Traffic Engineering and Highway Safety Bulletin 20-04
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Roundabout Planning

In This Issue…

Overview

Roundabouts are a subset of circular intersections that conform to specific geometric design criteria that promotes driver awareness, reduced traffic speeds, and improved traffic flow.

Roundabouts are a subset of various forms of circular intersections. Other circular intersections include rotaries and neighborhood traffic circles; however these should not be confused with roundabouts since they do not offer the same horizontal deflection characteristics and may even be uncontrolled. **Key roundabout features include yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically 25 mph or less. Also, traffic travels counterclockwise around a central island through the roundabout. At roundabouts, all approaches are given equal priority.**

Roundabouts conform to specific geometric design criteria that promotes driver awareness, reduced traffic speeds, and improved traffic flow. Since each approach to the roundabout is essentially an intersection with a one-way street, only right turns are allowed, and the driver is no longer delayed by traffic flow from two directions.

Since roundabouts promote slower speeds due to the diversion in travel path, crashes that occur within roundabouts are less severe. Right angle and head-on crashes are also eliminated due to the one-way configuration and approach angle.

Roundabouts can range from a very simplistic single-lane design to complex double lane configurations. Single-lane designs are rather straightforward because of one travel path for all traffic. Multi-lane roundabouts require drivers to appropriately choose the correct lane in advance of the roundabout and then drivers may need to switch lanes once inside the roundabout (depending on their destination).

The key features of a typical roundabout are illustrated in figure 1 on the following page. This bulletin discusses roundabouts at a planning level with the intent of providing an awareness of the use of roundabouts.

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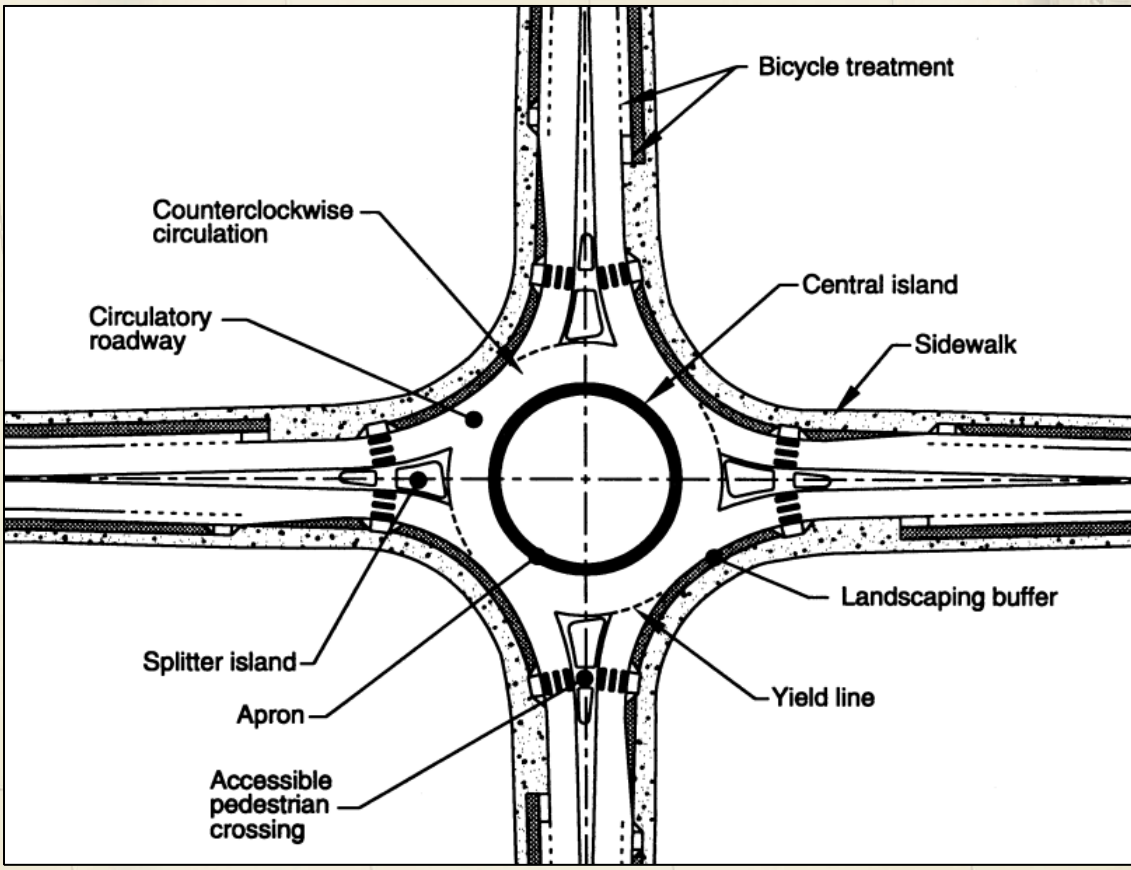
Figure 1 – Roundabout Diagram and Key Features



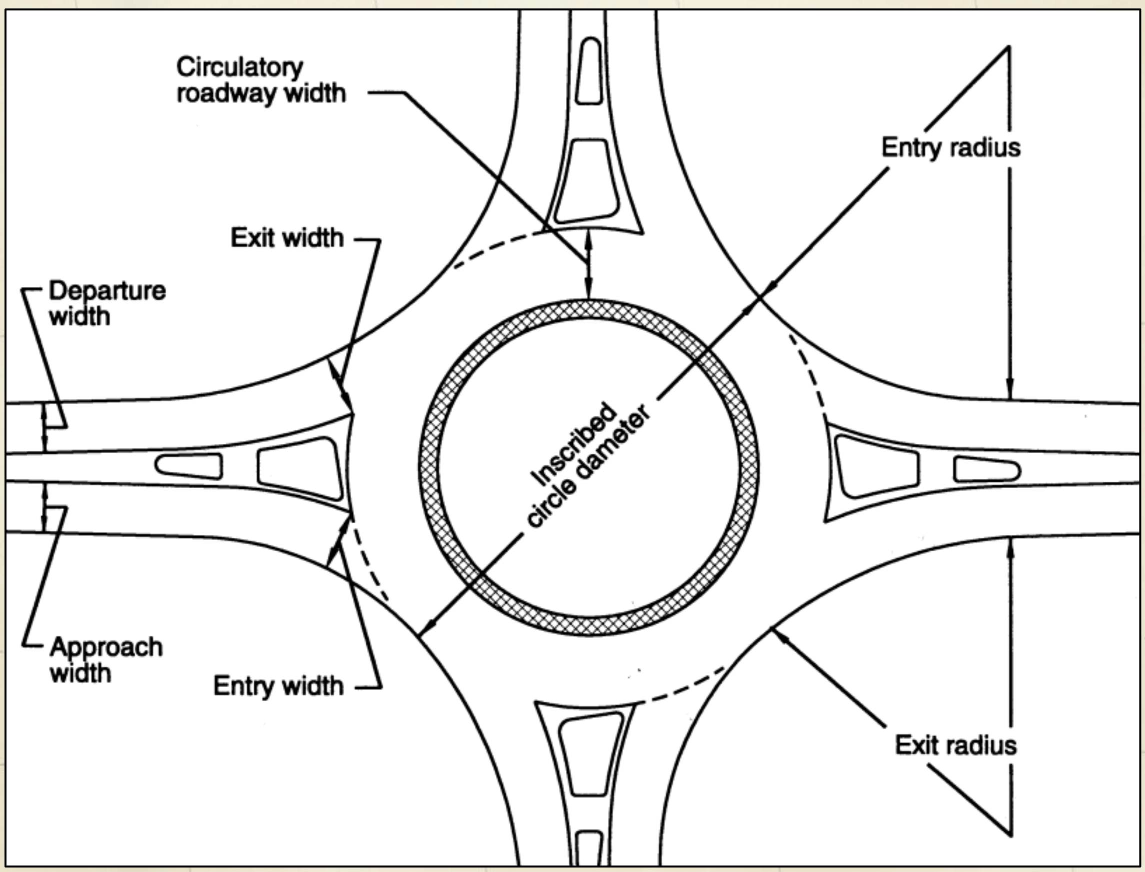


Image Source: https://www.fhwa.dot.gov/publications/research/safety/00067/00067.pdf

Roundabout Selection

Intersection control types such as all-way stop-controlled and signalized intersections have specific criteria (i.e., warrants) outlined in the *Manual on Uniform Traffic Control Devices* (MUTCD) based on traffic conditions, pedestrian characteristics, and physical characteristics of the locations. There is no such established criteria for when to select a roundabout for control of intersecting roadways. Instead, it is recommended that roundabouts should be considered in, but not limited to, any of the following circumstances:

- ☑ When traffic signal warrants are not met and stop control (two-way or all-way) provides inadequate operations
- ☑ At existing signalized intersections, where operations are inadequate, or a crash problem exists (and a roundabout would be a potential solution to reduce the types of crashes occurring)
- ☑ Where there is a desire to control speeds
- ☑ Where there is significant conflict between left-turn traffic versus through traffic
- ☑ Where there are vertical restrictions, such as near a runway clear zone area at an airfield
- ☑ Where the local region is already familiar with roundabouts.

While detailed analysis should be performed as part of the planning process for evaluating any form of traffic control, figure 2 below compares when single or double lane roundabouts may be appropriate.

If the volumes fall within the ranges identified in figure 2 as "additional analysis needed," a single-lane or two-lane roundabout may still function acceptably, but a closer look at the actual turning-movement volumes during the design hour is required. The procedure for such analysis is presented in the 2010 Highway Capacity Manual, Chapter 21.

A roundabout can be a candidate where traffic signal warrants are not met but where unsignalized operations are unsatisfactory. With roundabouts, all approaches are treated equally. Versus, with a two-way stop controlled intersection, one roadway is designated as the major road and the other as a minor where the minor roadway approaches must stop for the major traffic flows. Because all approaches of a roundabout are equal, the minor roadway is not delayed for traffic on the major street. With all-way stop control, where the volumes on the intersecting roadways should be similar and all approaches must stop, the busier approach may queue regularly. The confusion over who has the right of way can increase delay. With roundabouts, since the entrance to a roundabout is yield-controlled versus stop-controlled, and traffic moves continuously, queues are less common.

Figure 2 – Planning Level Daily Intersection Volumes

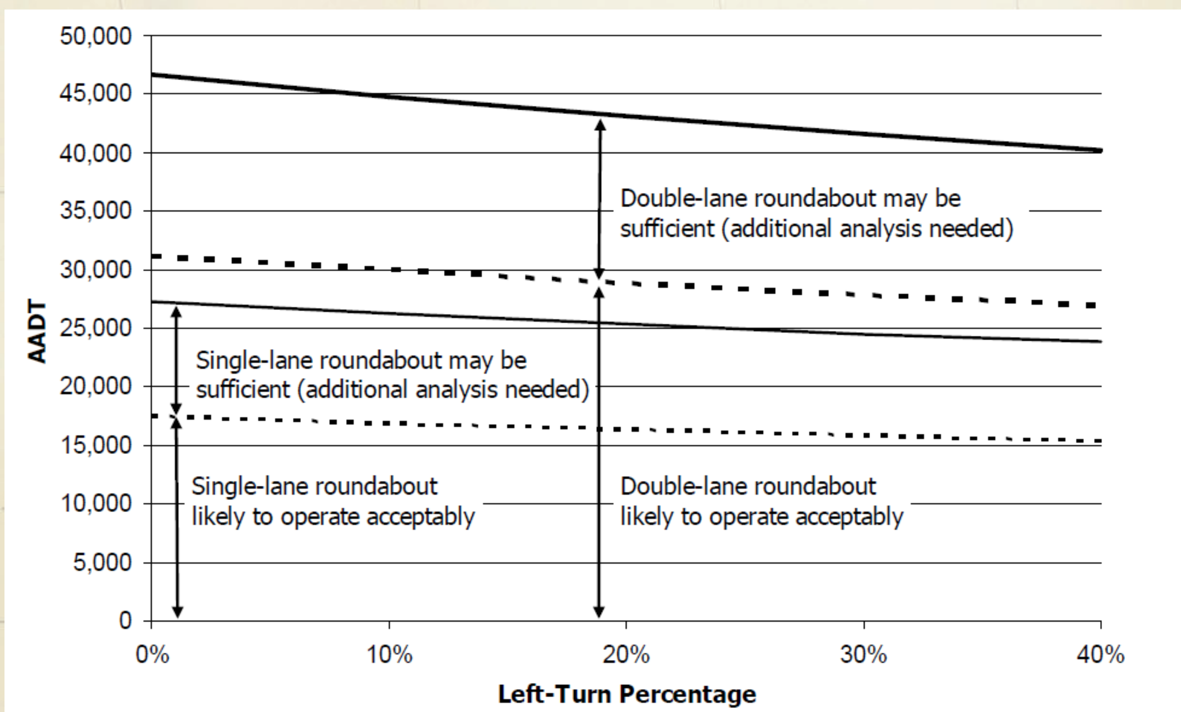


Image source: http://virginiadot.org/business/resources/4-Roundabout_Design_Guidance.pdf

Roundabouts are generally ideal where approach traffic volumes for all approaches are similar in volume. When volumes are balanced across all approaches, roundabouts can service the traffic by treating all approaches equally without delays as can occur at all-way stop or at signals.

Roundabouts can also have advantages over signalized intersections in some situations. Signals can have more capacity than roundabouts when enough lanes are present; but, in the absence of auxiliary lanes, roundabouts may have higher capacity. Additionally, roundabouts can be preferable when traffic volume patterns vary by day or season. When signals have defined timing plans, variations in traffic from that for which the timings are designed can lead to inefficiencies.

Roundabouts slow traffic by deflecting the vehicle's travel path upon entry, and are geometrically designed to reduce vehicle speeds to generally 25 mph or less. Vehicles must slow to enter a roundabout, thereby serving as a means to calm traffic. The slower speeds can reduce crash severity.

At traditional intersections, whether they be signalized or unsignalized, left-turns and opposite direction through traffic can lead to conflicts and delays. When these volumes are significant, left-turn drivers can be prone to accepting unsafe gaps in the traffic stream. Additionally, left-turn traffic can delay through traffic in the same direction if a left-turn lane is not present for a sufficient length. Roundabouts can mitigate this, provided the capacity of the roundabout is not exceeded.

With traffic signals, the mast arms are overhead structures. While rare, there are cases (particularly on military bases) where intersections are located so closely to flightlines that the location falls within the runway clear zone or the graded approach, where vertical restrictions exist. In this case, the traffic signal mast arms exceed the height limit. Since roundabouts have no vertical components other than signing, they may be a solution to this vertical limitation.

When roundabouts are new to an area, they often encounter community resistance, largely due to unfamiliarity. After a roundabout opens and communities learn how to properly navigate them and become accustomed to them, the community accepts them positively, and often wants them constructed in more locations.

Roundabout Safety

Roundabouts are documented to have lower crash rates than traditional intersections. Furthermore, crashes that do occur are less severe than at traditional intersections since speeds are lower and all turns are right turns. Figure 3 illustrates the conflict points at a conventional, four-legged intersection and also at an equivalent single lane roundabout. There are 32 conflict points associated with a conventional intersection – 8 merging (or joining), 8 diverging (or separating), and 16 crossing. In contrast, there are only 8 total conflict points at an equivalent roundabout – 4 merging and 4 diverging. Not only are conflict greatly reduced with a roundabout, the type of conflicts that remain are the same-direction variety – resulting in substantially less severe crashes and a lower likelihood of injury. The reduction of conflict points and crash severity is also true for pedestrians.

Figure 3 – Vehicle Conflict Point Comparison

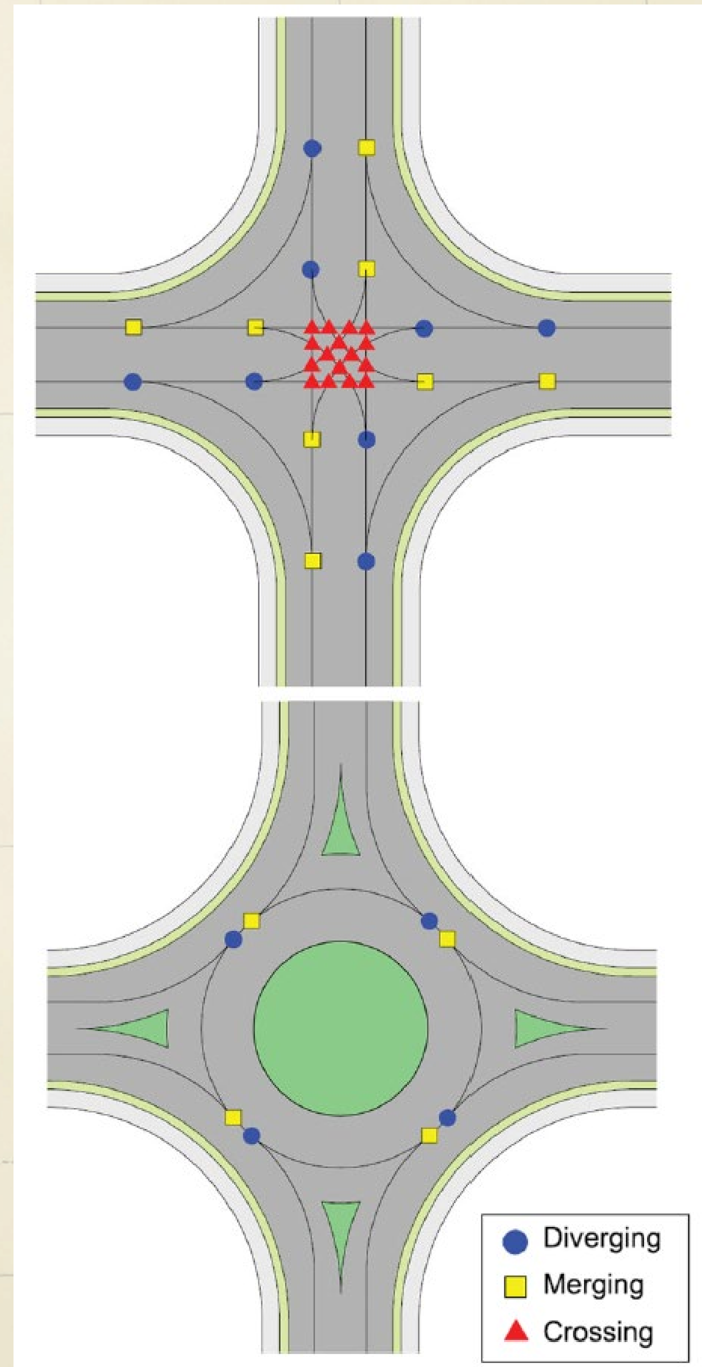


Image source: SDDCTEA Pamphlet 55-17, Exhibit 10.3, reformatted.

The Pennsylvania Department of Transportation (PennDOT) studied roundabout safety (comparing roundabouts to intersections controlled by traffic signals) and determined the following:

- ☑ Roundabouts have a 90 percent reduction in fatal crashes
- ☑ Roundabouts have a 75 percent reduction in injury crashes
- ☑ Roundabouts have a 30-40 percent reduction in pedestrian crashes
- ☑ Roundabouts have a 10 percent reduction in bicycle crashes.

In September 2020, PennDOT released data for 22 roundabouts on state routes at intersections that were previously stop- or signal-controlled. The roundabouts were reviewed based on having at least 3 years of data available before and after construction. These 22 roundabouts comprised all the roundabouts on state routes that met the review parameters. Department data based on police-submitted crash reports spanning the years 2000 through 2019 showed the following:

- ☑ Fatalities were reduced by 100 percent
- ☑ Suspected serious injuries were reduced by 77 percent
- ☑ Suspected minor injuries were reduced by 57 percent
- ☑ Possible/unknown severity injuries were reduced by 82 percent
- ☑ Crashes causing only property damage increased by 21 percent
- ☑ The total number of crashes dropped 21 percent.

These findings are similar to those found by other agencies. The Federal Highway Administration (FHWA) Office of Safety identified roundabouts as a Proven Safety Countermeasure because of their ability to substantially reduce the types of crashes that result in injury or loss of life. Per the American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual*, as compared to conventional stop-controlled and signalized intersections, a 78-82% reduction in fatal and serious injury crashes is achieved by roundabouts. Roundabouts are designed to improve safety for all users, including pedestrians and bicyclists.

Roundabouts and Speed Control

As mentioned earlier, roundabouts slow traffic by deflecting the vehicle's travel path. An appropriately designed roundabout with raised channelization forces vehicles to physically change direction, making it difficult for drivers to speed. Roundabouts can be used effectively at the interface between rural and urban areas where speed limits change.

Per FHWA, the desirable maximum entry speeds for the various types of roundabouts are:

- ☑ Mini-roundabouts: 15 mph
- ☑ Urban compact roundabouts: 15 mph
- ☑ Urban single-lane roundabouts: 20 mph
- ☑ Urban double-lane roundabouts: 25 mph
- ☑ Rural single-lane roundabouts: 25 mph
- ☑ Rural double-lane roundabouts: 30 mph.

Roundabout operational performance is best with low, consistent vehicle speeds. Low and consistent speeds facilitate appropriate gap acceptance by drivers entering the roundabout. Travel path operating speeds should be designed for between 15 mph and 30 mph, as noted above based on the type of roundabout. Low-speed differentials (12 mph or under) between entering and circulating traffic is ideal. Double lane roundabouts might have higher speeds along their respective travel paths, but generally 30 mph or less.

The ideal design speed would be such that the entry and circulating speeds are similar. The actual speed varies based on the size, shape and context of the roundabout. As the vehicle travels into and through the circulation lane, the design speed of the circulating lane controls the speed. The circulating design speed controls the exit speed; therefore, the exit design speed is not as critical.

Designing geometric entry speed control encourages lower speeds and lower speed differentials at conflict points, which reduces the potential for collisions.

These different types of roundabouts are appropriate on different types of roadways. A compact roundabout may be appropriate in residential areas, where lower speeds are desired. If residential areas have posted speed limits of 25 mph, a reduction to 15-20 mph is appropriate. Single lane roundabouts would calm traffic speeds on collectors and arterials with speeds of 35 mph or greater, as would be the case with double lane roundabouts.

Traffic calming is often needed on roadways not intended to be a major through route. In this situation where a roadway is used as a "cut-through", a roundabout can serve as a traffic calming method. Using roundabouts along the "cut-through" path requires traffic to slow and may deter some motorists from using the route.

Roundabout Categories

As presented in the previous section, there are six primary categories of roundabouts, which are based on environment, number of lanes, and size.

Figure 3 below summarizes considerations for these categories. Each of the categories have distinct features, as described in the following paragraphs.

Figure 3 – Roundabout Category Comparison

Design Element	Roundabout Categories					
	Mini-Roundabout	Urban Compact	Urban Single-Lane	Urban Double-Lane	Rural Single-Lane	Rural Double-Lane
Recommended maximum entry design speed	15 mph	15 mph	20 mph	25 mph	25 mph	30 mph
Maximum number of entering lanes per approach	1	1	1	2	1	2
Typical inscribed circle diameter	45' - 80'	80' - 100'	100' - 130'	150' - 180'	115' - 130'	180' - 200'
Splitter island treatment	Raised if possible, crosswalk cut if raised	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised and extended, with crosswalk cut	Raised and extended, with crosswalk cut
Typical daily service volume on 4-leg roundabout (veh/day)	10000	15000	20000	*	20000	*

*Service volumes not documented for double lane roundabouts in *Roundabouts, An Informational Guide*, FHWA.

Mini-roundabouts

Mini-roundabouts are small roundabouts used in low-speed urban environments, with average operating speeds of 35 mph or less. Figure 4 provides an example of a typical mini-roundabout. They can be useful in low-speed urban environments in cases where conventional roundabout design is precluded by available land. In retrofit applications, mini-roundabouts are relatively inexpensive because they typically require minimal additional pavement at the intersection roads – for example, minor widening at the corner curbs. They are mostly recommended when there is insufficient right-of-way for an urban compact roundabout. Because they are small, mini-roundabouts are perceived as pedestrian-friendly with short crossing distances and very low vehicle speeds on approaches and exits. The mini-roundabout is designed to accommodate passenger cars without requiring them to drive over the central island. To maintain its perceived compactness and low speed characteristics, the yield lines are positioned just outside of the swept path of the largest expected vehicle. However, the central island is mountable, and larger vehicles may cross over the central island, but not to the left of it. Speed control around the mountable central island should be provided in the design by requiring horizontal deflection. Capacity for this type of roundabout is expected to be similar to that of the urban compact roundabout.

Figure 4 – Mini Roundabout

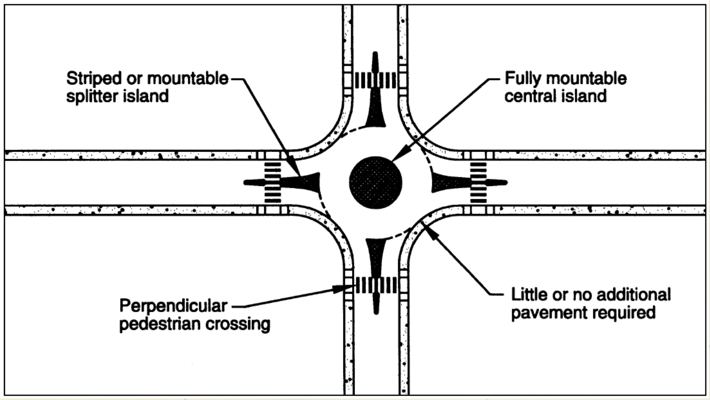
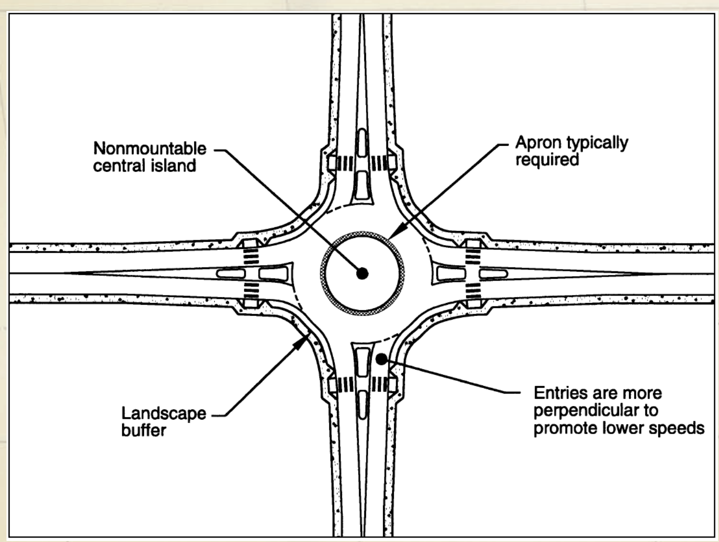


Image Source: Section 1.6 of FHWA publication "Roundabouts: An Informational Guide" Publication Number FHWA-RD-00-067

Urban compact roundabouts

Like mini-roundabouts, urban compact roundabouts are intended to be pedestrian and bicyclist friendly because their perpendicular approach legs require very low vehicle speeds to make a distinct right turn into and out of the circulatory roadway. All legs have single-lane entries. However, the urban compact treatment meets all the design requirements of effective roundabouts. The principal objective of this design is to enable pedestrians to have safe and effective use of the intersection. Capacity should not be a critical issue for this type of roundabout to be considered. The geometric design includes raised splitter islands that incorporate at-grade pedestrian storage areas, and a nonmountable central island. There is usually a (truck) apron surrounding the nonmountable part of the compact central island to accommodate large vehicles. Figure 5 provides an example of a typical urban compact roundabout.

Figure 5 – Urban Compact Roundabout



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Urban single-lane roundabouts

This type of roundabout is characterized as having a single-lane entry at all legs and one circulatory lane. The figure below provides an example of a typical urban single-lane roundabout. They are distinguished from urban compact roundabouts by their larger inscribed circle diameters and more tangential entries and exits, resulting in higher capacities. Their design allows slightly higher speeds at the entry, on the circulatory roadway, and at the exit. The speed ranges recommended for this type of roundabout are intended to enhance safety for bicyclists and pedestrians. The roundabout design is focused on achieving consistent entering and circulating vehicle speeds. The geometric design includes raised splitter islands, a nonmountable central island, and preferably, no apron as shown on figure 6.

Figure 6 – Urban Single Lane Roundabout

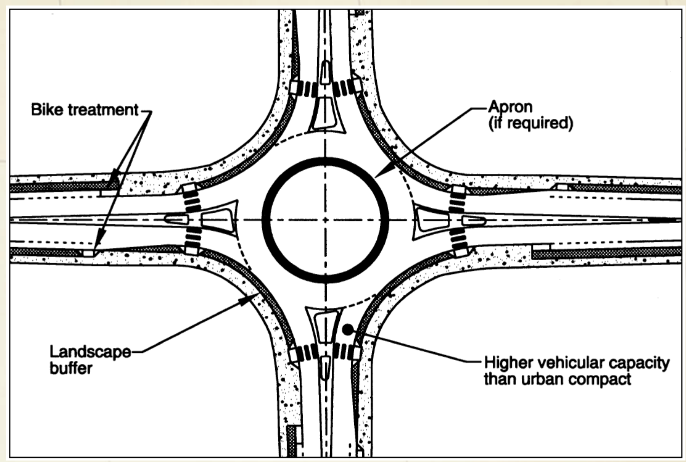


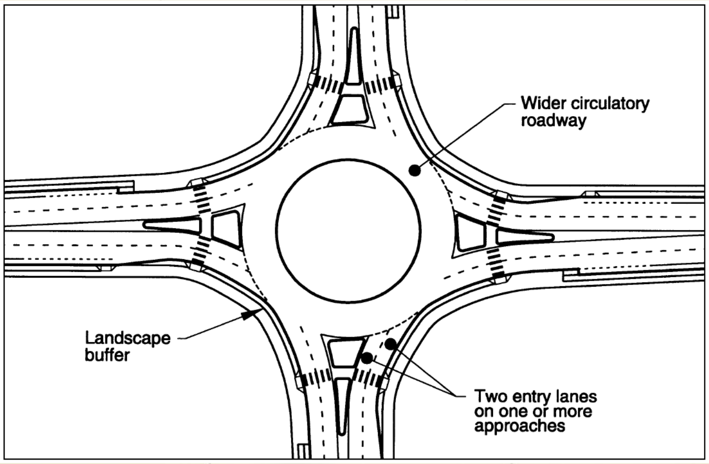
Image Source: Section 1.6 of FHWA publication "Roundabouts: An Informational Guide" Publication Number FHWA-RD-00-067

Urban double-lane roundabouts

Urban double-lane roundabouts include all roundabouts in urban areas that have at least one entry on one or more approaches that flare from one to two lanes. These require wider circulatory roadways to accommodate more than one vehicle traveling side by side. Figure 7 provides an example of a typical urban double-lane roundabout. The speeds at the entry, on the circulatory roadway, and at the exit are similar to those for the urban single-lane roundabouts. As with most categories, it is important that the vehicular speeds be consistent throughout the roundabout. The geometric design must include raised splitter islands, no truck apron, a nonmountable central island, and appropriate deflection.

Alternate routes may be provided for bicyclists who choose to bypass the roundabout. Bicycle and pedestrian pathways must be clearly delineated with sidewalk construction and landscaping to direct users to the appropriate crossing locations and alignment. Urban double-lane roundabouts located in areas with high pedestrian or bicycle volumes may have special design recommendations such as those provided in the FHWA publication.

Figure 7 – Urban Double Lane Roundabout



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Rural single-lane roundabouts

Rural single-lane roundabouts generally have high average approach speeds in the range of 50-60 mph. They require supplementary geometric and traffic control device treatments on approaches to encourage drivers to slow to an appropriate speed before entering the roundabout. Rural roundabouts may have larger diameters than urban roundabouts to allow slightly higher speeds at the entries, on the circulatory roadway, and at the exits. This is possible if few pedestrians are expected at these intersections, currently and in the future. There is preferably no apron because their larger diameters should accommodate larger vehicles. Supplemental geometric design elements include extended and raised splitter islands, a nonmountable central island, and adequate horizontal deflection. Figure 8 provides an example of a typical rural single-lane roundabout.

Rural roundabouts that may one day become part of an urbanized area should be designed as urban roundabouts, with slower speeds and pedestrian treatment. However, in the interim, they should be designed with supplementary approach and entry features to achieve safe speed reduction.

Rural double-lane roundabouts

Rural double-lane roundabouts have speed characteristics similar to rural single-lane roundabouts with average approach speeds in the range of 50-60 mph. They differ in having two entry lanes, or entries flared from one to two

Figure 8 – Rural Single Lane Roundabout

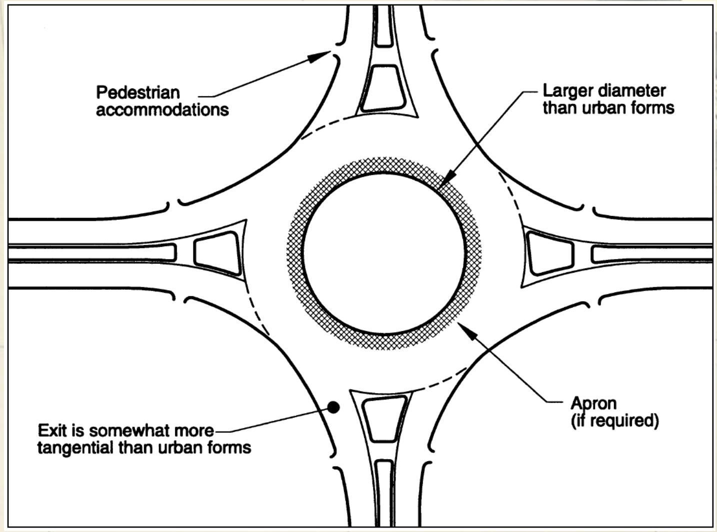
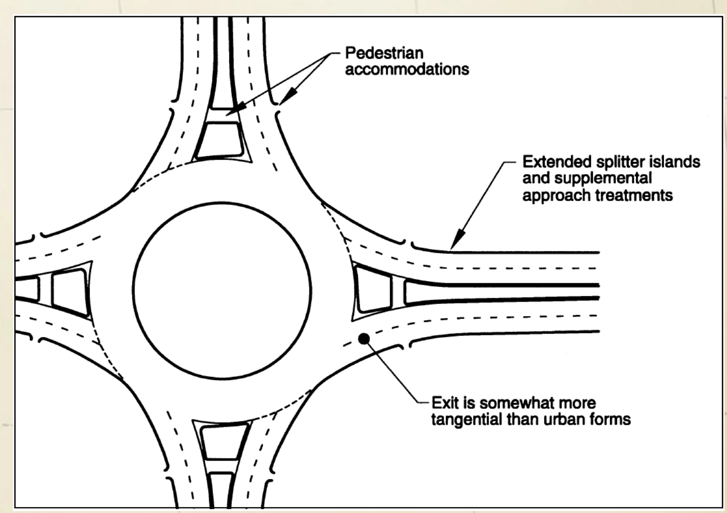


Image Source: Section 1.6 of FHWA publication "Roundabouts: An Informational Guide" Publication Number FHWA-RD-00-067

lanes, on one or more approaches. Consequently, many of the characteristics and design features of rural double-lane roundabouts mirror those of their urban counterparts. The main design differences are designs with higher entry speeds and larger diameters, and recommended supplementary approach treatments. Figure 9 provides an example of a typical rural double-lane roundabout. Rural roundabouts that may one day become part of an urbanized area should be designed for slower speeds, with design details that fully accommodate pedestrians and bicyclists. However, in the interim they should be designed with approach and entry features to achieve safe speed reduction.

Figure 9 – Rural Double-Lane Roundabout



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Associated Issues

There are considerations special to roundabouts that differ from traditional roadway facilities.

Pedestrians

Pedestrians are accommodated by crossings that are located around the perimeter of the roundabout. Pedestrian crossings are set back from the yield line by one or more car lengths. This placement results in shortened crossing distances when compared with locations adjacent to the inscribed circle. This crossing placement also separates vehicle-vehicle and vehicle-pedestrian conflict points. Entering motorists are able to devote their entire attention to crossing pedestrians while waiting for the vehicle at the yield line to enter the circulating roadway.

There are important design considerations that must be kept in mind. Pedestrians should be discouraged from crossing the circulatory roadway to the central island. Items such as benches, plaques and monuments should not be placed in the center island as they would entice pedestrians to travel to the central island. Providing landscape buffers at the corners of the roundabout will discourage pedestrians from jaywalking.

An important issue with roundabouts is access for blind or visually impaired pedestrians. According to the FHWA publication, *Roundabouts: An Informational Guide*, crossing roundabouts may be difficult for visually-impaired pedestrians to perform without assistance. The following describes some of the problems that visually impaired pedestrians may encounter when attempting to navigate through a roundabout:

- ☑ Visually-impaired pedestrians must be able to locate the crosswalk. The crosswalks at roundabouts are located at positions that differ from those at a typical four-leg intersection. Landscaping can be utilized to indicate the crosswalk's location
- ☑ Visually-impaired pedestrians must listen for a safe gap to cross the entrance or exit lane(s). The pedestrian may have a problem differentiating the sounds of the entering/exiting traffic from those of the circulating traffic
- ☑ Visually-impaired pedestrians must be able to locate the splitter island refuge area. The refuge area must be curbed with ramps at the crossings, and equipped with detectable warning surfaces to aid the disabled pedestrians
- ☑ Visually-impaired pedestrians must be able to locate the correct walkway to either continue their path or locate the adjacent crosswalk to cross the next leg of the roundabout. The use of landscaping can again be utilized to indicate the different locations.

Additional design remedies to the problems include using pedestrian crossings with actuated signals, raised pavement markers with in-roadway warning lights, and raised crosswalks. It should be noted that the use of these remedies would, most likely, reduce the capacity of the roundabout by interfering with the yield conditions entering and exiting the facility. Designers must adhere to the federal guidelines that dictate the use of in-roadway warning lights.

Unfortunately, many studies documenting safety improvements of roundabouts versus traditional intersections concentrate on vehicular data and lack significant pedestrian data. As a result, there is no actual documented impact to crash rates for pedestrians, particularly visually-impaired pedestrians.

Bicyclists

Accommodating bicyclists at a roundabout can be a difficult task. Designers must begin with the policy that bike lanes should never be used within a roundabout due to the complexity of traffic interaction. On a single-lane roundabout, bicyclists should have the option of either mixing with traffic or using the roundabout as a pedestrian. With double-lane roundabouts, bicyclists require special attention especially when bicycle traffic is moderate to heavy. A bicycle path that is located outside of the roundabout is the preferable choice.

Educating the Public

Public acceptance of roundabouts has often been one of the biggest challenges that a jurisdiction faces when installing its first roundabout. The initial public reaction may be negative. Where roundabouts have been installed, public attitudes toward roundabouts improve significantly after construction.

Motorists unfamiliar with roundabouts may often experience driver confusion when traversing the intersection for the first time. Therefore, when a new roundabout is planned, it is extremely important that the public be educated on the various aspects of a roundabout. There are several means by which education can take place. Public meetings can provide a good forum for bringing the public into the design process and allowing them to ask questions and provide some fresh ideas. Informational brochures and videos can also be used to educate the community. Public service announcements on social media, in newspapers, or on television and radio can also assist in the education process.

Maintenance

Once a roundabout has been constructed and is in service, the need to maintain the facility follows. It should be noted that maintenance of the pavement and associated infrastructure would be more challenging than standard signalized intersections. The ability to perform half-width construction may be eliminated if the circulating roadway is too narrow. Because the roundabout uses more land area compared to a standard intersection, the ability to construct a temporary roadway around the facility during construction will likely require a very large amount of land, which may not be available in highly developed areas. A detour could be implemented if a suitable route that can handle additional traffic is located near the roundabout. A public information campaign could also be used to encourage motorists to avoid the area by using other routes within the region. For these reasons, the cost of roadway maintenance of a roundabout will be higher than standard signalized intersections primarily due to the maintenance and protection of traffic issues. An adequate pavement design should be used to ensure years of service and minimize the frequency of maintenance.

Also of concern is the removal of snow from the facility during the winter season. The geometry of the roundabout will make snow removal more difficult. There may be a need to use smaller (pick-up truck) plows within the roundabout to effectively remove the snow while negotiating the circulating roadway as well as the approach roadways and the splitter islands. Additionally, care must be taken when stockpiling the snow to avoid impacting land adjacent to the roundabout, or interfering with sight distance in and approaching the roundabout.

Alternatively, in addition to capacity and safety benefits discussed in this bulletin, roundabouts have other advantages. From a maintenance standpoint, compared to a signalized intersection, there is no power fee, cameras or loop maintenance costs, and they function with no impacts during power outages. From an access standpoint, they offer turnaround capabilities. U-turns are often not allowed at signalized intersections for safety reasons, but they are always possible at roundabouts. When properly designed, they also accommodate large vehicles.

All of these factors must be considered before a decision can be made to utilize a roundabout facility as the costs and concerns associated with these issues will be around for the life of the facility.

Roundabout Costs

Roundabouts often require significant construction, since when compared to a traditional intersection, the footprint is normally larger. Larger roundabouts are required in some situations, and these would have an even higher cost. For smaller urban intersections, a roundabout can be installed for approximately $25,000 to $100,000, with landscaped roundabouts raising the cost to $45,000 to $150,000. For arterial streets, the cost is approximately $250,000, but can be more than $500,000 depending on the size and site conditions. Two-lane roundabouts cost approximately $330,000. Roundabouts usually have lower ongoing maintenance costs than traffic signals, depending on whether or not the roundabout is landscaped. Note that these dollar values are planning-level only; actual construction costs can vary significantly due to factors such as location, material availability, contracting method, and actual site conditions.

When compared to an intersection controlled by a traffic signal, costs for roundabout design and construction are often higher. Traffic signal costs can range from $150,000 to $250,000 depending on the size of the intersection and design efforts required. Note however, that signals have much higher operation and maintenance costs than roundabouts, averaging approximately $5,000 to $10,000 annually, so this can result in more comparable life cycle costs.

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for pamphlets, bulletins and studies

Reference List

- ☑ *Better Military Traffic Engineering*, SDDCTEA Pamphlet 55-17. 2016. https://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pamphlets/SDDCTEA_Pamphlet_55-17.pdf
- ☑ *Roundabouts: An Informational Guide*, FHWA Publication No. FHWA-RD-00-067. Federal Highway Administration. June 2000. https://www.fhwa.dot.gov/publications/research/safety/00067/00067.pdf
- ☑ *Guide to Roundabouts,* PennDOT Publication 414. May 2001. https://www.dot.state.pa.us/public/bureaus/design/GuideToRoundabouts.pdf
- ☑ *Traffic Calming Handbook,* PennDOT Publication 383. July 2012. http://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20383.pdf
- ☑ PennDOT Roadway Design Information: Roundabouts https://www.penndot.gov/ProjectAndPrograms/RoadDesignEnvironment/RoadDesign/Pages/Roundabouts.aspx
- ☑ Roundabout Design Guidance, Virginia Department of Transportation. March 2014. http://virginiadot.org/business/resources/4-Roundabout_Design_Guidance.pdf