

Load shifting may be problematic for the contents of any vehicle while navigating a turning maneuver. Load shifting is a common concern for liquid or semi-liquid loads where the weight of the load may shift in a manner to exacerbate overturning. It is not uncommon for a vehicle with a high center of gravity to overturn when navigating a turn at speeds that exceed the laws of mechanics. A roundabout is designed to minimize load-shifting problems with larger vehicles; however, speed is major factor related to overturning. Problems such as minimal entry deflection may lead to high entry speeds, long tangents leading into tight curves, sharp turns at exits, excessive cross slopes, and adverse cross slopes have been the principle causes of load shifting. See FDM 11-26-30.5 for geometric design of roundabouts.

10.2.3 Oversized Overweight (OSOW) Vehicles

During the preliminary design, check with local officials and the public to determine if there are any special OSOW vehicles that regularly use the route and refer to the WisDOT OSOW vehicle inventory in FDM 11-25 Attachment 2.1. Coordinate OSOW Truck Route (OSOW-TR) and routing activities with the regional freight operations engineer.

Review the truck guidance provided in FDM 11-25-1.4 and FDM 11-25-2, which includes additional information related to truck routes, the OSOW-TR and intersection design guidance. The Department maintains a map showing designated state and federal truck routes and the OSOW-TR in Wisconsin, which is available on the web, see the link in FDM 11-25-1. This map may experience occasional to frequent updates and changes, therefore use the most current on-line version.

It is becoming somewhat common to widen the truck apron along the sides to accommodate OSOW vehicle through movements. Additional pavement (behind a mountable curb) may also be provided along the right side of the entries to accommodate wheel off-tracking. Signposts may also have to be mounted in removable sleeves to provide additional lateral space for OSOW vehicles (see FDM 11-26-35.1.12). In rare cases, roundabouts have been designed with a gated bypass roadway to accommodate turns. See FDM 11-26-30.5.6 for design guidance to accommodate OSOW vehicles.

10.2.4 Emergency Vehicles

Emergency vehicles passing through a roundabout encounter the same problem as other large vehicles and may require the use of the truck apron. On emergency response routes, compare the delay for the relevant movements with alternative intersection types and controls.

Roundabouts provide the benefit of lower vehicle speeds, which may make them safer for emergency vehicles to negotiate than conventional intersections.

The Wisconsin Motorist's Handbook provides information on what to do when the driver encounters an emergency vehicle. The driver must yield the right of way for emergency vehicles using a siren, air horn or a red or blue flashing light. The driver in the circulatory roadway should exit the roundabout before pulling over. Emergency vehicles will typically find the safest and clearest path to get through an intersection. This may include driving the emergency vehicle, with caution and with lights and siren on, in the opposing lane(s) or however the operator sees as the most desirable alternative path.

10.99 References

[1] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, December 2010, http://www.trb.org/Publications/Blurbs/164470.aspx

FDM 11-26-15 Agency & Public Coordination — May 17, 2022

15.1 Public Meetings

Public meetings provide an excellent opportunity to bring the public into the design process. It is generally desirable to present the concept layouts of all feasible alternatives from the Intersection Control Evaluation on an equal basis at a public meeting and explain that a roundabout appears to be a reasonable alternative. Inform the public that no preference to any alternative is indicated at that stage, but that input to all alternatives is being gathered. Try to be as specific as possible about the real estate impacts, access impacts and anticipated operations (LOS) between the various alternatives. At this level of design, it may be important to let the public know that you do not have all the answers about the various impacts. An effective education and communication method applicable to some projects with roundabouts includes scheduling a specific time at each PIM of approximately 10-20 minutes to explain the following:

- The project time-line
- Source(s) of funding
- Concept of roundabouts
- Why the Department has included the roundabout as an alternative
- Construction duration and possible detours or road closures
- Illustrations of how pedestrians, bicyclists, and vehicles should travel through the roundabout
- Holding an open house and public information “exchange” meetings, and attending village and town board meetings or local service organizational meetings are good formats for education and consensus building

After the initial public meeting, a screening evaluation accounting for public support can be completed. Refer to FDM 11-25-3. At the next public meeting, the preferred alternative can then be presented.

15.2 Public Outreach Resources & Methods

The success or failure of a project can often be attributed to how well the Department included the public in its development. This can be particularly true when introducing the roundabout due to its confusion with past circular intersections. There are excellent resources to assist the designer in explaining roundabouts to the public and to help educate drivers:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/design.aspx

Typically, in the project planning process, alternatives are considered. The alternatives generally include traffic signal, stop sign, or roundabout control; some of which are familiar to drivers and pedestrians. Presenting a comparison of traffic operations and safety between alternatives is a good way to introduce roundabouts. It is essential to inform the public of the planning process that led to the decision favoring a roundabout as the preferred traffic control. A traceable transparent planning process engenders trust and validates the process of wise investment in infrastructure. Designers are encouraged to generate project-specific roundabout outreach materials on their region’s web site. Coordination of this effort must be through the Central Office (IT) coordinator and the web site content coordinator.

The common dilemmas for most agencies that want to start using roundabouts are:

- Recognized public perception of roundabouts vs. their proven performance
- Driver education: way-finding and lane choice
- Pedestrian perception of safety vs. proven conditions
- Bicyclist education
- Permitted trucking (typical large trucks)

Pitfalls in the initial push for roundabouts can be avoided by developing detailed components of project outreach resources for internal stakeholders (local agencies) and external stakeholders (the public) early and continuously. A public acceptance and education campaign is critical to the successful implementation of roundabouts at the State level and for local communities. A successful project oriented public outreach campaign involves assembling a collection of educational and acceptance resources of a general nature. Many of these are readily available through the department’s website:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/design.aspx

but some require adaptation to the project location and context. Examples of the kinds of resources that should be collected and distributed through various media include:

- Case studies
- Testimonials
- National and Wisconsin-specific statistics
- How-to videos
- Web-cam
- Driver training
- Website
- Brochures
- Talking points/discussion bulletins for legislators and staff to respond to calls
- Vulnerable user training materials

A strategy to apply these components requires starting with internal staff (planning, design and maintenance operations); State legislators; District Attorney, State Patrol; then moving to external stakeholders, e.g., interest groups, trucking associations and mobility advocacy groups. Finally, once a consensus is reached with internal and external stakeholders a general public meeting or outreach contact can be arranged.

Prior to any general public outreach, a local officials meeting should be held with local council members, police and fire services, senior staff, and maintenance operations staff. The general education process is exercised with this group and the project specific presentation of the engineering study that led to the choice of a roundabout as an alternative control is made. A consensus must be the goal of the local officials meeting in order that the subsequent public contact, e.g., open house goes smoothly with upper and lower tier agency agreement on why the use of a roundabout and how the project will be implemented, including proposed education for the locally affected.

Preparation for the local project public contact requires development of context specific education and outreach components. An inventory of resources that have proven effective for local project outreach is as follows:

- Scale model (1:87, 1 inch = 7.25 feet) of the layout accompanied by scale model trucks and cars
- Animation/simulation of the expected operation of the roundabout and possibly a comparison to the alternative(s)
- Renderings or visualizations
- A project location brochure
- How-to driver, pedestrian and bicycle user resources
- Talking points bulletins for local councilors that give a summary of the planning process, traces the results of studies and documents funding sources, schedule and staging of construction

When introducing compact roundabouts to local officials or the public, refrain from using the term “compact”. A compact roundabout is simply a smaller roundabout and should just be referred to as a “roundabout”. The use of the term “compact” may confuse the general public or erroneously imply that the roundabout is substandard.

15.99 References

[1] National Safety Council. Estimating the Costs of Unintentional Injuries, 2008. National Safety Council Website:

www.nsc.org/news_resources/injury_and_death_statistics/Pages/EstimatingtheCostsofUnintentionalInjuries.aspx

[2] Boardman, A., Greenberg, D., Vining, A., and Weimer, D. Cost Benefit Analysis: Concepts and Practice. Prentice Hall; 3rd Edition, 2005.

[3] Gómez-Ibáñez, J. A., Tye, W. B., and Winston, C. Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Mayer. Brookings Institution Press, 1999

FDM 11-26-17 System Considerations — May 17, 2022

17.1 System Considerations

Roundabouts may need to fit into a network of intersections with the traffic control functions of a roundabout supporting the function of nearby intersections and vice versa. Because the design of each roundabout generally follows the principles of isolated roundabout design, this guidance is at a conceptual and strategic level and generally complements the planning of isolated roundabouts. In many cases, site-specific issues will determine the appropriate roundabout design elements. Closely spaced roundabouts are characterized by the operations of one roundabout having an impact on the operations of an adjacent roundabout and may have overhead lane signs and spiral designs with additional lanes for lane balance and lane continuity issues that arise with closely spaced roundabouts in a series.

17.2 Adjacent Intersections and Highway Segments and Coordinated Signal Systems

It is generally undesirable to have a roundabout located near a signalized intersection. A strategic level traffic assessment of system conditions of a series of roundabouts analysis is needed to determine how appropriate it is to locate a roundabout within a coordinated signal network. There may be situations where an intersection within the coordinated signal system requires a very long cycle which is caused by high side road traffic or large percentage of turning movements and is dictating operations and reducing the overall efficiency for the coordinated system. On rare instances, replacing a signalized intersection with a roundabout may allow for the system to be split into two systems thus improving the efficiency of both halves while also improving the efficiency of the entire roadway segment. A traffic analysis is needed to evaluate each specific location.

17.3 Roundabouts in an Arterial Network

In order to understand how roundabouts operate within a roadway system, it is important to understand their fundamental arrival and departure characteristics and how they may interact with other intersections and highway features. Lane use and lane balance on an approach can vary from ideal conditions where roundabouts are in a system and at times closely spaced. Sensitivity testing of alternative lane use patterns and lane designation alternatives in geometric design is necessary. Microsimulation of traffic patterns is recommended for roundabouts being treated as a system.

17.3.1 Planned Network, Access Management

Rather than thinking of roundabouts as an isolated intersection or replacement for signalization, identify likely network improvements early in the planning process. This is consistent with encouraging public and other stakeholder interaction to prepare or update local comprehensive or corridor plans with circulation elements. Project planning and design are likely to be more successful when they are part of a larger local planning process. Then, land-use and transportation relationships can be identified, and future decisions related to both can be applied.

Roundabouts may be integral elements in village, town, and city circulation plans with multiple objectives of improving circulation, safety, pedestrian and bicycle mobility, and access management. Roundabouts rely on the slowing of vehicles to process traffic efficiently and safely which results in a secondary feature of “calming” traffic. It can be expected that local studies and plans will be a source of requests for roundabout studies, projects, and coordination on state arterials. A potential use of arterial roundabouts is to function as gateways or entries to denser development, such as villages or towns, to indicate to drivers the need to reduce speed for upcoming conflicts including turning movements and pedestrian crossings.

Retrofit of suburban commercial strip development to accomplish access management objectives of minimizing conflicts can be a particularly good application for roundabouts. Raised medians are often designed for state arterials to minimize left turn conflicts; and roundabouts accommodate U-turns. Left-turn exits from driveways onto an arterial that may currently experience long delays and require two-stage left-turn movements could be replaced with a simpler right-turn, followed by a U-turn at the next roundabout. Again, a package of improvements with driveway consolidation, reverse frontage, and interconnected parking lots, should be planned and designed with close local collaboration. Also, a roundabout can provide easy access to corner properties from all directions. When large volumes of U-turns are expected, the use of compact roundabouts should be avoided. Larger vehicles (e.g. WB-65) may not be able to make a U-turn at a compact roundabout depending on the size.

17.3.2 Platooned Arrivals on Approaches

Vehicles exiting a signalized intersection tend to be grouped into platoons. Platoons, however, tend to disperse as they move down-stream. Roundabout performance is affected by its proximity to signalized intersections and the resulting distribution of entering traffic. If a signalized intersection is very close to the roundabout, it causes vehicles to arrive at the roundabout in closely spaced platoons. The volume of the arriving platoon and the capacity of the roundabout will dictate the ability of the roundabout to process the platoon. Analyze these situations carefully to achieve a proper design for the situation. Discuss proposed roundabout locations with the regional traffic section staff. Microsimulation of traffic patterns is recommended for roundabouts in close proximity (500’ or less) to traffic signals.

17.3.3 Roundabout Departure Pattern

Traffic leaving a roundabout tends to be more random than for other types of intersection control. Downstream gaps are shorter but more frequent as compared to a signal. The slower approach and departing speeds along with the gaps allow for ingress/egress from nearby driveways or side streets. The slowing effects are diminished as vehicles proceed further downstream. However, the gaps created at the roundabout are carried downstream and vehicles tend to disperse again providing opportunities for side street traffic to enter the main line roadway.

Sometimes traffic on a side street can find it difficult to enter a main street at an un-signalized intersection. This happens when the side street is located between two signalized intersections and traffic platoons from the signalized intersections arrive at the side street intersection at approximately the same time. If a roundabout replaced one of these signalized intersections, then its traffic platoons would be dispersed, and it may be easier for traffic on the side street to enter the main street. Alternatively, when signals are well coordinated they may provide gaps at nearby intersections and mid-block for opportunities to access the main line.

If a roundabout is used in a network of coordinated signalized intersections, then it may be difficult to maintain the closely packed platoons required. If a tightly packed platoon approached a roundabout, it could proceed through the roundabout as long as there was no circulating traffic or traffic upstream from the left. Only one circulating vehicle would result in the platoon breaking down. Hence, this hybrid use of roundabouts in a coordinated signalized network needs to be evaluated carefully.

Another circumstance in which a roundabout may be advantageous is as an alternative to signal control at a critical signalized intersection within a coordinated network. Such intersections are the bottlenecks and usually determine the required cycle length or are placed at a signal system boundary to operate in isolated actuated mode to minimize their effect on the rest of the surrounding system. If a roundabout can be designed to operate within its capacity, it may allow a lowering of the system cycle length with resultant benefits to delays and queues at other intersections.

17.4 Closely Spaced Roundabouts

It is sometimes desirable to consider the operation of two or more roundabouts near each other. Closely spaced roundabouts can potentially reduce queues and balance traffic flows. The spacing between any two roundabouts is considered closely spaced if they are less than 1,000 feet from center to center (see FDM 11-26-30.5.13). They also can accommodate a wide range of access, both public and private. In any case, the expected queue length at each roundabout becomes important. Compute the expected queues for each approach to check that sufficient queuing space is provided for vehicles between the roundabouts. If there is insufficient space, then drivers may occasionally queue into the upstream roundabout, potentially causing a reduction from the typical operations. However, the roundabout pair can be designed to minimize queuing between the roundabouts by limiting the capacity of the inbound approaches.

Closely spaced roundabouts may improve safety and accessibility to business or residential access or side streets by slowing the traffic on the major road. Drivers may be reluctant to accelerate to the expected speed on the arterial if they are also required to slow again for the next close roundabout. This may benefit nearby residents.

For additional information, see NCHRP 672, §6.9.

17.5 Roundabout Interchange Ramp Terminals

Freeway ramp junctions with arterial roads are potential candidates for roundabout intersection treatment. This is especially true if the subject interchange typically has a high proportion of left-turn flows from the off-ramps and to the on-ramps during certain peak periods, combined with limited queue storage space on the bridge crossing, off-ramps, or arterial approaches. In such circumstances, roundabouts operating within their capacity are particularly amenable to solving these problems when compared with other forms of intersection control. Refer to FDM 11-25 and FDM 11-25 Attachment 2.1 for OSOW vehicle inventories and FDM 11-25 Table 2.1 for required intersection OSOW design vehicle checks, including at the junction of OSOW truck routes.

Occasionally, an OSOW vehicle may have to bypass a bridge by taking the off-ramp and making a through movement and entering the on-ramp (a.k.a. “ramp-on/ramp-off”). Design the median island to accommodate the OSOW through movement. Refer to FDM 11-30-1 for additional guidance on interchange design.

The benefits and costs associated with this type of interchange also follow those for a single roundabout. Some potential benefits of roundabout interchanges are:

- The queue length on the off-ramps may be less than at a signalized intersection. In almost all cases, if the roundabout would operate below capacity, the performance of the on-ramp is likely to be better than if the interchange is signalized.
- The intersection site distance is much less than what it is for other intersection treatments.
- The headway between vehicles leaving the roundabout along the on-ramp is more random than when signalized intersections are used. This more random ramp traffic allows for smoother merging behavior onto the freeway and a slightly higher performance at the freeway merge area similar to ramp metering.

There are no unique design parameters for roundabout interchanges. They are only constrained by the physical space available to the designer and the configuration selected. Several geometric configurations for ramp terminals with roundabouts exist:

- The raindrop form, which does not allow for full circulation around the center island, can be useful if grades are a design issue since they remove a potential cross-slope constraint on the missing circulatory road segments. However, raindrop shapes lack the operational consistency, because one entry will not be required to yield to any traffic. Because of this, an undesirable increase in speed may occur. If an additional road connects to the ramp terminal, the raindrop form should not be used.
- A single-point diamond interchange incorporates a large-diameter roundabout centered either over or under the freeway. While remaining somewhat compact, this solution may not be cost-effective, especially for retro-fit locations, as existing overpass structures may not be adequately sized or oriented.
- Dual roundabouts are the common choice for interchange locations. This design may delay or eliminate the need for overpass reconstruction, while also allowing for easier future roundabout expansion. It offers the greatest flexibility in location of the roundabouts while improving ramp geometry and minimizing the need for retaining walls. It may require additional right of way to be acquired, as this design typically requires the most space.

For additional information, see NCHRP 672, §6.10.

17.6 At-Grade Rail Crossings

Locating any intersection near an at-grade railroad crossing is generally discouraged. However, due to necessity, intersections are sometimes located near railroad grade crossings. When considering locating a roundabout within 1,000 feet of a railroad, contact the region railroad coordinator early in the process. It is preferable to cross one of the legs of a roundabout and leaving a typical distance of at least 100 feet from the center of the track to the yield line. Treatment should follow the recommendations of the Wisconsin MUTCD whenever possible. Consider allowing the railroad track to pass directly through the circle center of the roundabout rather than through another portion of the circular roadway if the at-grade crossing is not on one of the legs. Also, consider the design year traffic on the roadway, the number of trains per day, speed of trains, length of trains, type of crossing warning devices, and anticipated length of vehicular queues when evaluating the intersection control needed in close proximity to the railroad.

Refer to FDM 17-1-1 for additional railway information. Expert assistance is required to address rail pre-emption requirements of roundabouts in close proximity.

17.99 References

[1] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, Chapter 7, Section 6.

FDM 11-26-20 Operations — August 16, 2022

20.1 Operational Analysis References and Methods

The growing number of roundabouts in the United States (US) has led to an increase in national and local research of roundabout operations and capacity. The National Cooperative Highway Research Program (NCHRP) published the first major study in the US on roundabout operations in the 2007 NCHRP Report 572 [1]. The findings of the NCHRP Report 572 reflect 2003 data from approximately 300 roundabouts. A Federal Highway Administration (FHWA) sponsored project [5], completed in 2015, built upon the methodologies of NCHRP Report 572 [1]. The 2015 FHWA report [5] incorporates 2012 data collection efforts and significantly increases the number of useable data points as compared to the NCHRP Report 572 [1].

This research found that driver behavior and the number of entry lanes has the largest effect on the performance of US roundabouts. The capacity and operations of US roundabouts is more sensitive to the interaction between drivers entering and circulating the roundabout and the number of entry lanes than the detailed geometric parameters (e.g., lane width, entry radius, phi angle, and inscribed circle diameter) used in the Australian [2] and UK models [3]. Although important to ensure the safety and efficiency of travel through a roundabout, the fine details of geometric design are secondary and less significant than variations in driver behavior when analyzing capacity at roundabouts in the US.

The Highway Capacity Manual 7th Edition (HCM7), Chapter 22, provides analytical procedures for the analysis of planned and existing roundabout. The 2015 FHWA report [5] provides the foundation for the HCM7, Chapter 22 roundabout methodology. The methods of the HCM allow traffic engineers and designers to assess the operational performance of a roundabout, given information about the demand levels for motor vehicles, pedestrians and bicycles. The following sections provide guidance on operational analysis for Wisconsin DOT projects considering the installation of a new roundabout or evaluating the capacity of an existing roundabout.

20.2 Roundabout Operation

A roundabout brings together conflicting traffic streams at reduced speeds, allowing the streams to cross paths safely, traverse the roundabout, and exit. Roundabouts do not have merging or weaving between conflicting traffic streams. Compactness of circle size and geometric speed control make it possible to establish priority to circulating traffic. The geometric elements, signage and pavement markings of the roundabout reinforce the rule of circulating traffic priority and provide guidance to drivers approaching, entering, and traveling through a roundabout.

Gap acceptance (i.e., headway) behavior determines the operation of vehicular traffic at a roundabout. Drivers at each approach look for and accept gaps in circulating traffic. The low speeds of a properly designed roundabout facilitate this gap acceptance process. The width of the approach roadway, the curvature of the roadway, and the volume of traffic present on a given approach govern this speed. As drivers approach the yield point, they must first yield to pedestrians and then to conflicting vehicles in the circulatory roadway. The size of the inscribed circle affects the radius of the driver's path, which in turn determines the speed at which drivers travel in the circulatory roadway.

20.2.1 Planning Level Analysis and Space Requirements

The inscribed circle diameter needed for a roundabout is one of the most critical space requirements when considering impacts to right of way, costs, design vehicle and others. The following table gives general inscribed circle diameters and daily service volumes for the different types of roundabouts. The typical daily service volumes ranges described in Table 20.1 are derived from Exhibit 3-12 in the NCHRP Report 672 [7] and are dependent on the left turn percentage of the daily service volume. For a planning level analysis, it may be appropriate to assume that three-leg roundabouts will have a capacity that is 75% of the service volumes shown in Exhibit 3-12 of the NCHRP Report 672 [7]. Use Table 20.1 for inscribed circle diameter values to help in the initial steps of considering a roundabout as a feasible alternative. Diameters will vary, and in some situations, may fall outside these typical ranges.

Table 20.1 Typical Inscribed Circle Diameters and Estimated Daily Service Volumes

Roundabout Type	Typical Inscribed Circle Diameter[1]	Typical Daily Service Volume[2,3] (vpd) 4-leg roundabouts
Compact	80 – 120 ft *(25 – 35 m)*	less than 15,000
Single-lane	120 -160 ft *(35 – 50 m)*	less than 25,000
Multi-lane (2-lane entry)	160 - 215 ft *(50 – 65 m)*	25,000 to 45,000
Multi-lane (3-lane entry)	215 - 275 ft *(65 – 85 m)*	45,000 or more

[1] For additional guidance based on design vehicle see Exhibit 6-9 Inscribed Circle Diameter Ranges in NCHRP Report 672 [7]

[2] Capacities vary substantially depending on entering traffic volumes and turning movements.

[3] Consult with Exhibit 3-12, "NCHRP Report 672, Roundabouts: An Informational Guide, Second Edition" [7] to estimate the ADT for a specific left-turn percentage.

The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout during a given time period under prevailing traffic and geometric conditions. An operational analysis considers entering and circulating traffic flow rates defined for the morning and evening peak periods for each lane at a roundabout. Analysis of the peak hour period is critical to assess the level of performance at each approach and the roundabout as a whole.

For a properly designed roundabout, the entry area is the relevant point for capacity analysis. The approach capacity is the capacity provided at the yield point. The interaction between entering and circulating streams of traffic, the basic number of entry and circulating lanes and to a lesser degree the geometric parameters, signage and pavement markings that control entry and circulating speed determine approach capacity.

The maximum flow rate that a roundabout entry can accommodate depends on two factors: the circulating flow in the roundabout that conflicts with the entry flow, and the number of entering lanes on the approach to the circulatory roadway. When the circulating flow is low, drivers at the entry can enter the roundabout without significant delay. The larger gaps associated with low circulating flows make it easier for drivers to enter the roundabout and provide the opportunity for more than one vehicle to enter each gap. As the circulating flow increases, the size of the gaps in the circulating flow decreases, thus the rate at which vehicles can enter also decreases.

Evaluate each approach leg of the roundabout individually to determine the number of entering lanes that are required based upon the conflicting flow rates. Base the number of lanes within the circulatory roadway on the number of lanes needed to provide lane continuity. More detailed lane assignments and refinements to the lane configurations must be determined through a more formal operational analysis as described later in this section.

On multi-lane roundabouts, it is important to balance the traffic use of each lane to avoid overloading some lanes while underutilizing other lanes. In addition, poorly designed exits may influence driver behavior and cause lane imbalance and congestion on the opposite leg.

20.2.2 Planning Estimates of Lane Requirements

If existing or projected turning-movement data is available at the planning level, the analyst should estimate the potential lane configurations of the roundabout prior to performing detailed operational analysis. Figure 20.1 shows the capacity curves for one and two-lane roundabouts. WisDOT developed the capacity curves shown in Figure 20.1 based on a 2020 research study on the operations of Wisconsin Roundabouts [6]. As shown in Figure 20.1, the capacity of each entry lane of the roundabout is based on the conflicting traffic flow in the circulatory roadway, which comprises the various turning movements from other approaches that pass in front of (and thus conflict with) the subject entry. For planning purposes, the analyst can use the capacity curves shown in Figure 20.1 to identify the potential lane configurations of the roundabout. As an example, for a given circulatory (conflicting) flow rate of 800 passenger cars per hour (pc/h) a one-lane roundabout could accommodate an entry capacity of approximately 650 pc/h/lane while the right lane of a two-lane roundabout could accommodate an entry capacity of approximately 710 pc/h/lane.

HCM7, Chapter 22 provides additional details on how to approximate capacity and lane requirements for a roundabout, including sample calculations of roundabout volumes, conversion of vehicles per hour (vph) to passenger cars per hour (pc/h), lane use, capacity, and performance measures. Use Figure 20.1 for preliminary estimation of the number of entry and circulatory lanes per approach when considering a roundabout during the scoping phase of the Intersection Control Evaluation (ICE) and during planning studies.

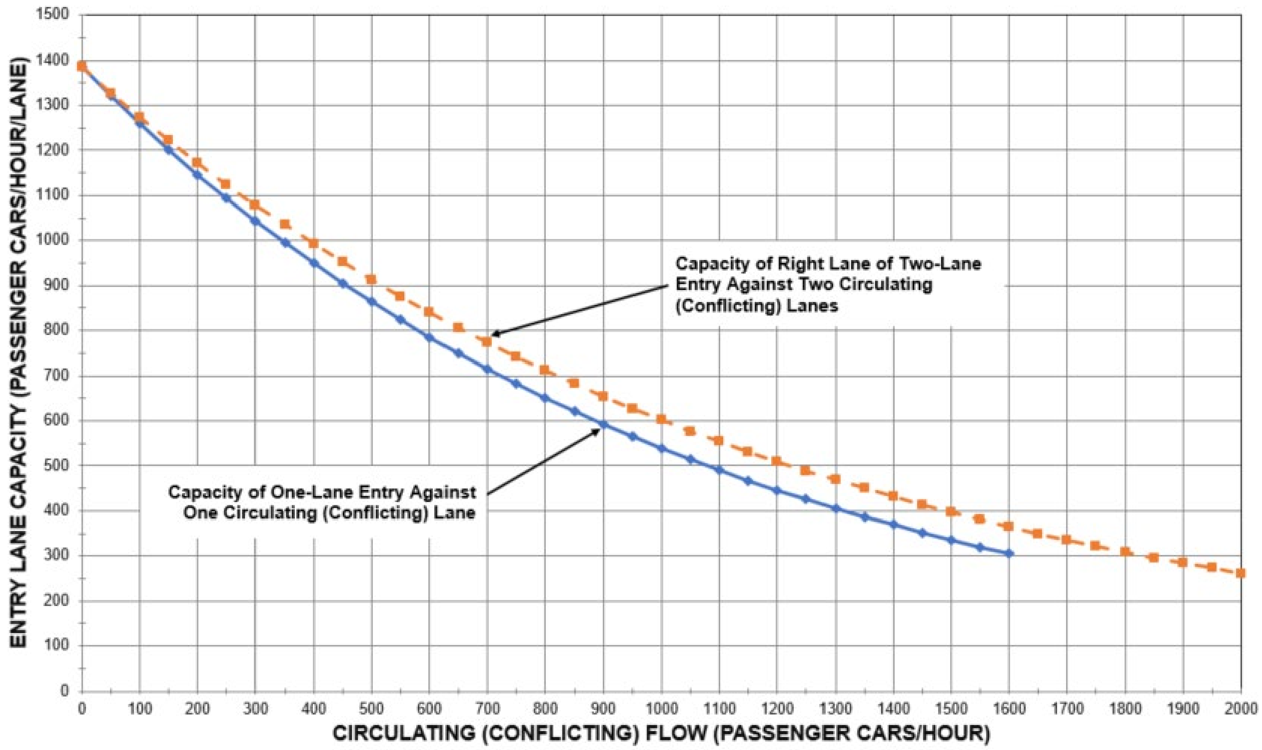


***Figure 20.1* WisDOT Roundabout Capacity Curves (for planning purposes) [6]**

20.3 Pedestrian Effects on Entry and Exit Capacity

Pedestrians crossing at a marked crosswalk have priority over entering motor vehicles. As such, pedestrian traffic can have a significant effect on the capacity of a roundabout entry, especially if there are high pedestrian volumes. To approximate the effect of pedestrian traffic, multiply the vehicular capacity by the entry capacity adjustment factor for pedestrians (fped) according to the relationship shown in Exhibit 22-18 and 22-20 of HCM7 Chapter 22 for single-lane and two-lane entry roundabouts, respectively.

Note that the effects of conflicting pedestrians on the approach capacity decrease as conflicting vehicular volumes increase, as entering vehicles become more likely to have to stop regardless of whether pedestrians are present. Consult the HCM for additional guidance on the capacity of pedestrian crossings if the capacity of the crosswalk itself is an issue. A similar effect in capacity may occur at the pedestrian crossing on the roundabout exit.

20.4 Operational Analysis Methodology

As is shown in Figure 20.2, the first steps to roundabout analysis and design are to gather traffic data for the existing intersection and to complete an HCM analysis. The lane configuration selected for typical operations with design year traffic conditions should be the basis of the roundabout design. Typically, a lane configuration for typical operations means that all or most movements operate at LOS D or better with a volume to capacity ratio less than one. See FDM 11-5-3.2 for further discussion on intersection LOS. For further discussion on the typical level of service evaluation, see FDM 11-5-3.5.

Supplemental software analysis tools include microsimulation traffic models and three deterministic models SIDRA Standard, Rodel and ARCADY. Depending on the purpose and need of the project, the use of microsimulation may be appropriate for operational analysis that does not fit within the methodological limitations of the HCM (see TEOpS 16-15-20 for additional details). Designers may use SIDRA Standard, Rodel, ARCADY or other design-aid tools to refine the roundabout geometric design. Prior to using supplemental design-aid tools, the analyst should first determine the basic lane configuration using the HCM-based operational analysis and any other pertinent considerations. When the results of the HCM analysis show that a multi-lane roundabout is necessary where the existing roads are single-lane, then designers should confirm the results using supplemental design-aid tools. Use of supplemental software tools may also be appropriate for evaluating operations for in-service roundabouts whereby collection of data under capacity conditions are available to calibrate the capacity equations. FDM 11-26-20.5 and TEOpS 16-15-20.3 discuss the analysis of existing roundabouts and the application of supplemental tools in more detail.

Only after the analysis is completed, and the preferred lane configuration determined, should the preliminary design of the roundabout begin. Exhibit 22-10 from HCM7 provides an overview of the HCM roundabout analysis. Chapter 22 of the HCM7 (Section 3) provides detailed descriptions and equations for each step. Chapter 33, Roundabouts Supplemental of the HCM7 (Section 3) goes through each of the computational steps for two example problems: one for a single-lane roundabout with bypass lanes and one for a multi-lane roundabout. These steps describe how to calculate the capacity, LOS, and queue for a roundabout by hand. The use of software makes analyzing the operations of a roundabout much quicker. Figure 20.2 provides a diagram illustrating WisDOT's approved method for analyzing roundabouts using HCM guidance with additional detail provided in TEOpS 16-15-20.

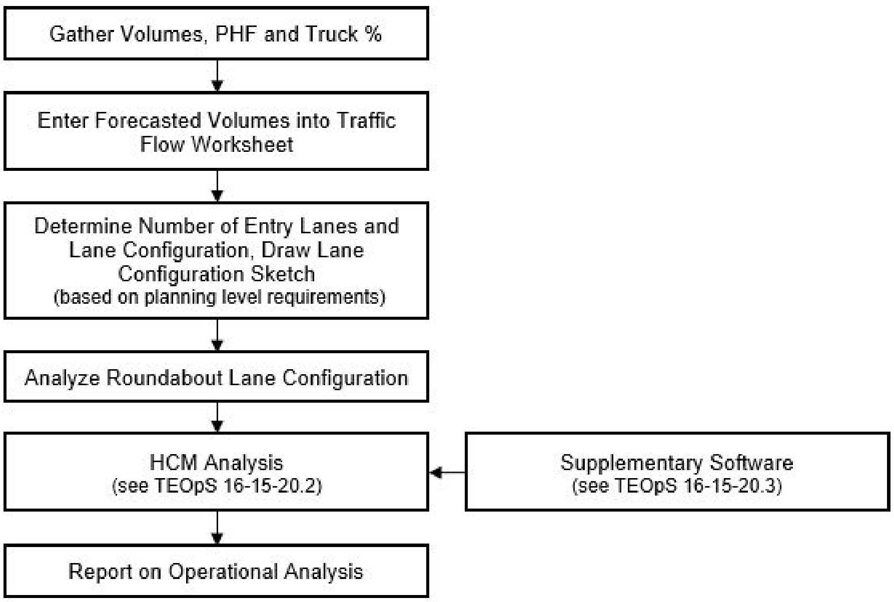


Figure 20.2 WisDOT Approved Method for Analyzing Roundabouts

20.4.1 Gather Traffic Volumes, Peak Hour Factors, and Truck Percentages

Obtain existing turning movement counts for the intersection and establish the peak traffic hours for analysis. Gather turning movement counts for off peak, midday, or special event times as applicable. Note any special lane utilizations or imbalances, especially if the existing intersection is a roundabout. Calculate the peak hour factor for each peak period. Determine percentages of trucks by approach, and, if present, include the number and percentage of bicycles and pedestrians.

Submit existing turning movement counts to the Traffic Forecasting Section if required for development of the traffic forecast. See FDM 11-5-2 for more information on traffic forecasting. Consider intermediate design year forecasts in preparation for sensitivity analysis to determine capacity expansion (e.g. one to two lane entries or two to three lane entries).

20.4.2 Enter Forecasted Traffic Volumes into Traffic Flow Worksheet

A volume diagram can be developed using Attachment 20.1 to provide existing peak hour turning volumes (AM, PM, Weekend/Special Event) and design year peak hour turning volumes. Before starting the capacity analysis, a person who is familiar with the site should check the traffic forecasts for reasonableness.

For example, growth rates throughout the intersection should be consistent, unless local factors such as new development are expected to increase specific movements disproportionately. Similarly, the dominant movements in the forecasted volume set should be similar to the existing pattern, unless changes in land use or highway routing are expected. In areas with high commuter traffic, corresponding AM and PM movements should be compared, for example a high westbound left turn movement in the morning is usually accompanied by a high northbound right turn movement in the afternoon.

If the intersection is part of a corridor project, the consistency of forecasts along the corridor should also be reviewed, since the outputs of one intersection are usually the inputs to the next, plus or minus the driveway traffic in between. Attachment 20.1 provides a format for summarizing the traffic volumes at a 3-leg, 4-leg, or interchange ramp roundabout.

20.4.3 Determine Number of Entry Lanes and Lane Configuration, Draw Lane Configuration Sketch

Based on planning level capacity requirements determine how many entry lanes a roundabout would require to serve the traffic demands (see Table 20.1 and Figure 20.1). Determine the entry volumes for each lane of the roundabout approach. Adjust lane volumes based on observed or estimated lane utilization patterns or imbalances. If no lane utilization patterns are observed, the HCM7 default values are 47% of entry flow in the left lane and 53% of entry flow in the right lane for left-through plus through -right (Option 1 in Figure 20.3) and left-through-right plus right lane configurations, and 53% in the left lane and 47% in the right lane for left plus left-through-right (Option 3 in Figure 20.3) lane configurations.

A lane configuration sketch of the roundabout should accompany the traffic volumes to facilitate the selection of the number of lanes and the lane assignments. This step precedes the roundabout capacity analysis and the layout process and is critical because it affects the geometry. In Figure 20.3, the assessment of lane assignments for the example traffic flows could include three different options. Unless traffic demand for a given approach is indicative of the potential need for an exclusive left turn lane, Option 1 is preferred for its simplicity of design and because the configuration should accommodate both peak and off-peak traffic demand. In the example Options 2 and 3 would require spiral geometry and marking treatment for the upstream entry left turn. Additionally, Options 2 and 3 imply a single-lane exit for lane continuity of the through movement. These alternatives complicate the design and may influence driver behavior by causing confusion when navigating the circulatory roadway. Figure 20.4 is an example of the roundabout lane configuration sketch employing Option 1.

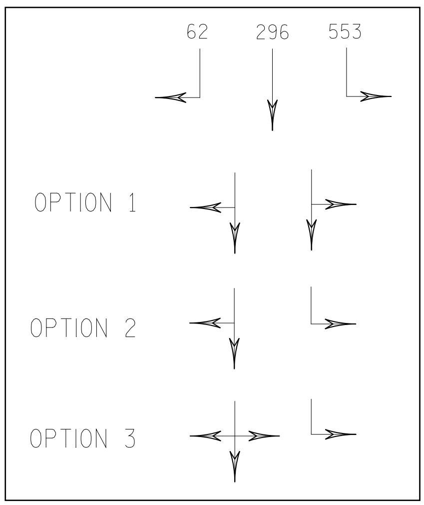


***Figure 20.3* Lane Configuration Options**

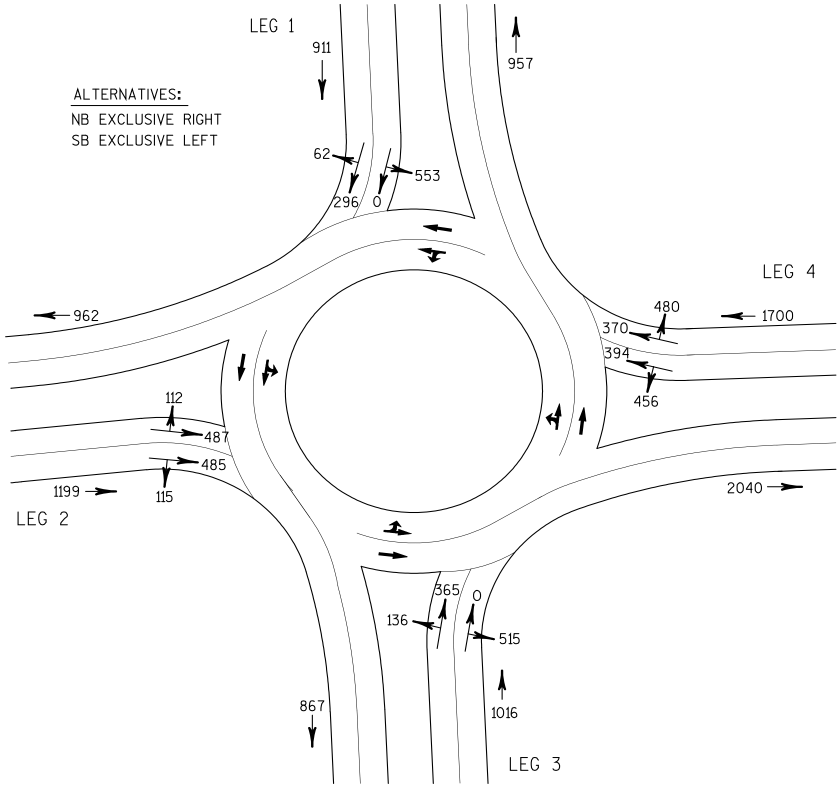


***Figure 20.4** Lane Configuration Sketch*

20.4.4 Analyze Roundabout Lane Configuration

Evaluate the preliminary lane configuration estimated in FDM 11-26-20.4.3 with HCM procedures using one of two WisDOT supported analysis tools: Highway Capacity Software (HCS) or SIDRA Intersection (refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version of HCS and SIDRA Intersection that WisDOT currently supports). WisDOT requires the use of Wisconsin based headway values for the calibration of the HCM roundabout capacity equation. Refer to TEOpS 16-15-20 for the Wisconsin recommended headway values and additional details on conducting HCM-based analyses of roundabouts.

After obtaining traffic forecasts for the study intersection, the general approach to analyzing, building, and adjusting existing roundabouts begins by establishing the general footprint of a new roundabout.

Following FDM guidance and HCM methodologies, a lane configuration for acceptable operations is determined and the detailed design completed. Existing roundabouts may need to be field adjusted to improve capacity; use of supplemental tools may be appropriate to help determine potential improvements for an existing roundabout.

20.4.5 Compact Roundabout Analysis

As compact roundabouts are relatively new to the US, little research has been completed. Subsequently, *HCM* currently does not have operational analysis methodologies that can account for the geometric influences smaller roundabouts have on operations. As compact roundabouts become an acceptable alternative in Wisconsin, WisDOT developed a procedure to apply volume calibration factors (VCFs) to *HCM* methodologies to more accurately analyze roundabouts with ICDs smaller than 120 ft. TEOpS 16-15-20.3 provides more information on how to use and apply these calibration factors.

20.5 Capacity Analysis of an Existing Roundabout

The analyst shall use the HCM procedure to evaluate the capacity of existing roundabouts. For existing roundabouts experiencing delays or significant queuing, the analyst should collect the headway data to calibrate the HCM model. Consult with the Bureau of Traffic Operations Traffic Analysis and Safety Unit (BTO-TASU) for the specifications on how to collect capacity data at existing roundabouts. The results of the HCM procedure may indicate that the existing roundabout requires additional lanes to achieve increased capacity; however, depending on the site-specific conditions, it may be possible to add capacity through changes in pavement markings, signage, geometry, or a combination of the three. Changes to pavement markings, signage and geometric parameters are often less expensive and easier to implement than the construction of additional lanes. The analyst can conduct geometric sensitivity testing using SIDRA Standard, Rodel, ARCADY or other geometric sensitive tools to determine if geometric changes will increase the capacity of the existing roundabout without adding more lanes. Although geometry is secondary to driver behavior in terms of its impact on the capacity of the roundabout, it may be beneficial to conduct geometric sensitivity testing. The ability to measure the capacity of an existing roundabout in the field allows the analyst to calibrate the models (HCM-based models, microsimulation models, and other design-aid tools) to verify the true influence of geometric parameters such as radius at the entry, inscribed circle diameter, conflict angle and flare length.

20.99 References

[1] NCHRP 572, *Roundabouts in the United States*, 2007

[2] Akcelik, R., E. Chung, and M. Besley. *Roundabouts: Capacity and Performance Analysis*. Research Report ARR No. 321, 2nd ed. ARRB Transport Research Ltd, Australia, 1999

[3] *The Traffic Capacity of Roundabouts* TRRL Report LR 942, 1980. Kimber, R.M.

[5] Rodegerdts, L.A., A. Malinge, P.S. Marnell, S.G. Beaird, M.J. Kittelson, and Y.S. Mereszczak. *Assessment of Roundabout Capacity Models for the Highway Capacity Manual: Volume 2 of Accelerating Roundabout Implementation in the United States.* Report FHWA-SA-15-070. Federal Highway Administration, Washington, D.C., Sept. 2015

[6] Traffic Analysis and Design, Inc. (TADI), *Statewide Roundabout Traffic Operations Analysis*, Mar. 2020

[7] NCHRP 672*, Roundabouts: An Information Guide Second Edition*, 2010

LIST OF ATTACHMENTS

Attachment 20.1 Roundabout Traffic Flow Worksheet

FDM 11-26-25 Access Control May 17, 2022

25.1 Access Management

Management of access to arterial roads is vital to creating a safe and efficient transportation system for motorists, bicyclists, and pedestrians. Access guidance is provided through the region access coordinator, FDM Chapter 7, and the WisDOT Traffic Impact Analysis (TIA) Guidelines.

The operational characteristics of roundabouts may offer advantages when compared to existing conventional approaches to access management. Some roundabout benefits include:

- Increased capacity along arterial roads
- Reduction of traffic congestion and delay
- Improved safety
- More efficient use of land
- Savings on infrastructure investments

For example, connecting two roundabout intersections with a raised median will preclude lefts in/out from the side street or business access to protect main-line capacity and improve safety. U-Turns are not problematic at roundabouts (except possibly at compact roundabouts due to the smaller size) and can increase safety. This provides the typical capacity protection and safety along the mainline with less impact to business accessibility.

Preliminary design for any intersection including roundabouts should include a comprehensive access management plan for the site. Consider the possible need to realign/relocate existing driveways and include their associated costs in the project's preliminary estimate. Account for pedestrian accessibility and safety during all stages in the development of a comprehensive access management plan.

25.2 Physical and Functional Intersection Area

See FDM 11-25-2.2 for definitions of physical and functional areas at a roundabout.

25.3 Corner Clearance and Driveway Location Considerations

Corner clearance represents the distance that is provided between an intersection and the nearest driveway. See FDM 11-25-2.5 for guidance on corner clearance to driveways.

Driveway access to the circulating roadway may be allowed and should be reviewed with the regional access coordinator. The preferred method to accommodate driveways at the circulating roadway is as a leg of the roundabout, including providing a splitter island and speed control similar to a standard roadway leg of the roundabout.

Direct driveway access to the circulating roadway (curb cut) is not recommended; however, some situations may dictate the need for a direct driveway and must be analyzed on a case-by-case basis and discussed with the regional access coordinator. For a driveway to be located with direct access (curb cut) into the circulatory roadway of a roundabout, the following items should exist:

- No alternative access points are feasible.
- Residential or low traffic volume business driveway with traffic volumes low enough that the likelihood of erratic vehicle behavior is minimal. Driveways with higher traffic volumes, or higher proportion of unfamiliar drivers should be designed as a regular roundabout approach with a splitter island.

25.4 Parking near Roundabouts

Prohibit on-street parking; within 75 feet of the roundabout entry/exit or further depending on site-specific conditions. Factors that influence the decision to prohibit on-street parking near a roundabout may include: adjacent access, location of pedestrian crossing, and approach or departing curvature. Generally, it is not typical to allow parking on either side of the roadway within the splitter island area or in the transition to the splitter island.

25.5 Interchange Ramps

According to FDM 11-5-5, a distance of 1,320 feet between a ramp terminal and any adjacent intersection is required. This distance (1,320 feet) is typically needed to provide progression for a series of signalized intersections. Roundabouts need less space between adjacent intersections to operate at a high level of service. Operational concerns at an interchange resulting from reduced access spacing, such as traffic blocking adjacent intersection, can be better understood through the analysis of forecasted queue lengths. Queue lengths for a roundabout should be predicted with the use of traffic modeling and the impacts to the adjacent intersections reviewed using other appropriate traffic modeling software. A traffic analysis is required to justify a distance less than 1,320 feet between a ramp terminal and any adjacent intersection.

FDM 11-26-30 Principle Based Design Guidance *November 15, 2022*

30.1 Introduction

In a general sense, roadway engineering is often an iterative process of design exploration against a set of project constraints. The geometric design of a roundabout requires the balancing of competing interests. Design considerations of safety, capacity and cost. Roundabouts operate most safely when their geometry positively guides traffic to enter and circulate at slow speeds. Poor roundabout geometry has been found to negatively impact roundabout operations by affecting driver lane choice and behavior through the roundabout. Roundabout layouts are also governed by the space and swept path requirements of the design vehicle.

Thus, designing a roundabout is a process of determining the optimal balance between safety provisions, operational performance, and accommodation of the design vehicle.

Even though a step-by-step design process is presented in this section, the designer must understand that adherence to design principles, awareness and understanding of the inherent design tradeoffs are the central points of design regardless of whether any design procedure is followed.

The geometric design, signage and pavement markings of roundabout intersections can influence their capacity and operational performance. Therefore, it is essential that a roundabout be properly designed to ensure that its expected capacity is not limited by the design.

30.2 Design Principles

This section describes the principles and objectives common to the design of all categories of roundabouts. Note that some features of multi-lane roundabout design are significantly different from single-lane roundabout design, and some techniques used in single-lane roundabout design may not apply to multi-lane design. However, several overarching principles should guide the development of all roundabout designs. With the primary goal of an operationally adequate facility that also provides good safety performance.

The principles that should be applied to achieve a safe and efficient roundabout design are:

- The roundabout should be clearly visible from the approach sight distance at the road operating speed in advance of the roundabout approach (See FDM 11-26-30.5).
- The number of legs should typically be limited to four (although up to six may be used at an appropriately designed roundabout).
- Legs should typically intersect at approximately 90-degrees, especially for multi-lane roundabouts (See also NCHRP 672, §6.3).
- It is essential that appropriate entry curvature is used to limit the entry speed (See also NCHRP 672, §6.2.1 and FDM 11-26-30.5.2).
- The roundabout should be designed to enable large vehicles to enter, circulate and depart efficiently. The circulating roadway (generally 1.0 to 1.2 times the widest entry) should be wide enough to accommodate the swept paths of the design vehicle, with a truck apron provided around the central island for overtracking of the vehicle trailer. A large exit radius or tangential exit is common. (See also NCHRP 672, §6.2.4.).

- Entering drivers must be able to see from the left early enough to safely enter the roundabout. However, excessive intersection sight distance can lead to higher vehicle speeds that reduce the safety of the intersection for all road users (motorists, bicyclists, pedestrians). Landscaping within the central island can be effective in restricting sight distance to the minimum requirements while creating a terminal vista on the approach to improve visibility of the central island (See also NCHRP 672 and FDM 11-26-30.5).
- Provide the appropriate number of lanes and lane assignment to achieve adequate capacity, lane volume balance, and lane continuity to ensure that the roundabout operates at an appropriate level of service. (See also NCHRP 672, §6.2.2).
- Design such that the driving task is as simple as possible, avoiding the use of spiraled designs unless it's clearly warranted by traffic (i.e. high left turning traffic volume).
- Provide smooth channelization that is intuitive to drivers and results in vehicles naturally using the intended lanes. (See also NCHRP 672, §6.2.3 and FDM 11-26-30.5).
- Design to meet the needs of pedestrians and cyclists. (See also NCHRP 672, §6.2.5)

The design criteria for potential non-motorized roundabout users (e.g., bicyclists, pedestrians, skaters, wheelchair users, strollers) should be considered when developing many of the geometric components of a roundabout design. These users span a wide range of ages and abilities and can have a significant effect on the design of a facility. There are two general design principles that are most important for non-motorized users. First, slow motor vehicle speeds make roundabouts both easier to use and safer for non-motorized users. Second, one-lane roundabouts are generally easier and safer for non-motorized users than multi-lane roundabouts; therefore, if a single-lane roundabout is feasible for most of the design life of the intersection that has pedestrian traffic then due consideration is given for the sake of pedestrian comfort and safety.

While the basic form and features of roundabouts are usually independent of their location, many of the design outcomes depend on the surrounding speed environment, typical capacity, available space, required number and arrangements of lanes, design vehicle, and other geometric attributes unique to each individual site. In rural environments where approach speeds are high and bicycle and pedestrian use may be minimal, the design objectives are significantly different from roundabouts in urban environments where bicycle and pedestrian safety are a primary concern. Additionally, many of the design techniques are substantially different for compact or single-lane roundabouts than for roundabouts with two or more lanes. Maximizing the operational performance and safety for a roundabout requires the engineer to think through the design rather than rely upon a design template.

For additional information, see NCHRP 672, §6.2.

30.2.1 Designing with Trade-offs in Mind

The selection and arrangement of geometric design elements and their relationships to one another is referred to as design composition. Minor adjustments in geometry can result in significant changes in safety or operational performance. The relationship between safety and capacity, that exists for a roundabout is in most cases inverse that of a typical intersection. Table 30.1 below identifies the trade-offs of adding to one element at the expense of another. When composing an initial layout, the tradeoffs of safety, capacity and cost must be recognized and assessed throughout the design process. The effect of improving one aspect of design impacts another.

Table 30.1 Effects of Design Elements on Safety and Operations

Element	Safety	Capacity	Speed
Wider entry (gore area)	Decrease	Increase	Increase
Wider Circulatory lanes	Decrease	Increase	Increase
Larger entry radius	Decrease	Increase	Increase
Larger inscribed circle diameter	Decrease	Increase	Increase
Smaller entry angle (phi)	Decrease	Increase	Increase
Longer flare length	Neutral	Increase	Neutral

30.2.2 Staging and Expandability

Providing excess capacity at typical intersections usually has very little (if any) negative effect on vehicular safety or crash rate and usually improves vehicular safety. Inadequate capacity at a typical intersection could result in reduced safety and increased crash rates. Conversely, excess capacity at roundabout intersections can have a negative effect on safety, while inadequate capacity may have minimal effect on safety.

The design and analysis process should consider the potential to stage improvements to reduce excessive capacity in the early years and improve safety, and driver/public acceptance. The capacity analysis evaluates the duration of time that for example a single-lane or multi-lane roundabout would operate acceptably before requiring additional lanes. When sufficient capacity is provided for much of the design life of a roundabout, designers should evaluate whether it is best to first construct a roundabout that is easy to convert when traffic volumes dictate the need for expansion and additional capacity. Reducing the number of entry and exit lanes reduces the number of potential conflicts and reduces navigation complexities associated with multi-lane roundabouts. Minimizing the necessary entry, exit and circulating lanes improves safety for all modes. Pedestrian safety is improved by minimizing the crossing distance and limiting their exposure time to vehicles while crossing an approach.

When considering an interim roundabout that may be converted, the designer should evaluate the right of way and geometric needs for both the interim and multi-lane configurations as part of the initial design exercise. Consideration should also be given to the future construction staging for the additional lanes.

Specific expansion design is a function of many variables. Some situations will dictate that expanding from the inside is more advantageous while other locations may benefit from widening to the outside.

Compact roundabouts should not be designed to be expanded.

For additional information, see NCHRP 672, §6.12.

30.2.3 Impact of Cost Reduction on Roundabouts

In many cases, the process of developing and designing a roundabout may involve many design modifications, which are intended to increase cost savings. While this is common to conventional design practices it can have a hidden detrimental effect on design and operations of roundabouts.

Landscaping is often considered an aesthetic feature, which can be removed from the plan to reduce overall cost. Reduction of right of way acquisition is often seen as an obvious cost reduction measure, but the trade-offs of safety and operations may not be apparent to the deciding authority. Other elements such as overhead signing (on approaches) is similarly looked at as excessive and is often replaced with terrace signing, despite the rationale that these features improve the function and safety of the intersection. Designers should be sensitive to the need for cost savings and should strive to effectively document and communicate the impact that the proposed design modifications will have on the function and safety of the roundabout. The designer should be given the opportunity to recommend an alternate modification, which will provide required cost savings while having the minimum amount of impact on function and safety.

Eliminating certain project design elements can result in lower cost and improved value without adverse effect on the safety and capacity. As an example, while it is ideal to align the legs to intersect at approximately 90-degrees (see Figure 30.1), roundabouts can be designed to leave an existing skew in place (see Figure 30.2). Depending on the design vehicle, overtracking pads can be used for large trucks when the skew angle is small. In some cases, the use of an oval rather than a circle can help facilitate truck turning movements and reduce the amount of the overtracking pad (see Figure 30.3).

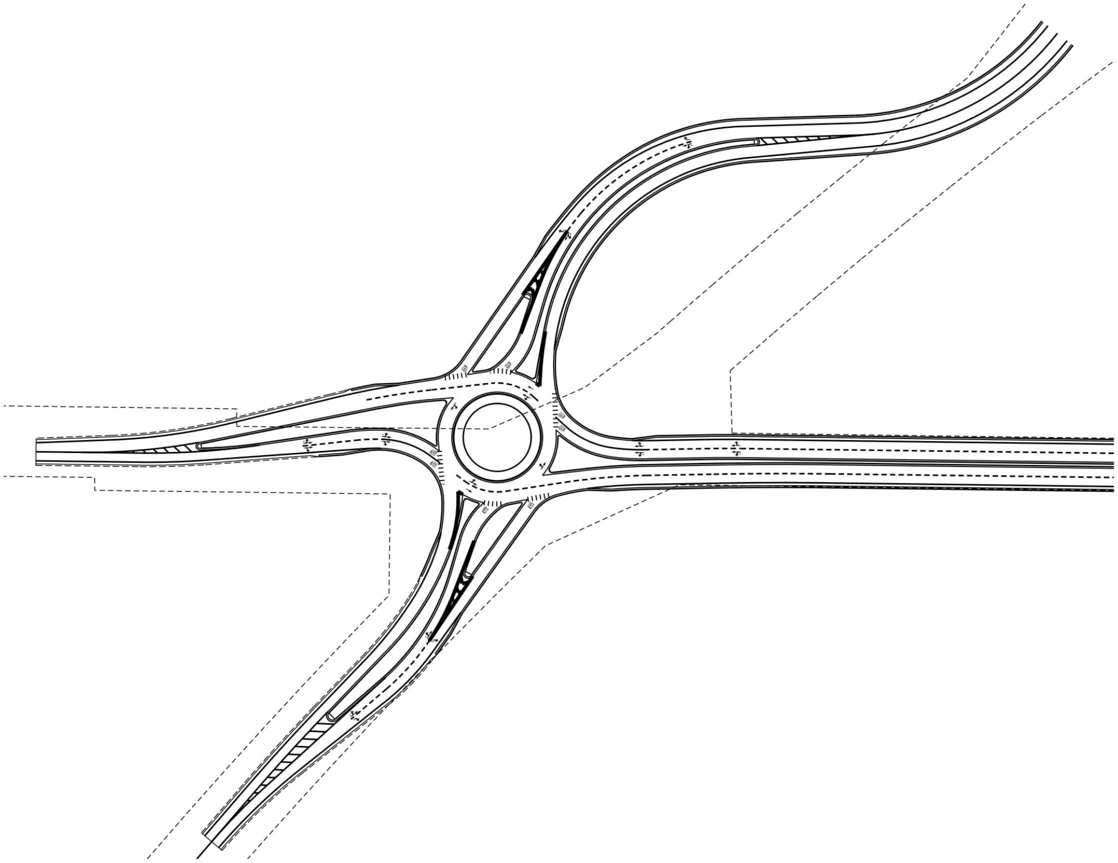


Figure 30.1 Squared Roundabout

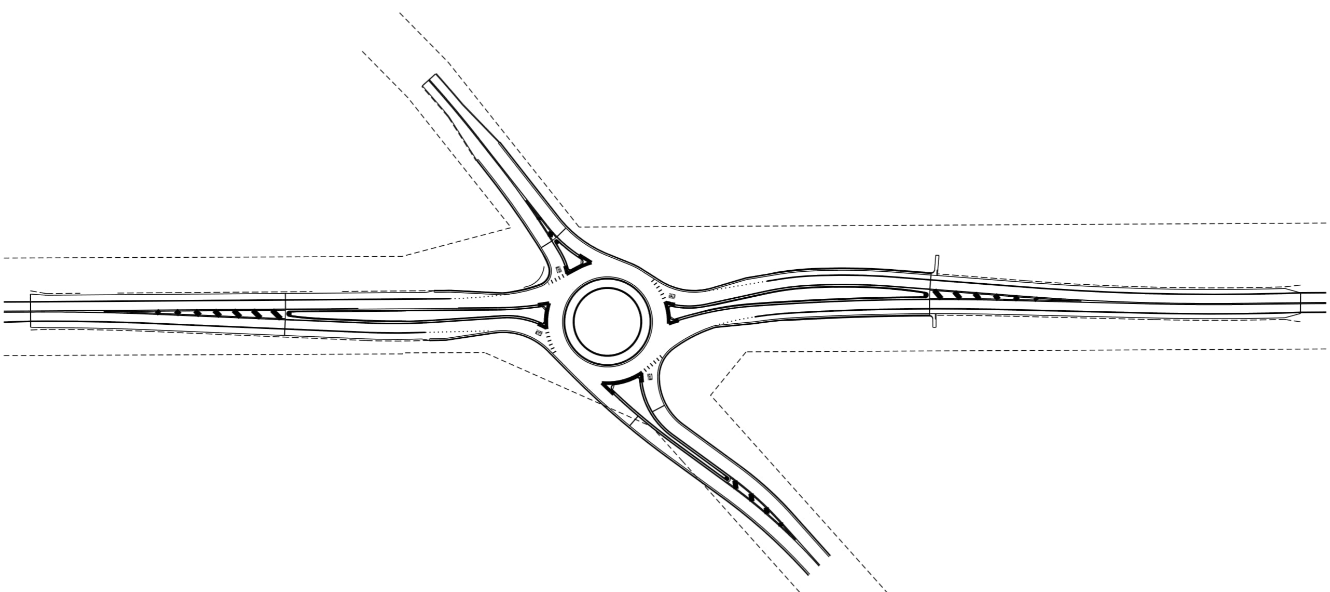


Figure 30.2 Skewed Roundabout

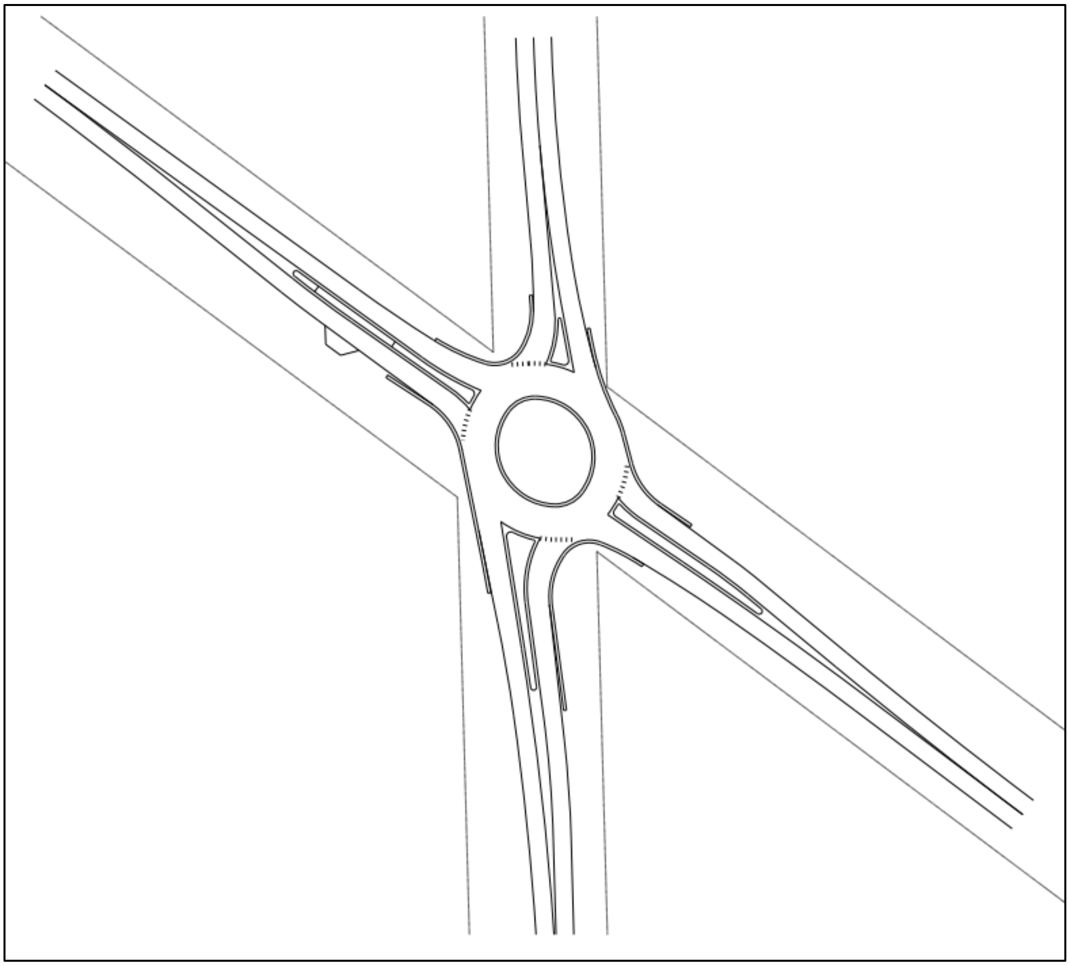


Figure 30.3 Oval Roundabout

The use of compact roundabouts in place of single-lane roundabouts can also save costs. However, the operations and safety of the compact roundabout may be less than that of a single-lane roundabout. Consider the trade-offs carefully when considering a compact roundabout. The decision to use a compact roundabout rather than a single-lane roundabout should be documented in the Intersection Control Evaluation.

30.3 Roundabout Design Process – Horizontal Geometry

The process of designing roundabouts may require a considerable amount of iteration for the geometric design. It is not typical to produce an optimal geometric design on the first attempt. The majority of this iterative design process occurs prior to Final Scoping Certification approval, see Figure 5.1.

It is advisable to prepare the initial roundabout layout at a sketch level detail. It is important that the individual components are compatible with each other so that the roundabout will meet its overall performance objectives. Before the details of the horizontal geometry are finalized, three fundamental elements must be determined:

1. The optimal size
2. The optimal position
3. The optimal alignment and arrangement of the approach legs

An initial estimate of the space (footprint) required for a roundabout is a common question and may affect the feasibility of a roundabout at any given location. Important questions to be explored include:

- Is sufficient space available to accommodate an appropriately sized roundabout?
- What property impacts might be expected?
- Is additional right of way likely to be required?
- Are there physical constraints that may affect the location and design of the roundabout?

Due to the need to accommodate large trucks through the intersection, roundabouts typically require more space than conventional intersections. However, this may be offset by the space saved compared with turning lane requirements at alternative intersection forms. The key indicator of the required space is the inscribed circle diameter.

There are many different types of roundabouts and roundabout components, such as compact, single-lanes, two-lanes, three-lanes, circles, ellipses, bypass lanes, yielding bypass lanes, double roundabouts, spirals, etc., in which a number of combinations or multiple combinations of the above can be in one roundabout (see FDM 11-26-1.4). Each roundabout is unique where each potential "type" of roundabout is applied in different situations in which site-specific problems require special and distinctive solutions. The major differences in design techniques and skill levels fall between single-lane roundabouts and multi-lane roundabouts where different principles apply.

Figure 5.1 depicts the steps and process that guide a designer through the entire Roundabout Design Process (see also NCHRP 672, Exhibit 6-1).

For additional information, see NCHRP 672, §6.3.

30.4 General Design Steps & Explanation

The following general design steps will typically apply to most roundabout design practices. However, each roundabout requires a different design and thinking process depending on the unique design constraints, traffic volumes, roadway speeds, existing topography, and geometric alignments of the roadways. Not all aspects of design or the design process are included herein, however, the provided general design steps should be sufficient to get most designers started in a preliminary roundabout design for Final Scope Certification approval.

Step 1 - Document Existing Conditions

Review the most recent site plans and roadway alignment information in an electronic format (e.g., CAD-based software). Review existing roadways with respect to surrounding topography, centerlines, curb faces, edge of pavement, roadway lane markings, existing or proposed bike lanes, nearby crosswalks, environmental constraints, buildings, drainage structures, adjacent access points, shared-use paths, rail crossings, school zones, and right of way constraints. This should include any special design constraints such as specific properties that cannot be encroached or specific lane widths. Review any traffic study, which should include final future design year traffic volumes and assumptions of the proposed intersection or corridor project.

These items should provide adequate background traffic conditions, existing traffic conditions within and outside the project area, as well as the level of detail, design parameters, right of way constraints, restricted historical or wetland areas, and location for the proposed roundabout.

Step 2 - Document Future Conditions

The future traffic flows of the existing roadways should be reviewed and possibly discussed with the lead jurisdiction for project understanding and existing operational issues. These operational issues, including potential excessive delay, should be recognized in the design process and geometric criteria. In addition, any potential changes to adjacent sites, access points, or roadway cross-sections that may affect the roundabout design should be provided, reviewed, and incorporated.

Review the future AM & PM peak-hour, and off-peak turning movement volumes (also include mid-day in tourist areas) at the intersection developed from the design year projected traffic volume data. In order to accurately identify the roundabout geometric and capacity needs, the following are required:

- Traffic Conditions
  - Future turning movement volumes: AM & PM peak, off-peak, and mid-day (in tourist areas)
  - Future percent heavy vehicles (by type and approach) for each peak hour
  - OSOW truck route (OSOW-TR) considerations
  - Design vehicle type by turning movement. Refer to FDM 11-25-2 and FDM 11-25 Attachment 2.1 for description of OSOW-MT and OSOW-ST design vehicles and their inventories. Refer to FDM 11-25 Table 2.1 for required intersection design vehicle checks for various trucking route scenarios.
- Constraints
  - Vertical constraints
  - Right of way constraints
  - Existing and proposed roadway alignment base map (with travel lanes, proposed curb tie-in, pavement marking, bike lanes, right of way, etc.)
- Other Modes
  - Pedestrian volumes (if significantly high)
  - Identify if bike lanes and sidewalks will be needed

Step 3 - Understand the Specific Design Problem(s)

Prior to commencing a design, the designer must first understand the basic intersection problem; is it safety, congestion, or a combination of both and what is the design problem(s) to be solved (right of way issues, acute angles, grades, approach legs, roadway alignment, etc.)? After evaluating the traffic volumes, the designer should understand how many lanes may be initially required.

A general roundabout diameter can then be chosen based on the traffic needs, proximity to constraints, design vehicle, and the relative speeds of the roadways (i.e. if high speed approaches are present). The designer must be conscious of the design vehicle when choosing a diameter. Refer to FDM 11-25 Table 3.1 as a first step in the evaluation process if no other values have been stated.

Step 4 - Perform Capacity Analysis for Lane Configuration Development (also refer to FDM 11-26-20)

After obtaining all of the pertinent information regarding the roadways, site, and traffic volumes, and a general roundabout diameter has been initially identified, the designer should perform a geometric analysis of the proposed roundabout using roundabout design software. The capacity analysis results will assist in developing the initial lane geometry and capacity requirements for the roundabout based on the future design volumes.

This will set the design requirements for the conceptual roundabout design. The AM and PM, and sometimes a weekend peak, traffic volumes will need to be analyzed at the intersection. This analysis should ensure that the roundabout will operate appropriately under all peak hour traffic conditions. The results of this analysis will produce key information to include in the roundabout design, some of which are:

Geometry	***Operations***
- Initial roundabout diameter (estimated size) - Entry lane configurations at each approach - Minimum approach widths and entry radii of the roundabout	- Future traffic volume capacity by approach - Delay of each approach and the overall delay of the intersection - Predicted 95th percentile queue lengths for each approach - Future level of service

The allowed movements assigned to each entering lane are key to the overall design. Basic pavement marking layouts should be considered integral to the preliminary design process to ensure that lane continuity is being provided. In some cases, the geometry within the roundabout may be dictated by the number of lanes required or the need to provide spiral transitions (see FDM 11-26-30.5.21 for more information). Lane assignments should be clearly identified on all preliminary designs to retain the lane configuration information through the various design iterations. In some cases, a roundabout designed to accommodate design year traffic volumes, typically projected 20 years from the construction year, can result in substantially more entering, exiting, and circulating lanes than needed in the earlier years of operation. To maximize the potential safety during those early years of operation, the engineer may wish to consider a phased design solution that initially uses fewer entering and circulating lanes. As an example, the interim design would provide a single-lane entry to serve the near-term traffic volumes with the ability to cost-effectively expand the entries and circulatory roadway to accommodate future traffic volumes. To allow for expansion at a later phase, the ultimate configuration of the roundabout needs to be considered in the initial design. This requires that the ultimate horizontal and vertical design be identified to establish the outer envelope of the roundabout. This method helps to ensure that sufficient right of way is preserved and to minimize the degree to which the original roundabout must be rebuilt.

Step 5 - Sketch

Once the minimum design requirements have been established, a roundabout design can be sketched by initially identifying the flow of traffic, lane configuration, and approach lane assignment requirements, the circulatory roadway width and the exits of the roundabout. This task includes the placement of the roundabout's circle to roughly determine its location. Special consideration should be taken for any skewed intersection or right of way constraints. A general roundabout diameter can then be chosen based on the traffic needs, proximity to constraints, design vehicle, and the relative speeds of the roadways.

Step 6 – Refine the Initial Layout

The hand sketch or initial conceptual layout should be refined. The designer should refine the concept iteratively to suit the site constraints while attending to the design performance criteria of speeds, truck space and site distance. The purpose of this process is to achieve an optimal layout that serves the design objectives without excessive CAD effort. Often designers are wrongly focused on details and do not have the patience to produce multiple iterations of a CAD design.

Step 7 - Formalize the Preliminary Design

Once the general location and roundabout configuration has been developed and all of the design issues have been resolved, a full conceptual design can be initiated.

In multi-lane designs, the lane pavement marking is applied to establish natural entry and exit paths, i.e., to minimize entry and exit path overlap. Applying the lane pavement marking ensures proper lane widths and widening and confirms the lane designations and possible spiraled lane movements.

Step 8 - Safety and Fastest Path Review

Fastest path design speeds as well as a number of other safety factors and design features, such as the phi angle, must be checked. The fastest paths should be developed and reviewed to see if they are adequate and reasonable. If deficiencies or deviations in any of the design features or safety factors are found, the design must be modified, either with many small changes or by shifting alignments, geometry, or placement of the circle. This is an iterative process which may require an entire redesign.

Step 9 - Design Vehicle Check & Modifications

A CAD-based software program such as AutoTURN or AutoTrack should be used to verify proper accommodations are provided through the roundabout for each approach and every truck turning movement. In addition, the truck apron minimum width is 12-feet and may be wider in some situations to better accommodate OSOW vehicles. All truck movements should have a buffer space between the swept path of trucks and the face of curb equal to 2 feet. Contact the regional freight coordinator for the OSOW vehicle.

Step 10 - Accessorize the Design

When a preliminary design (and pavement marking for multi-lane roundabouts) has been completed, additional amenities should such as crosswalks, detached sidewalks, bike paths and ramps, truck aprons, disabled access (ADA) ramps, etc. should be added. All efforts should be made to avoid or limit impacts to right of way.

Once a roundabout design has been properly designed with respect to horizontal geometry, there are many other geometric and non-geometric design components that must now be completed for a roundabout to function as it was designed. These design components are key to the public driving the roundabout as it was intended without further safety or operational issues. Refer to FDM 11-26-5.3 for an overview of the additional roundabout design components, and the requirements for QRD review.

Continual practice, mentoring from experts, training & education, and quality roundabout review greatly assists the designer in understanding all aspects of the design of roundabouts. However, all designers must spend time in the field reviewing roundabout construction and completed roundabouts in order to understand roundabouts and their design completely. After years of daily practice, one can still learn. Small changes in roundabout design elements can influence the operation and safety of a roundabout.

30.5 Design Considerations

This section provides guidelines for each geometric element. Further guidelines specific to two-lane entries are provided in the latter part of Chapter 6 of NCHRP 672. Note that two-lane entry roundabout design is significantly more challenging than single-lane entry design. Many of the techniques used in one-lane entry roundabout design do not directly transfer to multi-lane design. This procedure provides recommended changes to NCHRP 672, Chapter 6. Therefore, designers must become very familiar with Chapter 6 in the NCHRP 672.

Compact roundabouts are also significantly more challenging than other single-lane entry designs. The basic principles described in the following sections that apply to single-lane roundabouts generally apply to compact roundabouts with a few exceptions. Additional guidance for compact roundabouts is discussed in FDM 11-26-30.5.25.

30.5.1 Alignment of Approaches and Entries

Adherence to the principles of deflection is crucial to the operation and safety of roundabouts. WisDOT considers this design element to be of the utmost importance. Figure 30.4 shows the typical composition of approach alignment and curves to generate typical speed reduction at entries. It is not good practice to generate entry deflection by sharply curving the approach road to the left close to the roundabout and then to the right at entry.

It is recommended design practice (especially in multi-lane roundabouts) to provide an offset to the left of the center of the central island. In some situations, it may be appropriate to provide an offset of approximately 20 to 30 feet (or more), left of the center of the roundabout to achieve proper deflection and appropriate entry speeds.

For additional information, see NCHRP 672, §6.2.1 & 6.7.1.

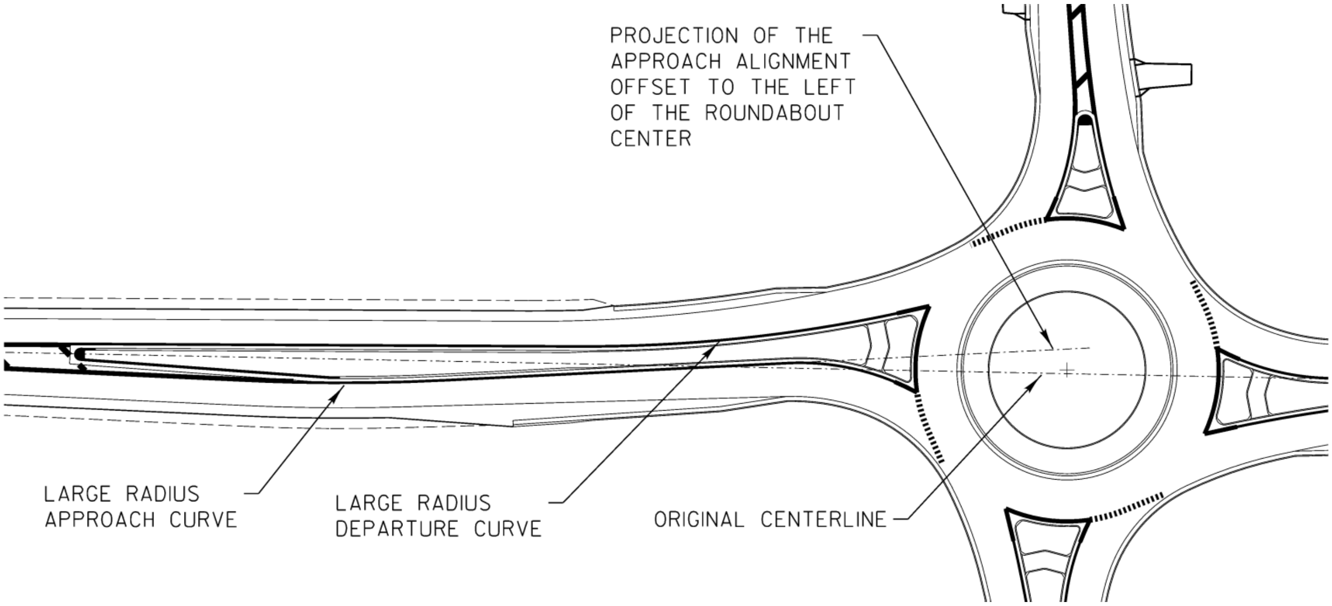


***Figure 30.4* Entry Deflection**

30.5.2 Assessing Vehicle Paths

Determine the smoothest, fastest path (using a spline curve) possible for a single vehicle, in the absence of other traffic and ignoring all lane line markings, traversing through the entry, around the central island, and out the exit. A step by step process for creating AutoCAD Civil 3D and MicroStation spline curve are provided in Attachment 50.1 and 50.2. Usually, the critical fastest path is the through movement; but, depending on the angle between arms, in some situations it may be a right turn movement.

Fastest speed path is a critical performance measure in the design of roundabouts. Use NCHRP 672, Exhibit 6-46 for the definition of vehicle path radii. NCHRP 672 Exhibit 6-48 and Exhibit 6-49 illustrate the definition of fastest vehicle path for single-lane and multi-lane designs. Use Figure 30.5 to determine the radii values for R1 based on the arc and spline definitions. Vehicle speed estimation is in accordance with NCHRP 672, Section 6.7.1.2 Equations 6-1 and 6-2. Equation 6-3 may be used to estimate actual entry speed, but it will not govern the design.

R2 and R4 are determined using the same vehicle path offsets for R1. The R3 exit radius fastest speed path is determined based on the R2 speed plus acceleration over the distance to the point where R3 is measured. Use NCHRP Exhibit 6-50 to determine the radius value for R5 fastest speed path. The vehicle path offsets of 5 feet, as shown in Figure 30.5, are measured from the curb face (not the flange line). In the situation where the approach to the roundabout has centerline pavement marking on the left side with no curb face, then the offset is 5 feet from the centerline pavement marking.

a. The radius should be measured over a distance of 65 to 80 feet. It is the minimum that occurs along the approach entry path near the yield point but not more than 165 feet in advance of it.
b. The beginning point is 3 feet from a pavement marking (if no raised median), or 5 feet from the left curb face (if raised curb median) at a point approximately 165 feet from the yield line. This point is a continuation of a vehicle path spiraling from tangent to a curve, not a point with deflection.
c. Vehicle entry path curvature.

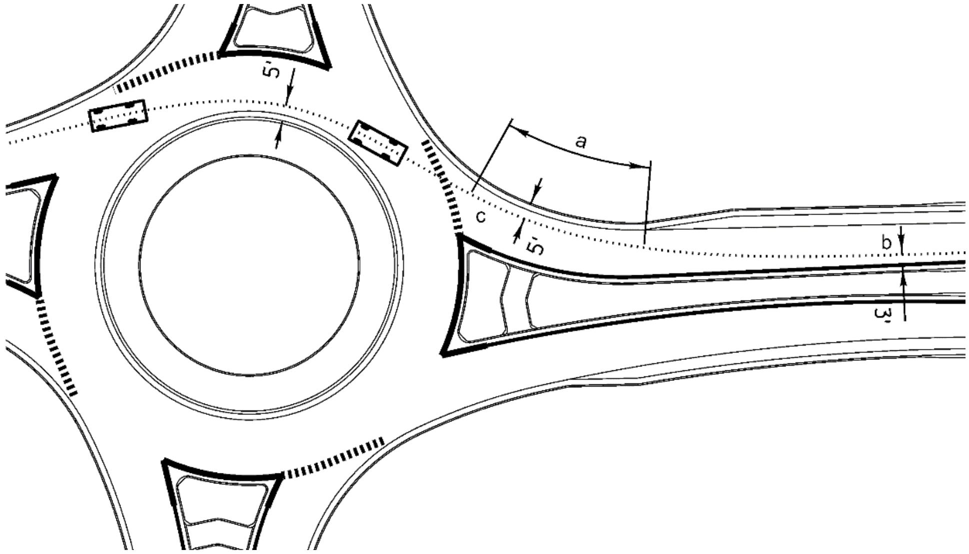


Figure 30.5 Determination of Entry Path Curvature
(See NCHRP 672 Exhibit 6-49 for multi-lane entries and Exhibit 6-50 for right turns)

The radii described in Table 30.2 are used to define the fastest path through a roundabout. They are illustrated in Exhibit 6-12 of NCHRP 672.

Table 30.2 Roundabout Radii

Radius	Description	Range of Speeds
Entry Path Radius, R_1	The minimum radius on the fastest through path prior to the yield line. This is not the same as Entry Radius.	Compact or Single-lane 20 to 25 mph* Multi-lane 25 to 30 mph*
Circulating Path Radius, R_2	The minimum radius on the fastest through path around the central island.	15 to 25 mph
Exit Path Radius, R_3	The minimum radius on the fastest through path into the exit.	R_2 + Acceleration over the path to the exit crosswalk*
Left Turn Path Radius, R_4	The minimum radius on the path of the conflicting left-turn movement.	10 to 20 mph
Right Turn Path Radius, R_5	The minimum radius on the fastest path of a right-turning vehicle.	15 to 20 mph*

* Notes: Under conditions where sufficient numbers of pedestrians are present, values of fast path speeds should be lower than maximum values shown in the table. Check the design speed control of sensitive designs that may have high entering or circulating speeds or where the pedestrian activity is anticipated to be medium to high, check for a conservative design by determining the fastest speed paths using a 3.28 ft. (1 m) offset to each of the critical controlling feature locations (i.e. raised curb face on the approach and exit median, curb face at the central island, or centerline pavement marking between opposing traffic).

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.1.

For additional information, see NCHRP 672, §6.2.3 & 6.7.1.

30.5.3 Speed Consistency

In addition to achieving the appropriate design speed for the fastest path movements, the relative speeds between consecutive geometric elements should be minimized as well as between conflicting traffic streams. Ideally, the relative differences between all speeds within the roundabout will be no more than 10 to 15 mph. Typically, the R2 values are lower than the R1 values. With either single or multi-lane entries, R2 values should be lower than the R3 values.

The typical maximum R1 radius is 250 ft. Generally, for urban roundabouts with pedestrian accommodations a lower speed entry is desirable. A typical R1 may range between 150 and 230 feet. Rural roundabouts typically allow slightly higher entry speed than urban roundabouts. The R1 and R2 should be used to control exit speed. Typically, the speed relationships between R1, R2, and R3 as well as between R1 and R4 are of primary interest. Along the through path, the typical relationship is R1> R2< R3, where R1 is also less than R3. Similarly, the relationship along the left-turning path is R1> R4.

For most designs, the R1 - R4 relationship will be the most restrictive for speed differential at each entry. However, the R1 - R2 - R3 relationship should also be reviewed, particularly to ensure the exit speed is not overly restrictive. Design criteria in past years advocated relatively tight exit radii to minimize exit speed; recent best practice suggests a more relaxed exit radius for improved drivability.

30.5.4 Design Guidance for Trucks

WisDOT is a freight friendly state and accommodates not only for the typical large legal-size trucks, but also the OSOW (permitted) vehicles that use our highways. FDM 11-25-2.1 describes the types of design vehicles and check vehicles that should be accommodated at intersections, including roundabouts.

Accommodating turning movements for large trucks and OSOW vehicles can be challenging, especially at single-lane roundabouts.

To accommodate these vehicles, the designer will have to balance the entry width and circulating roadway width with the need for small truck aprons (overtracking pads) behind the outside curb for off-tracking. The design vehicle should stay within the curb lines, whereas the check vehicle may utilize overtracking pads. It is generally a safer design to keep the roundabout entry width as narrow as possible, usually less than 24 feet between curb faces.

The following are guidelines to assist the designer in accommodating large trucks and OSOW vehicles at roundabouts:

1. Slope truck apron at 1% toward the roadway on all roundabouts. It should be capable of being mounted by the trailers of large trucks, but unattractive to passenger cars and smaller trucks.
2. Provide a truck apron around the central island that is a minimum of 12 feet wide on single-lane and multi-lane roundabouts. Additional width may be needed depending on the size of the roundabout, the size of the truck, or the skew of the intersection. The truck apron should be 12-inch thick to provide ample structural integrity while providing adequate tie bar clearances along back of curbs. Apply ties where required per FDM 11-26-30.5.20.2. The 12-inch truck apron also minimizes constructability issues between compaction levels and is expected to improve long-term performance.
3. Widen the truck apron as needed to accommodate the anticipated OSOW turning maneuver. Discuss with the regional Freight coordinator.
4. Roundabouts must have the recommended circulatory roadway crown installed, 2/3 inward and 1/3 outward on all roundabouts, not just those on the OSOW-TR. Refer to Figure 30.11 for cross-section clarification.
5. Keep drainage structures away from the travel path of the possible OSOW vehicle wheel tracking.
6. The compaction levels under the concrete pad along the back of curb near the entrance and in the splitter island areas must be equal to the compaction levels under the roadway and truck apron.
7. If a central island landscape buffer area is desired behind the truck apron, avoid the use of hard surfaces that look like concrete sidewalk.
8. Refer to FDM 11-26-35.1.12 for guidance on removable signs at roundabouts.

For further guidance on designing for trucks at compact roundabouts, see FDM 11-26-30.5.25.2.

30.5.5 Geometric Design Guidance for Large Trucks at Multi-lane Roundabouts

The inscribed circle diameter, the width of the circulatory roadway, and the central island diameter are interdependent. Once any two of these are established, the remaining measurement can be determined. However, the circulatory roadway width, entry and exit widths, entry and exit radii, and entry and exit angles also play a significant role in accommodating the design vehicle and providing deflection.

Roundabouts are designed with a truck apron. Truck drivers that use the inside lane at multi-lane roundabouts are expected to off-track onto the truck apron.

Wisconsin law prohibits vehicles driving next to trucks on the roundabout entries or while circulating within a roundabout; however, it may be difficult at times for vehicles to avoid arriving at the roundabout entry at the same time as a truck. Therefore, multi-lane roundabouts can be designed in three different ways to accommodate legal-size large trucks, identified as categories Case 1, Case 2, and Case 3:

- Case 1:

  Roundabouts which are designed to allow trucks to encroach into adjacent lanes as they approach, enter, circulate, and exit the intersection. Refer to Figure 30.6 for an example of a Case 1 design. Where a single-lane roundabout approach flares to a multi-lane entry, Case 1 design is preferred as the truck can easily block out other vehicles as it approaches the entry, see Figure 30.7.

- Case 2:

  Roundabouts which are designed to accommodate trucks in-lane as they approach and enter the roundabout but may require trucks to encroach into adjacent lanes as they circulate and exit the intersection. Case 2 roundabouts have a painted “gore” area between lanes on the approaches. Refer to Figure 30.8 for an example of a Case 2 design. Case 2 design is preferred on four-lane facilities as these configurations can be more difficult for a truck to block out other vehicles approaching the roundabout.
- Case 3:

  Roundabouts which are designed to accommodate trucks in-lane as they approach and traverse the entire intersection. Case 3 roundabouts have a painted “gore” area between lanes on the approaches. Case 3 roundabouts typically are designed to allow trucks to stay in lane for through and left turning movements, while right turning trucks may occupy multiple lanes as they exit. Refer to Figure 30.9 for an example of a Case 3 design. Because Wisconsin law gives priority to trucks in the roundabout, Case 3 designs are unnecessary in most circumstances. Case 3 design may be considered at intersections that have a truck percentage greater than 20% and should only be considered after consultation with the Region Traffic unit.

Well-designed Case 2 and Case 3 roundabouts do not compromise accepted design principles, as outlined in this chapter. Tables 30.3, Table 30.4, and Table 30.5 show the advantages and disadvantages of Case 1, Case 2, and Case 3 roundabout designs.

Table 30.6 depicts typical design parameters for each of the three design cases. Refer to FDM 11-25-1.4, FDM 11-25-2 and FDM 11-26-10.2 for additional information on OSOW routes and vehicles.

In the case of three-lane entries, off-tracking is assumed to overlap lane lines. If high volumes of large trucks are present and capacity is a concern, a painted gore width of 4 to 6 feet may be placed between the right two lanes.

***Table 30.3* Advantages and Disadvantages for Case 1 Roundabout Designs**

Advantages	Disadvantages
Wide variety of approach alignment design methods can be used More likely to fit in tight right of way locations, including built-up urban environments Potentially lower costs in some situations Less pavement marking maintenance	May result in increased delays due to trucks occupying both lanes on entries and while circulating Trucks may off-track over outside curbs, resulting in more damage and maintenance May result in additional truck-car crashes

***Table 30.4* Advantages and Disadvantages for Case 2 Roundabout Designs**

Advantages	Disadvantages
Surveys indicate this entry design is preferred over Case 1 by truck drivers Safety benefits at entries due to no truck encroachment Potentially less damage to curbs Trucks can maneuver more freely at entries May have greater entry capacity/less delay Can be used in urban or rural environments	Fewer approach alignment design methods can be used May require geometry with more right of way Potentially higher cost in some situations May require more pavement marking maintenance Slightly higher circulating speeds and worse lane discipline possible Requires greater designer and contractor skill Possibly lower safety in circulatory roadway due to truck encroachment

Table 30.5 ***Advantages and Disadvantages for Case 3 Roundabout Designs***

Advantages	Disadvantages
Surveys indicate this design is preferred by truck drivers and the trucking industry Safety benefits at entries and in circulatory roadway due to no truck encroachment Less damage to curbs Trucks can maneuver more freely at entries and in the circulatory roadway May have greater entry capacity/less delay Can be used in urban or rural environments Better operations in the circulatory roadway No truck/trailer encroachment required for turning movements - more lateral clearance	Fewer approach alignment design methods can be used May require larger geometry with more right of way Potentially higher cost in some situations May require more pavement marking maintenance Slightly higher circulating speeds and worse lane discipline possible Requires greater designer and contractor skill

Table 30.6 ***Typical Design Parameters for Two-Lane Roundabouts****

	Case 1 - No lane discipline entering or circulating	Case 2 – Lane discipline entering only	Case 3 – Lane discipline entering and circulating
ICD[A]	150-190 ft	160-210 ft	180-220 ft
Inner Circulatory Lane Width[B]	12-14 ft		12-14 ft
Outer Circulatory Lane Width[B]	14-16 ft		15-20 ft
Approach Gore Widths	Not used	2-6 ft	4-7 ft
Entry Width[A]	28-32 ft	32-34 ft	32-34 ft
Entry Radius	65 ft or greater	80 ft or greater	80 ft or greater
Entry Angle (measured per FDM 11-26-30.5.2)	16-30 degrees		
Flared Entry Lane Addition (based on 95%ile Queue)	> 100 ft Generally, 100 ft to 300 ft		
Exit Widths[A]	28-32 ft		28-32 ft (where large radius or tangential exit is used)

* Based on site conditions, right of way constraints, specific design vehicle, and other factors, designers may choose to implement geometries outside these recommended ranges; however, the overall design should comply with WisDOT general roundabout design practices

A Measurements are from the face of curb to face of curb, (includes 2-ft gutter pans on each side)

B Measurements are from flange line to lane line

30.5.5.1 Geometric Design Guidance for Case 1 Roundabouts

Case 1 roundabouts are designed with a single solid white paint line dividing the entry lanes. Trucks encroach on adjacent lanes at the approaches and when circulating and exiting the roundabout. Designers should consider implementing features that would result in a clear encroachment by trucks into adjacent lanes rather than a subtle encroachment (such an approach would typically include avoiding wide lanes, long sweeping curves, large ICDs, and large radii).

Additionally, Case 1 designs can allow for the approaching roadways to have more tangential alignments with short, tighter entry radii. Figure 30.6 shows the basic design features of a Case 1 roundabout. Case 1 designs are also ideal when there is a single-lane approach flaring to a two-lane entry as illustrated in Figure 30.7.

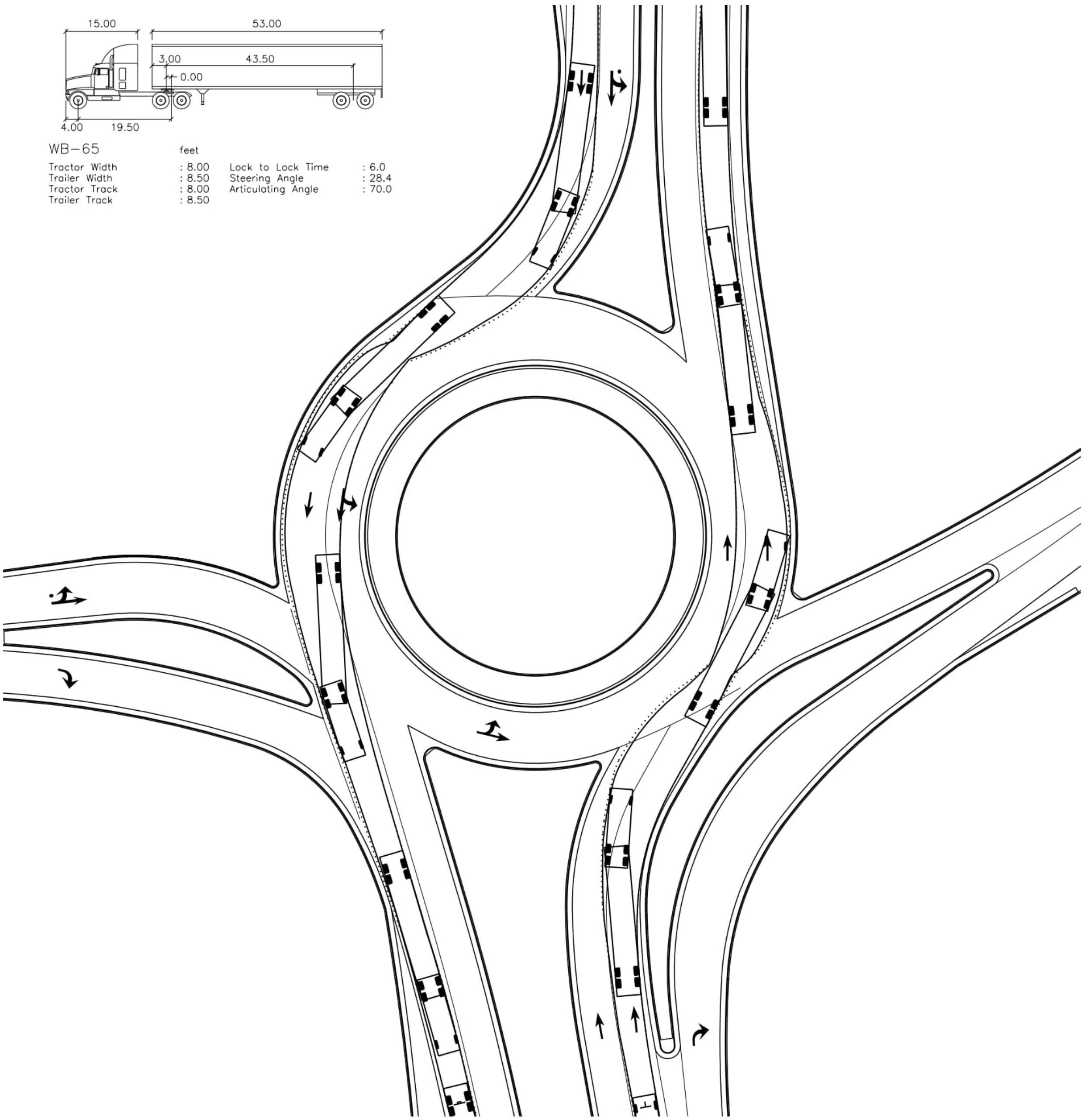


***Figure 30.6* Case 1 Roundabout Design (Single lane line dividing the entry lanes)**

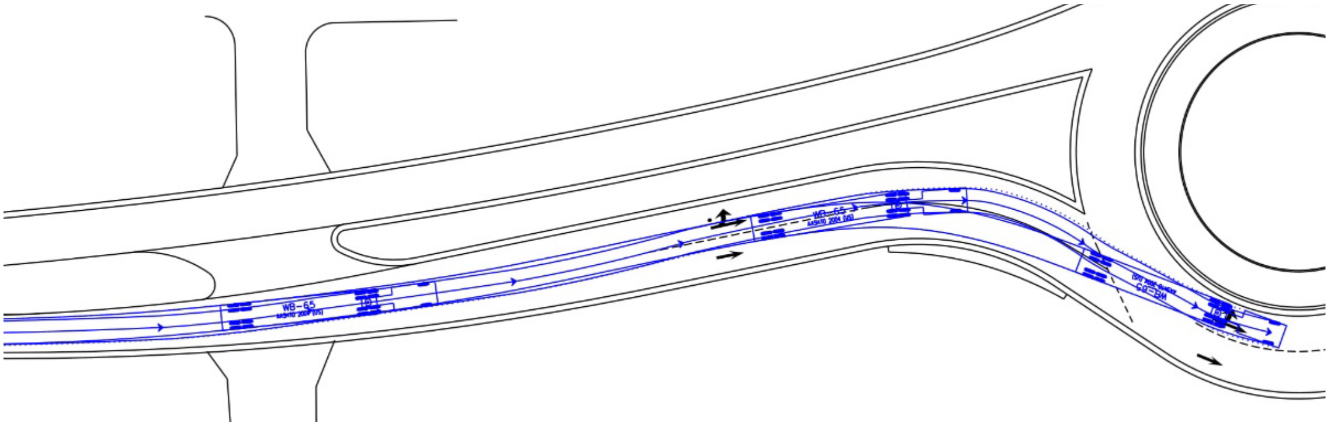


Figure 30.7 Case 1 Flared Entry Truck Movement

30.5.5.2 Geometric Design Guidance for Case 2 Roundabouts

Once the primary design principles from this guidance have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry while still maintaining the primary design. Although there are some specific design characteristics which are unique to Case 2 roundabouts, the overall approach, methods, and iterative design process remain the same as multi-lane roundabouts in general.

Case 2 roundabout ICDs are typically 10-20 feet smaller than for Case 3 roundabouts. Designers must maintain appropriate fastest path entry speeds and speed differentials between entering and circulating traffic. Figure 30.8 shows the basic design features of a Case 2 roundabout.

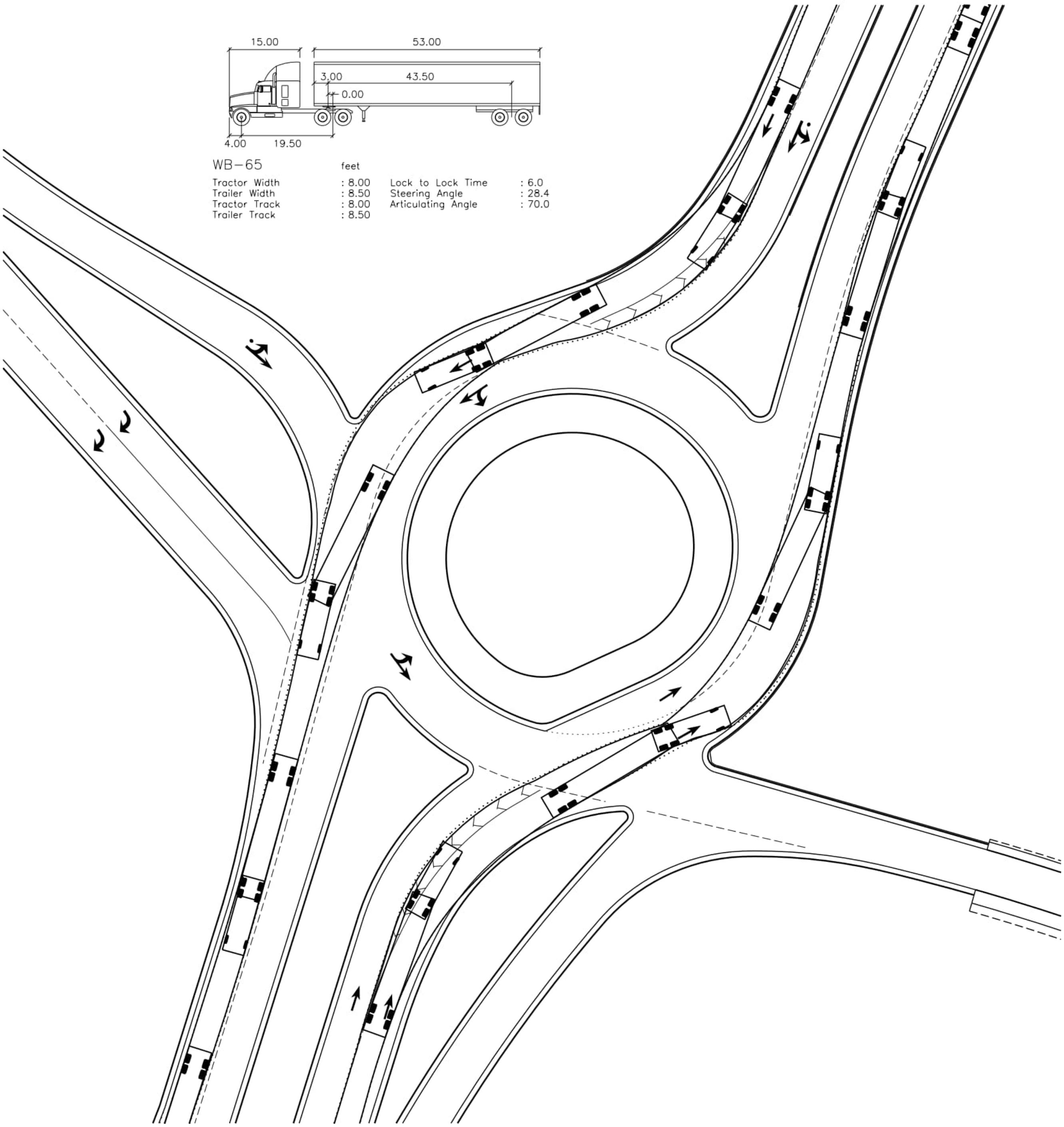


***Figure 30.8* Case 2 Roundabout Design (6-ft gore pavement marking between lanes)**

30.5.5.3 Geometric Design Guidance Common to Case 2 and Case 3 Roundabouts

1. Often have slightly wider entries (typically 2 to 6 feet wider) than a comparable Case 1 roundabout at the same location. For example, a Case 1 roundabout may have an entry width of 28 to 32 feet (including gutter pan width) wherein a typical Case 2 or 3 roundabout could increase the entry width to about 32 to 34 feet (including gutter pan width and gore pavement marking area) to allow trucks to stay in lane in entry.
2. Usually have longer curve lengths than Case 1 roundabouts on the approach geometry and within the entries. Offset left alignments (i.e., alignment directed to the left of the center of the ICD) are generally preferred where possible.
3. Should avoid tight entry radii curves and closely spaced curves in opposite directions. Instead, larger, longer radii with straight tangent sections between curves are common at Case 2 and 3 roundabouts,

resulting in gradual sweeping curvature which makes it easier for trucks to stay in lane. Optimal entry radii values will vary based on the ICD, approach alignment, and entry design method. Typically, an urban Case 2 or 3 design may have a controlling curb radius value of 100 feet or greater, while a larger rural Case 3 design may range as high as 120 feet or more (note: per definition above, controlling radius is not the same as the R_1 radius). Regardless of the actual values (which are site specific), the designer still must maintain other design requirements such as appropriate fast path speeds, while still accommodating for trucks in-lane. Considerable designer skill is typically needed to accomplish these competing objectives.

4. Use of width transitions. With Case 2 and 3 roundabouts relatively long width transitions may be needed to allow trucks to use more roadway width to stay in lane. Designers should ensure that the total length of the combination of the taper and the second full lane width utilized accommodates the design truck as well as queuing and capacity needs. Not including the gore area between entry lanes, the lanes should typically have continual tapers between the normal width upstream location and the entry, (Figure 30.8 and FDM 11-26-35.2.1), and at no point should lane widths become narrower over this distance. The design of the gore area may require variable widths, including narrowing toward the entry as needed.
5. A slightly wider entry width than usually provided at Case 1 roundabouts. The designer should keep the entry width as narrow as possible while still allowing trucks to stay in lane. Total two-lane entry width should typically not exceed 34 feet (from curb face to curb face, including painted gore area) unless special circumstances are present. Lane widths at the entry typically vary from 12 to 14 feet, not including the two-foot gutter or gore area.
6. The relationship between width transitions, entry widths, lane widths, and gore widths should be carefully considered by the designer when determining how to optimally serve trucks and passenger vehicles. As a general principle, widths should be minimized while still accommodating the design truck.
7. Typically, a Case 1 design would have a controlling radius value of 65 feet or greater, while a more common range is 100 to 130 feet for Case 2 and 3 designs.

30.5.5.4 Additional Geometric Design Guidance for Case 3 Roundabouts

When preparing a Case 3 design, once the primary design principles from this guide have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry and circulating road while still maintaining the primary design principles. Although there are some specific design characteristics that are unique to Case 3 roundabouts, the overall approach, methods, and iterative design process remain the same as multi-lane roundabouts in general.

Overall, Case 3 roundabouts embody similar geometric characteristics as Case 1 and 2 roundabouts. However, there are specific geometric elements where Case 3 roundabouts differ from Case 1 and 2 designs.

1. The outside circulating lane is often in the range of 15 to 18 feet (from edge of gutter flange line to lane line). Inside lanes range from 13 to 15 feet (from edge of central island gutter flange line to nearest lane line).
2. Usually include relatively large or flat exit radii which allow trucks to depart from the circulating road with minimal curvature to the right, thus allowing them to stay in lane more easily. Case 3 roundabouts may have larger ICDs in some situations where a double left turn is required. This type of design may be quite complex. Figure 30.9 shows the basic design features of a Case 3 roundabout.

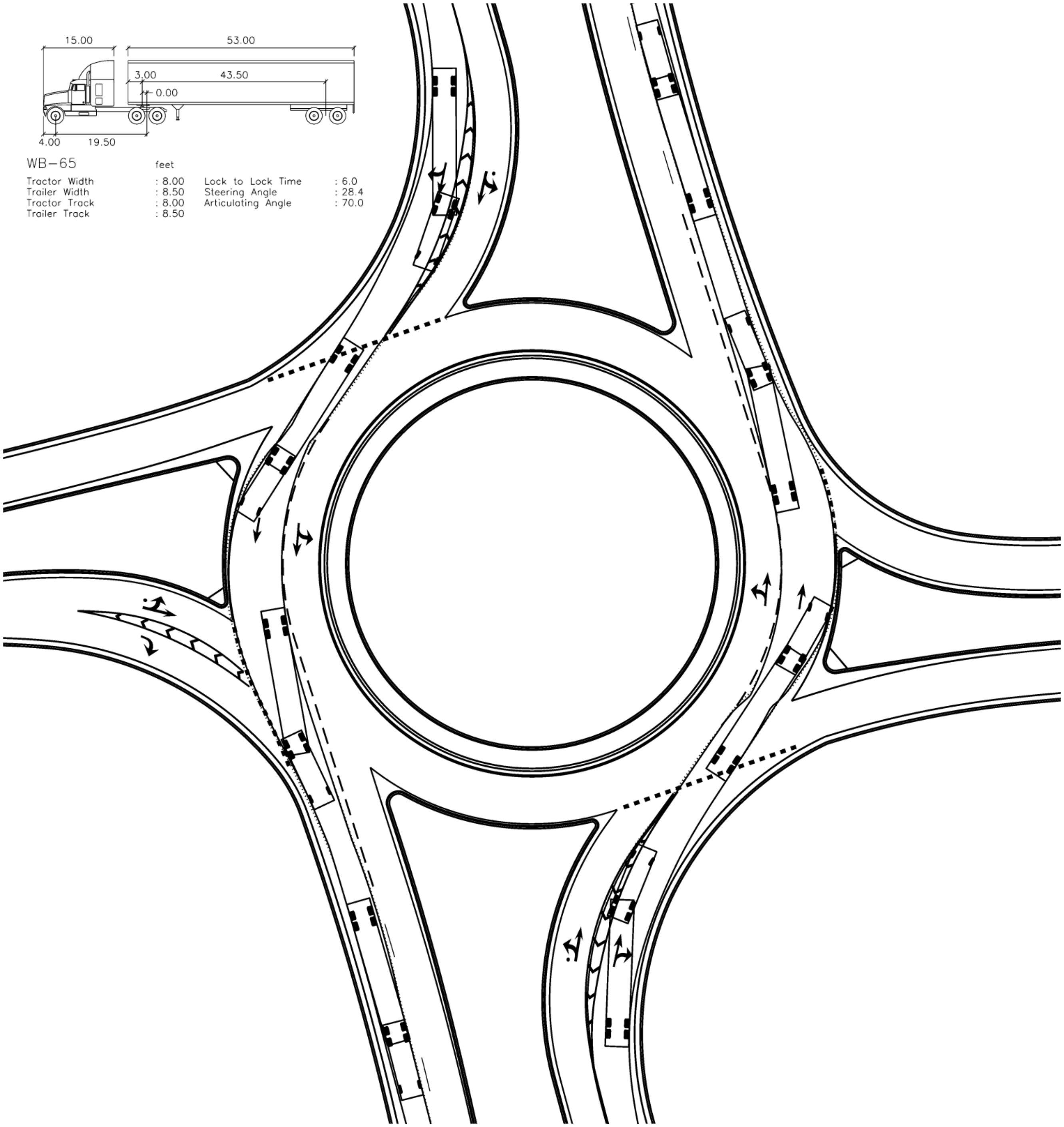


***Figure 30.9* Case 3 Roundabout Design (6-ft to 8-ft gore pavement marking between lanes)**

30.5.6 Geometric Considerations for OSOW Vehicles

If a roundabout is located on the OSOW Truck Route or it is thought that OSOW vehicles may use the intersection, conduct a vehicle horizontal turning and a low vertical clearance check with the OSOW vehicle inventory. AutoTurn or AutoTrack software may be used for the horizontal checks. AutoTURN Pro may be used for horizontal analysis and is required to determine if low vertical clearance conflict points are present.

Additional guidance on horizontal accommodations for OSOW vehicles include:

- Install a 12-inch thick, red-colored concrete truck apron behind the back of curb along the outside entrance area where OSOW vehicle off-tracking is anticipated. The slope of the pad should be a maximum of 1% sloped towards the roadway. Evaluate the entrance for pedestrian crossings and placement of the concrete pad to prevent these areas from overlapping if possible (see FDM 11-26-30.5.13.3). The width of this pad will depend on the amount of off-tracking anticipated. Provide tie bars when the adjacent truck apron width is less than 3 feet along its entire length. To limit pavement stress and crack propagation, do not tie the outside truck apron to the back side of curb when the variable-width truck apron is 3 feet wide or greater at any location. The same 12-inch thick, red-colored concrete pad, without stamping, should be installed in the splitter islands where OSOW vehicles may drive to negotiate the roundabout. Signposts placed in truck aprons located along the outside entrance area or in the splitter islands should be mounted in removable sleeves (see FDM 11-26-35.1.12).

- Install a Type A or D 4-inch sloped curb and gutter modified with 8" minimum flange thickness along the outside of the approach or the splitter islands where large vehicles may off-track onto a concrete truck apron located behind the curb.
- Produce a swept path diagram showing the vehicle movements and directions for the purpose of supplying the permitting office with diagrams to aid route choice.

The DST lowboy is the critical vehicle for analyzing vertical clearance at roundabouts. Use a low clearance of 5 inches for the DST lowboy evaluation. If clearance issues are found, reconfigure the slopes within the conflict areas and check the surrounding area (i.e., approaches) for additional conflict points. Refer to Figure 30.10 for typical ground clearance problem areas.

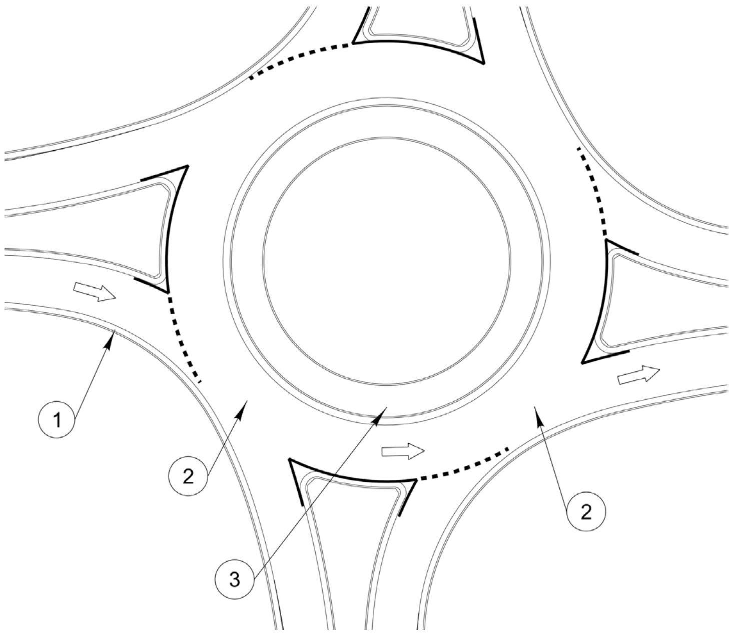


***Figure 30.10* Typical Ground Clearance Problem Areas**

1. Off-tracking at the entry curve/lowboy hitting the outside curb head
    a. Consider a Type A or D 4-inch sloped curb and gutter modified with 8" minimum flange thickness and concrete truck apron behind the back of curb along the outside entrance area. The slope of the truck apron should be a maximum of 1%. Evaluate the entrance for pedestrian crossings and placement of the concrete pad to prevent these areas from overlapping.
2. Entry and exit rollover
    a. Consider flattening the circulatory roadway crown in these areas if needed, while providing approximately 2/3 sloped inward and 1/3 sloped outward.
    b. Avoid break-over grades over 3% within 200 feet of the entry yield line location and exiting the roundabout
3. Truck Apron
    a. Slope truck apron 1% toward the roadway on all roundabouts. Consider a pill shaped central island or other shape where appropriate to accommodate the anticipated OSOW turning maneuver.
        i. See if the vehicle can track more on the circulatory roadway. In rare situations, the designer may consider a 3-inch height R/T type curb and gutter. This will require an evaluation of the inlet casting height/location (out of the vehicle path).
    b. Look at the circulatory roadway profile
        i. Keep it as flat/gentle as possible and still maintain drainage (0.75% - 1.0%)
        ii. Locate the crest away from the area(s) of concern

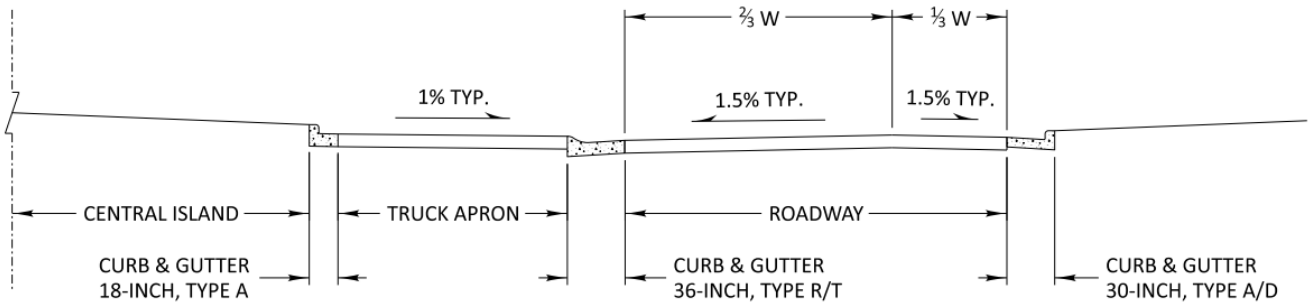


***Figure 30.11* Cross-Section Example**

In some cases, abnormally long vehicles may not be able to negotiate a roundabout regardless of geometric adjustments to the truck apron and approaches when making left turns. In some cases, special median crossings may be required, which allow the vehicle to bypass the circle portion of the roundabout by traveling the opposite direction. Such maneuvers should be avoided, if possible, due to the extra planning required for escorting a vehicle in such a maneuver. Discuss such alternatives with the regional traffic section and the OSOW-TR coordinator and document route testing produced by turn analysis software for future use by the OSOW Permitting Unit.

For further guidance on compact roundabouts, see [FDM 11-26-30.5.25.3].

30.5.7 Overturning Considerations for Large Vehicles

A further consideration associated with large trucks in roundabouts is the potential for overturning or shifting of loads. There is no simple solution in relation to layout geometry to completely prevent load shifting and roll-overs. Experience suggests that at roundabouts where these problems persist, there are frequently combinations of the following geometric features:

- Long straight high-speed approaches
- Inadequate entry deflection or too much entry deflection
- Low circulating flow combined with excessive visibility to the left
- Significant tightening of the turn radius partway around the roundabout (spirals with arcs that are too short).
- Cross-slope changes on the circulatory roadway or the exit
- Outward sloping cross-slope on the entire width of the circulatory roadway

A problem for some vehicles may be present even if speeds are low because of a combination of grade, geometry, sight distance and driver responsiveness. Research has shown that an articulated large goods vehicle with a center of gravity height of 8 feet above the ground can overturn on a 65-foot radius curve at speeds as low as 15 mph. See Transport Research Laboratory Report LR788.

Layouts designed to mitigate the above noted characteristics will be less prone to load shifting or load shedding. In addition, pay attention during design and construction to ensure that pavement surface tolerances are complied with and that abrupt change in cross-slopes are avoided.

30.5.8 Roadway Width

The width of the roadway at locations with curb and gutter on both sides should accommodate the design vehicle and allow for passing a stalled vehicle. The design width for entries, exits and bypass lanes is shown in AASHTO GDHS 2018, Table 3-26a, page 3-106, as a 19-foot face-face minimum and 20-foot face-face typical to allow a stalled vehicle to pass.

30.5.8.1 Entry Width

Entry width is measured perpendicularly from the outside curb face to the inside curb face nose P.C. at the splitter island point nearest to the inscribed circle.

Narrow entries tend to promote lower speeds and improved safety. However, a WB-65 may require a 20 to 24-foot-wide entry (curb face to curb face) for single-lane approaches to be able to make a right turn. Design single-lane roundabouts to accommodate a WB-65 without encroachment onto the truck apron or the curb and gutters.

For further guidance on compact roundabouts, see [FDM 11-26-30.5.25.4].

30.5.8.2 Entry Flare

Flaring an entry from one lane to two or from two to three creates additional entry capacity without extensive mid-block widening. When lane choice options are even, or no preference is given to either lane, it is ideal to split the approach width at a point where the lane width reaches 9.5 feet or 19 feet overall (flange of curb dimensions).

The development of horizontal geometry and pavement marking of a flared entry is balanced and smooth making lane choice options obvious and entry paths clear.

30.5.9 Exit Tapers

Tapering the number of lanes on an exit from two lanes to one lane or from three lanes to two lanes allows for additional roundabout capacity without extensive mid-block widening. The continuous flow nature of roundabouts typically results in less saturated traffic streams exiting the intersection. This is in sharp contrast to a signalized intersection where platoons of traffic are much more concentrated, and consequently typically require more downstream distance to merge. Speeds are also much slower for traffic exiting roundabouts which eliminates the need for long parallel section downstream of the roundabout exit.

Design exit tapers from roundabouts based on the anticipated in lane exiting speed, not the fastest path, typically in the range of 15 to 25 mph. Merging taper rates should be based on the lengths shown in FDM 11-25 Attachment 2.3, typically 20:1 to 30:1. The length of full width lanes beyond the circulating roadway to beginning the merging taper may vary between 100 and 300 feet depending on volume, potential for upstream lane choice, and other factors that may be unique to the site, Consider the farther the full lane widths are extended upstream, the potential for increase in speed and the potential for a longer merge taper. See Figure 30.12.

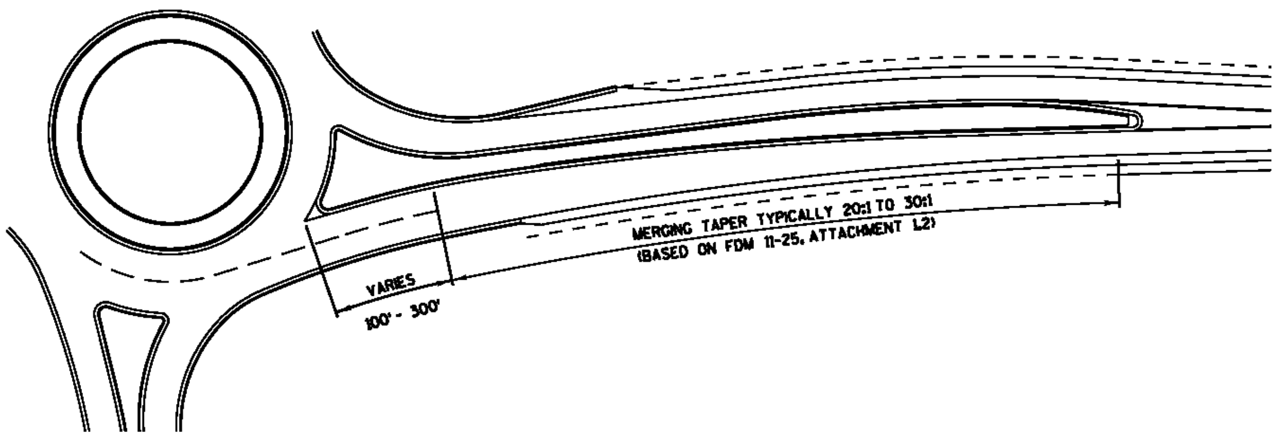


***Figure 30.12* Exit Lane Taper**

30.5.10 Circulatory Roadway Width

Circulatory roadway width is the width between the outer edge of the inscribed diameter at the curb face and the central island curb face. It is typically 1.0 to 1.2 times the width of the widest entry with potential exceptions for Case 2 and Case 3 designs. It does not include the width of any traversable apron, which is defined to be part of the central island. The circulatory roadway width defines the roadway width, curb face to curb face, for vehicle circulation around the central island. The circulatory roadway width does not need to remain constant. A two-lane entry may be appropriate for the major through highway, however, the minor side road may be single-lane approaches. The circulating roadway may often have a different width to accommodate the through traffic than for the side road traffic. Alternative lane configurations also produce varying circulatory widths as shown on NCHRP 672 Exhibit 6-27.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.5.

30.5.11 Central Island

The central island of a roundabout is always a raised, non-traversable area encircled by the roundabout circulatory roadway. The central island is stepped up from the traversable truck apron to the non-traversable island area. The central island is raised and landscaped to enhance driver recognition of the roundabout upon approach and to limit the ability of the approaching driver to see through to the other side. The inability to see through the roundabout reduces or eliminates headlight glare at night and driver distraction by other vehicles on the circulating roadway.

Landscaping the central island and the roundabout area is further addressed in FDM 11-26-40.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.6.

30.5.12 Entry Curves

The minimum entry radii should be approximately 65 feet. Capacity will increase with increased entry radii, but so may the entry speed. Entry radius is not R1.

NCHRP 672 Exhibit 6-14 illustrates the composition of entry curves to produce natural entry paths. This method is useful but has limitations where large trucks making right turns will require even larger outside radii, particularly on single-lane roundabouts with narrow entry widths. In such cases, the larger outside radius may increase entry speeds undesirably. A preferred design technique for single-lane roundabouts is not to make the inside radius/arc tangential to the central island, but to create a flare in the entry such that the large truck path can preserve the outside radius which controls entry speed. The effect gives the entry a flare, typically ranging from 18 feet to 24 feet.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.7.

30.5.13 Non-motorized Users

Roundabouts like other intersections need to accommodate bicyclists and pedestrians. The types of facilities provided vary based on the existing urban, suburban and rural conditions as well as future land uses. Evaluate regional and local land use plans including stand-alone bike and pedestrian plans for communities when determining the appropriate bike and pedestrian facilities at a roundabout. See FDM 11-46-1 for guidance on including bike and pedestrian facilities on projects.

Pedestrian accommodations include sidewalks, shared-use paths and roundabout sidepaths. See FDM 11-20-1, FDM 11-46-5, and FDM 11-46-10 for design standards on Pedestrian Facilities. See FDM 11-46-15 and Wisconsin Bicycle Facility Design Handbook for shared use paths design standards. A sidewalk transitions to/from a roundabout sidepath as it approaches/departs an isolated roundabout. At locations with consecutive closely spaced roundabouts, a sidewalk transitions to a roundabout sidepath at the first upstream roundabout, and transitions from a roundabout sidepath at the last downstream roundabout. See FDM 11-26-30.5.13.1 for further design guidance.

Bicycle accommodations include bike lanes, wide curb lanes, urban paved shoulders, rural paved shoulders, shared-use paths and roundabout sidepaths. Although a shared roadway is not a bicycle accommodation, shoulders or bike lanes taper down and end just prior to the entrance to a roundabout. Tapers are necessary to help achieve proper speed control for vehicles at entry. Design requirements do not allow bike lanes or shoulders at the yield line or within the circulatory roadway of a roundabout. Bicyclists in Wisconsin have the right to use the roadway in the same manner as motor vehicles. Bicyclists may have concerns when traveling into, through, or around roundabouts depending on traffic volume, vehicle type composition, experience of the bicyclist, lighting or other factors. Therefore, a bicyclist approaching a roundabout may proceed in a travel lane (“take the lane”) or exit the roadway by way of a ramp and ride on a roundabout sidepath (or a shared use path, if applicable). See FDM 11-26-30.5.13.4 for guidance on bike exit and entrance ramps. These ramps are where the shoulder or bike lane tapers and a typical 5-foot sidewalk transitions to/from a roundabout sidepath.

Shared-use paths are typically community or regional facilities in their own corridors that may extend for miles. Shared-use paths support a wide variety of non-motorized travelers like bicyclists, in-line skaters, roller skaters, wheelchair users, walkers, runners, people with baby strollers or people walking dogs (typically not equestrian users or motorized users - although some state trails in Wisconsin allow snowmobiles). Shared-use paths are designed for bi-directional bicycle travel. Continue a shared-use path around roundabouts (and between consecutive roundabouts if applicable) following shared-use path design criteria. See FDM 11-46-15.6 and the Wisconsin Bicycle Facility Design Handbook for more guidance on shared-use paths. Also, see FDM 11-35-1.6 and FDM 11-35 Attachment 1.1.

The roundabout splitter islands provide pedestrian refuge and pedestrian crossings. At roundabouts with high traffic volumes, or where pedestrian or bicyclist volumes are high, consider accommodating both users by enhancing the pedestrian crossings with features such as:

- 6-inch white crosswalk marking next to colored concrete (Wisconsin MUTCD (WMUTCD), 3B.18, 3G.01, 7C.02)
- Colored concrete with 6-inch wide patterned borders with white crosswalk markings, note main walking surface is smooth
- Activated (push button or automatic detection) warning beacons (e.g., Rectangular Rapid Flashing Beacon)

30.5.13.1 Roundabout Sidepaths and Terraces

Roundabout sidepaths are a variant of shared-use paths that apply specifically to roundabout intersections and between consecutive closely spaced roundabouts. A roundabout sidepath is located around the perimeter of an isolated roundabout, or between consecutive closely spaced roundabouts and around their perimeters. Consecutive roundabouts are closely spaced if they are 1,000 feet or less from center to center. Roundabout sidepaths are designed with the expectation that bicyclists are traveling in a unidirectional manner (i.e. one-way bicycle travel in the same direction as traffic flow on that side of the roadway) and do not connect to shared-use paths.

Where an existing or proposed standard (5-foot) sidewalk approaches either end of a roundabout, provide at least an 8-foot wide roundabout sidepath when sidepath use is anticipated to be low or medium around and between the roundabout(s). The width of the sidepath should remain consistent through the roundabout(s). When two-way bicycle travel is expected, or the facility leading up to the roundabout is a shared-use path, or path use is anticipated to be high (frequent passing of users), install a 10-foot wide sidepath. There are many reasons to anticipate high use such as nearby parks, schools, universities, gas/convenience stores, restaurants, limited crossing locations, etc.

In a suburban or rural area, there may be locations with on-road bicycle accommodations but without sidewalks (existing or proposed) (see FDM 11-46-1.3.1.4). In this case, 6-foot wide roundabout sidepaths are appropriate. Coordinate with the regional bicycle and pedestrian coordinator to determine the appropriate widths.

For a series of closely spaced roundabouts, extend the roundabout sidepath or shared use path from the first bicycle exit ramp to the last bicycle entrance ramp, for the bicyclist to leave the roadway and travel through all roundabouts on the roundabout sidepath. Do not provide entrance ramps for bicyclists to re-enter the roadway between closely spaced roundabouts (1,000 feet or less between roundabout centers). However, provide exit ramps from the roadway to the sidepath prior to the approaching roundabout.

When the distance between any two roundabouts is greater than 1,000 feet, center to center, then the roundabout sidepath may be discontinued beyond the last roundabout. Provide entrance ramps for bicyclists to re-enter the roadway downstream from each roundabout as well as exit ramps from the roadway to the sidepath. Where pedestrian facilities are provided, existing or proposed, continue the facility (e.g., sidewalk) between the roundabouts.

For roundabouts at rural locations, sidepaths around the roundabout should be considered, but are not required. In these instances, the bike ramps and sidepaths should be discussed and displayed at an initial public meeting. If support for sidepaths is not shown, coordinate with the regional bicycle and pedestrian coordinator on whether sidepaths should be included on the project, or if a platform should be graded for future facilities (e.g., grading for a 5-foot terrace and a 6-foot sidepath). There may be situations where grading for future facilities would have extensive right of way or environmental impacts, in which case grading would not be required.

Construct cut-throughs and curb ramps in the splitter island for the future pedestrian crossings (see FDM 11-26-30.5.13.2 for guidance on the cut-through width) unless the region determines to postpone construction of the cut-throughs until sidepaths are installed.

A terrace is required between roundabout sidepaths and the back of curb. Terraces should be designed to be 5 feet wide, or greater. Where space is limited, the terrace may be no less than 3 feet wide. If there is an overtracking pad adjacent to a roundabout entry or exit, a minimum terrace of 3 feet is required between the sidepath and the overtracking pad. Terraces should be planted with grass to facilitate wayfinding to aid pedestrians with visual impairments to the appropriate crossing location. Smooth concrete and most stamped concretes do not meet ADA requirements for separation per PROWAG and NCHRP 834. Detectable warning fields are not to be used as an edge treatment. Tactile walking surface indicators are an emerging edge treatment currently being researched nationally and may become a future option.

30.5.13.2 Crosswalks and Splitter Islands

Crosswalk placement at roundabouts effects all users, particularly for people with visual impairments. Research and national guidance have identified four principal tasks necessary for crossing the street, these are:

- finding the crosswalk and identifying the crossing location;
- aligning to cross in the direction of the crosswalk;
- deciding when to initiate crossing or identifying a gap in traffic; and
- maintaining alignment while crossing and staying within the crosswalk.

To facilitate these crossings, the design of the roundabout must provide the geometric and informational cues needed for pedestrians to make decisions in crossing.

For WisDOT roundabout projects, an angled crosswalk design alignment for each leg of the crosswalk is to be provided at both entry and exit lanes (Figure 30.13). Only compact roundabouts may use straight crosswalks if necessary. The cross slope of the roadway at the pedestrian street crossing (crosswalk) shall be 2% or less.

The standard angled crosswalk placement is 25-30 feet from the yield line on single-lane roundabouts, as illustrated in Figure 30.13. At multi-lane roundabouts, the crosswalk can be angled as shown in Figure 30.14 or offset as shown in Figure 30.15. For angled crossings on multi-lane roundabouts, place the crosswalk 30-50 feet from the yield line, which results in the exit crosswalk located approximately 40-60 feet from the circulating roadway. For offset crossings on multi-lane roundabouts, place the crosswalk 25-30 feet from the yield line and 40-60 feet from the exit. This space between the circulatory roadway and the roundabout exit crosswalk for both multi-lane crossing configurations allows drivers more time to react to crossing pedestrians, especially for right turning vehicles, provides more time for motorists to transition focus from exiting the roundabout to focusing on the downstream crosswalk, and allows for two vehicles to queue at the crosswalk without blocking the circulating roadway. For all single-lane and multi-lane crosswalk designs, the crossings should be perpendicular to the outside curb and gutter to help align pedestrians to the crossing.

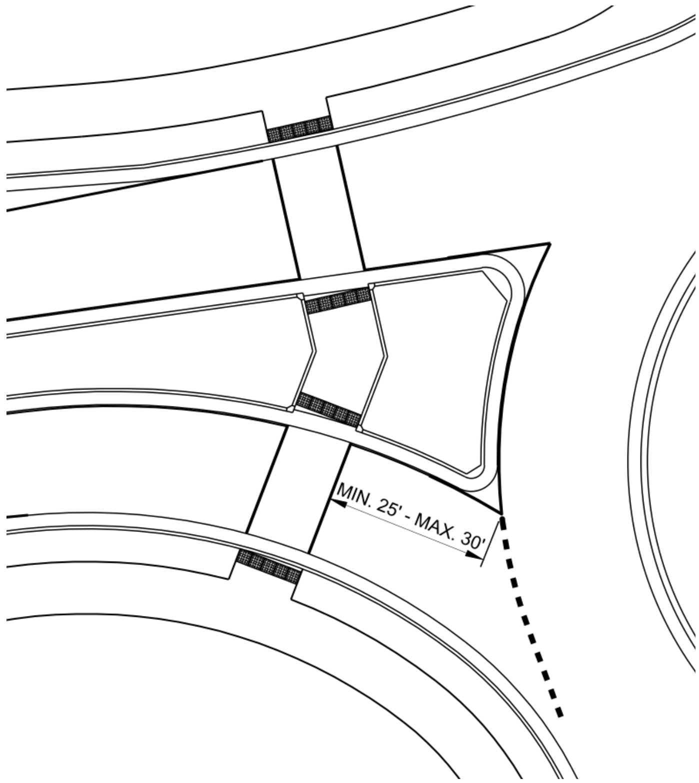


Figure 30.13 Single-lane Angled Crosswalk Design

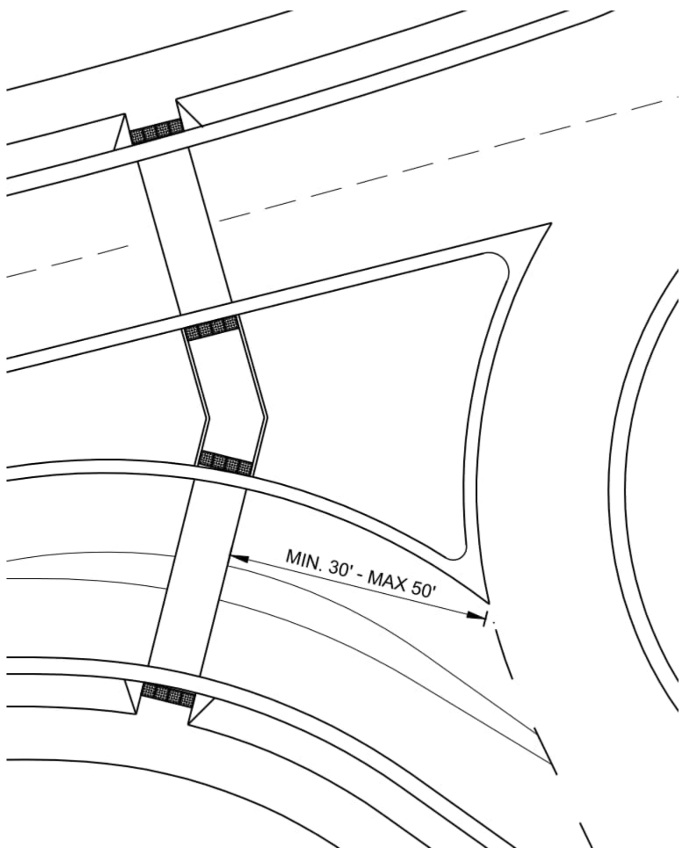


Figure 30.14 Multi-lane Angled Crosswalk Design

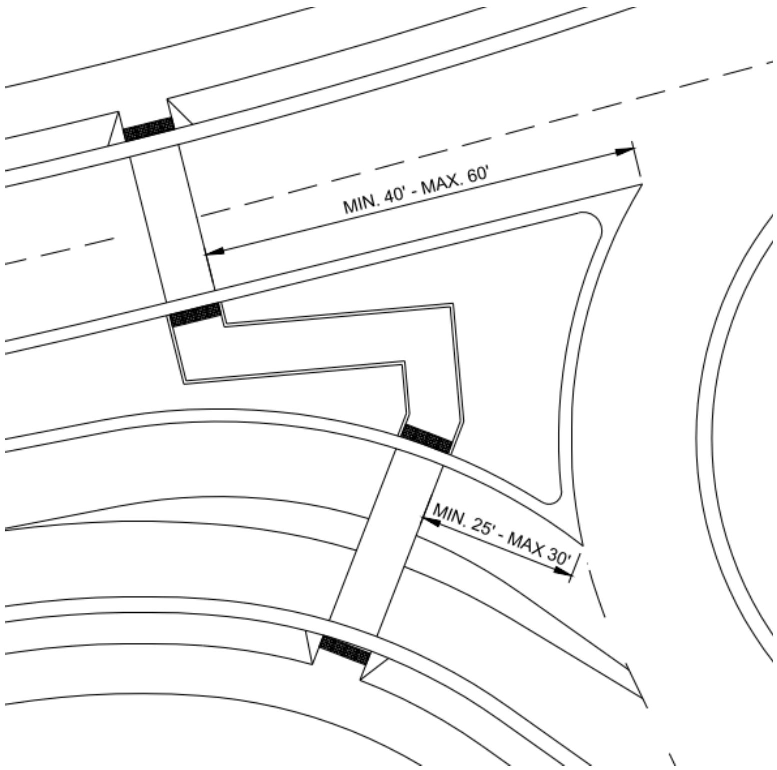


Figure 30.15 Multi-lane Offset Crosswalk Design

Both angled and offset crosswalk designs are acceptable at multi-lane roundabouts. There are advantages and disadvantages for each of these crossing designs; a few are listed in Table 30.7. It is important to consider the roundabout geometrics, location context, site conditions, frequency in gaps for crossing, crossing sight distance, and ease of alignment of the crossing for people of all ages and abilities to use. Overall maintenance, including snow removal, is also a consideration. If the offset crosswalk design is used, it should be discussed and agreed upon with the maintaining authority due to the extra challenge with snow removal.

Table 30.7 Advantages and Disadvantages of Multi-lane Crosswalk Types

Category	Advantages	Disadvantages
Angled	Perpendicular alignment often easier for crossing. Minimizes crossing distance. Snow removal may be easier through the splitter island. Splitter island can be narrower, usually requiring less right of way.	If RRFB's are installed, more separation is needed between the push buttons on the poles in the splitter island (10' required) and the two-stage crossing is not as clearly defined. The crosswalk on the entry to the roundabout is moved farther away from the yield line, and speeds at the crosswalk location may be faster.

Category	Advantages	Disadvantages
Offset	More clearly defines the two-stage crossing for pedestrians. If RRFB's are installed, adequate separation of the push buttons on the poles is more easily accommodated. The crosswalk on the entry to the roundabout can remain closer to the ideal location of behind one queued vehicle.	Construction may be more difficult and costly. A wider splitter island is required which may need right-of-way. Snow removal may be challenging in the splitter island.

The width of the pedestrian cut-through in the splitter island should match the width of the approaching crosswalk facility (e.g., a 10-foot wide shared-use path requires a 10-foot wide pedestrian cut-through in the splitter island). If the approaching facilities are less than 6 feet, then the splitter island cut-through shall be a minimum of 6 feet wide. The length of the pedestrian refuge within the splitter island should be a minimum of 6 feet long (between curb backs) with detectable warning fields that shall extend the full width of the crossing. Detectable warning fields in the splitter island must be separated by a minimum of 2 feet. See Figure 30.16. If rectangular rapid flashing beacons (RRFBs) will be installed with the roundabout construction, or if future RRFB installation is anticipated, a longer pedestrian refuge is required, see FDM 11-26-30.5.13.5.

Splitter islands can be crowned upward with a slope between 1% and 10% toward the center of the island or can be sloped at 1% to 10% in one direction as shown in Figure 30.16. This improves visibility of the splitter island for rural conditions. The maximum overall height above the top of the curb within the splitter island area should be approximately 18 inches from top of curb to the top of any concrete/asphaltic surface. Some islands may become quite wide near the circulating roadway however limit the height to 18 inches. The approach nose separating the entering traffic and the exiting traffic shall be a Concrete Median Sloped Nose, Type 1. This splitter island nose should be 6-foot face-to-face where the R4-7 (KEEP RIGHT) sign is located. The other noses at the edge of the circulatory roadway and the splitter island shall be Concrete Median Sloped Nose, Type 2. Both nose types are shown in SDD11b2. Where there is a divided highway approaching the roundabout the approach nose is eliminated.

For additional information, see NCHRP 672, §6.4.1.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.9.

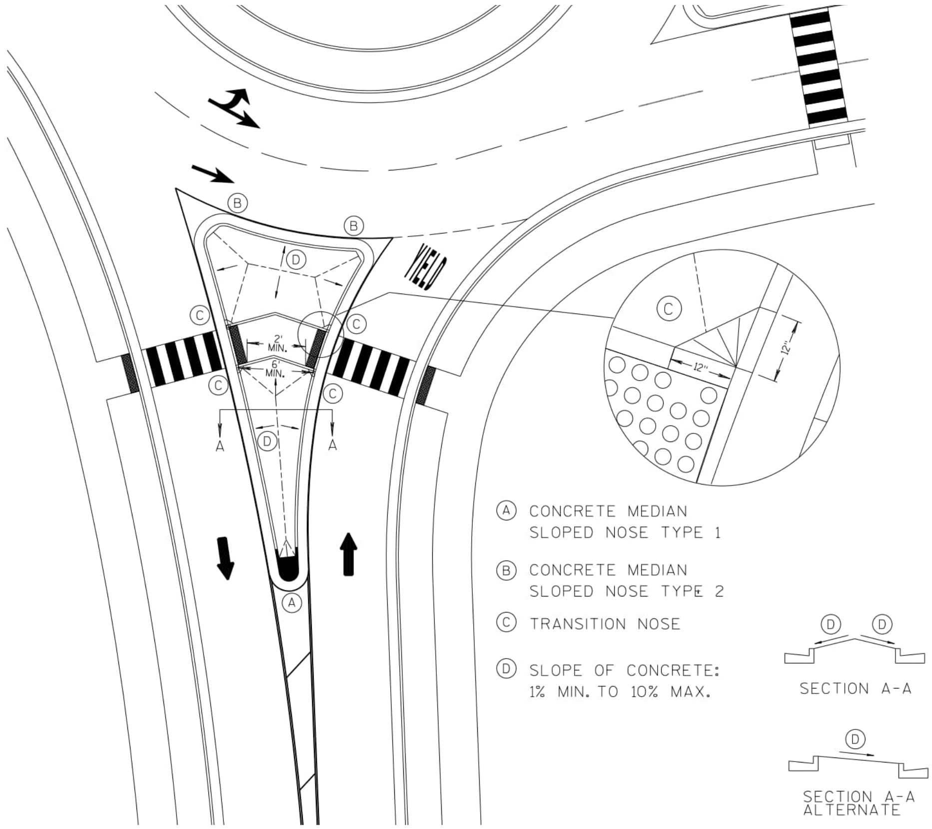


Figure 30.16 Typical Splitter Island

30.5.13.3 Pedestrian Crossing and Overtracking Pad Design Guidance

If overtracking pads are to be provided on the outside of the roundabout, attempt to keep the crossing from going through the overtracking pad. For situations where crosswalks are not able to be placed outside the limits of overtracking pads, provide ADA compliant curb ramps within the overtracking pad. The curb ramp within the overtracking pad should remain the same concrete thickness and coloring as the rest of the overtracking pad. The detectable warning field is to be placed at the back of curb. See Figure 30.17 for a typical design of a curb ramp through an overtracking pad.

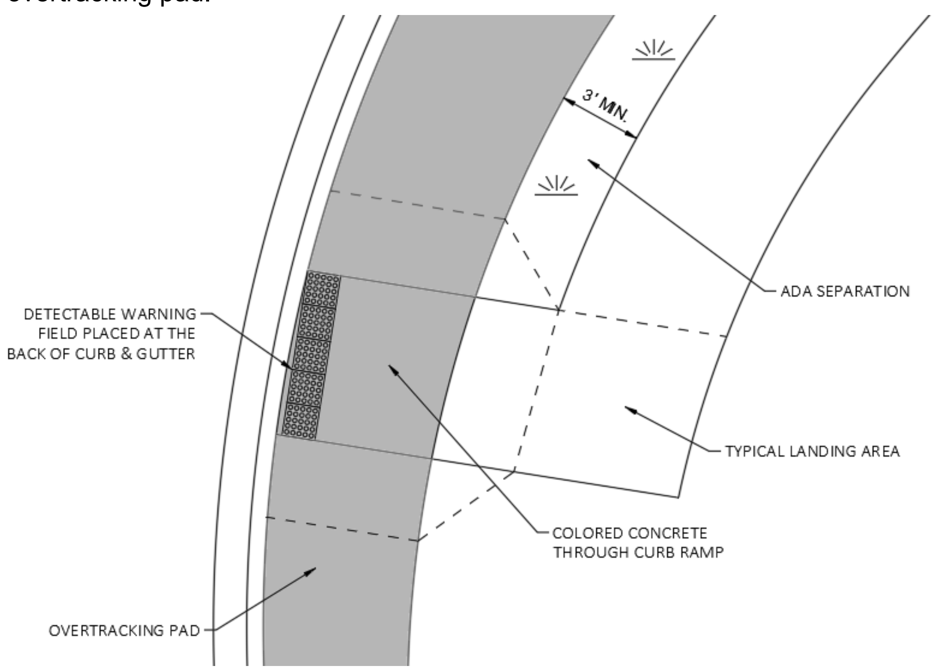


Figure 30.17 Curb Ramp Through an Overtracking Pad

If the proposed outside sidewalk is not going to be installed with the initial construction of the roundabout, the overtracking pad should be sloped for future accommodation of a curb ramp and landing. Detectable warning fields should not be installed with the initial construction.

30.5.13.4 Bike Ramp Entrance and Bike Ramp Exit Design Guidance

End the on-road bicycle accommodations approximately 75 to 150 feet upstream of the yield line and allow the bicyclist an opportunity to leave the roadway by way of a bicycle exit ramp. More distance is needed when a right turn bypass lane is provided. The bike ramp exit should have relatively flat angles as shown so that bicyclists are not directed into the path of pedestrians. The bike ramp entrance should have relatively flat angles as shown so that bicyclists are not directed into the travel lane of motorized vehicles. The bike entrance ramp should not be directed parallel to the bike lane.

The location of bike ramps and driveway aprons need to be spaced as not to conflict with each other.

Design the bike ramps 4 feet wide between the roadway and the multi-use path such that they angle up (25 to 35 degrees) to the path where the bicycles exit the roadway, Figure 30.18. Angle down (25 to 35 degrees) toward the roadway where the bicycles re-enter the roadway, Figure 30.18.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.8.

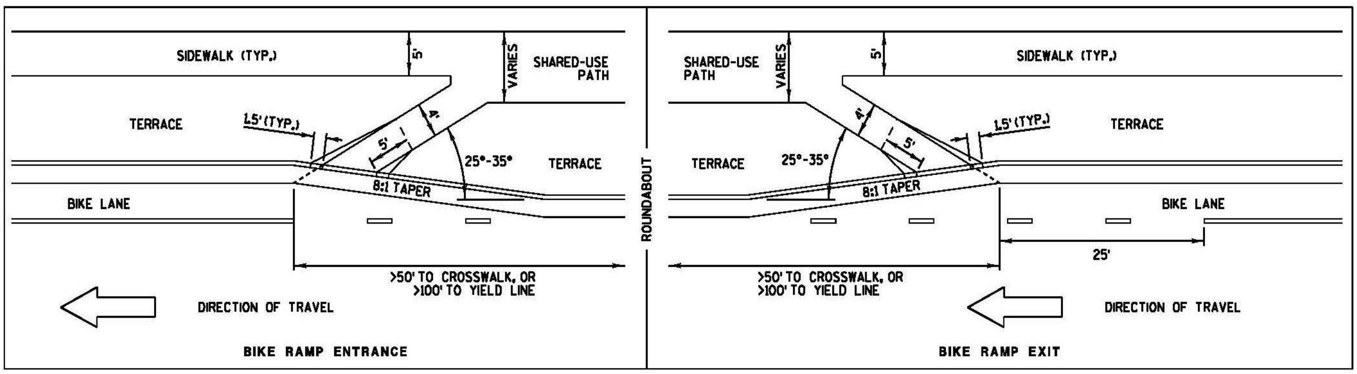


***Figure 30.18* Bike Ramp Entrance and Exit**

30.5.13.5 Rectangular Rapid Flashing Beacons (RRFB) Placement Guidance

When used, RRFBs should be placed in front of/upstream of the crosswalk. RRFBs should be set up as two-staged crossings where the signal is only activated for the entry or exit that the pedestrian is crossing. Pedestrians would then be required to activate the second stage of the crossing within the splitter island to complete their crossing of the leg. RRFBs should include an audible push button and poles should be placed a minimum of 10 feet apart per ADA standards. See TEOpS 4-5 for the design and installation of RRFBs. See Figure 30.19 on the typical placement of RRFBs.

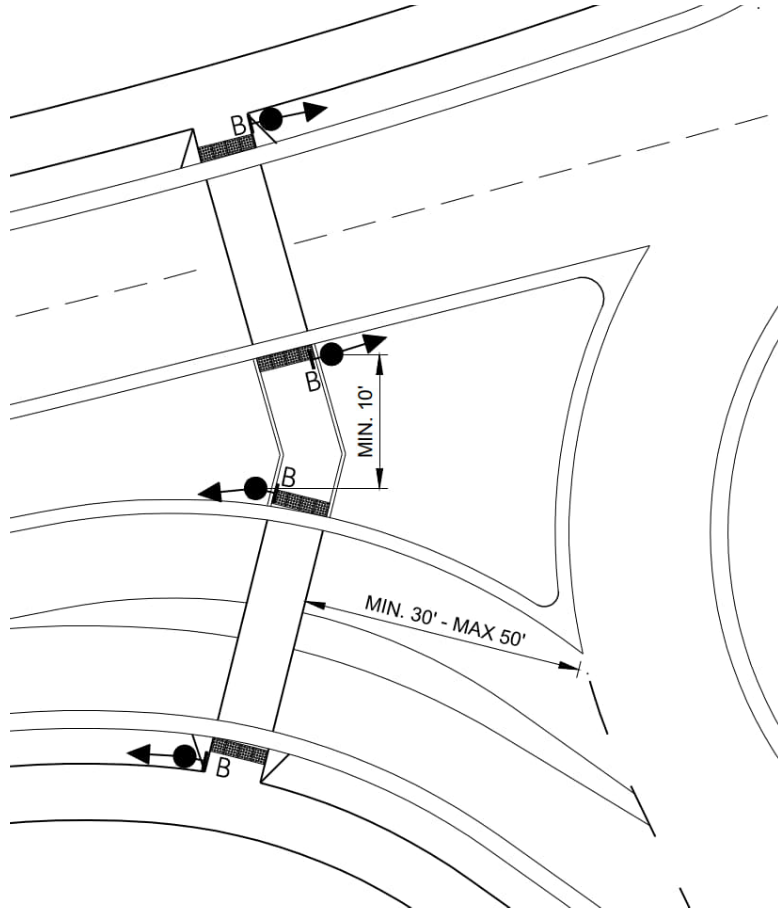


Figure 30.19 RRFB Placement at Roundabouts

30.5.13.6 Roadway Width, Clear Roadway Width of Bridges, and Underpasses between Closely Spaced Roundabouts

At a minimum, multi-lane roadways with a raised curb median between opposing roadways and between closely spaced roundabouts require a 2-foot median shoulder, two or more 12-foot lanes, and a 4-foot minimum outside shoulder, a 5-foot terrace adjacent to a shared-use path or roundabout sidepath. If there are trees planted in the terrace the minimum terrace width is 6-foot wide.

At a minimum, single-lane roadways with a raised curb median between opposing roadways and between closely spaced roundabouts require 19 feet minimum from curb face to curb face. This typically allows for a 2-foot median shoulder, one 12-foot lane and a 5-foot minimum shoulder on the outside, followed by a 5-foot terrace and either a roundabout sidepath or a shared-use path. If there are trees planted in the terrace the minimum terrace width is 6-foot wide. A single-lane roadway between opposing roadways and between closely spaced roundabouts without a raised curb median requires a minimum 32 feet from curb face to curb face.

If there is an overpass structure between two closely spaced roundabouts (1,000 feet or less between roundabout centers), and a roundabout sidepath is provided around the outside of the roundabouts, then the roundabout sidepath is at least 2 ft wider on the structure (Figure 30.20). A roundabout sidepath will typically not have a barrier wall separating the path from the roadway. Vehicle travel speeds between closely spaced roundabouts is considered a low-speed environment (40 mph or less) and bicycle travel is expected to be unidirectional thus barrier walls between the roadway and path are not required. When there is a barrier proposed between the roadway and a roundabout sidepath, the sidepath is level with the roadway (not a raised sidewalk). See Figure 30.20 and FDM 11-35-1.6 and FDM 11-35 Attachment 1.1 pages 1 and 2. Section B-B shows a section view of a raised curb roundabout sidepath. A barrier between the roadway and roundabout sidepath is unique and maybe a provision requested that requires WisDOT approval, including the regional bicycle and pedestrian coordinator.

When a shared-use path is provided around the outside of roundabouts, the shared-use path design criteria on structures are followed. See FDM 11-46-15, FDM 11-35 Attachment 1.1 pages 1 and 2. Section B-B shows a section view of a raised curb shared-use path, and Section C-C shows a section view of the barrier wall between the roadway and the path. See FDM 11-35-1.6.3 for required separation distance between outside travel lane and front face of barrier wall to determine the minimum barrier wall height.

The roadway and structure width will depend on the median width, lane width, number of lanes, shoulder width, and path width requirements.

For the STH system, the WisDOT minimum roadway width and clear roadway width of bridge from curb face to curb face, between two closely spaced roundabouts that are less than 1,000 feet apart, is:

- 2 lane divided (each side) - 2' median shoulder, 12' lane, 5' outside shoulder = 19'.
- 2 lane undivided - 4' shoulder width, + 12' lane +12' lane + 4' shoulder width = 32', independent of ADT.
- 4 lane divided (each side) - 2' median shoulder, + 12' inside lane, + 12' outside lane, + 4' shoulder = 30'.
- 4 lane undivided - 4' shoulder, 12' outside lane, + 12' inside lane +12 inside lane, + 12' outside lane, + 4' shoulder = 56'.
- 6 lane divided (each side) - 2' median shoulder, + 2 inside lanes at 12', + 12' outside lane, + 4' shoulder = 42'

The above widths provide a minimum roadway width between closely spaced roundabouts.

To reduce structure width, the designer should consider a narrow-raised median between the splitter islands. A 4-foot raised curb median face to face will provide an 8-foot median measured from flange line to flange line with 2-foot gutters just off the end of the structure. The distance between roundabouts should be sufficient to allow for any curved curb and gutter portion that is formed at the ends of the splitter islands to remain off the structure. The tangent narrow section in the middle between splitter islands could be 4-foot-wide face to face providing there are no signs or other road side elements in that area.

Under structures the roundabout sidepath and terrace widths are consistently provided through and between the roundabouts. If there will be road signs, power poles, light poles or other fixtures installed along the roadside then provide at least a 5-foot-wide terrace between the curb face at the outside of the shoulder and the front of the path. The cross-section under the structure provides at least the median shoulder width, lane width(s), outside shoulder width and path width plus 2 ft. if no obstructions are in the terrace. Follow shared-use path design criteria for under structures.

The above minimum roadway widths between closely spaced roundabouts are not appropriate for rural highway applications or where the distance between consecutive roundabouts is greater than 1000 feet. If existing or proposed sidewalk approaches between consecutive roundabouts are not closely spaced (i.e. greater than 1,000-feet between roundabout centers), provide roundabout sidepath(s) around the roundabout(s) but not between them - provide bike and pedestrian accommodations see FDM 11-46-1.

The roadway between the roundabouts transitions to a cross-section roadway width and clear roadway width of bridges based on the design class of the roadway (see FDM 11-15-1, FDM 11-20-1, FDM 11-35-1.2, and FDM 11-46-1).

If bike or pedestrian facilities are omitted around or between roundabouts, discuss with the regional bicycle and pedestrian coordinator the need to provide an 8-foot roundabout sidepath on or under the structure. Structures have a longer life-span and even if a roundabout sidepath is not immediately included on a structure it is necessary to consider constructing a wider substructure to allow widening of the superstructure in the future to accommodate a roundabout sidepath. In such cases, the pedestrian refuge in the splitter islands should still be constructed.

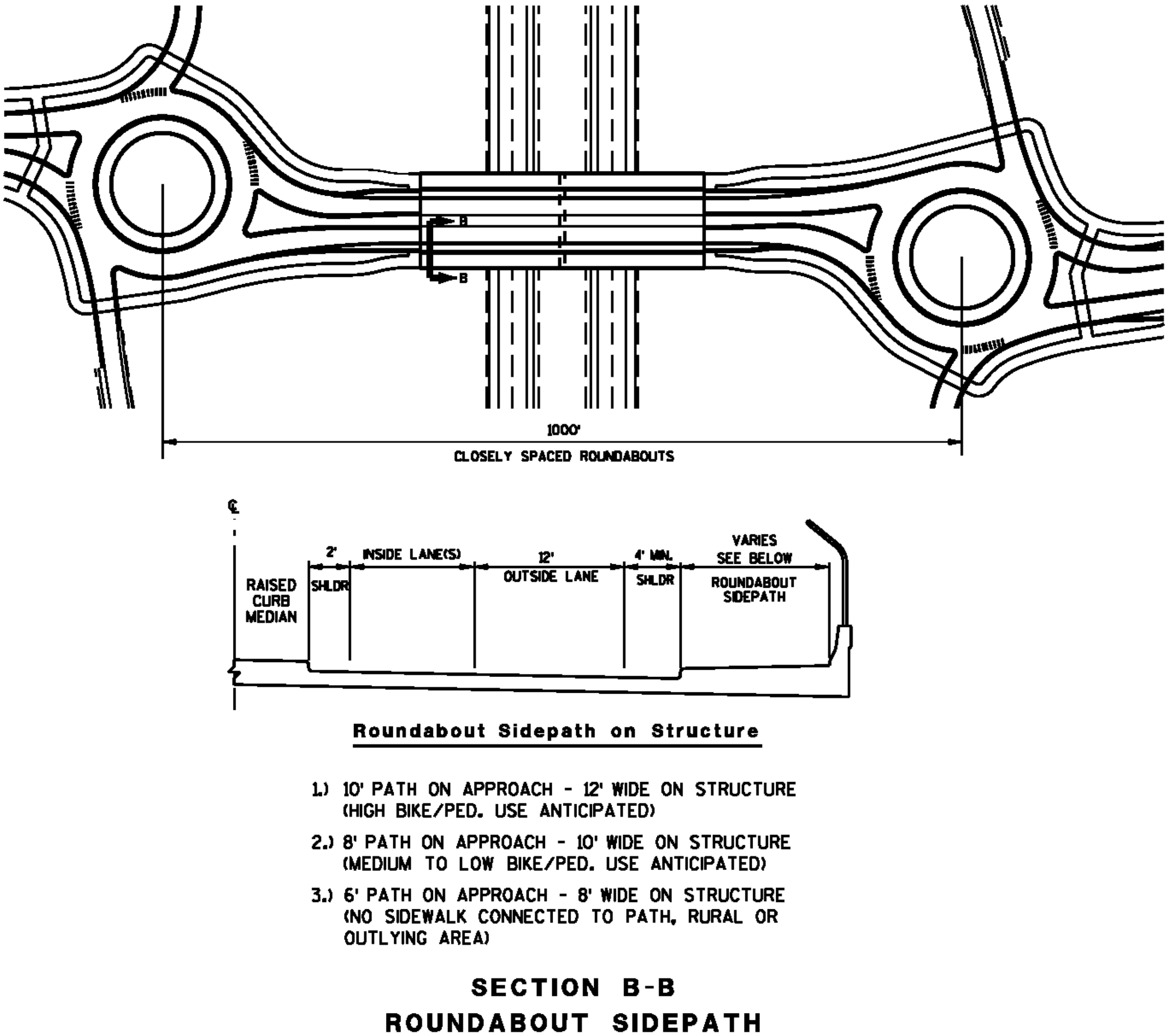


***Figure 30.20* Roundabout Sidepath**

30.5.14 Intersection Sight Distance (ISD) and Length of Conflicting Leg of Sight Triangle

See NCHRP Report 672 starting on page 6-63 for guidance on Intersection Sight Distance (ISD) for roundabout approaches. The basis for ISD in NCHRP Report 672 is providing the critical headway time gap (tc) for entering the roundabout. The critical headway time gap (tc) for entering the roundabout is based on the amount of time required for a vehicle to safely enter the conflicting stream. If the perceived available headway time gap is less than tc then most drivers will slow down or stop and wait for an acceptable gap. The critical headway time gap will possibly change over time. WisDOT has revised this time gap per FDM 11-26-20.4.4 however at this time WisDOT will use the critical headway time gap (tc) equal to 5 seconds as stated in NCHRP Report 672 for intersection sight distance. This is less than the 6.5 second required by the 2000 FHWA Roundabout Guide, but greater than the previous FDM requirement of 4.5 seconds. Table 30.8 shows computed distance for various speeds based on a critical headway time gap (tc) = 5.0.

Table 30.8 Roundabout Intersection Sight Distance

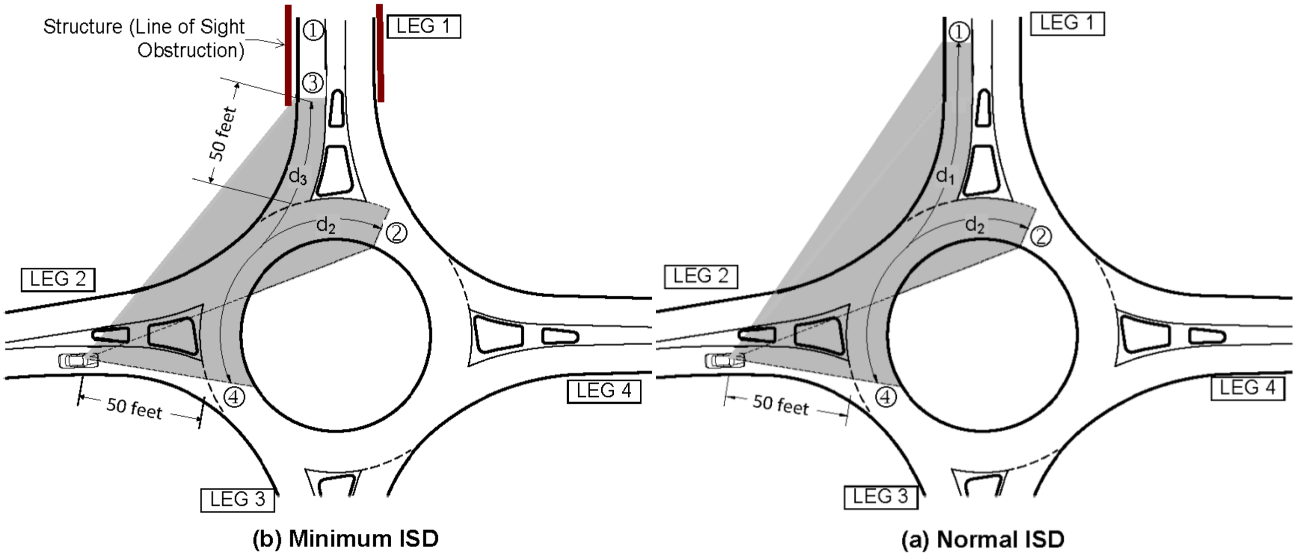
Conflicting Approach Speed (mph)	* Computed Distance (ft) for t_c = 5.0s
10	74
15	110
20	147
25	184
30	221

*distance in feet = speed (mph) multiplied by time (seconds) multiplied by a factor of 1.468.

The "clear sight window" requirements for critical headway time gap (t_c) are shown on Exhibit 6-58 of NCHRP Report 672. Use an eye height above the roadway surface of 3.5 feet for passenger cars and 7.6 feet for trucks in establishing sight lines through a clear sight window. Use an object height above the roadway surface of 3.5 feet.

Figure 30.21a shows "Normal ISD" for a roundabout approach; Figure 30.21b shows "Minimum ISD" for a roundabout approach. Use the following guidance when designing the ISD "clear sight window" for a roundabout approach:

- **[Normal ISD & Minimum ISD - driver's eye position on approach]** Set the initial position of the driver's eye at 50 feet behind the yield line, as depicted on Exhibit 6-58 of NCHRP Report 672, and as shown in Figure 30.21a and b or the vehicle approaching on Leg 2.
- **[Normal ISD & Minimum ISD - to circulating roadway]** Provide ISD based on [t_c=5.0 seconds *x* "circulating speed X factor"] for the circulating stream distance d_2, as depicted on Exhibit 6-58 of NCHRP Report 672, and shown on Figure 30.21a and b as the distance from point 2 to point 4. For example, if the circulating speed is 20 mph, the distance between point 2 and point 4, per Table 30.8, is 147 feet.
- **[Normal ISD - to adjacent leg to the left]** Provide ISD based on [t_c=5.0 seconds *x* "fastest path speed X factor"] for the entering stream distance d_1, as depicted on Exhibit 6-58 of NCHRP Report 672, and shown on Figure 30.21a as the distance from point 1 to point 4. For example, if the "fastest path speed" is 25 mph, the distance between point 1 and point 4, per Table 30.8, is 184 feet.
- **[Minimum ISD - to adjacent leg to the left]** It may not be possible to provide "Normal ISD" at some approaches because of a sight obstruction whose removal would cause unacceptable impacts. For these locations, provide ISD to at least 50-feet behind the yield line of the adjacent leg to the left - as shown on Figure 30.21b. The resulting reduced entering stream distance d_3 from point 3 to point 4 is less than [t_c=5.0 seconds *x* "fastest path speed X factor"]. However, it is unlikely that all vehicles will be traveling at the "fastest path speed" between points 3 and 4 because some drivers will slow down or stop behind the yield line if there is an unacceptable gap.



Legend

d_1 Entering Stream Distance

d_2 Circulating Stream Distance

d_3 Reduced Entering Stream Distance starting at least 50-feet behind the Leg 1 yield line

ISD Clear Sight Window for vehicle on Leg 2

***Figure 30.21* Example of Roundabout ISD Clear Sight Window (Leg 2 ISD shown - other legs are similar)**

Designer experience and judgment is needed to balance the impacts where ISD is severely restricted or where excess ISD is available. More is not better when it comes to Intersection Sight Distance for roundabouts. Research on sight distance has determined that excessive intersection sight distance results in a higher frequency of crashes because excessive forward visibility at entry or visibility between adjacent entries can result in approach and greater typical entry speeds for intersection geometry.

Consider limiting visibility using selective landscaping. This refers to landscaping or a visual block down the side road or median to restrict visibility between adjacent entries, as well as the forward visibility through the central island. Limiting visibility in this way helps encourage drivers to slow down on the roundabout approach, which provides a safer environment for both drivers and pedestrians.

Forward visibility for the driver entering to have sight of the circulatory roadway ahead of the driver's entering path can also be checked but is generally accounted for by ensuring sight to the left of circulating vehicle upstream (see Figure 30.21b for vehicle along path d_2).

30.5.15 Angles of Visibility

The intersection angle between consecutive entries must not be overly acute in order to allow drivers to comfortably turn their heads to the left to view oncoming traffic from the immediate upstream entry. The intersection angle between consecutive entries, and the angle of visibility to the left for all entries, should conform to the same design guidelines as for conventional intersections. Based on guidance for designing for older drivers and pedestrians, the recommended angle for visibility to the left at entry is 90° ±15°. NCHRP 672 Exhibit 6-62 illustrates an example of a visibility angle for a roundabout entry at a ramp terminal.

Designers should also be aware of the visibility angle for conditions when the entering traffic does not yield, i.e. drivers looking left upstream of the yield line when not needing to yield or stop, a common condition for off-peak traffic conditions. The view to the left is then executed when the driver is well upstream of the roundabout entry unlike what NCHRP 672 Exhibit 6-62 shows. Thus, visibility angles must also be checked for non-yielding driving conditions from a distance upstream of the point of entry. The designer is cautioned not to provide generous sight to the left as this can contribute to failure to yield conflicts and collisions.

For additional information, see NCHRP 672, §6.7.4.

30.5.16 Right Turn Lanes

Right turn lanes should only be used when capacity needs dictate or when other geometric layouts fail to provide acceptable traffic operations or accommodations for the design vehicle. The decision to use right turn lanes should consider pedestrian and right of way constraints. Choosing the proper alternative is dictated by the volume of right turns and the available space. See NCHRP 672, §6.8.6 for additional information. For further guidance on compact roundabouts, see FDM 11-26-30.5.25.10.

Three alternatives exist to provide for heavy right turn demand:

30.5.16.1 Free Flow Right Turn Lane (Figure 30.22 and NCHRP 672 Exhibit 6-72)

Free flow bypass lanes allow vehicles to bypass the roundabout and then merge into the exiting stream of traffic. A high right-turn demand when coupled with other approaching traffic may indicate the need for a full bypass lane to avoid a wider, faster entry. Roadway right-turn free-flow lanes are not recommended for pedestrians and bicyclists and should be avoided, if possible, in high pedestrian/bike use areas. If free flow right turn lanes are used keep vehicle speeds slow by using a small right turn radius.

30.5.16.2 Yielding Bypass Right Turn Lane (Figure 30.22b or c and NCHRP 672 Exhibit 6-73)

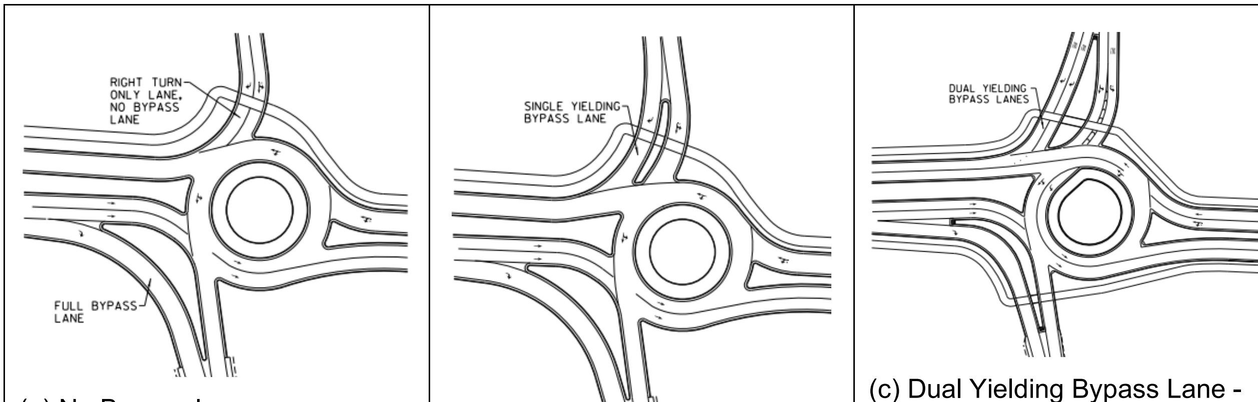
A yielding bypass lane with a curbed vane island requires approaching vehicles to yield to traffic leaving the adjacent exit. This alternative 'snags' the right turner from making a through movement while preserving good sight to the left for circulating/exiting traffic. Generally, an intersection angle of 70 degrees or higher is typical.

Dual yielding right turn bypass lanes with a curbed vane island may also be an appropriate alternative to accommodate heavy right turn demand, especially at interchange ramp terminals. Dual yielding bypass lanes may be problematic for pedestrians and should only be used at locations where there is not a crosswalk near the exit receiving the dual right turning vehicles. Pedestrians may have a hard time seeing a vehicle turning right from the left lane of the dual right turn entry.

When designing dual yielding right turns, special attention is required to ensure that vehicles in both right turning lanes have adequate sight of vehicles in the circulatory roadway. Speed of vehicles in the right turn lanes also need to be well controlled. Use a smaller entry radius to help reinforce that vehicles exiting the roundabout have the right of way. This will also minimize the potential for rear end crashes associated with larger right turn radii. Like the guidance provided for a Case 1 design, allow the design vehicle to encroach into adjacent lanes on the entry and exit while making the right turn.

30.5.16.3 Exclusive Right Turn Lane (Figure 30.22a and NCHRP 672 Exhibit 6-74)

Exclusive right turn lanes with or without a painted gore help to keep the overall roundabout layout compact while accommodating the heavy right turning movement. An exclusive right turn lane should be 'snagged' from making a through movement while preserving good sight to the left for circulating/exiting traffic.



(a) No Bypass Lane - SB Movement

(b) Yielding Bypass Lane - SB Movement

(c) Dual Yielding Bypass Lane - SB Movement

***Figure 30.22* Right Turn Bypass Lanes**
(See also NCHRP 672 Exhibit 6-74)

30.5.17 Vehicle Path Overlap and Methods to Avoid Path Overlap

Designing multi-lane roundabouts is significantly more complex than single-lane roundabouts due to the additional conflicts present with multiple traffic streams entering, circulating and exiting the roundabout in adjacent lanes. The natural path of a vehicle is the path it will take based on the speed and orientation imposed by the roundabout geometry. While the fastest path assumes a vehicle will intentionally cut across the lane markings to maximize speed, the natural path assumes there are other vehicles present and all vehicles will attempt to stay within the proper lane.

Designers should determine the natural path by assuming the vehicles stay within their lane up to the yield point. At the yield point, the vehicle will maintain its natural trajectory into the circulatory roadway. The vehicle will then continue into the circulatory roadway and exit with no sudden changes in curvature or speed. If the roundabout geometry tends to lead vehicles into the wrong lane, this can result in operational or safety deficiencies.

Path overlap occurs when the natural paths of vehicles in adjacent lanes overlap or cross one another. It occurs most commonly at entries, where the geometry of the right-hand lane tends to lead vehicles into the left-hand circulatory lane. However, vehicle path overlap can also occur at exits, where the exit geometry or pavement marking of the exit tends to lead vehicles from the left-hand lane into the right-hand exit lane. Figure 30.23 illustrates an example of entry path overlap at a multi-lane roundabout where the left lane geometry directs the approaching vehicle into the central island, while the right lane geometry directs the approaching vehicle toward the inside circulatory lane, thus creating entry path overlap.

For additional information, see NCHRP 672, §6.2.3 & 6.5.4.

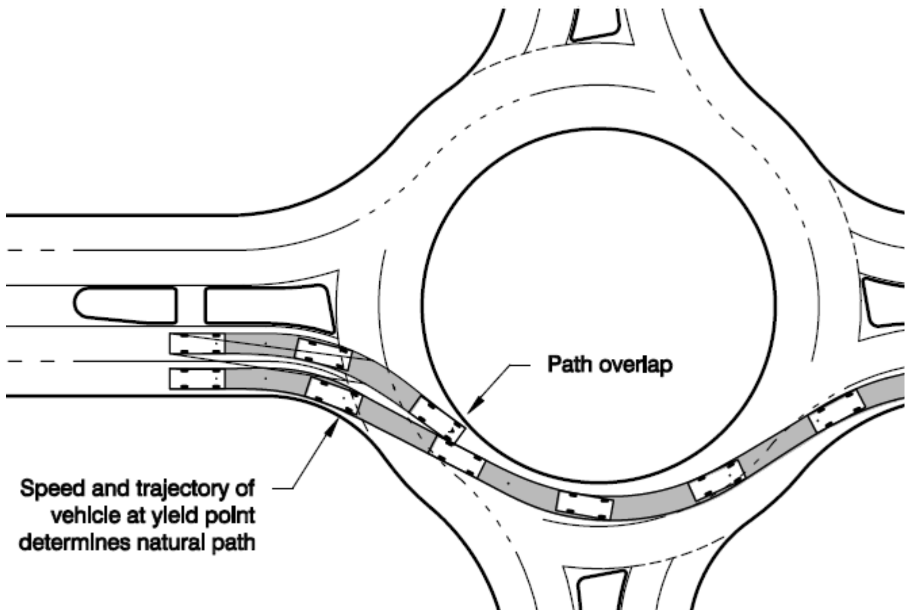


***Figure 30.23* Entry Path Overlap**

30.5.17.1 Method for Checking Path Overlap

Figure 30.24 provides a method for checking entry and exit path overlap. To avoid path overlap, the typical tangent length is 40-ft to 50-ft or two car lengths for the entry path tangent and 40-ft and greater for exit path tangent. The minimum tangent length to avoid entry and exit path overlap is 25-ft or one car length.

As a rule of thumb path overlap can be avoided if there is typically 5 feet between the face of the central island curb and the extension of the face of curb on the splitter island, see Figure 30.24.

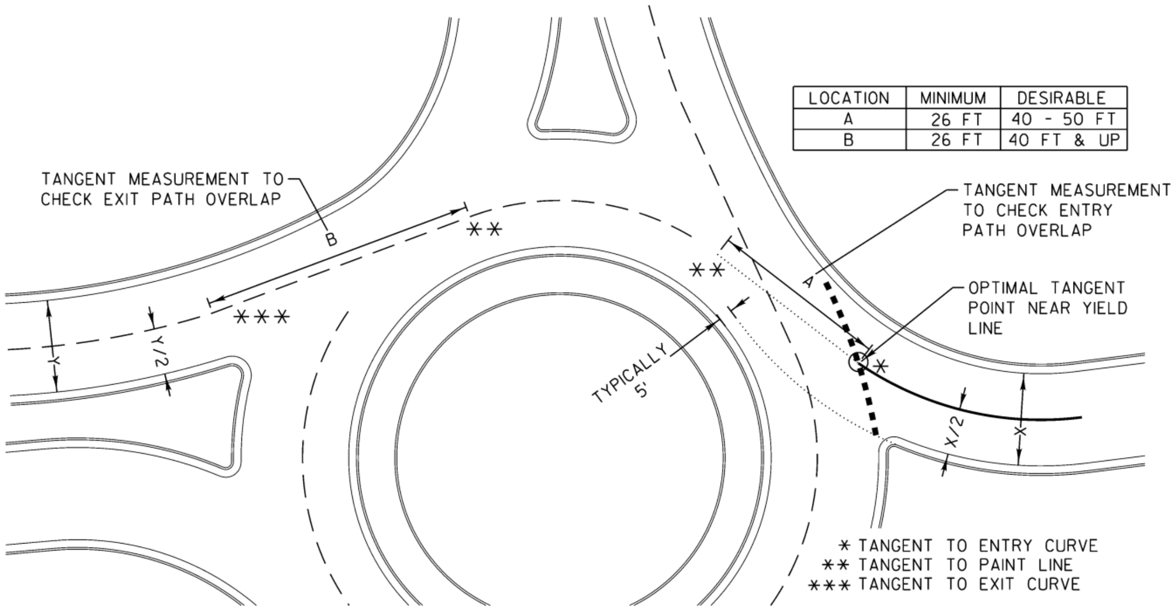


***Figure 30.24* Method for Checking Path Overlap**

30.5.17.2 Design Method to Avoid Path Overlap

Figure 30.25 shows the preferred method to avoid path overlap in multi-lane entries.

The location of the entry curve directly affects path overlap. If it is located too close to the circulatory roadway, it can result in path overlap. However, if it is located too far away from the circulatory roadway, it can result in drivers accelerating to the yield point.

For additional information, see NCHRP 672, §6.4.3.

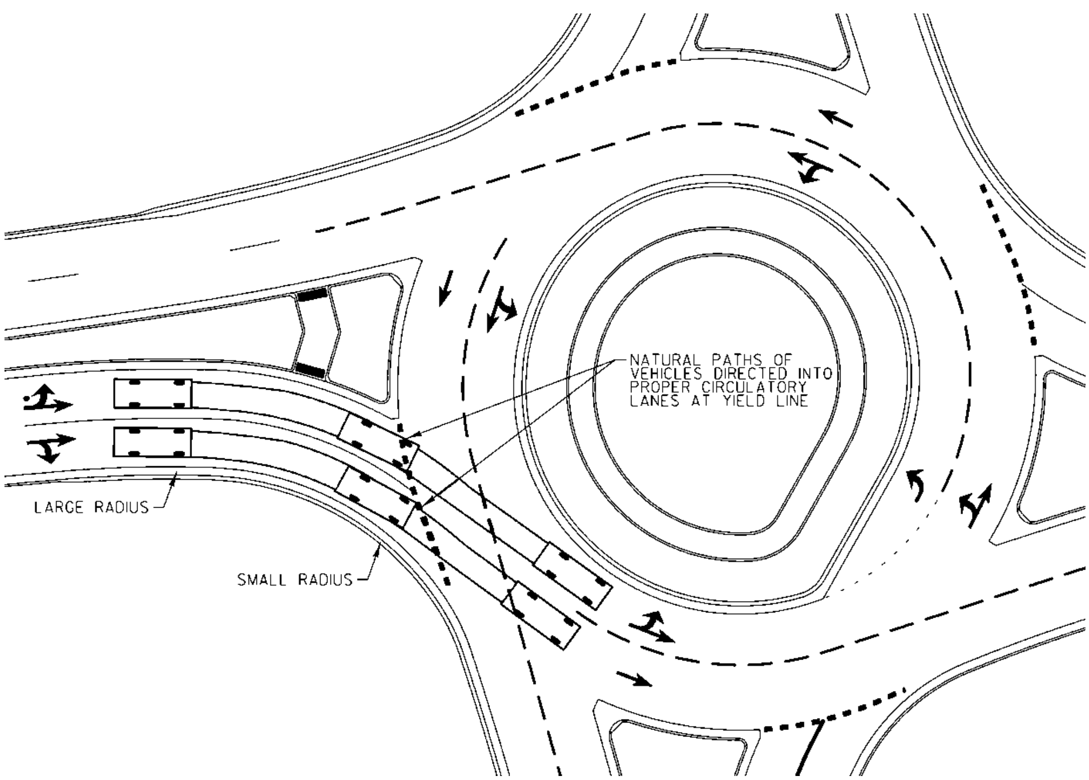


***Figure 30.25* Multi-lane Entry Design**

30.5.18 Approach Design

Roundabout approach design is important to provide clarity of the driving situation, that is, to make drivers aware of the roundabout with ample distance to comfortably decelerate to the appropriate speed. Therefore, designs should follow these principles:

- Provide the typical stopping sight distance of the entry point based on approach design speed.
- Align approach roadways and set vertical profiles to make the central island conspicuous.
- Splitter islands should extend upstream of the yield line to the point at which entering drivers are expected to begin decelerating.
- Approach curves should be gentle, become successively smaller as they get closer to the roundabout entry, and should be sized based on the design speed and expected speed change.
- Tangents should be used between reverse curves.
- Consider using landscaping on extended, wide splitter islands and along the roadside to create a tunneling effect.
- Provide illumination in transition to the roundabout.
- Use signs and pavement marking effectively to advise of the appropriate speed and path for drivers.

The consequences of an inconspicuous central island or splitter island is mainly loss of control crashes as motorists unfamiliar with the roundabout are not given sufficient visual information to elicit a change in speed and path.

30.5.18.1 High-speed Approaches

High-speed approaches (posted speed limit of 45 mph or greater) are often comprised of a series of curves that become successively smaller to encourage drivers to reduce speeds. The roadway curvature, pavement marking gore, introduction of a splitter island, signing, lighting, and landscaping help to increase driver awareness that conditions are changing, and speed reduction is required. Follow the design guidance discussed in this section and illustrated in Figure 30.26 for a typical high-speed roundabout approach. Splitter islands on high-speed approaches shall be a minimum of 250 feet long, unless the approach is not a STH and the AADT is less than 2,000 vehicles, as discussed in FDM 11-26-30.5.18.2.

Superelevation of curves on approaches to high-speed roundabouts is counterproductive to the objective of transitional speed reduction, and approach curves should be designed to use a 2% normal crown. The selection of the curve radius is dependent on whether the curve is located in the high-speed zone or the deceleration zone. The length of the deceleration zone is dependent on the distance required to decelerate from the approach design speed to 0 mph at the yield line, as listed in Table 30.9 (from AASHTO GDHS 2018 Figure 2-34). Some roundabout approaches may only have one approach curve, in which case the curve design should be based on which zone the curve is located in.

Roundabout approach curves that start in the high-speed zone (i.e., curve AR1 in Figure 30.26) should be designed to use a 2% normal crown using the minimum radii values listed in Table 30.10 for the given approach design speed (based on AASHTO GDHS 2018 Equation 3-8 and Figure 3-4). Note that the minimum radius is dependent on the direction of curve AR1. If the existing roadway is superelevated, then begin the transition from the existing superelevation to normal crown at the beginning of curve AR1.

Approach curves located within the deceleration zone (i.e., curve AR2 in Figure 30.26) should be designed for normal crown based on the distance of the beginning of the curve from the yield line and the estimated speed at that location. Reference AASHTO GDHS 2018 Figure 2-34 to estimate speed at the curve location using approach design speed decelerating to 0 mph. Table 30.11 lists minimum radii that can be used for curve AR2 based on the estimated speed for a curve to the left at normal crown (from AASHTO GDHS 2018 Table 3-13, normal crown = -2% for curves to the left).

Table 30.9 Deceleration Length for Design Speed to 0 mph

Approach Roadway Design Speed	Deceleration Length
50 mph	360 ft
55 mph	410 ft
60 mph	460 ft
65 mph	520 ft
70 mph	580 ft

Table 30.10 Minimum Approach Radii for Curve AR1

Approach Roadway Design Speed	AR1 Minimum Approach Radius	
	If Curve to the Right	If Curve to the Left
50 mph	1100 ft	1400 ft
55 mph	1400 ft	1900 ft
60 mph	1800 ft	2400 ft
65 mph	2200 ft	3200 ft
70 mph	2800 ft	4100 ft

Table 30.11 Minimum Approach Radii for Curve AR2

Estimated Speed	AR2 Minimum Approach Radius (If Curve to the Left)
25 mph	198 ft
30 mph	333 ft
35 mph	510 ft
40 mph	762 ft
45 mph	1039 ft

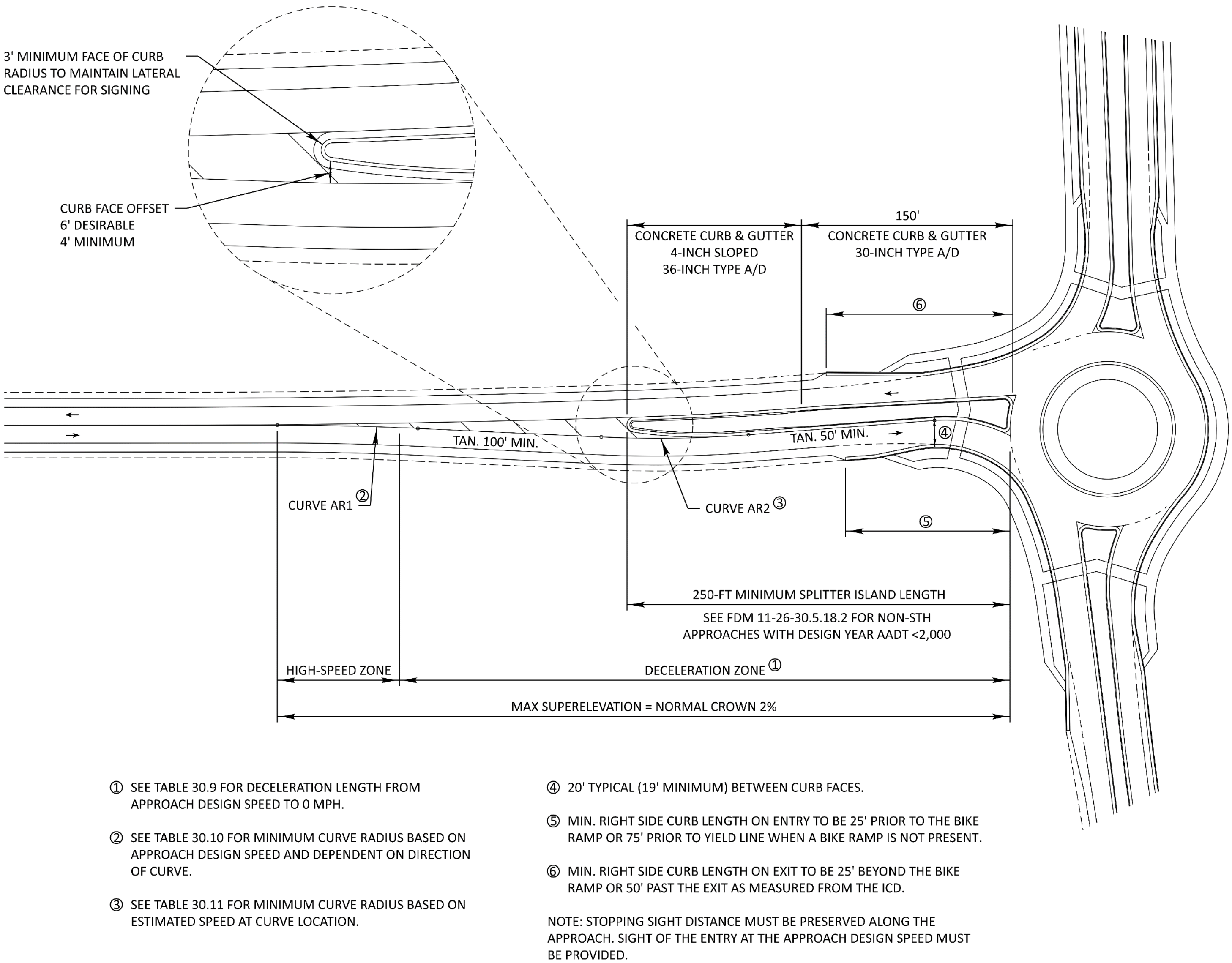


***Figure 30.26* High-speed (45 mph Posted Speed or Greater) Roundabout Approach**

30.5.18.2 Low Volume, Non-STH Side Road Approaches

For an intersection having non-STH side road approaches with low traffic volumes, a reduction in roundabout approach construction length - including the splitter island length - may be appropriate if meeting all these side road conditions:

- Design year AADT is less than 2,000
- Must be single-lane roundabout entry
- Existing side road intersection control is stop-controlled, as motorists are already conditioned to yield to mainline traffic
- Typical stopping sight distance (SSD) is attained or exceeded at all approaches

If all the above conditions are met, continue evaluating the non-STH roundabout approaches based on post-construction side road posted speeds and other considerations cited below.

Where side road roundabout approaches have posted speeds 45 mph and higher, provide a combination of alignment deflection or offset and non-superelevated curvature that spans the deceleration distance from the entry. This will produce gradual deceleration to avoid forcing all the reduction in speed to be completed through the curvature at the roundabout. The length of roundabout splitter island should be a minimum of 200 feet for design year AADT between 1,000 and 2,000 vehicles, and a minimum of 100 feet for design year AADT less than 1,000 vehicles. Always verify that the side road approach and entry condition, including the roundabout splitter island, provide deflection per the design principles of FDM 11-26-30.5 to safely and effectively slow traffic.

Where side road roundabout approaches have posted speeds 40 mph and lower, use a lower minimum 50-foot raised splitter island (typical 100-foot) length to alert drivers of the upcoming roundabout as described in NCHRP 672 [2]. A splitter island also provides refuge for crossing pedestrians and needs to be long enough to contain the pedestrians. Always verify that the side road approach and entry condition, including the roundabout splitter island, provide deflection per the design principles of FDM 11-26-30.5 to safely and effectively slow traffic.

During preliminary design, consider whether any major development is planned along the side road. Any significant development may result in additional trips and more unfamiliar drivers. Field running speed assessments may be used to ascertain current side road speed conditions and determine prudent splitter length selection. Additionally, assess current access locations along with the real estate, environmental and utility impacts with the selected side road approach lengths. Document all findings in the DSR, including any known future local land development plans and whether access control is planned along the side road.

For non-STH roundabout approaches with traffic volumes greater than 2,000 AADT, apply the high-speed roundabout approach design principles as prescribed under FDM 11-26-30.5.18 and Figure 30.26.

30.5.19 Vertical Design

The most critical vertical design area of the roundabout is the portion of roadway from the approach end of the splitter island to the circulatory roadway. This area requires special attention by the designer to ensure that the user can safely enter the circulatory roadway, especially for OSOW vehicles. This area usually requires pavement warping or cross-slope transitions to provide an appropriate cross-slope transition rate through the entire transition area and within the circulatory roadway.

Roundabouts typically should be constructed on relatively flat or rolling terrain with an approach grade that is typically less than 3%, but not greater than 5%. Grades approaching 4% and steeper terrain may require greater transitions to provide an appropriate grade through the intersection. If possible and practical, avoid grades in excess of 3% within the area of the approach where vehicles may be required to stop. When crosswalks are present, the profile through the crosswalk area should be 2% or less when possible. In some situations, it may be difficult to get the profile to be 2% or less. Designers should try to decrease the slope as much as possible, but it must be less than 5% to meet ADA requirements.

It is typical to match the exit grades and the entry grades. Adjustments to the circulatory roadway cross-slope may be required to meet these criteria but should be balanced with the effects on the circulatory roadway.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.11.

30.5.19.1 Circulatory Roadway

The profile grades along the central island should generally not exceed 4%, (typically 3% or less).

- Compact Roundabout – See FDM 11-26-30.5.25.11.
- Single-lane Roundabout – crown the roundabout circulating roadway with a 1.5% cross-slope with approximately 2/3 width sloping toward the central island and 1/3 width sloping outward (see Figure 30.27).
- Multi-lane Roundabout – Same crown guidance applies where possible. However, when considering factors such as paver screed width, contraction joint location for concrete pavement, pavement marking location, and the total width of the circulatory roadway, it may be a challenge to comply with the 2/3 sloping inward and 1/3 sloping outward. Therefore, another alternative (independent of material type) on multi-lane roundabouts is to slope the inside lane, or left lane, toward the central island and slope the outside lane (typically wider lane) to the outside. This alternative will allow the contraction join on concrete pavement to generally coincide with the lane line pavement marking and allow asphalt pavement roundabouts to be similar in design. On triple lane roundabouts, it may be possible to slope the two inside lanes toward the central island and slope the outside lane to the outside.

The crown vertical design feature provides good drivability, keeps water from draining across the circulating roadway which is particularly important in a northern climate with freeze-thaw cycles, and provides a smooth transition in/out of the approaches and departures. This ‘crown’ also reduces the probability of load shifting or truck overturning.

The typical truck apron slope is one percent toward the circulatory roadway (see Figure 30.27). Greater than one percent slope should not be used on OSOW routes.

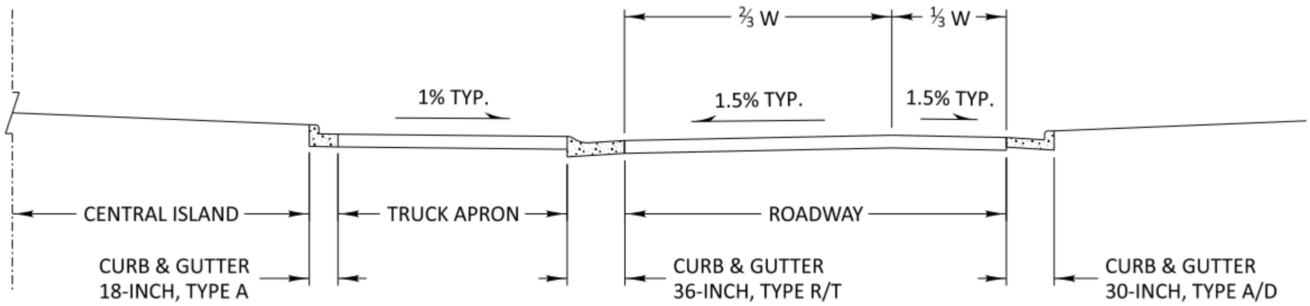


Figure 30.27 Circulatory Roadway Typical Section

30.5.20 Curbing

30.5.20.1 Approach Curbs

Low speed approaches (40 mph posted speed limit and lower) should incorporate 6-inch vertical face curbs, on both sides of the roadway. The purpose of the vertical face curbs is to control the fastest speed paths at the roundabout entrances and exits. Where OSOWs need to overtrack the curb, a 4-inch mountable curb and gutter may be used in limited situations to better accommodate truck tires. Refer to FDM 11-26-30.5.4 and FDM 11-26-30.5.6 for suitable curb type along the outside and FDM 11-26-30.5.20.2 for curb type adjacent to the truck apron.

High-speed approaches to roundabouts usually occur where there is a rural cross-section (45 mph posted speed limit and greater). Provide 6-inch vertical face curbs on the splitter islands within 150 feet of the roundabout entry; the remaining splitter island length shall be 4-inch mountable curb. See Figure 30.26 for additional information and for guidance on the minimum lengths of curb adjacent to the roundabout entries and exits.

Consider drainage in the area of the curb/gutter by providing a flume or inlet structure.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.12.

30.5.20.2 Curb and Gutter Separating the Circulatory Roadway from the Truck Apron

Use Type R or T curb and gutter, 4-inch sloped, between the circulating roadway and the truck apron shown in SDD 8D1. Use a Type T inlet casting on the drainage structure, as shown in SDD 8A5. This curb and gutter is gentle to large truck tires but should be unfriendly for SUVs and autos to traverse. When the circulatory roadway is concrete it shall be tied to the gutter flange with tie-bars, but not to the truck apron. When the circulatory roadway is asphalt, the apron shall be tied to the back of curb with tie-bars. See FDM 14-10-35 for pavement related topics.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.12.

30.5.20.3 Curb at the Inside of the Truck Apron or Edge nearest the Central Island

This curb shall be a reverse-slope 18-inch curb and gutter. The adjacent pavement will be a concrete truck apron. There may be situations when this inside curb could be deleted, but this is rare and should be addressed in the DSR.

For further guidance on compact roundabouts, see FDM 11-26-30.5.25.12.

30.5.21 Spirals

A spiral system involves a series of lane gains and lane drops around the circulatory roadway to lead drivers into the appropriate lane for their desired exit. Spirals guide drivers that enter the roundabout on the inside lane to shift to the outside lane at the appropriate location within the circulatory roadway to exit from the outside lane, unless there are dual lefts then the two inside lanes could be shifted. The spiral is designed to prevent vehicles from becoming trapped on the inside lane and then drivers making a quick lane change to exit all while maximizing the use of the circulating space and reducing potential conflicts between adjacent vehicles. Spirals can also accommodate for heavily biased turning movements.

Spirals should only be considered where the circulatory roadway has sufficient width to provide two or more lanes of traffic and where the geometry and traffic volumes are determined to warrant the use of spirals. Circulatory roadway spirals require considerable engineering judgment to design and locate properly, although they are intended to guide drivers, they may be confusing to properly understand and not always intuitive to the driver.

Small compact two-lane circles do not function as well with spiral designs because the lengths of arcs are too short to guide drivers to ‘spiral out’. In such cases speed reduction occurs in the circulatory roadway where the spiral often begins. Drivers are more likely to turn tight across the spiral rather than follow it to the next outside lane. Spirals can be very effective on larger circles where the spiraling curves are longer, intuitive to drivers and more easily detectable.

A spiral should be developed from the central island by curb and gutter until a full lane width is available. Observations of previously installed spiral crosshatch pavement markings without a ‘hard surface’ indicate that some drivers ignore the pavement markings, which increases the potential for vehicle conflict in the circulatory roadway.

An example of a curbed spiral is shown in Figure 30.28. This spiral is used to shift the westbound left turn to the outside lane. The spiral is used because the southbound exit is only a single-lane exit and the southbound entrance allows dual left turns. To exit without conflict, the westbound left turn needs to be spiraled to the outside lane. Without the spiral, the left turn would be trapped on the inside lane and would do a U-turn or have to crossover lanes.

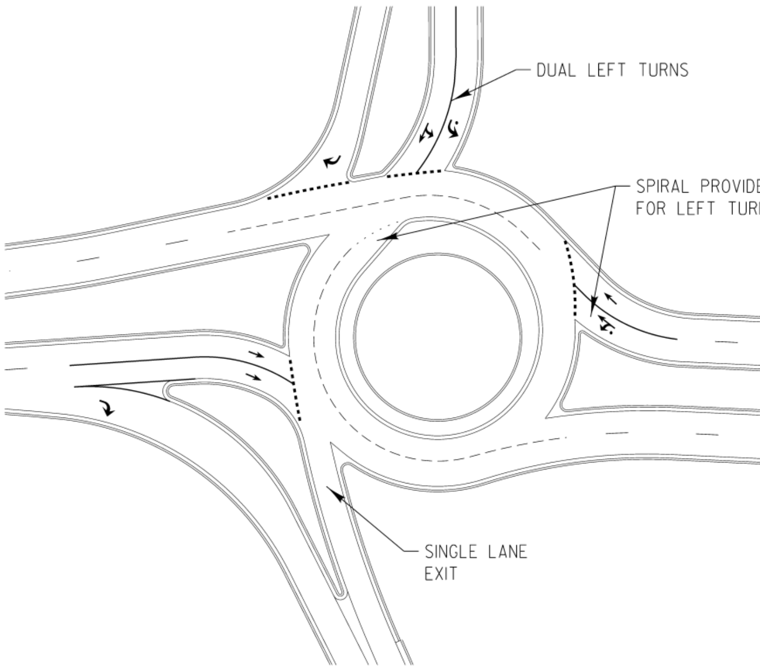


***Figure 30.28* Spiral**

30.5.22 Entry Angle, phi

Phi is not discussed in detail in NCHRP 672. This angle is not a controlling design parameter but instead a gauge of sight to the left and ease of entry to the right. This affects both capacity and safety at the intersection. The typical range for the Phi angle is between 20 and 30-degrees with 25-degrees or greater being the optimal, although there are designs that operate safely and efficiently with a Phi angle as low as 16 degrees.

Designers may find it difficult to attain Phi angle values in the typical range, but provided that the fast path speeds are relatively low, the Phi angle is not a controlling criterion. It is more important to achieve a minimum 16 degree Phi angle when there are two entering lanes and two exiting lanes. In those cases, a smaller than desired Phi angle makes it more difficult for the entering drivers to know if the circulating drivers are exiting or continuing around the circle, which can lead to excessive crashes.

There are three situations or design conditions in which Phi can be measured. They are:

1. Condition 1: Phi = $2\frac{Phi}{2}$ where the distance between the left sides of an entry and the next exit are NOT more than approximately 100 feet. In Condition 1, the acute angle is denoted as 2 PHI in which the actual value must be divided by two to obtain Phi (see Figure 30.29, Method 1).
2. Condition 2: Phi = Phi if the distance between the left sides of an entry and the next exit are more than approximately 100 feet (see Figure 30.30, Method 2).
3. Condition 3: Applicable when an adjacent exit does not exist, or an exit located at such a distance or obtuse angle to render the circulatory roadway a dominating factor of an entry (such as in a “3-leg” intersection). Used at “T” intersections or where the adjacent entrance and exit lane(s) are far apart (see Figure 30.30, Method 2).

The two methods of measuring Phi are described below in Figure 30.29 and Figure 30.30.

Method 1 phi is measured by dividing the entry and exit radii into three segments. The midpoint of the lane for each segment is best fit with a curve that extends to the face of curb of the splitter island extended. Begin line (a-b) and (c-d) at the intersection of the best fit arc and face of curb of the splitter island extended. Line (a-b) and (c-d) are then projected tangent from the best fit arc towards the circulating roadway, the angle formed by the intersection of the two lines is twice the value of Phi see Figure 30.29.

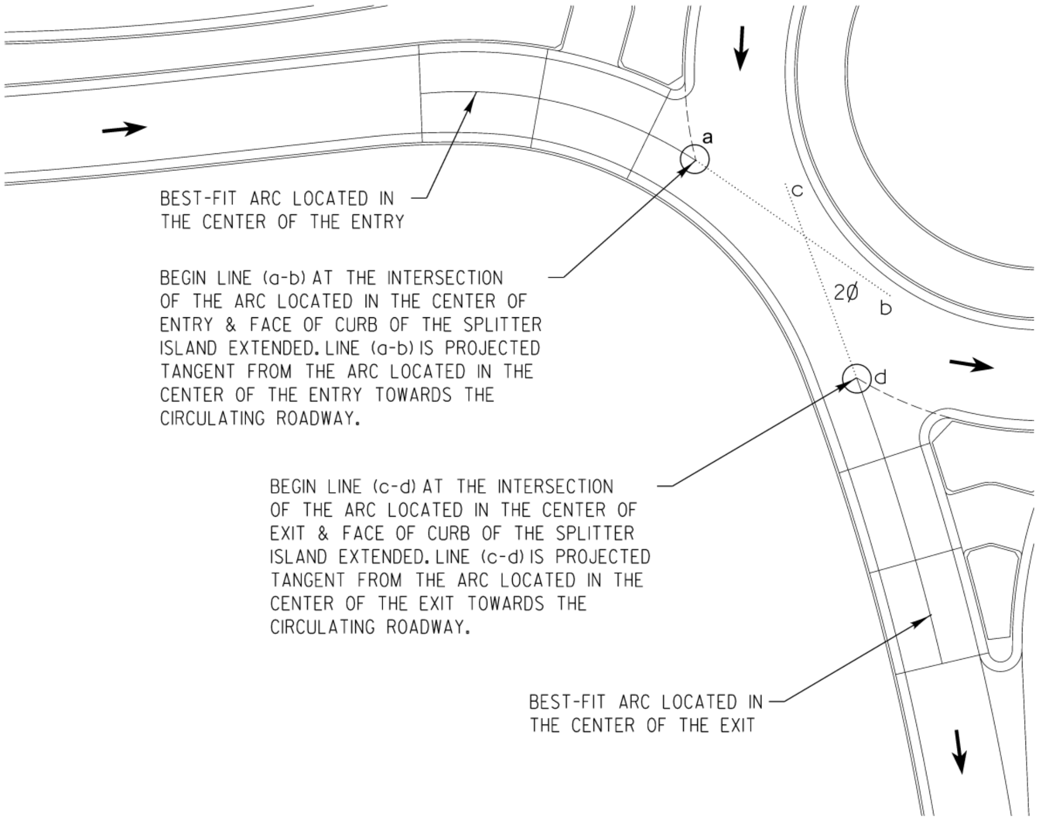


***Figure 30.29* Method 1 Phi Measurement**

Method 2 Phi is measured by dividing the entry radii into three segments. The midpoint of the lane for each segment is best fit with a curve that extends to the face of curb of the splitter island extended. Begin line (a-b) at the intersection of the best fit arc and face of curb of the splitter island extended. Line (a-b) is then projected tangent from the best fit arc towards the circulating roadway. Begin line (c-d) at the intersection of line (a-b) and the arc located at the center of the circulating roadway. Line (c-d) is then projected tangent from the arc located in the center of the circulating roadway. The angle formed by the intersection of (a-b) and (c-d) is Phi.

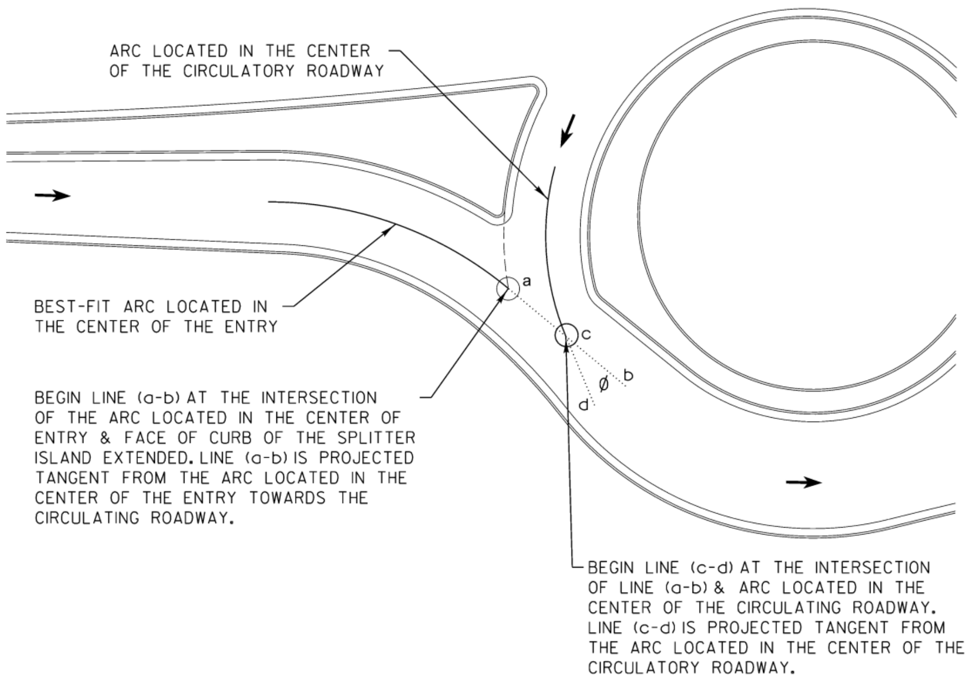


***Figure 30.30* Method 2 Phi Measurement**

30.5.23 Clear Zone

Clear zone guidance for roundabout installations requires consideration of the approach speeds, fastest path speeds, adjacent side slopes leading into and through the roundabout, and average daily traffic on the facility. The guidance for the determination of clear zone is provided in the current AASHTO Roadside Design Manual and FDM 11-15, Attachments 1.9 and 1.10.

The vehicle speed approaching an intersection and the speed allowed through an intersection, along with the ADT and side slopes, will determine the required clear zone. A traffic signal-controlled intersection allows vehicles to go through the intersection at the posted speed, does not require the vehicle to reduce speed as it approaches the intersection, and therefore the clear zone is maintained through the intersection. A stop sign controlled intersection located in a high speed rural condition will require less clear zone as the vehicle slows down to stop. As the approaching vehicle reduces speed it may be appropriate and typical to reduce the corresponding clear zone. The designer has the responsibility to balance the need for clear zone and right of way acquisition.

The yield condition for a roundabout and the fastest path design speed approaching and traveling through the roundabout are similar to the stop sign controlled intersection. The horizontal geometrics leading to and through the roundabout intersection requires the vehicle to slow down leading to the approach and through the roundabout. The approaching speed transition distance for a roundabout is determined by the posted highway speed and the deceleration needed to enter the roundabout in accordance with the fastest speed path calculation, R_1 value. FDM 11-26-30.5.25.1 and Figure 30.26 show how to determine the roundabout approach layout for high-speed highways. The design speed to use for clear zone around the perimeter of the roundabout is the average of the entry speed (R_1) and the circulating path speed (R_2) values. The maximum average entry speed (R_1) and circulating speed (R_2) for any type of roundabout is approximately 25-30 mph. The average fast path, $(\frac{R1 + R2}{2})$, of approximately 25-30mph will produce a clear zone between 7 and 18 feet depending on ADT. The exit ramps from an interchange are also considered to be low speed in close proximity of the approach to the roundabout. In an urban environment, lateral clearance is typically used rather than clear zone to determine the minimum distance to fixed objects such as power poles, light poles, fire hydrants, trees etc. In a rural environment, it is typical to use a clear zone based on the design speed, ADT and slopes. The side slopes adjacent to a roundabout are generally quite flat to accommodate a small terrace and a shared-use path around the perimeter. When the shared-use path is not installed at the time of the roundabout the area should be graded such that at some time in the future the path could be installed. The side slopes in the approach area having an approach speed of 40mph or less and the perimeter of the roundabout, outside of the shared-use path, should be 4:1 (recoverable slope) but may be steeper depending on meeting the clear zone requirement and local impacts.

Central island clear zone is considered to be within a low-speed environment therefore needs to meet the lateral clearance for urban streets, typically 2 feet back from the face of curb. Having stated this WisDOT believes there are precautions, which are dependent upon the approach speed that need to factor into the central island landscaping design. See FDM 11-26-40, for additional guidance on central island landscaping.

30.5.24 Coloring and Stamping Concrete

The truck apron shall be red colored concrete conforming to Standard Spec 405.

Other areas using colored pavement materials are a community and designer agreed upon preference. Pedestrian paths or crosswalks should not be stamped as this is not normally ADA compliant.

Colored concrete pavement could be used for splitter islands and may be stamped, if not a walking surface, but stamping pattern must be specified in the special provisions.

See FDM 14-10-35 for additional information relating to colored concrete, pavement design, tie bar location, dowel bar location, contraction joint layout, and other pavement guidance.

30.5.25 Compact Roundabouts

Many of the same principles are used in the design of compact roundabouts as in full-sized roundabouts. Key considerations include vehicle channelization, design vehicle paths, and intersection visibility. Given that the central island of a compact roundabout may be fully traversable, the overall design should provide channelization that naturally guides drivers to the intended path. Sub-optimum designs may result in drivers turning left in front of the central island (or driving over the top of it), improperly yielding, or traveling at excess speeds through the intersection. The following sections provide more detail on designing compact roundabouts.

30.5.25.1 Assessing Vehicle Paths

For compact roundabouts on roads with a 25 mph speed limit or lower, the methodology of determining a fastest path is not required. However, deflection for the entering vehicle is still important. The entering vehicle should deflect to the right as they enter and travel around the central island (approach has a positive offset). Avoid negative offset approach designs that do not deflect the entering driver. See Figures 30.31 and 30.32. For compact roundabouts on roads with 30-40 mph speed limits, the traditional methodology of measuring fast paths should be used to limit the R1 (entering) speed to 25 mph or less.

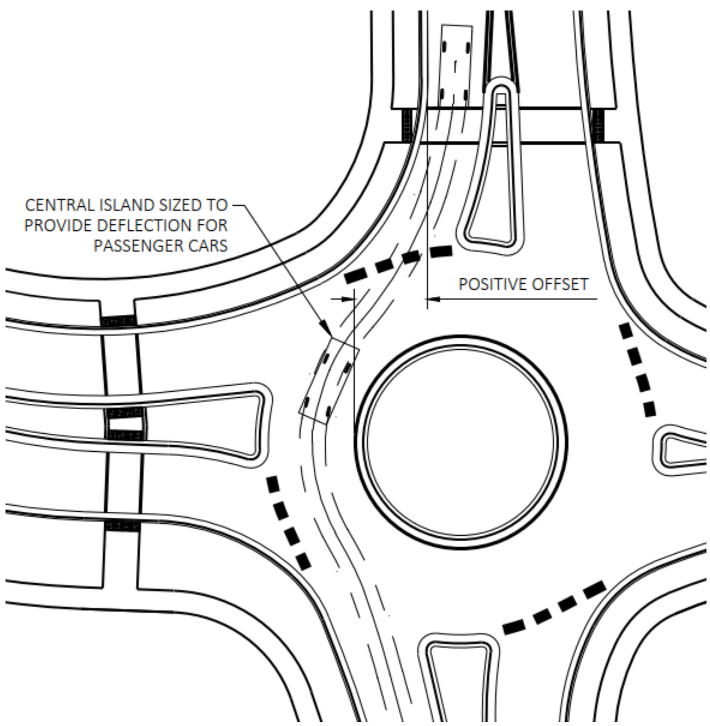


***Figure 30.31* Proper Vehicle Deflection**

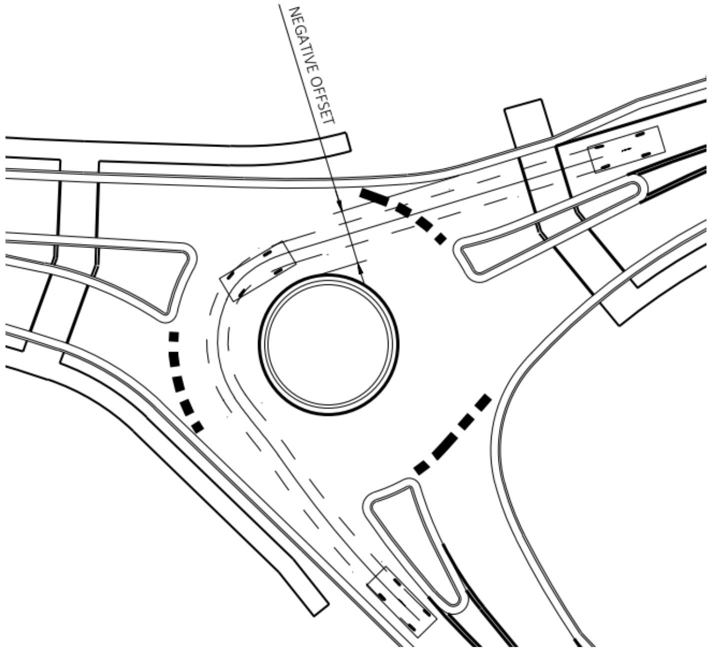


***Figure 30.32* Poor Vehicle Deflection**

30.5.25.2 Design Guidance for all Trucks

Unlike traditional roundabouts, the central island may be completely traversable for compact roundabouts. Larger design vehicles may make direct left turns over the central island. See Figure 30.33. The splitter islands can also be traversable. Larger vehicles may need to traverse over the splitter islands to make certain turning movements. See Figure 30.34.

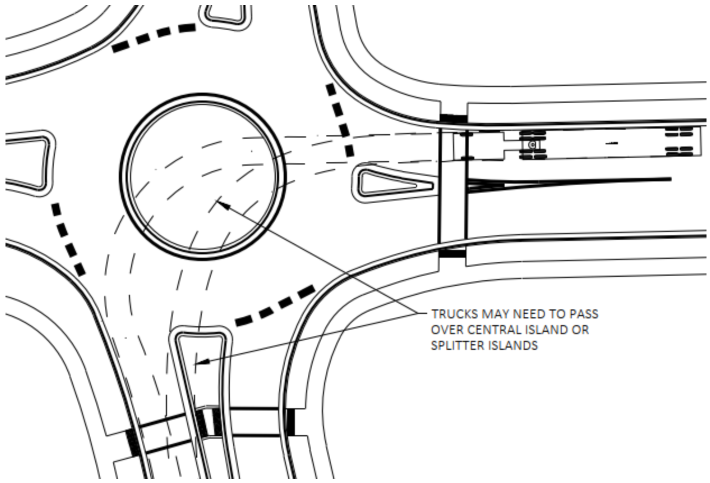


***Figure 30.33* Large Vehicle Over-Tracking, Left-Turn**

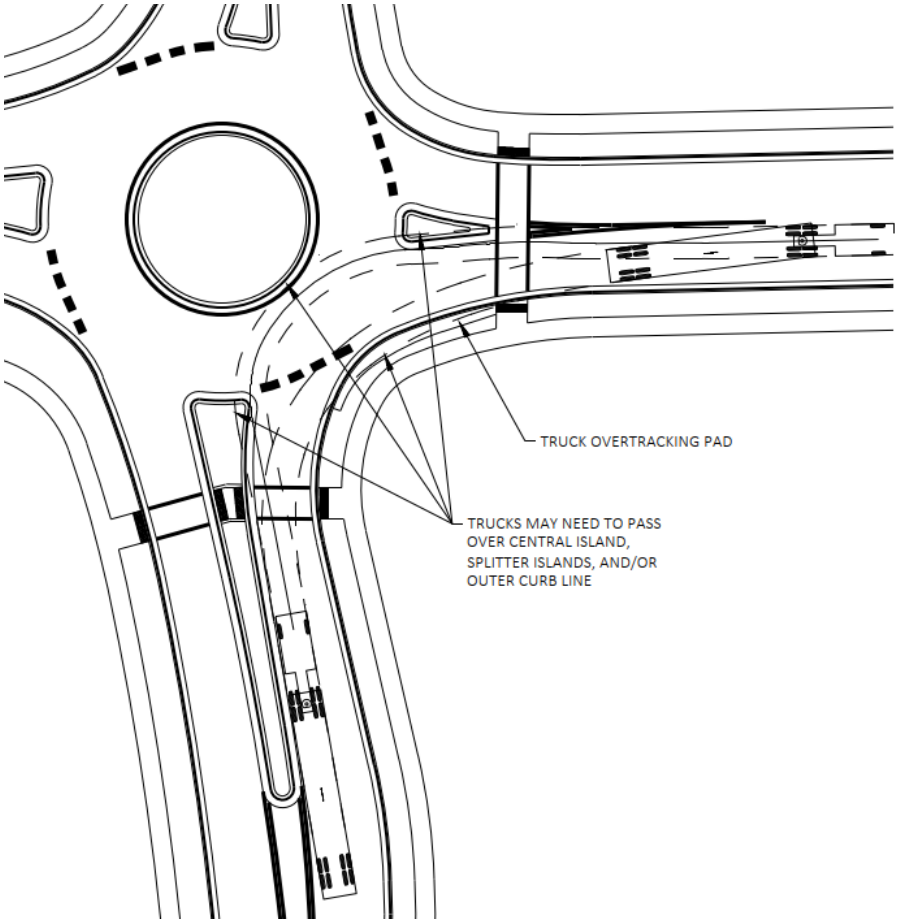


***Figure 30.34* Large Vehicle Over-Tracking, Right-Turn**

If WB-65s are expected to make a lot of turns at the intersection, the addition of overtracking pads to the outside may be necessary to accommodate right turns. As this is done, the benefits of the compact roundabout become less (larger, more impactful footprint) and a larger traditional roundabout may be better suited for the location. These factors should be reviewed when completing the ICE.

30.5.25.3 Vertical Considerations for OSOW Vehicles

As with larger roundabouts, the compact roundabout should be designed to accommodate the necessary OSOW vehicles, including the vertical clearance checks.

30.5.25.4 Entry Width

Unlike standard single-lane designs, a compact roundabout may require the WB-65 to encroach onto the truck apron or the curb and gutters for making right or left turns. The entries should be designed for WB-65 through movements to not encroach onto the truck apron or curb and gutters. This allows the designer to minimize the entry width to help promote slower speeds at the entry of the roundabout. The compact roundabout entry width, measured perpendicularly from the outside curb face to the inside curb face nose P.C. at the splitter island point nearest to the inscribed circle, should be no less than 18 feet and no more than 24 feet.

30.5.25.5 Circulatory Width

The circulatory roadway width may be narrower than larger roundabouts to help promote slower speeds, similar to the entry widths. The width can range from 20 feet to 24 feet, measured from the outer edge of the inscribed diameter at the curb face and the central island curb face. It is desirable to accommodate buses within the circulatory roadway to avoid jostling passengers by running over a traversable central island.

30.5.25.6 Central Island

The central island of a compact roundabout will in most cases be completely traversable. It should be constructed using the same material as used for truck aprons discussed in FDM 11-26-30.5.24. With some of the larger compact roundabouts (ICD 100-feet to 120-feet), a small non-traversable central island with a standard truck apron may be possible depending on the size and turning movements of the design vehicle. In those cases, refer to FDM 11-26-30.5.11.

30.5.25.7 Entry Curves

Since the inscribed circle diameter of a compact roundabout is smaller, the entry radii may be smaller to help control entry speeds and to better facilitate turning movements. The minimum entry curve radii should be approximately 50 feet.

30.5.25.8 Bike Ramp Entrance and Bike Ramp Exit Design Guidance

Similar to larger roundabouts, bike ramp entry and exit ramps should be provided where possible when sidewalks, shared-use paths, or roundabout sidepaths are present or being proposed. When sidewalks or shared-use paths are present approaching the intersection, sidewalks should be included around the roundabout with pedestrian crossings. However, the use of a compact roundabout is often in an urban setting with tight physical constraints that may not allow for wider multi-use paths to be placed around the roundabout. In those tightly constrained urban environments, the designer may choose to not install bike ramps and allow the bicyclists to use the travel lane through the compact roundabout. If a bicycle or multi-use path is present, then bike ramps should be installed. Decisions on the use of bike ramps should be discussed with the region bicycle and pedestrian coordinator and documented accordingly.

30.5.25.9 Splitter Islands

As with larger roundabouts, splitter islands are generally used at compact roundabouts to align vehicles, encourage deflection and proper circulation, and provide pedestrian refuge when possible. Splitter islands should be raised but may be traversable. Raised splitter islands with pedestrian refuge should be provided if possible (See Figure 30.35). In some cases, the splitter island may be too narrow for a pedestrian refuge. In those cases, the crosswalk should be straight across the road to provide the most direct and shortest path across the road and detectable warning fields should not be used. (See Figure 30.35). On minor side streets (less than 1,000 AADT), when the existing roadway is narrow, the use of paint to delineate the splitter island is acceptable but should be avoided if at all possible (See Figure 30.36). The splitter island should be designed with a curved entry to assist in guiding vehicles into the circle. In some cases where a large design vehicle is making right turns, the curb line may be straight into the circle and pavement marking used to help curve vehicles into the circle (See Figure 30.37). Whenever possible, the curved splitter island curb should be used.

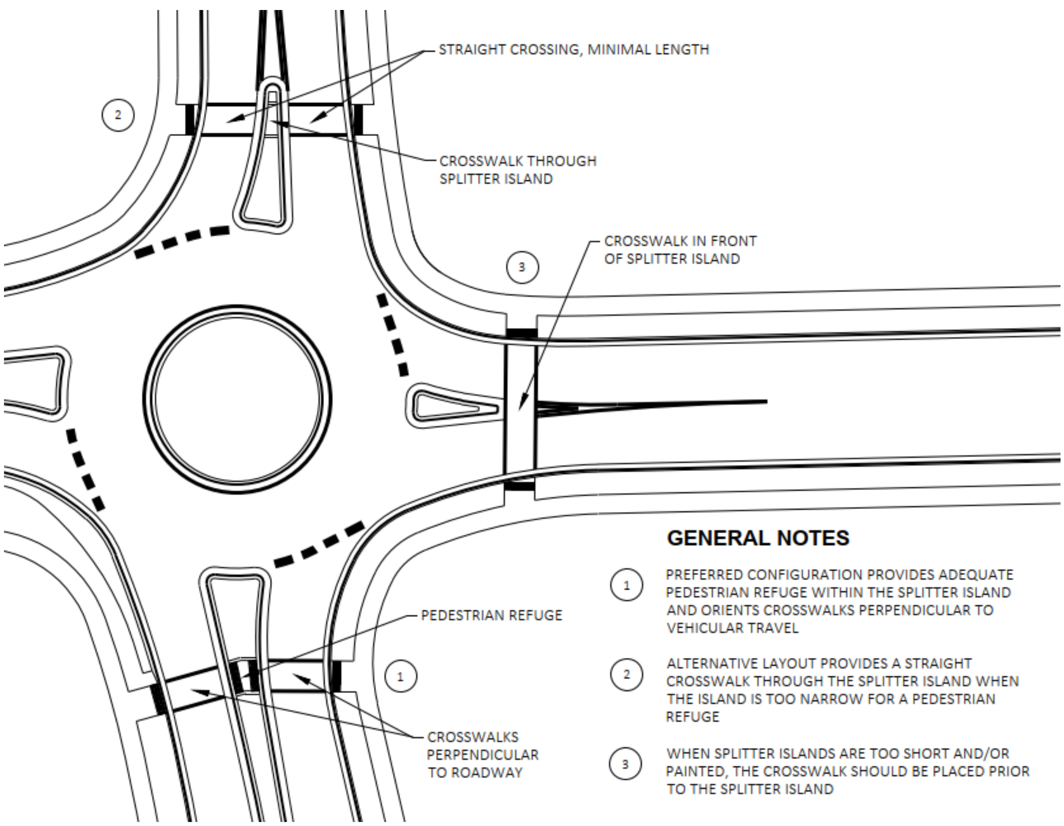


***Figure 30.35** Splitter Island Options*

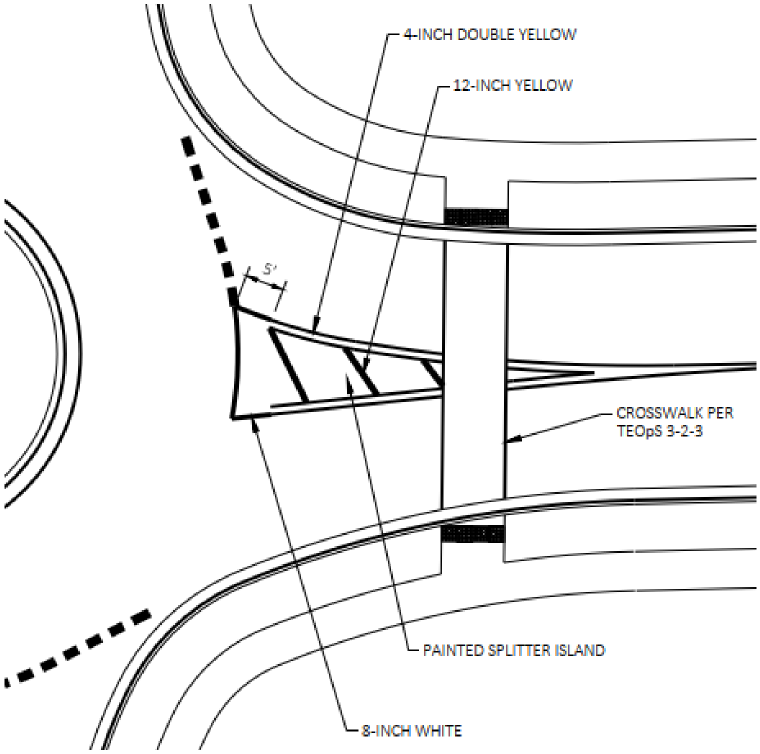


Figure 30.36 ***Painted Splitter Island Alternative***

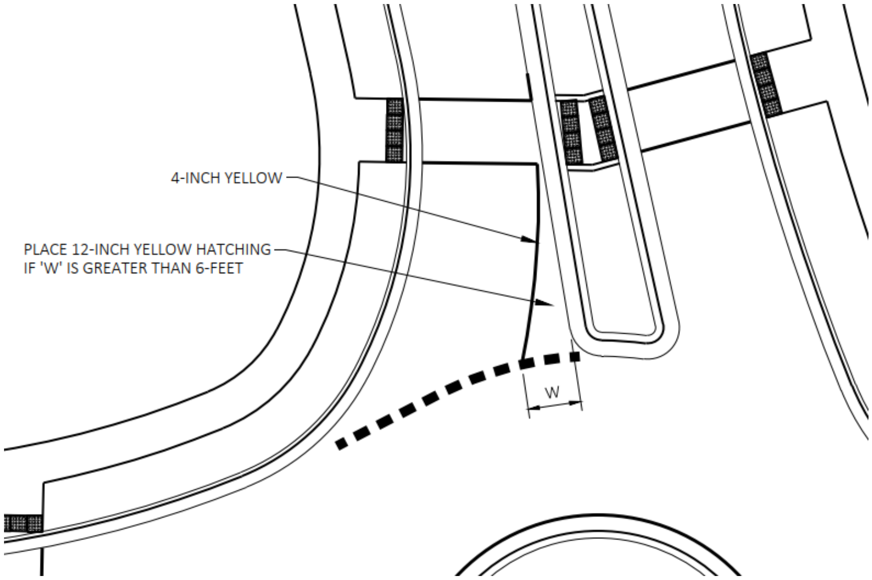


Figure 30.37 ***Large Vehicle Accommodation Alternative***

30.5.25.10 Right Turn Lanes

Right turn lanes can be used with compact roundabouts when capacity needs dictate or when other geometric layouts do not allow the design vehicle to make right turns. This can be especially useful when intersecting roads have an acute angle which makes right turns more difficult. The use of right turn lanes at compact roundabouts is limited to Yielding Bypass Right Turn Lanes as described in FDM 11-26-30.5.16.2. An example is shown in Figure 30.38.

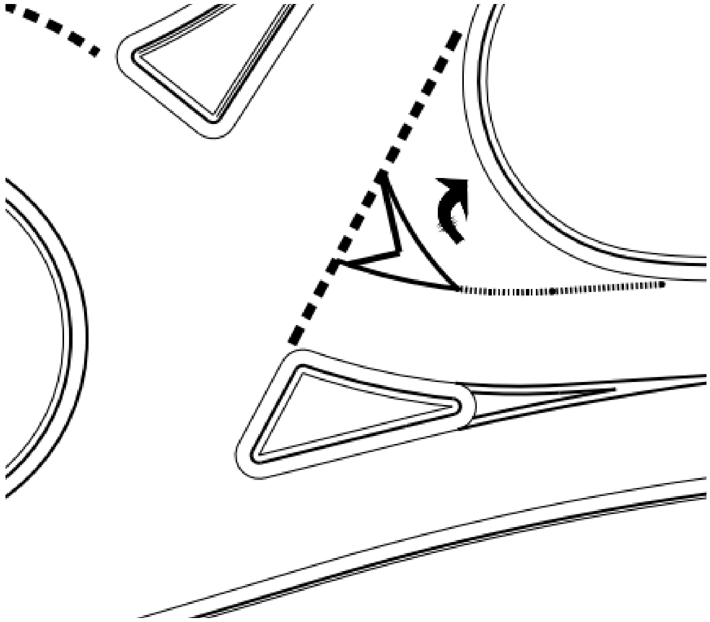


***Figure** 30.38 Yielding Bypass Right Turn Lane*

30.5.25.11 Vertical Design – Circulatory Roadway and Central Island

Circulatory Roadway

The circulatory roadway of a compact design should not contain a crown and should be sloped outward from the central island. The slope should typically be 1.5% but should be no less than 1% and no greater than 3%. This is done to help keep vehicle speeds slow and eliminate the need for storm inlets within the central island. See Figure 30.39. Since the roadway is sloping away from the center, the profile around the central island should still be designed with a minimum grade of 0.8% to ensure drainage along the splitter island curb and gutter at the ICD.

Central Island

A high point should be placed in the middle of the central island to assist with driver sight of the island. As shown in Figure 30.39, the center of the island should be raised if possible from the highest point of the profile around the circle. The high point of the central island does not need to be placed in the center of the circle. The maximum slope across any point of the central island should not exceed 4%. If dictated by vertical clearance when doing the OSOW vertical checks, the central island can be sloped straight across from one side to the other as long as the slope is at least 0.5%, as shown in Figure 30.40. This should only be incorporated if achieving a high point is not possible.

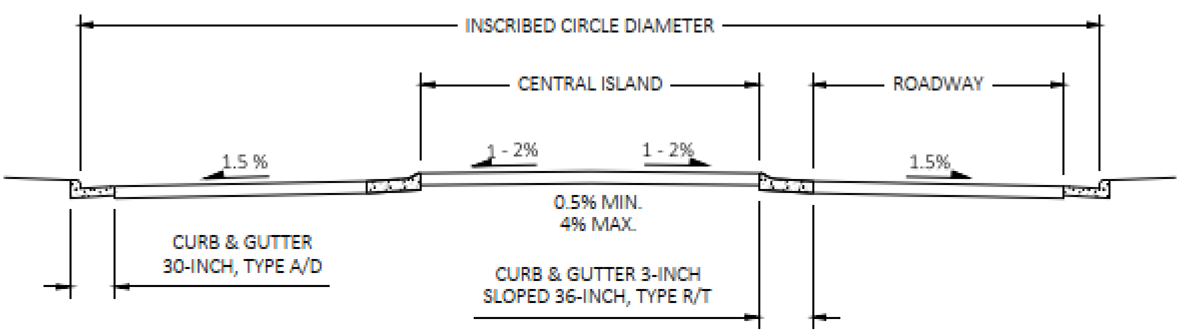


***Figure 30.39** Domed Central Island*

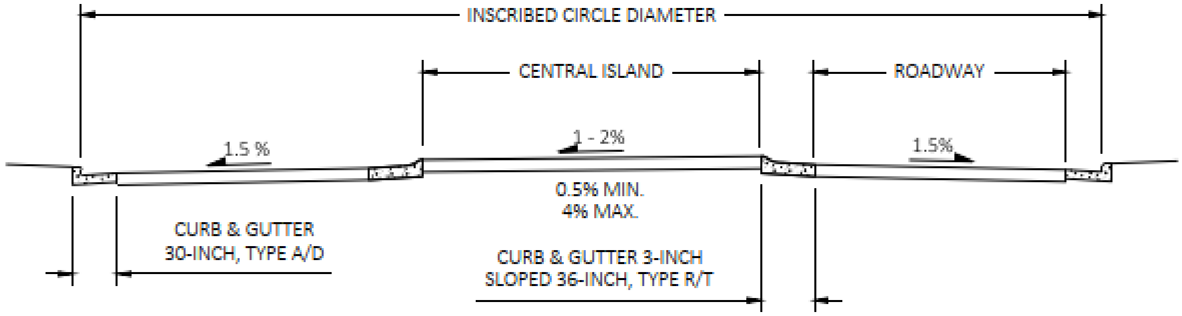


Figure 30.40 ***Single Slope Central Island***

30.5.25.12 Curbing

Due to the smaller inscribed circle diameters of compact roundabouts, larger vehicles may need to overtrack the splitter islands. If after completing truck turning movements or OSOW movements, the need to overtrack splitter islands is necessary, use Curb & Gutter 4-inch Sloped 36-Inch Type A/D. The use of reverse slope on the gutter may be desirable to eliminate the need for storm inlets along the splitter island.

For the central island curb, use Curb & Gutter 3-Inch Sloped 36-Inch Type R/T with reverse gutter slope. As mentioned in FDM 11-26-30.5.26.11, the circulating roadway should not be crowned, and the use of 4-inch sloped curb would be more pronounced and challenging for low clearance vehicles.

If a small non-traversable central island with a standard truck apron is possible as discussed in FDM 11-26-30.5.26.6, use a reverse-slope 18-inch curb and gutter on the inside edge of the truck apron as discussed in FDM 11-26-30.5.20.3.

On the outside of the compact roundabout, Curb & Gutter 30-Inch Type A/D should be used except in areas where outside overtracking areas are needed. In that case, Curb & Gutter 4-Inch Sloped 36-Inch Type A/D should be used. See Figure 30.41.

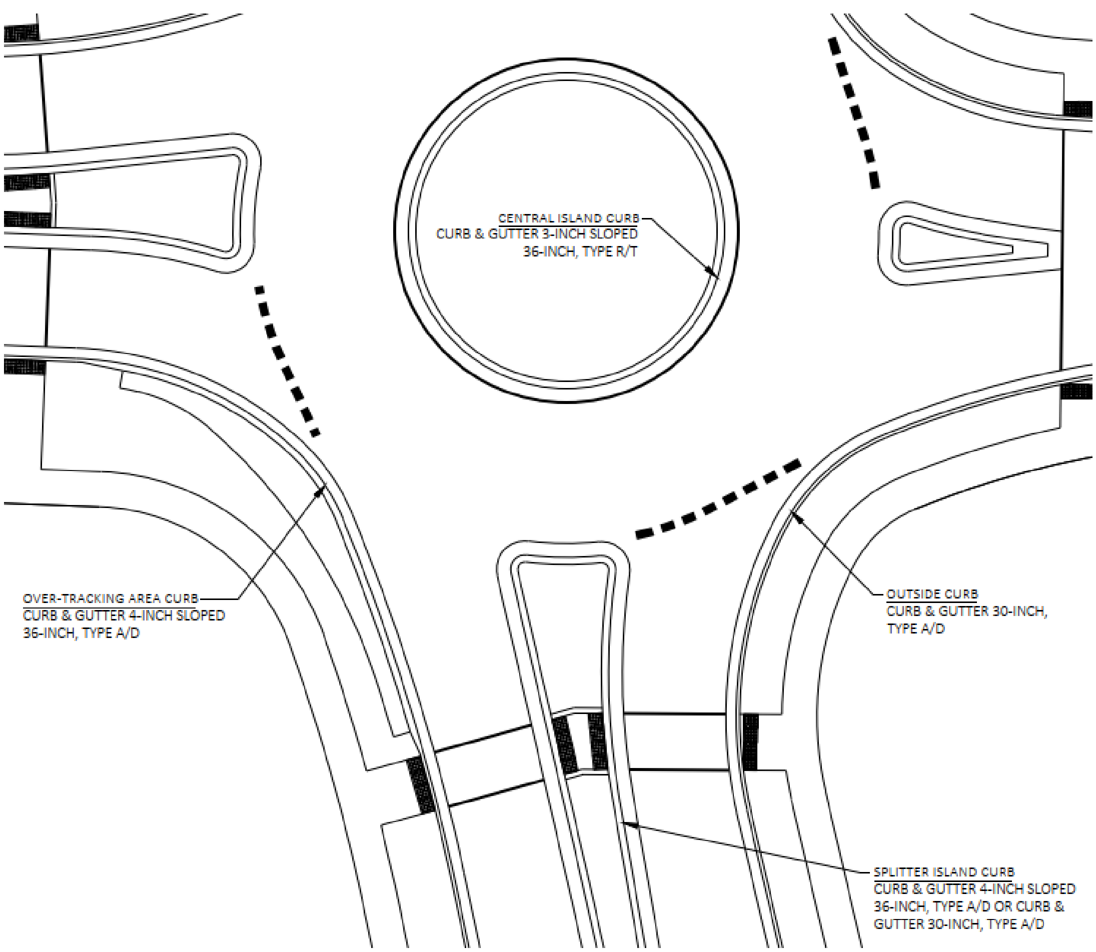


Figure 30.41 ***Curb & Gutter Selection***

30.6 Plan Preparation

30.6.1 Plan Preparation Considerations

The overall concept of roundabout plan preparation is similar to other intersection types (see example plan sheets in FDM 11-26-50). The designer should provide the following plan information when designing roundabouts. At a minimum, roundabout plans should include the following plan details:

- Layout details for any alignments utilized for the roundabout
- Layout details for any crosswalks and bike ramps if utilized
- Elevation at low points, high points, island noses, and 25-foot intervals within circulatory roadway
- Provide one 1” = 40’ scale plan sheet for each concrete roundabout in the plans (1” = 20’ scale is preferred if it will fit on one sheet). Plan sheet will be used by the contractor to prepare the concrete transverse joint details. This plan sheet must show all curb and gutter lines, longitudinal joint lines, proposed pavement marking lane lines, surface utilities such as manhole covers, valve box covers, and inlet covers in the concrete circulatory roadway and concrete truck apron.
- Storm sewer plans
- Landscaping and erosion control plans
- Permanent signing plans
- Lighting plans
- Pavement marking, and pavement marking-layout plans

30.6.2 Alignment Plans

When considering the location of alignments, the designer should consider their usefulness in generating cross-sections, profiles, layout details, and ease of use during construction layout. Alignments along both flange lines of the splitter islands are required. The designer should also consider additional alignments for the following locations:

- Along the curb and gutter flange line located between the truck apron and the circulatory roadway
- Along the curb and gutter flange lines at locations where the width is varying from the main alignments (usual from bike ramp to bike ramp)
- Along the curb and gutter flange lines for both sides of right turn bypass lanes
- Along the back of sidewalks or shared use paths where the distance from the back of curb varies
- On OSOW routes: Along the inside of the central island and along the back of additional pavement placed outside the entry/exit curbs

30.6.3 Profile Information

The designer should consider placing profiles on all of the alignments mentioned above. Some general guidelines for creation of the profiles are:

- It is ideal from a drivability and safety perspective to design and construct the circular component of the roundabout in one plane (planar) with one low point and one high point around the circle.
- Once the circulatory roadway profile is established, the approach and exit leg profiles can be adjusted to match the outside edge of the circulatory roadway.
- Varying of cross-slopes may be done on the circulating lane(s), but the variance from 1.5% should generally be minimized where possible except where OSOW profile and grading design governs (see FDM 11-26-30.5.6). Varying of cross-slopes may require the approach and exit profiles to be modified.
- The designer should also complete a profile on the outside edges to verify a smooth transition from the approach roadway, roundabout and exit roadway. The designer may have to adjust profiles or cross-slopes on the approach, in the roundabout or on the roundabout exit if there are major kinks in the profile.

30.6.4 Typical Sections

At a minimum, roundabout plans should include typical sections at the following:

- Approaches and exits to the roundabout
- Within the splitter island
- Within the central island

The plans should include a sufficient number of cross-sections through the roundabout to allow for accurate construction of the roundabout.

30.99 References

[1] Roundabout Design Guidelines, Ourston Roundabout Engineering, page 36 and 37

[2] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, December 2010

[3] Joint Roundabout Truck Study, Minnesota DOT and Wisconsin DOT, June 2012

[4] FHWA-RD-00-067, Roundabouts: An Informational Guide. FHWA, June 2000, p. 177

FDM 11-26-35 Signing and Pavement Marking   *May 17, 2022*

35.1 Signing

The overall concept for roundabout signing is similar to general intersection signing. Proper regulatory control, advance warning, and directional guidance are required to provide positive guidance to roadway users. Locate signs where roadway users can easily see them when they need the information in advance of the condition. Sign location should be checked so they are not in conflict with vehicle turning movements, the swept path of vehicles with a long overhang, or vehicle navigation on the OSOW Truck Route. Signs should never obscure pedestrians, motorcyclists or bicyclists. Signing needs differ for urban and rural applications and for different categories of roundabouts. On connecting highways coordinate sign selection with the Region Traffic Section and local agency to maintain consistency on the facility.

The signing and pavement marking can get complex on roundabout projects. To assist project managers and contractors, the designer should use a minimum of 40 scale drawings for signing and pavement marking plan sheets.

The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), the Wisconsin Manual on Uniform Traffic Control Devices (WMUTCD), Wisconsin DOT Traffic Engineering, Operations and Safety Manual (TEOpS) and appropriate sign plate details govern the design and placement of signs. To the extent possible, this text follows the principles outlined in the 2009 MUTCD and the WMUTCD.

35.1.1 Regulatory Signs

Several regulatory signs are appropriate for roundabouts and are described below and shown in Figure 35.1.

1. Install a YIELD sign (R1-2) on both the left (in splitter island) and the right side of all approaches, single-lane and multi-lane entrances, to the roundabout. Attention should be given to ensure that the left side YIELD sign and right-side YIELD sign are mounted at the same height. Place a note on the signing plans directing the contractor to make sure the YIELD signs are at the same mounting height (7’ - 3” ± to bottom of YIELD signs.
2. A chevron sign (series of 4 chevrons, R6-4b) shall be used in the central island opposite the entrances in combination with the ONE WAY sign (R6-1R). The mounting height to the bottom of the Chevron sign is 48-inches, measured from the surface of the truck apron to the bottom of sign. Specify the four (4) foot mounting height from the surface of the truck apron in the Miscellaneous Quantities.
3. Install a ONE WAY sign, R6-1R, in the central island opposite each entrance and mounted above the chevron sign (R6-4b) to emphasize the direction of travel within the circulatory roadway.
4. Install a KEEP RIGHT sign (R4-7) at the nose of raised curb splitter islands. The mounting height of the R4-7 ranges from 5-feet to 7-feet to the bottom of the sign. In urban areas where pedestrians or bicyclists are expected to use the crosswalk it is recommended to use the 7-foot mounting. The Down Arrow, W12-1R, may be used but is less typical for consistency and driver expectancy but may be mounted 2-feet to the bottom of the sign. Attention should be given to the location of the KEEP RIGHT sign and light poles on the right side to ensure that conflicts do not occur with larger width vehicles. This is especially critical with single-lane entry roundabouts.

Lane use signs such as the R3-8 sign are not used for single-lane entries. For multi-lane entries consult the Regional Traffic Engineer for sign placement. Roundabout operation will dictate which R3-8 sign is installed.

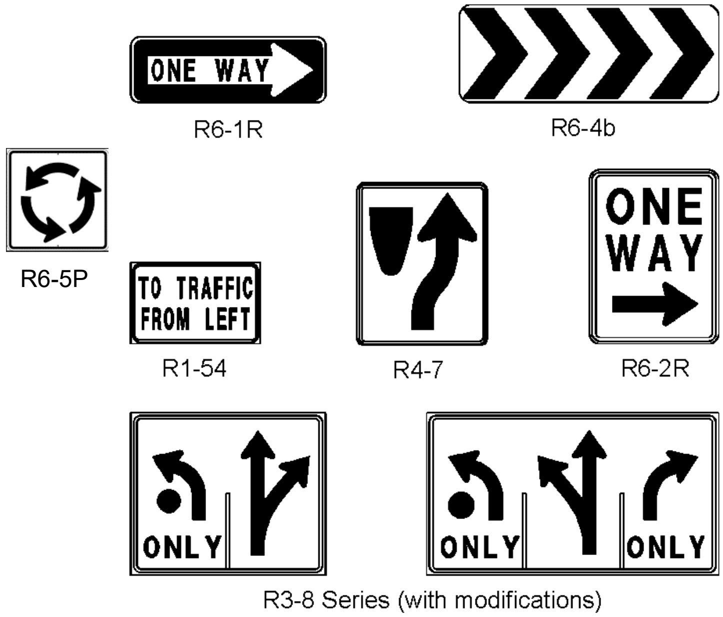


***Figure 35.1* Regulatory Signs**

* The R3-8 sign is modified to show the placement of a dot under the left arrow, which graphically helps depict the presence of a roundabout. Use the dot under the left arrow, only for the left most lane.

35.1.2 Warning Signs

Several warning signs are appropriate for roundabouts and are described below and shown in Figure 35.2. The amount of warning a motorist needs is related to site-specific intersection conditions and the vehicular speeds on approach roadways. The applicable sections of the TEOpS and WMUTCD govern the specific placement of warning signs.

1. Install a circular intersection sign (“chasing arrows”, W2-6) on each approach in advance of the roundabout if minimum visibility distance is not met (WMUTCD 2C.36) OR if posted speed is 40-mph or greater. Below the W2-6 sign, install an advisory speed plate (W13-1). Rural roundabouts have a typical advisory speed of 20 mph, urban roundabouts have a typical advisory speed of 15 mph. Check with the Regional Traffic Engineer before assigning an advisory speed. The speed given on the advisory speed plate should be no greater than the design speed of the circulatory roadway. Advisory speeds are posted in multiples of 5 mph. For conventional highways with posted approach speeds of 45 mph or greater or 3 or more approach lanes, use size 3 W2-6, and W13-1 signs. For expressways, use size 4 W2-6, and W13-1 signs. Coordinate with the Region Traffic Section on the proper sign sizes and type of roadway (conventional highway or expressway).
2. The usage of the pedestrian crossing sign assembly is optional per the 2009 MUTCD and should be based on the guidance found in TEOpS 2-3-51. The designer needs to coordinate the usage of pedestrian crossing signs with the Region Traffic Section. In general, rural roundabouts will not have pedestrian accommodations and therefore would not require signing. For closely spaced roundabouts, the pedestrian crossing sign assemblies may be omitted, see FDM 11-26-35.1.7 below for guidance as to when these signs may be omitted, when used. If used, the pedestrian crossing sign assembly shall be placed at the actual pedestrian crossing as well as in advance for locations where the posted speed is 45 mph or greater. If there is a school crossing at the roundabout, the school warning sign assembly with arrow (S1-1 and WF16-7L) is required at the crosswalk location. In addition, install the school warning sign, AHEAD plaque and FINES HIGHER plaque (S1-1, WF16-9P and R2-6P) in advance of the school crosswalk assembly. Install the pedestrian crossing sign (W11-2 and W16-7L) or school crossing sign assembly (S1-1 and WF16-7L) just in front of the crosswalk for approaching traffic at entries and exits. School crossing signs are required if there are any school pedestrians. If the crosswalk at a roundabout is not considered to be part of the intersection and is instead considered a marked mid-block crossing, pedestrian crossing signs are required.

   The Combination Bike/Pedestrian Crossing sign (W11-15 and W16-7L) may be used in lieu of the pedestrian crossing sign assembly if there are recreational trails crossing the roundabout, where the primary trail users are bicyclists and pedestrians. The TRAIL CROSSING word message sign (W11-15A and W16-7L) may be used in lieu of the pedestrian crossing sign assembly if there are multi-use recreational trails crossing the roundabout. The usage of these signs is optional per the 2009 MUTCD and the designer is encouraged to coordinate the usage of these signs with the Region Traffic Section. Placement criteria for these signs are the same as that of the pedestrian crossing signs mentioned above.

3. A bicycle sign may be needed to designate the exit to the bike path (D11-1a and M7-2, federal sign plate).

Locate pedestrian crossing signs in such a way to not obstruct the approaching driver's view of the YIELD sign or pedestrians standing at the crosswalk.

Flashing beacons may be used above some warning signs as a long-term awareness technique for areas with approach speeds of 45 mph or higher.

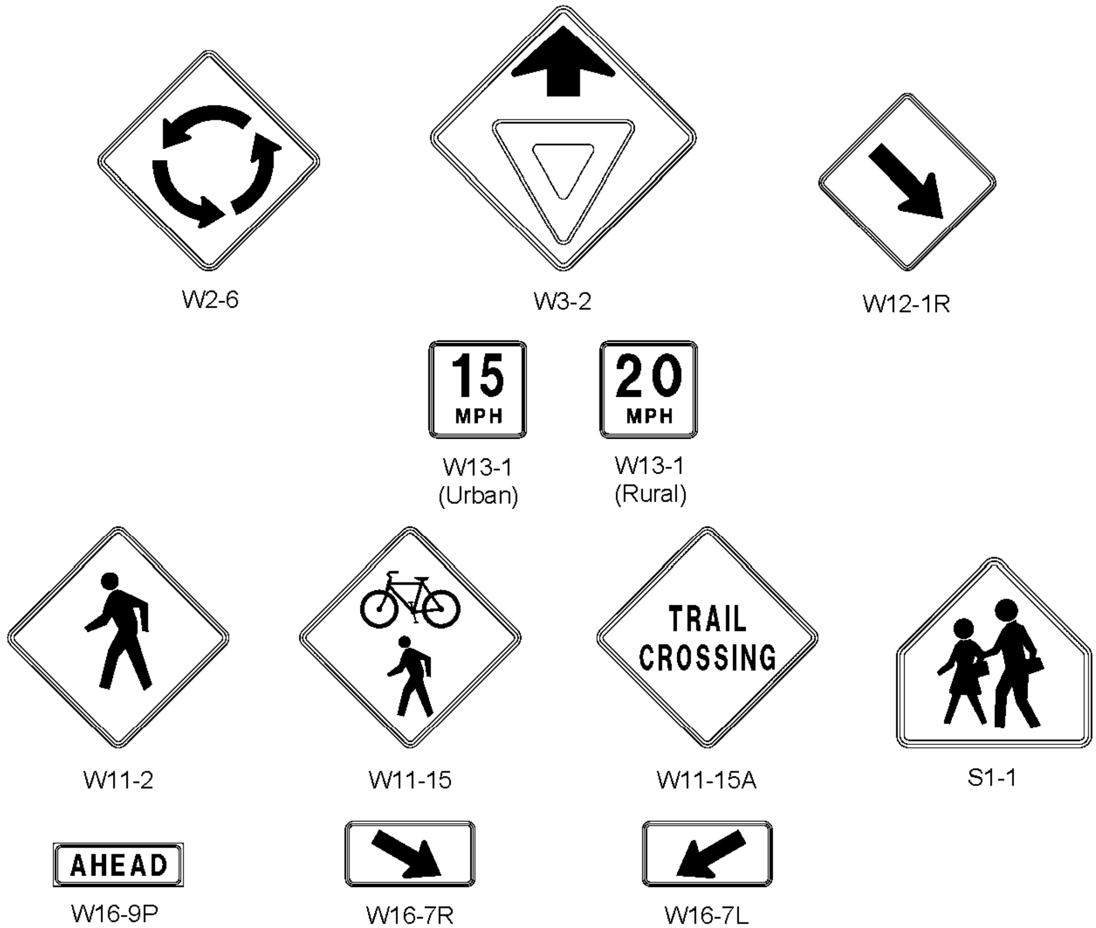


***Figure 35.2* Warning Signs**

35.1.3 Guide Signs

Guide signs provide drivers with needed navigational information. They are particularly needed at roundabouts since circular travel may disorient unfamiliar drivers. Overhead guide signs should be considered at multi-lane roundabout approaches to guide motorists into the proper travel lane in order to navigate the roundabout properly and help avoid lane changing within the roundabout. A number of guide signs are appropriate for roundabouts and are described below.

35.1.3.1 Intersection Destination/Direction Signs

Use intersection destination/direction style signs in all single-lane approach roundabouts for rural locations and in urban/suburban areas where space allows and is appropriate. The diagrammatic style guide sign is preferred over the text style sign (D1 series sign); examples of both are shown in Figure 35.3. The circular shape in a diagrammatic guide sign provides an important visual cue to all users of the roundabout. Diagrammatic guide signs are preferred because they reinforce the form and shape of the approaching intersection and make it clear to the driver how they are expected to navigate the intersection. If lack of terrace space or longitudinal location spacing are issues, use a text style sign or overhead diagrammatic guide sign.

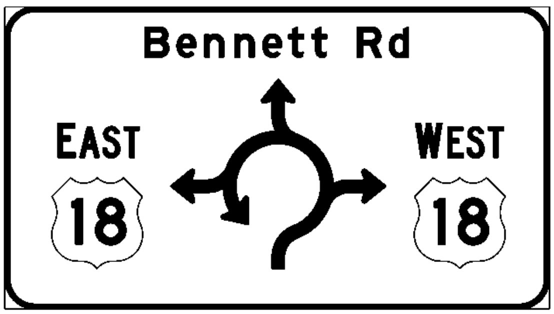
Use 4 1/2" lower case / 6" upper case letters with 18" Interstate, U.S. and State route shields and 15" County route shields for ground mounted signs in urban and rural areas where posted speed is less than 45 mph, and 2 or less approach lanes. Use 6" lower case / 8" upper case letters with 24" Interstate, U.S. and State route shields and 20” County route shields for signs in urban and rural areas if the signs are overhead, posted speeds are 45 mph or greater or there are 3 or more approach lanes. In general, the lettering height rule of thumb is to provide approximately 1-inch in letter height for each 40-foot of distance from the sign. All capital letters are harder to read than the first letter capitalized with the following letters small case. Cardinal directions shall be all capital letters with the first letter slightly larger.

The arrow direction conventions for the text signs follow the same convention as that for conventional intersections as shown in the WMUTCD, 2D.37. The ahead destination is on top, the left destination in the middle and the right destination on the bottom. The curved-stem arrow (D1-1d signs) shown in the WMUTCD, 2D.38 shall not be used.

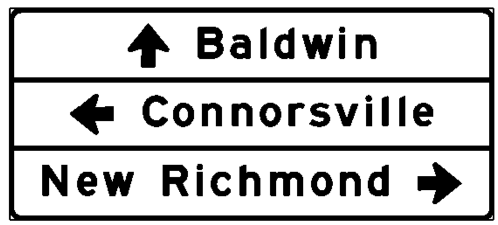
Occasionally, Specific Information Signs (SIS - GAS, FOOD, LODGING, CAMPING or ATTRACTIONS) may need to be included on roundabout approaches. The arrow direction convention and placement of SIS signs follows the WMUTCD, 2J.09.

Sample dimensioned details on the designs of diagrammatic signs, including the arrow and shaft dimensions are shown on the Bureau of Traffic Operations A11-12 sign plate.

Intersection destination signs may not be necessary at local street roundabouts or in urban settings where there are no significant destinations, and the majority of users are familiar with the site.



D1-62



D1-3

***Figure 35.3* Destination Signs**

35.1.3.2 Overhead Lane Guide Signs

In general, overhead lane guide signs are encouraged at roundabouts with multiple approach lanes. By giving destination guidance to the motorist in advance, the motorist will be able to be in the correct lane at the roundabout approach and be discouraged from making a lane change within the roundabout. Qualifying criteria for overhead lane guide signs would include two or more approach lanes, higher vehicle ADT’s, lane splits approaching roundabouts, dual turn lanes, if the major route is turning, closely spaced roundabouts, narrow terrace widths, unfamiliarity of drivers, and lane drops within the roundabout. Since these are lane use guide signs, they would have an up arrow. A sign is placed over each travel lane (see multi-lane layout example in Attachment 35.4) and the arrow is typically placed over the center of the lane. Coordinate sign designs with the Region Traffic Operations section and the Bureau of Traffic Operations Traffic Design unit. If overhead guide signs are used on an approach, then the circular diagrammatic guide sign should not be used. The circular diagrammatic guide sign is good for showing destinations and directions; however, it does not depict proper lane assignments like the overhead lane guide signs do.

There may be situations in urban, multi-lane roundabout approaches where the overhead lane guide signs (Type I) may not be feasible, (space constraints). Options for the overhead guide signs are shown in Attachment 35.4. Region Traffic Section approval is required to use these options.

If the roundabout is part of a closely spaced corridor of roundabouts, (i.e., ramp terminals), the design of all Overhead Lane guide signs in each direction shall match. If designs are mixed along the same direction, motorists may become confused by the change in location of lane control information. Refer to Attachment 35.5 for further design guidance in addition to consulting the Regional Traffic Engineer.

Use 8” lower case / 10.67” upper case letters with 24” Interstate, U.S. and State route shields and 20” County route shields for all overhead signs. For situations with overhead structure loading limitations or on approaches with posted speeds of 35 mph or less, 6” lower case / 8” upper case letters with 18” Interstate, U.S. and State route shields and 15” County route shields may be used. Use a dot with the left arrow to designate the roundabout. The dot shall only be used to depict the left-most lane of the approach. Use an ONLY plaque over thru lanes that become turn lanes. The ONLY plaque is optional elsewhere. Consult the Regional Traffic Engineer for further design guidance.

Sample details of overhead lane guide signs are shown in Figure 35.4. Additional dimensioned details on the designs of diagrammatic signs, including the arrow and shaft dimensions are shown on the Bureau of Traffic Operations A11-13 sign plate.

Generally, use overhead sign supports, not sign bridge trusses. See FDM 11-55-20 for overhead sign support design guidance.

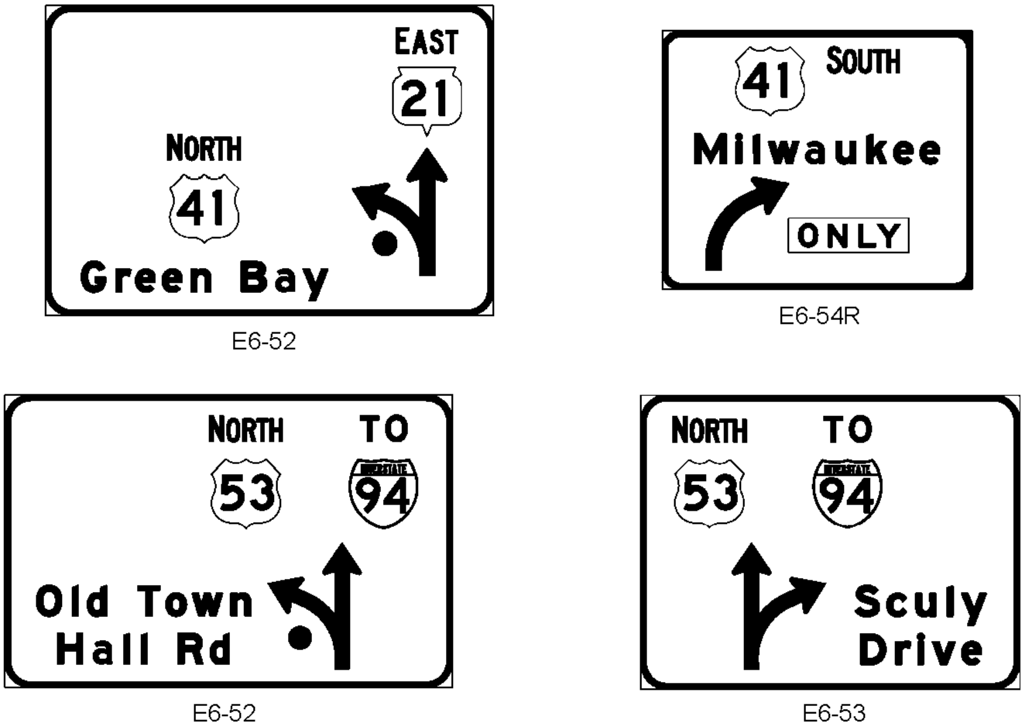


***Figure 35.4* Overhead Lane Guide Signs**

35.1.3.3 Exit Guide Signs - In Splitter Island

Exit guide signs reduce the potential for disorientation. Use them to designate the destinations of each exit from the roundabout. These signs are conventional intersection direction signs (D1 series signs). Exit guide signs with route shields should have the shield incorporated into the sign with cardinal direction and arrow. If the same route marker is used in more than one direction, the route shield should be accompanied with the cardinal direction. The arrow is slanted up and to the right. At freeway ramp situations utilize the route continuation with exit on the exit guide sign. Letter heights for signs are 4 1/2” lower case / 6” upper case with 12” route shields. Signs are placed in the splitter island facing the circulating traffic. The mounting height is to be a minimum of 60-inches from the ground to the bottom of the sign. Specify the revised mounting height in the special provisions.

Sample details of exit guide signs are shown in Figure 35.5. Additional dimensioned details on the designs of the exit guide signs are shown on the Bureau of Traffic Operations A11-14 sign plate.

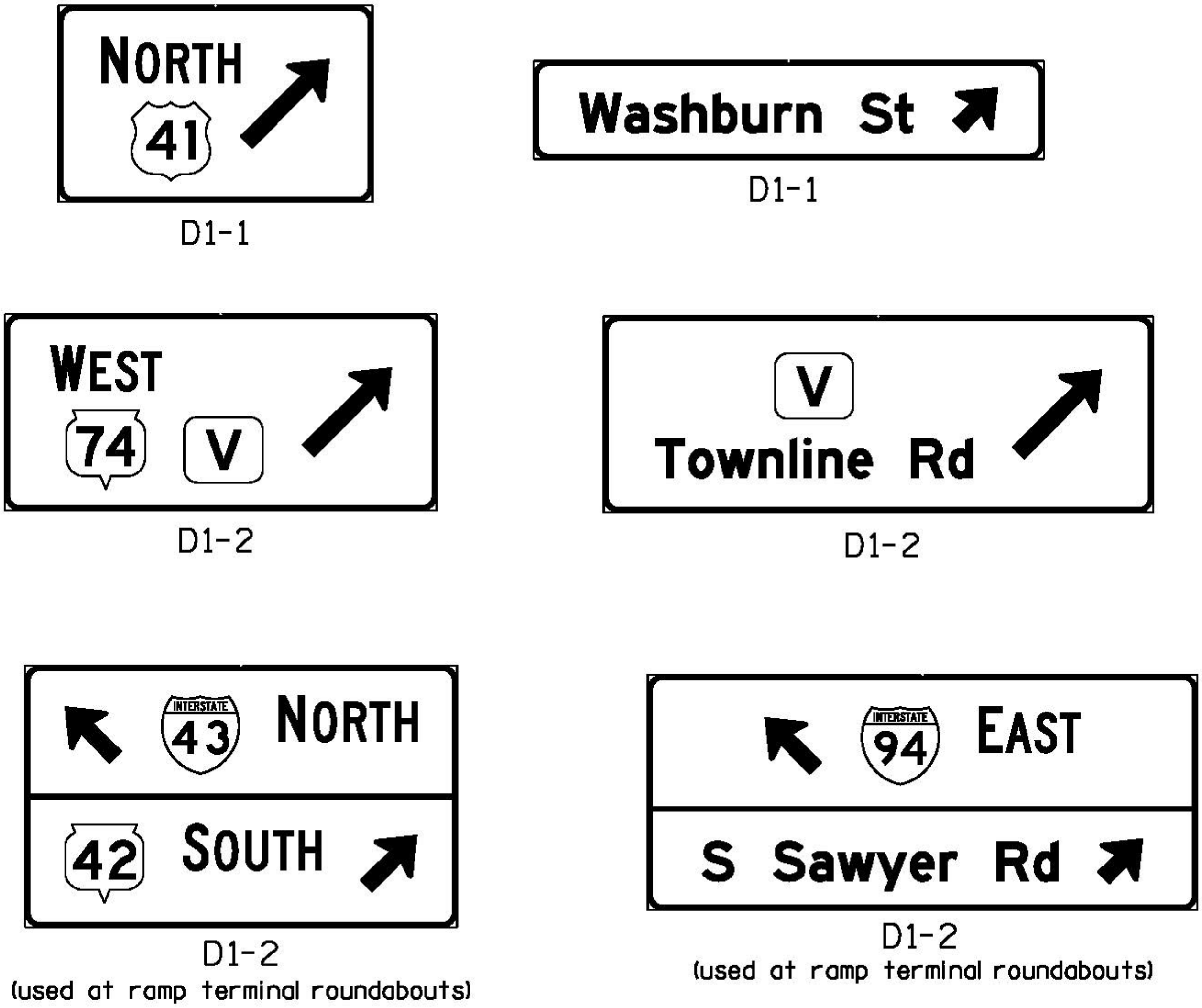


***Figure 35.5* Exit Signs**

35.1.3.4 Junction Assemblies

As with traditional intersections, consider using junction assembly consisting of either a “JCT” (M2-1) auxiliary sign with the appropriate route markers or a junction (J1-1) assembly in advance of the roundabout.

35.1.3.5 Route Confirmation Signs

For roundabouts involving the intersection of one or more numbered routes, install confirmation assemblies (J4’s) directly after the roundabout exit to reassure drivers that they have selected the correct exit at the roundabout. Locate confirmation assemblies no more than 500 feet beyond the intersection in urban or rural areas. If possible, locate the assembly’s close enough to the intersection so drivers in the circulatory roadway can see them.

35.1.4 Urban Signing Considerations

Urban intersections tend to exhibit lower speeds. Consequently, the designer can, on a case-specific basis, consider using fewer and smaller signs in urban settings than in rural settings. However, include some indication of street names in the form of exit guide signs or typical street name signs. Also review proposed signing to ensure that sign clutter will not reduce its effectiveness. Avoid sign clutter by prioritizing signing and eliminating or relocating lower priority signs.

There are sometimes situations with multi-lane approach urban roundabouts where the right of way is tight and there is no physical room for typical overhead sign structures. There may be aesthetic considerations for multi-lane approach urban roundabouts where large overhead guide signs may not fit in. Scaled-down versions of overhead guide signs or J-assemblies may be utilized for these situations that may show route assembly panels instead of large guide signs as shown in Attachment 35.4.

35.1.5 Rural and Suburban Signing Considerations

Route guidance emphasizes destinations and numbered routes rather than street names. The exit guide sign needs to be visible (but discrete) from within the roundabout and much smaller than the typical rural shields and lettering size. Six-inch upper case and 4-1/2-inch lower case lettering height is the maximum needed.

35.1.6 Compact Roundabouts

The smaller size of a compact roundabout requires additional caution to be used when placing signs so that the driver is not overwhelmed with a large number of signs in a small area. Accommodating large vehicles may also influence the type and location of sign in order to reduce the likelihood of signs being knocked down. Many of the standard signs used at regular single and multi-lane roundabouts may not have enough space to fit at a compact roundabout. Refer to Attachment 35.3 for a sample sign layout for a compact roundabout.

Signs shall not be mounted in fully traversable central islands or fully traversable splitter islands. When the central island is fully traversable, the Roundabout Circulation Plaque (R6-5P) will be installed under the Yield sign at the approach. If the splitter island is not traversable and lateral space permits, an additional Yield sign assembly should be placed on the left side.

Depending on the site context, intersection destination/direction signs may be omitted. These signs are less common for any intersections in denser, urban locations. As such, conditions may not make installing such a sign practical. Intersections of marked CTH, STH, or USH routes shall include J-assemblies at a minimum. If the intersection contains several marked routes sharing the same approach, consider the use of a D1-62 diagrammatic sign. Intersections with local system roadways may use a D1-60-series Advanced Crossroad Name Sign.

Roundabout exit signs have similar potential size constraints. D1-series or J-assembly signs shall be used on all roundabout exits as space permits. The size of the splitter island or the presence of a fully traversable splitter island may make this sign placement impractical. Alternatively, if space permits, a J-assembly may be mounted adjacent to the Yield sign assembly at the roundabout entry. For local system intersections a street name sign could be used. A street name sign should be mounted in such a fashion as to make it clear to the circulating driver, what exit the sign applies to. Consider placing an arrow on the street name sign to enhance wayfinding.

The Circular Intersection (W2-6) and Advisory Speed Plaque (W13-1) should only be placed the minimum visibility distance cannot be met. Refer to Table 35.1 for distances. When the assembly is needed, it should be located based on the distances shown for Condition B in Table 2C-4 of the WMUTCD.

35.1.7 Closely-spaced Multiple Roundabouts

Often multiple roundabouts may be installed in close proximity to each other (roundabouts 1,000 feet apart center to center, or less). This can often happen at interchange ramp terminals and roundabouts beyond ramp terminals at frontage roads. Multiple roundabouts in close proximity to each other can cause signing challenges due to longitudinal space constraints between the roundabouts. As a result, some signing may be eliminated between the roundabouts. Visibility distance is based on stopping sight distance of vehicles. The roundabout warning assembly signs (W2-6, W2-6P and W13-1), pedestrian warning signs (W11-2, W11-15, W11-15A, W16-9P and W16-7L/R) and YIELD AHEAD (W3-2) may be eliminated between roundabouts if the visibility distance between the roundabouts exceed the minimum visibility distance shown in Table 35.1. Other signs may be eliminated with consultation with the Region Traffic Section. The roundabout warning assembly signs and YIELD AHEAD would continue to be placed at the approaches to the first roundabouts in the series.

Table 35.1* Minimum Visibility Distance

Posted or 85th Percentile Speed	Minimum Visibility Distance
25 mph	280 ft
30 mph	335 ft
35 mph	390 ft
40 mph	445 ft
45 mph	500 ft
50 mph	555 ft
55 mph	610 ft

* Minimum Visibility Distances are from Section 2C.36 of the WMUTCD

35.1.8 Roundabouts in Close Proximity to Railroad Crossings

Railroad crossings in close proximity to roundabouts can present additional signing challenges due to safety concerns involving railroad crossings and the installations of additional signs in spaces already containing numerous signs. Because each railroad crossing is unique, roundabout designers need to contact the Bureau of Traffic Operations Traffic Design unit and the appropriate Region Traffic Operations section for the proper signing and marking layout if the railroad crossing is 1000 feet or less from the roundabout.

35.1.9 Wrong Way Movements in Roundabouts

There is a potential for wrong way movements at roundabouts, especially roundabouts that are new in an area. The typical signing applications include the usage of a chevron sign (series of 4 chevrons, W1-8a) in the central island with a One Way sign (R6-1R sign) mounted above it. In addition, a One Way sign is mounted below the left side YIELD sign. If wrong way movement problems persist, there are some signing options that can be employed:

- Oversize ONE WAY (R6-1R) sign in the central island, above the chevron sign
- DO NOT ENTER (R5-1) signs mounted in the circular island to face potential wrong way traffic
- DO NOT ENTER (R5-1) and NO RIGHT TURN (R3-1) signs is required for roundabouts at ramps per TEOpS 2-15-12 mounted on the outside radius of roundabout as shown in the detail in 2-15-12

35.1.10 Wide Turning Trucks in Roundabouts

As large trucks maneuver a multi-lane roundabout, often times they need to encroach into the adjacent travel lanes. In many multi-lane roundabouts, this happens by design. Occasionally there may be issues resulting from large trucks encroaching into the adjacent travel lanes as they make the turn. For these problem areas, it may be necessary to warn the motorist that the large trucks will encroach into the adjacent travel lanes in the roundabout circle. The WATCH FOR WIDE TURNING TRUCKS (W8-73) sign may be installed on the roundabout approaches for multi-lane roundabouts exhibiting these problems

35.1.11 Maintenance of Signs

For roundabouts on the STH System with county highway approaches or local road approaches, it is recommended that early in the design process, a Maintenance Agreement needs to be developed. By having the Maintenance Agreement developed early in the design process, the county or local unit of government will clearly have knowledge of what they are to maintain.

Some particular items that should be included in the Maintenance Agreement would include:

- Specific signs that WisDOT would maintain and what the locals/county would maintain. This would also include signposts.
- Specific overhead sign supports (if any), that WisDOT would maintain, and what the locals would maintain.
- Recommended inspection frequencies for overhead sign supports that the locals would maintain.

Further guidance on the maintenance of signs for roundabouts is included in the Traffic Engineering, Operations and Safety Manual, policy TEOpS 2-15-52.

35.1.12 Sign Installation for OSOW Vehicle Routes

Give careful attention to signs that are installed for roundabouts on OSOW vehicle routes. Periodically signs and posts may need be temporarily removed to accommodate the vehicles as they pass through the roundabout and turns properly. The designer should review the OSOW truck route maps in FDM 11-25-1.4 and contact the Region freight coordinator to confirm if the roundabout is located on an OSOW vehicle route. Confirm the proposed post usage type on these routes with the Region Traffic Operations.

For roundabouts on OSOW routes, install tubular steel signpost assemblies or a comparable system (approved by the Project Engineer) for the following signs:

1. Left side YIELD (R1-2)
2. Right side YIELD (R1-2)
3. Exit Guide signs (D1 series) in the splitter islands
4. PEDESTRIAN CROSSING (W11-2m W16-7R or similar) sign assemblies at the intersection crosswalks
5. Roundabout chevron bank (R6-4b) and ONE WAY (R6-1R) sign assembly in the circular island
6. Any signs located on the median island separating a right turn lane from the through lane(s)
7. Any additional signs on the outer portion of the roundabout circle, if directly impacted by OSOW vehicles.
8. Additional consideration should be given to sleeving, all signs on single-lane roundabout approaches with clear width less than 20'.

Install tubular steel signpost assemblies in accordance with Standard Spec 634.3.2 and standard sign plat A4-9. Refer to the sign plate manual at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/signplate/signplate.aspx

To help prevent bending of the anchor tube and potential puncturing of vehicle tires, place the top of the 2 1/4" x 2 1/4" anchor level with the top of the 18" diameter PVC box-out (which is at ground level). The box-out is typically filled with gravel or dirt which will require about 2" of it to be removed in order to access the corner bolt when removing/reinstalling the post. The designer will need to ensure that notes are placed on the permanent signing plan to notify contractors of the required height of the top of the anchor system.

35.2 Pavement Marking

Pavement marking is needed on single and multi-lane roundabouts. The more complex the roundabout and the higher the volume, the greater the need for proper pavement marking. Pavement marking must be closely evaluated when designing a roundabout. Pavement marking is part of a "whole system" to consider, meaning that various design concepts from geometric design, to signing, and pavement marking should complement each other.

Typical pavement marking for roundabouts consists of delineating the entries, exits, bike lane accommodations (only on approaches and exits), and marking the circulatory roadway. Single-lane roundabouts need no lane arrows or circulatory roadway pavement marking, except to continue edge line marking on the approaches. Attachment 35.1 shows various combinations of common roundabout lane configurations, including full and yielding right-turn bypass situations. In order for roundabout markings to be effective and sustainable, they must:

- Be integrated with and preferably designed at the same time as the roundabout geometry
- Be configured to guide proper usage of the roundabout
- Help the motorist identify the correct lane as early as possible using lane arrows on multi-lane approaches and circulatory roadways
- Be designed and implemented collaboratively between Regional Traffic Operations and project development staff with expertise in roundabouts and knowledge of maintenance considerations

Based on findings from the Department's pavement making evaluation, mark all roundabouts and their approaches with epoxy pavement marking.

Refer to TEOpS 3-10-1 of the Traffic Engineering, Operations and Safety Manual (TEOpS) for further guidance with roundabout pavement marking applications, including pavement marking preparation and installation at existing roundabouts.

Markings not covered in this policy shall follow practices established by standard detail drawings or require the approval of the Regional Traffic Engineer in collaboration with others who have knowledge of the design of roundabouts. On connecting highways, (local jurisdiction), coordinate pavement marking with the Regional Traffic Engineer and the local agency to maintain consistency on the facility.

It is just as important to make sure field layout and pavement marking application on the circulatory pavement is located and positioned correctly. A pavement marking layout detail showing the exact locations is required on all multi-lane roundabouts. Consider wheel tracking when developing the pavement marking layout detail.

Proper pavement marking within the circulatory roadway will help prevent left turns from the outer lane and thus reduce exit crashes. Complex lane configurations should be reviewed by an experienced roundabout designer and the Regional Traffic Engineer.

35.2.1 Approach Markings

1. Centerline marking on the approach to the splitter island may require a minimum of 500-foot segment no passing barrier line as shown in SDD 15C18 "Median Island Marking". Refer to Attachment 35.1 item *O*.
2. Lane lines on the approach shall match the width of the line extended. The markings are at the typical spacing of 12.5-ft segment, 37.5-ft gap, unless an even segment of 12-ft segment, 12-ft gap is needed. Start when flare widens to 9.5 feet for each lane. Refer to items *T* and *X* in Attachment 35.1.
3. The line shall be solid for a length of 50 feet in advance of the Point of Curve (P.C.) or as far as possible in advance of the P.C. to allow minimum marked lane widths of 9.5 feet, whichever is shorter. Refer to items *B* and *I* and its various marking width applications in Attachment 35.1.
4. When an approach lane is a turn only lane, the channelizing line *is 8-inches wide and solid*. A R3-8 series Lane Control sign *shall* be placed for this type of approach. Refer to FDM 11-26-35.1.1. The line shall be solid for a length of 50 feet in advance of the P.C., or as far as possible in advance of the P.C. to allow minimum marked lane widths of 9.5 feet, whichever is shorter. Refer to item *B* and its various marking width applications in Attachment 35.1.
5. When the left approach lane is a dropped lane/exclusive turn lane, the approach dotted marking *shall be 8-inches wide with 3-ft segment, 9-ft gap.* Consult with the Regional Traffic Engineer on the start of this marking. Refer to item *D* in Attachment 35.1.
6. The painted median splitter island marking on the approach *shall be double yellow with 12-inch yellow diagonal marking.* Do not place diagonal marking if the island is less than 6-ft wide. When the island nose width is greater than 6 feet, the diagonals shall be spaced every 25-ft if the median gore is longer than 50-ft; spaced every 10-ft if the median gore length is 50-ft or less. Refer to items *J* and *K* in Attachment 35.1.
7. Lane separation markings (truck gores) *shall be outlined by 8-inch white lines*. Refer to item *U* in Attachment 35.1. When the separation is greater than 6-ft, *12-inch white chevrons shall be placed and spaced every 25-ft if the truck gore length is longer than 50-ft; spaced every 10-ft if the truck gore length is 50-ft or less*. Do not install chevrons when the truck gore is 6 feet wide or less. The point of the chevron shall 'point' upstream. Refer to item *U* for chevron application in Attachment 35.1.
8. The edge line marking on the circle end of the splitter island will be white. Refer to Attachment 35.1 which shows the breakpoint from 8-inch white to 4-Inch yellow markings 5 feet in advance of the curb/splitter island P.C (items M and N of the *Special Case* in Attachment 35.1). Refer to TEOpS 3-10-1 and consult the Regional Traffic Engineer for further placement guidance of the yellow edge line upstream of the roundabout.
9. When two or more lanes approach a roundabout, lane use arrows shall be marked in each lane to denote proper lane usage. Full complement of signing *shall be installed* as shown in Figure 35.1, Regulatory Signs. Refer to item *V* in Attachment 35.1. *Lane use arrows should not be used on single-lane approaches.* Left turn arrows *with the oval (Type 2R or Type 3R) shall only be placed in the left most lane.* Refer to SDD 15C7-d for typical detail of a dot with left pavement marking arrow. *The fish-hook arrow shall not be used.*

   In addition to approach lane lines, appropriate lane arrows encourage balanced lane use, which improves capacity and safety. Left turn arrows are important on multi-lane approaches, since traffic otherwise has a bias towards the right-most lane. Place arrows to show the movements for each lane, and to indicate permitted dual right or left turns. Place the arrows at or just before the point where the channelizing or lane line begins or when the road widens to allow minimum lane widths of 9.5 feet. This is intended as a visual cue to the motorist to select an appropriate lane for entering the roundabout. Contact the Regional Traffic Engineer for guidance for multiple sets of arrows.
10. Crosswalk markings should be placed such that vehicles approaching the roundabout are not likely to stop on the crosswalk. A distance of 20 to 25 feet per stored vehicle back from the yield point is typically appropriate. Refer to Attachment 35.1 as well as crosswalk policy in TEOpS 3-2-3 or selection guidance of appropriate crosswalk markings.
11. The word, "YIELD" placed prior to the dotted edge line extension shall only be used when crashes are caused by motorists failing to yield. Refer to item X in Attachment 35.1 and SDD 15C7-b, Yield Markings.

12. Dotted Edge Line Extensions *shall be 18-inch-wide dotted white at 2-ft segment, 2-ft gap.* Place markings to avoid conflict between the entering vehicle and internal roundabout traffic, this is the point where entering traffic must yield. Refer to item *A* in Attachment 35.1.

Approach and entry pavement markings consist of lane line, channelization marking, dotted edge line extension marking (yield line) and symbol markings. Refer to TEOpS 3-10-1 for approved pavement marking materials and their locations at a roundabout. Consult with the Regional Traffic Engineer before determining final pavement marking materials.

35.2.2 Circulatory Roadway Marking

13. Lane lines within the roundabout *shall be 4-inch or 8-inch width, with a 6-ft segment, 3-ft gap marking cycle*. These lines shall be the same width as the lines they extend. Lane lines in the circle can have a spiral effect and together with proper lane assignment guide motorists through the roundabout to the appropriate exit eliminating the need to change lanes. Refer to item *C* in Attachment 35.1 along with guidance in selecting either the 4-inch or 8-inch width. For longevity, place the markings to avoid wheel paths of the intersecting traffic.
14. When used, dotted line markings shall be the same width as the lane lines and 1-ft segment, 3-ft gap marking cycle. Refer to item E in Attachment 35.1.
15. When two lanes are allowed to proceed around the circle, Lane use arrows *shall* be marked in each lane within the roundabout halfway between the splitter island to denote proper lane usage. Arrows placed within the circulatory roadway *shall not* include the oval. Refer to item *Q* in Attachment 35.1.

35.2.3 Exit Marking

16. Avoid chevron makings at the exit point adjacent to the splitter island and at the exit or on the approach. This former special case application has been discovered to provide limited benefits in speed control and directional guidance versus curb and gutter.
17. *Do not paint the noses of the splitter island yellow* (where the splitter island meets the circulatory roadway, unless there is a documented crash problem). Yellow nose paint is intended to separate opposing directions of traffic such as the approach nose.

35.2.4 Bicycle Marking

18. When required, bike lane markings should be placed as per Figure 35.6.

Bike lane marking within the circulatory roadway is not permitted on any roundabouts. Refer to Figure 35.6 for Bike Lane markings on roundabout approaches.

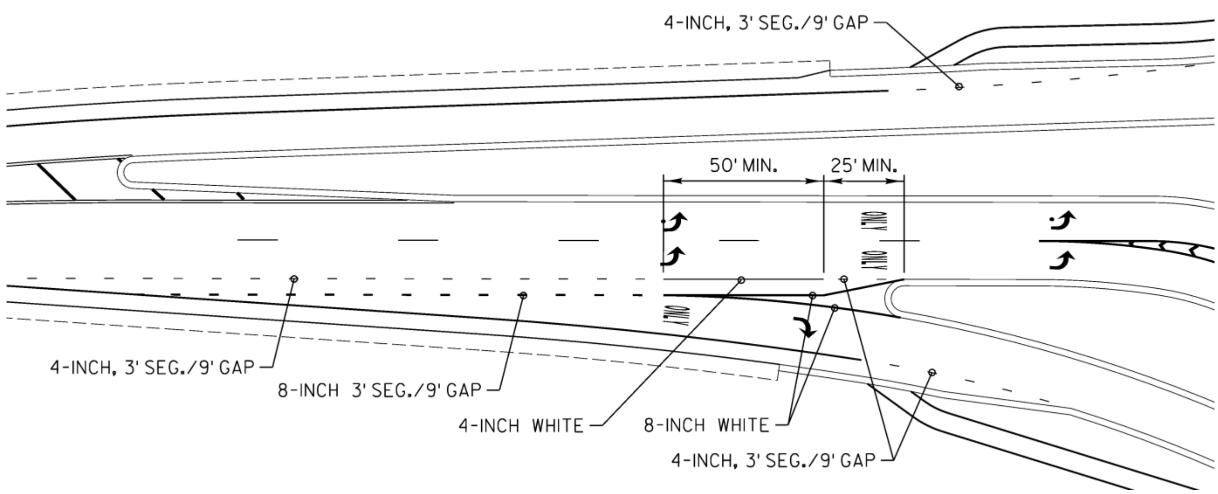


***Figure 35.6* Bike Lane Roundabout Marking**

35.2.5 Compact Roundabouts

A 4-inch yellow edge line shall be placed around the central island of a compact roundabout with a traversable central island. Place gore markings and edge lines based on TEOpS 3-2-1 speed and illumination policy for edge lines. White edge lines shall not be placed around the circulatory roadway. Refer to Attachment 35.3 for example markings for a compact roundabout.

35.2.6 Maintenance of Pavement Marking

For roundabouts on the STH System with county highway approaches or local road approaches, it is recommended that early in the design process no later than the time of the design study report, a Maintenance Agreement be developed. By having the Maintenance Agreement developed early in the design process, the county or local unit of government will clearly have knowledge of what they are to maintain.

LIST OF ATTACHMENTS

Attachment 35.1	Example Pavement Markings for Typical Designs
Attachment 35.2	Sample Signing Layout for Single-Lane Roundabout
Attachment 35.3	Sample Signing and Pavement Marking Layouts for a Compact Roundabout
Attachment 35.4	Sample Signing Layout for a Multi-lane Roundabout
Attachment 35.5	Sample Signing Plan for Roundabout Ramp Terminals

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Illumination can be found in chapter 11 of the Traffic Engineering, Operations and Safety Manual (TEOpS 11-1). Illumination of compact roundabouts should follow the same procedures as for larger roundabouts.

40.1 Central Island Landscaping and Other Aesthetic Treatments

Roundabout landscape elements are vital to the proper operation of the roundabout and should be in place when open to traffic. This does not apply to roundabout with traversable central islands (i.e., compact roundabouts).

40.1.1 Landscape Elements

The Department's primary approach to central island landscaping is mounding the earth and (optionally) providing low-level plantings.

The purposes of landscape elements in the roundabout are to:

- Make the central island conspicuous to drivers as they approach the roundabout
- Clearly indicate to drivers that they cannot pass straight through the intersection.
- Restrict the ability of a driver to view traffic from across the roundabout through mounding of the earth and optional plantings.
- Require motorists to focus toward on-coming traffic from the left
- Help break headlight glare
- Discourage pedestrian traffic through the central island
- Improve and complement the aesthetics of the area

Landscape elements at roundabouts contribute to lower entering speeds which improves the overall safety of the intersection.

When designing landscaping for a roundabout it is important to:

- Minimize driver distraction
- Consider maintenance requirements early in the program stages of development
- Develop a formal municipal agreement describing the landscaping and maintenance requirements for roundabouts elements early in the scoping process and prior to design of the facility
- Maintain adequate sight distances
- Avoid obscuring the view to signs
- Minimize fixed objects such as trees, poles, or guard rail
- Refer to FDM 11-26-40.2.1 for reference to Department-approved plant materials

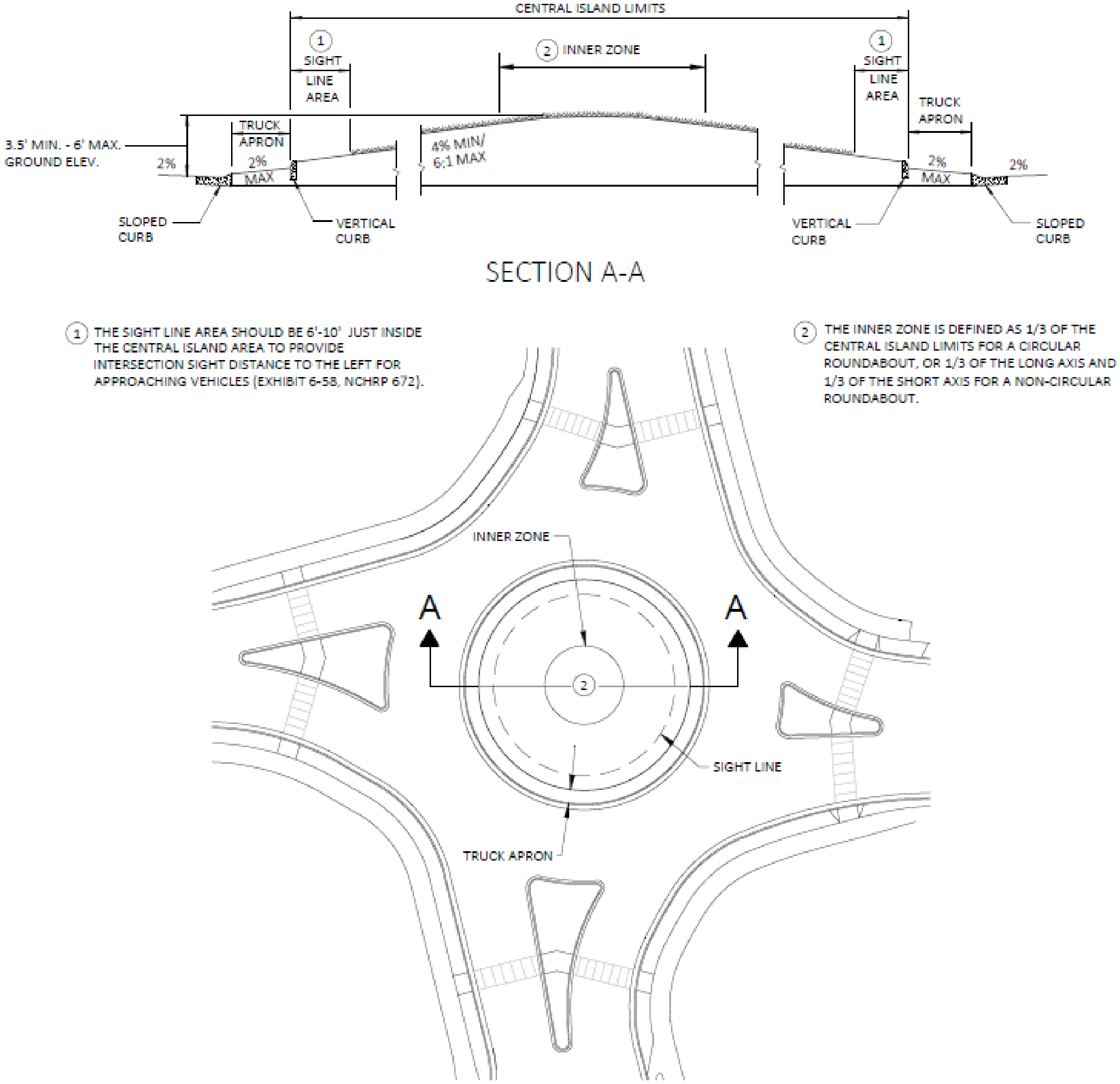

Figure 40.1 – Central Island Landscaping

Refer to Figure 40.1 for the general layout of the central island.

Design the slope of the central island with a minimum grade of 4% and a maximum of 6:1 sloping upward toward the center of the circle. Design the central island area so that the earth surface forms a mound that is a minimum of 3.5-feet to a maximum of 6-feet in height, measured from the circulating roadway surface at the curb flange. Keep the outside 6-10 feet of the central island free from landscape features to provide a minimum level of roadside safety, snow storage, and unobstructed sight distance. In some situations, this central island area may need to maintain a low profile beyond 6-10 feet to allow OSOW vehicle loads to pass over the central island without the axles passing over the central island, (i.e., 165-foot girder, wind turbine parts).

40.1.2 Other Aesthetic Treatments

Under certain conditions, WisDOT will allow a municipality to provide additional, non-standard landscaping and/or aesthetic treatments to the roundabout central island in addition to the earth mounding and low-level plantings. For purposes of determining allowable central island landscaping treatments, two conditions are identified:

- **Condition A - Roundabouts where any of the approach legs have a posted speed greater than 35 mph**

[Note: Tangent interchange exit ramps (e.g., diamond interchange ramps) departing from high-speed freeways and expressways will be considered as having a posted ramp termini approach speed exceeding 35 mph. Designers may consider slower ramp termini approach speeds of 35 mph or less for exit ramps with sharper ramp curvature (e.g., loop ramps) that reduce operational speeds prior to the ramp termini.]

Required central island landscaping for Condition A:
- Earth mounding

Allowable central island landscaping for Condition A:
- Low-level plantings

All other aesthetic treatments are prohibited. This includes, but is not limited to –
- concrete, stone, boulders, or wood walls
- fixed objects, including trees having a mature diameter greater than 4-inches

- **Condition B - Roundabouts where all the approach legs have a posted speed 35 mph or less**

Aesthetic treatments or non-standard design treatments as described below may be considered in the inner zone only (See Figure 40.1). The inner zone is defined as 1/3 of the central island limits for a circular roundabout, or 1/3 of the long axis and 1/3 of the short axis for a non-circular roundabout.

Required central island landscaping for Condition B:
- Earth mounding

Allowable central island landscaping for Condition B:
- Low-level plantings
- In addition to plantings, certain aesthetic treatments or non-standard design treatments (including but not limited to holiday trees, art representing local heritage or other gateway features, etc.) may be considered in the inner 1/3 of the central island area (see Figure 40.1) if all the following conditions are met:
    - The aesthetic treatment must be requested, planned, designed, maintained, and funded by the local municipality/community.
      See HMM 2-15-06 Section 3.1.
        - For proposed roundabouts, the aesthetic treatment could be constructed as part of the improvement project
        - For constructed roundabouts, the aesthetic treatment will be constructed by the municipality/community
    - Any aesthetic feature must be static, i.e., no moving part or parts, including no moving reflector disks.
    - Any sign that a municipality wishes to include within the central island is within state right-of-way and is covered under the provisions of TEOpS 2-1-41.
    - Aesthetic features shall not interfere with any WisDOT traffic signs.
    - Aesthetic features shall not interfere with intersection sight distance or vision corners, including driveways.
    - Any lighting in the island shall be solar powered. If the center traffic island landscaping has solar lighting, the lighting shall not interfere with motorists' vision. Breakaway or yielding lighting materials may be required.
    - Water fountains/features are prohibited. They could cause water on the pavement and/or spray mist, both of which could create a safety hazard for drivers in the circulating roadway. Water service is permitted for irrigation purposes only; not to supply water fountains/ features.
    - Attractions such as street furniture, benches, monuments, historic plaques, etc. are prohibited. They could encourage passersby to go to the central island

thereby possibly distracting drivers from the driving task and endangering pedestrians.

- Includes any seasonal/temporary aesthetic treatments (e.g., holiday trees) which the municipality adds to the central island and subsequently removes according to a set schedule.

40.2 Landscape Design

Landscape design is an important aspect of roundabout operation. Before starting the landscape design first determine the maintaining authority and comply with the intersection sight distance as described in FDM 11-26-30.5.14. More flexibility is allowed on projects that are not maintained by WisDOT.

Low-to-the-ground landscape plantings in the splitter islands and approaches can both benefit public safety and enhance the visual quality of the intersection and the community. In general, unless the splitter islands are very long or wide they should not contain trees, planters, or light poles.

Landscape plantings on the approaches to the roundabout can enhance safety by making the intersection more conspicuous and by countering the perception of a high-speed through traffic movement. Avoid landscaping within 50 feet in advance of the yield point. Plantings in the splitter islands (where appropriate) and on the right and left side of the approaches (except within 50 feet of the yield point) can help to create a funneling effect and induce a decrease in speeds approaching the roundabout. Low profile landscaping in the corner radii can help to channelize pedestrians to the crosswalk areas and discourage pedestrian crossings to the central island.

40.2.1 Owned, Operated, and Maintained by WisDOT

The goal for State-owned and maintained roundabouts is to achieve a landscape design that enhances the safety around the central island and splitter islands with little or no landscape maintenance required over time. Landscape design elements should minimize areas of mulch and the planted vegetation that requires maintenance.

Low maintenance planting plans for roundabout landscapes are required. Vegetation approved for use by the department requires minimum maintenance and has been demonstrated to tolerate highway site conditions.

The central island earth berm may be planted with trees and shrubs, a prairie grass mixture that doesn't require mowing, or both. Plant materials approved for use by the Department, including trees and shrubs listed in FDM 27-25 Attachment 1.3 are approved for use on roundabouts owned, operated and maintained by the Department. Certain native grasses are also approved at roundabouts and are included in the grasses portion of the "Table of Native Seed Mixtures" in Standard Spec 630.

Locations of plant materials shall be selected for salt tolerance and be located to allow for sufficient snow storage in the winter. Snow removal operations typically radiate out from the central island. Plant materials shall not be placed to impede snow removal practices.

The uses of pre-emergent herbicides are recommended for use in plant bed and "hardscape" areas. Follow label instructions provided on the product container for use and application procedures.

Contact the Highway Maintenance and Roadside Management Section in the Bureau of Highway Operations for additional landscape design guidance.

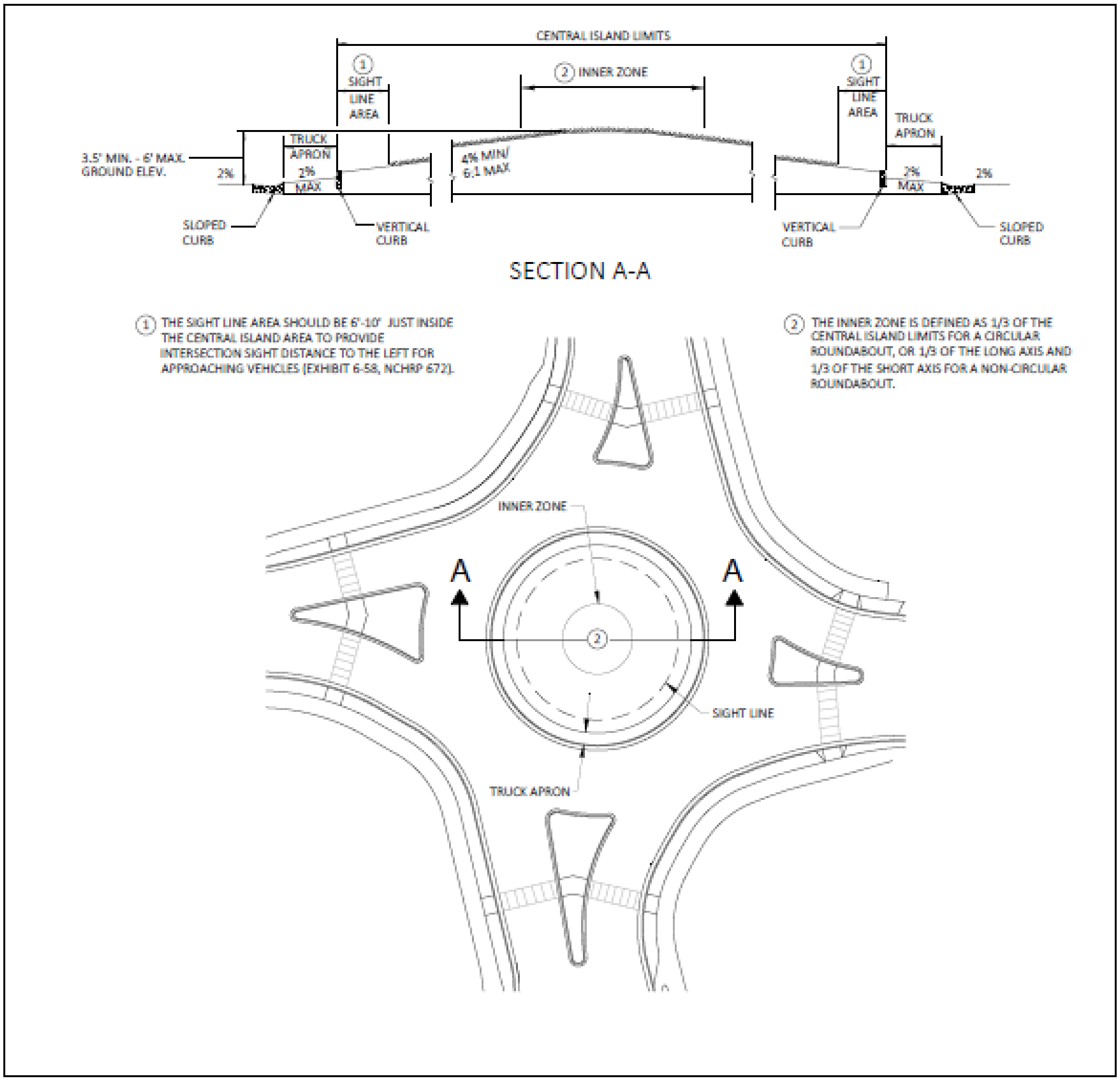

Figure 40.1 Low-Maintenance Central Island Landscaping

40.2.2 Owned by WisDOT but Maintained by Others

Landscape design requests in excess of FDM 11-26-40.2.1.1 will be considered only upon receipt of a formal, signed project agreement prior to design of the facility and are the sole responsibility of the requesting municipality. These agreements are to be obtained in the planning stages of the project.

40.2.3 Local Roads and Connecting Streets

Landscape design costs in excess of department's design criteria described in FDM 11-26-40.2.1.1 on local roads and connecting streets are the sole responsibility of the municipality.

40.3 Landscape Maintenance

Maintenance responsibilities for roundabouts will vary by ownership. Roundabouts are located on the local road system, on connecting state highways, and state highways.

40.3.1 Owned, Operated, and Maintained by WisDOT

All maintenance costs and operations of roundabout landscaping owned, operated and maintained by the department are the responsibility of the department, except as provided below. Landscape design elements and guidance have been outlined to minimize maintenance and operational costs to the department. Plants shown on the approved list have been selected to best meet these needs, FDM 27-25 Attachment 1.3. FDM 11-26-30 and Figure 40.1 provide detailed layout dimensions of the area to be planted within the central island area.

Only those landscape maintenance operations necessary to maintain the safe operation of the department roundabout will be undertaken.

40.3.2 Owned by WisDOT but Maintained by Others

Municipalities often request special landscaping. Landscape requests in excess of requirements contained in FDM 11-26-40.2.1.1 are the responsibility of the requesting municipality. Such requests will be considered only upon receipt of a formal, signed municipal agreement approved by the department prior to the design of those roundabouts. This procedure shall be completed early in the planning stages of project development.

40.3.3 Local Roads and Connecting Streets

Maintenance and operating costs of roundabouts located on local roads and connecting streets are the responsibility of the local government.

40.4 Shared-Use Path Maintenance

For urban, suburban, outlaying and rural locations for roundabouts, a roundabout sidepath or shared-use path is provided accordingly; see FDM 11-26-30.5.13. Facilities may be omitted if conditions are met as described in FDM 11-46-1. Appropriate cost share policies apply and maintenance agreements with the local unit of government are required, unless refusal to maintain omission conditions are met see FDM 11-46-1. If conditions are met to omit facilities, grading for future facilities apply as detailed in FDM 11-26-30.5.13 and cut-through crossing are to be provided in splitter islands. The cost of the path installation and maintenance after the original roadway improvement is the responsibility of the local unit of government. There have been situations where land uses change, the local government leaders change, attitudes about such improvements change, or that pedestrian or bicycle volumes increase over time, and later there is a strong desire to install the path.

FDM 11-26-45 Work Zone Traffic Control *March 28, 2014*

45.1 Work Zone Traffic Control

Roundabouts pose unique challenges when maintenance work is performed in or around these facilities. Each roundabout is unique so develop the traffic control plan to meet the specific conditions of the location, traffic volumes, duration, and work operation. Consider detour and staging as alternatives since they may provide better service for traffic movement.

During the design of temporary traffic control in roundabout work zone it is essential that the intended travel path for motorists, bicyclists, and pedestrians is clearly identifiable. Ensure turning radii can accommodate tractor-trailer vehicles. SDD 15D21 and SDD 15D31 show example device spacing at turning radii and curve transitions. Accomplish this through the temporary traffic control part 6 of WMUTCD

https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/wmutcd/mutcd-ch06.pdf

compliant traffic control channelizing devices, signing, delineation, and temporary pavement markings. There are occasions when guidance may be provided by law enforcement personnel or using flagging operation depending on the complexity of the work in the roundabout. Schedule work during off-peak hours to minimize traffic within the roundabout if feasible. A roundabout is not designed to hold stopped or waiting traffic during roadwork. Flagging or a detour may be required if it is likely that work may block traffic from using the circular roadway of a roundabout. Notify emergency services and law enforcement if work is anticipated to cause delays.

SDD 15D37 provides general guidance on the signing and device requirements for maintenance work in and around a roundabout location.

Work in a roundabout may involve any of the situations listed below.

- If work is within the roundabout, initial advance warning (ROAD WORK AHEAD) signs are required for each approach leg.
- If work occurs within the roundabout island and all work vehicles are out of the travel lanes and center island apron, a single “ROAD WORK AHEAD” sign is required per approach.
- If any of the roadway approaches cannot access the intersection due to workspace, a detour may be required. For short closures of less than 15 minutes or less, traffic may be held in place.
- If the center island apron will be impacted by the work or equipment, treat it as a shoulder closure for the duration of the work but consider diverting semi-trailer truck traffic due to large vehicle wheel tracking.
- If work occurs in an approach leg, a minimum of two flaggers should be used to control traffic. High approach volumes may require additional flaggers in the remaining legs. Use the “ROAD WORK AHEAD, BE PREPARED TO STOP” and the Flagger symbol signs in advance of each leg.
- If travel width of at least 10’ can be maintained for shoulder work on an approach lane, the lane can remain open to traffic. Close the workspace with shoulder taper and tangent cones/drums. An initial advance sign and a “SHOULDER (SIDEWALK) CLOSED” sign are required unless the work lasts less than 15 minutes.

- If work is in a multi-lane roundabout, and work can be done without closing both travel lanes, flaggers may not be needed. Appropriate signs for the lane closure at each entry are required. Merge traffic into one lane prior to entry into the roundabout. See the details in SDD 15D12 and part 6 of the WMUTCD
https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/wmutcd/mutcd-ch06.pdf
for merging details.
- If the splitter islands are raised, cones may not be needed along the approaches. In these situations, the flagger may have to move ahead on the splitter island so that traffic can maneuver into the roundabout.

When establishing the limits of the work zone ensure maximum possible sight distance to the flagger station, based on the posted speed limit. Motorists should have a clear line of sight from the flagger symbol sign to the flagger.

If sidewalks are impacted, provide a detour or temporary walkway that is a smooth, continuous hard surface (firm, stable and slip resistant) throughout the entire length of the temporary walkway. The following examples are typical work activities expected to occur in/around a roundabout.

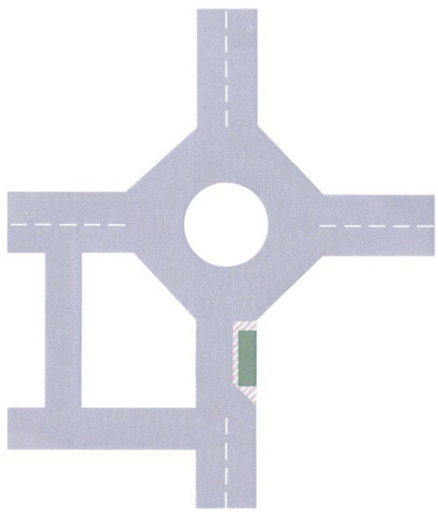

***Figure 45.1* Work Zone at Entrance to Roundabout**

Case A - Work Zone at the Entrance to a Roundabout

Two-way traffic should be maintained if possible. If not, entering traffic should be stopped using a flagger or a detour route provided.

In the case of a work zone illustrated in Figure 45.1, use channelizing devices to direct traffic to the proper travel path and restrict traffic to one lane going towards the roundabout. Advance warning signs “ROAD WORK AHEAD, NARROW LANES (if lanes are less than 10’), barricade with Lane Closed signs should be used. If no suitable detours are available, it may be necessary to adopt an alternating one-way layout.

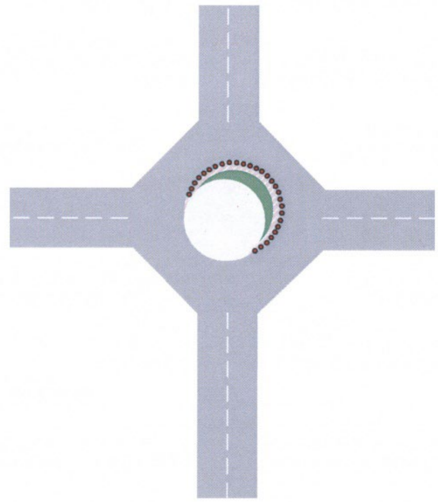

***Figure 45.2* Work Zone in the Circulatory Area of a Roundabout**

Case B - Work Zone in the Circulatory Area of a Roundabout

If possible, maintain all movements. Separate the work area from traffic using channelizing devices and advance warning sign such as “ROAD WORK AHEAD.”

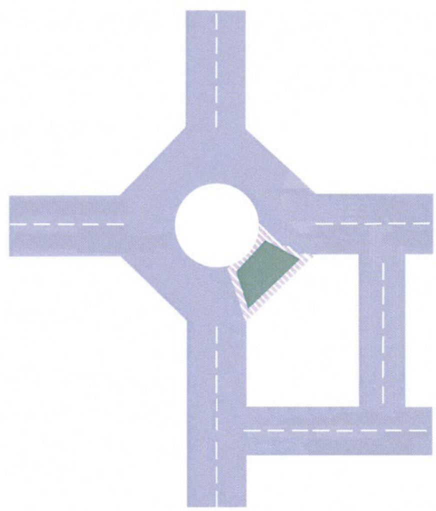

***Figure 45.3* Work Zone Completely Obstructing the Circulatory Area of a Roundabout**

Case C - Work Zone Completely Obstructing the Circulatory Area of a Roundabout

Refer to Figure 45.3 and the traffic control, 2-lane roundabout information in SDD 15D37.

At night, flagger stations should be illuminated except in emergencies. Portable changeable Message Signs should be considered as part of the traffic control plan to provide clear guidance to motorists on all approaches of the roundabout.

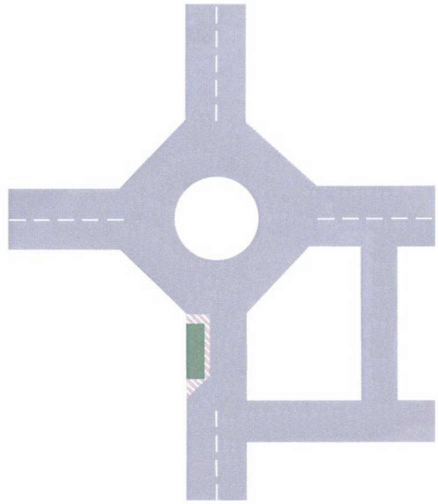

Figure 45.4 ***Work Zone at the Exit from a Roundabout***

Case D - Work Zone at the Exit from a Roundabout

Channelize traffic around the work area using appropriate channelizing devices. Provide buffers space if roadway width allows. Two-way traffic past the work area should be maintained if possible, otherwise the road should be operated as an exit only from the roundabout, and a signed detour route provided.

45.1.1 Pavement Markings

Because of the confusion of a work area and the change in traffic patterns, pavement markings must clearly show the intended travel path. Misleading pavement markings shall be removed or covered in accordance with the Wisconsin Standard Specifications. As new pavement courses are placed consider specifying in the plans that splitter island delineation and broken white lines on the outside edge of the circulatory roadway be marked the same day the pavement course is placed according to Wisconsin Standard Specifications. When pavement markings are not practical, or misleading markings cannot be adequately deactivated, use closely spaced channelizing devices to define both edges of the travel path. When possible, pavement markings used within the work zones should be the same layout type and dimension as those to be used in the final layout. Additional pavement markings may be necessary to avoid confusion from changing traffic patterns used in staging.

45.1.2 Signing

Construction signing for a roundabout should conform to the WMUTCD and the Standard Detail Drawings. Provide all necessary signing for the efficient movement of traffic through the work area, including pre-construction signing advising the public of the planned construction, and any regulatory and warning signs necessary for the movement of traffic outside of the immediate work area. The permanent roundabout signing may be installed, where practicable, during the first construction stage so that it is available when the roundabout is operable, but these signs must be covered until they are needed. Consider using portable changeable message signs when traffic patterns change.

45.1.3 Lighting

Illuminate the temporary construction area through the intersection where possible. Consider adjacent lighting conditions, traffic volumes during the evening when the roundabout is illuminated, and mixture of use such as pedestrians and trucks.

45.1.4 Construction Staging

The Transportation Management Plan, FDM 11-50-5, will consider detouring traffic away from the intersection during construction of the project. A detour will significantly reduce the construction time and cost, increase the safety of the construction personnel and will provide for an overall better finished product

It is typical to complete construction as soon as possible to minimize the time the public is faced with an unfinished layout or where the traffic priority may not be obvious. If possible, all work, including the installation of splitter islands and pavement marking, should be done before the roundabout is open to traffic.

If it is not possible to detour all approaches, detour as many approaches as possible. Carefully consider construction staging during the design of the roundabout if it must be built under traffic. Minimize the number of stages if at all possible. Staging should accommodate the design vehicle and maintain sightlines.

Prior to the work that would change the traffic patterns to that of a roundabout, certain peripheral items may be completed including permanent signing (covered), lighting, and some pavement markings that reflect actual conditions. These items, if installed prior to the construction of the central island and splitter islands, would expedite the opening of the roundabout and provide additional safety during construction.

As is the case with any construction project, install appropriate traffic control devices as detailed in the project plans and the Standard Specifications. This traffic control shall remain in place as long as it applies and be removed when it no longer applies to the condition. Maintain consistent traffic control; do not change between stop and yield control multiple times during construction.

Stage the construction as follows unless a different staging plan is approved during design:

- Install and cover proposed signing
- Remove or mask pavement markings that do not conform to the intended travel path
- Construct outside widening if applicable
- Reconstruct approaches if applicable
- Construct splitter islands and delineate the central island. Uncover the signs at this point and operate the intersection as a roundabout
- Finish construction of the central island

If it is necessary to leave a roundabout in an uncompleted state overnight, construct the splitter islands before the central island. Any portion of the roundabout that is not completed must be marked, delineated, and signed in such a way as to clearly outline the intended travel path. Remove or mask pavement markings that do not conform to the intended travel path. Consider adding temporary lighting if the roundabout will be used by traffic in an unfinished state overnight or install the permanent lighting that is in operational condition.

45.1.5 Public Education

The Transportation Management Plan, FDM 11-50-5, will advise the public whenever there is a change in traffic patterns. Education and driver awareness campaigns are especially important for a roundabout because a roundabout will be new to most motorists. The Regional Communication Manager coordination through both design and construction is typically vital to the success of a project. Provide brochures on how to drive, walk and bicycle through a roundabout. The following are some specific suggestions to help alleviate initial driver confusion:

- Hold public information meetings prior to construction
- Prepare news releases/handouts detailing what the motorist can expect before, during, and after construction
- Consider the creation of a project website, flash animation graphics, traffic simulation recording (such as Paramics, etc.) or the use of social media before and during construction
- Install portable changeable message signs or fixed message during construction and before construction begins. Advise drivers of anticipated changes in traffic patterns for about one week prior to the implementation of the new pattern.
- Use Wisconsin 511, news media (and Highway Advisory Radio, if available) to broadcast current status of traffic patterns and changes during construction. Also, if appropriate, establish a web site, to post up-to-date traffic and construction information.

45.99 References

1. Federal Highway Administration (2009), Manual on Uniform Traffic Control Devices, (MUTCD), U.S. Department of Transportation, Washington, D.C.
2. Washington State Department of Transportation, Work Zone Traffic Control Guidelines, M54-44.04, February 2012, http://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf.
3. American Traffic Safety Services Association (ATSSA), Temporary Traffic Control for Building and Maintaining Single and Multi-Lane Roundabouts, November 2012
4. Oregon Department of Transportation, “Temporary Traffic Control Handbook for Operations of Three Days or Less,” December 2011.
5. Maryland Department of Transportation, State Highway Administration; “Work Zone Traffic Control, Roundabout Flagging Operation Greater than 40 MHP/Over24 hrs.”

FDM 11-26-50 Design Aides — *June 24, 2016*

50.1 Example Plan Sheets

Several example plan sheets of the above information have been provided as an aide to the designer when completing roundabout plans. The plan sheets provided are examples and should only be used as guidance. FDM 11-26 File 1 is a .pdf of the various plan sheets. The PDF attached has bookmarks for the various plan sheets as noted above to assist you in viewing the sheets.

- Project Overview
- Typical Section
- Construction Details
- Pavement Elevation (Concrete)
- Pavement Elevation (Asphalt)
- Erosion Control
- Storm Sewer
- Landscaping
- Permanent Signing
- Lighting
- Pavement Marking
- Construction Staging
- Plan and Profile
- Cross-Sections

50.2 Creating Roundabout Fastest Paths (B-spline Curves) and Using AutoTurn software

Spline curves can be created in both AutoCAD and MicroStation. In AutoCAD, they are called polylines and in MicroStation they are called B-spline curves.

Instructions for creating roundabout fasted paths B-spline in AutoCAD 3D is in Attachment 50.1, and for creating roundabout fasted paths B-spline in Microstation Version 8i is in Attachment 50.2.

Instructions for using AutoTurn software in AutoCAD Civil 3D and MicroStation is in Attachment 50.3.

50.3 OSOW Vehicle Inventory Evaluation Overview

Use AutoTurn, AutoTurn Pro 3D or Autodesk Vehicle Tracking (AVT) software for OSOW horizontal evaluation with the exception of the Wind Tower 80M MID and Wind Tower 205'. For these vehicles, only use AutoTurn or AutoTurn Pro 3D. Use AutoTurn Pro 3D or Autodesk Vehicle Tracking for low clearance evaluation (DST lowboy). Refer to these links for videos and assistance in using these tools.

This is the link to the AutoTurn Pro 3D tutorial videos:

http://www.c3dkb.dot.wi.gov/Content/c3d/dsn-chk/swept-pth/swept-pth-grnd-clrnc.htm

Refer to FDM 11-25 Attachment 2.1 for OSOW vehicle inventories. Additionally, refer to FDM 11-25-2.1.1.3 for OSOW vehicle inventory evaluations overview for further guidance in evaluating the OSOW vehicle tracking.

LIST OF ATTACHMENTS

Attachment 50.1	Creating Roundabout Fastest Paths (Spline Curves) in AutoCAD Civil 3D
Attachment 50.2	Creating Roundabout Fastest Paths (Spline Curves) in Microstation Version 8i
Attachment 50.3	Guide for Using AutoTURN in AutoCAD Civil 3D and MicroStation Version 8i

FDM 11-26-55 Roundabout In-service Reviews and Crash Reduction Countermeasures *May 17, 2022*

55.1 In-service Reviews and Crash Reduction Countermeasures

WisDOT conducts network screening for intersections on the state trunk network on a routine basis to determine sites where the number of crashes are higher than expected, which may lead to further review. The department has conducted in-service reviews of roundabouts and found common countermeasures that could be implemented to improve the safety performance. These common countermeasures are listed in FDM 11-38 Attachment 10.3.