Roundabouts: Part 1

Course# TE403

EZ-pdh.com
Ezekiel Enterprises, LLC
301 Mission Dr. Unit 571
New Smyrna Beach, FL 32128
800-433-1487
helpdesk@ezpdh.com

Updated - Sept 2016

1 Introduction

Chapter 1 Introduction

Circular intersections were first introduced in the U.S. in 1905.

Traffic circles have been part of the transportation system in the United States since 1905, when the Columbus Circle designed by William Phelps Eno opened in New York City. Subsequently, many large circles or rotaries were built in the United States. The prevailing designs enabled high-speed merging and weaving of vehicles. Priority was given to entering vehicles, facilitating high-speed entries. High crash experience and congestion in the circles led to rotaries falling out of favor in America after the mid-1950's. Internationally, the experience with traffic circles was equally negative, with many countries experiencing circles that locked up as traffic volumes increased.

The modern roundabout was developed in the United Kingdom in the 1960's.

The modern roundabout was developed in the United Kingdom to rectify problems associated with these traffic circles. In 1966, the United Kingdom adopted a mandatory "give-way" rule at all circular intersections, which required entering traffic to give way, or yield, to circulating traffic. This rule prevented circular intersections from locking up, by not allowing vehicles to enter the intersection until there were sufficient gaps in circulating traffic. In addition, smaller circular intersections were proposed that required adequate horizontal curvature of vehicle paths to achieve slower entry and circulating speeds.

Modern roundabouts provide substantially better operational and safety characteristics than older traffic circles and rotaries.

These changes improved the safety characteristics of the circular intersections by reducing the number and particularly the severity of collisions. Thus, the resultant modern roundabout is significantly different from the older style traffic circle both in how it operates and in how it is designed. The modern roundabout represents a substantial improvement, in terms of operations and safety, when compared with older rotaries and traffic circles (1, 2, 3). Therefore, many countries have adopted them as a common intersection form and some have developed extensive design guides and methods to evaluate the operational performance of modern roundabouts.

1.1 Scope of the Guide

This guide provides information and guidance on roundabouts, resulting in designs that are suitable for a variety of typical conditions in the United States. The scope of this guide is to provide general information, planning techniques, evaluation procedures for assessing operational and safety performance, and design guidelines for roundabouts.

International consensus has not been achieved on some aspects of roundabout design.

This guide has been developed with the input from transportation practitioners and researchers from around the world. In many cases, items from national and international practice and research indicate considerable consensus, and these items have been included in this guide. However, other items have generated considerable differences of opinion (e.g., methods of estimating capacity), and some practices vary considerably from country to country (e.g., marking of the circulatory roadway in multilane roundabouts). Where international consensus is not apparent, a reasoned approach is presented that the authors believe is currently most appropriate for the United States. As more roundabouts are built, the opportunity to conduct research to refine—or develop better—methods will enable future editions of this guide to improve.

Despite the comprehensive nature of this document, it cannot discuss every issue related to roundabouts. In particular, it does not represent the following topics:

Topics not discussed in this guide.

- *Nonmountable traffic calming circles.* These are small traffic circles with raised central islands. They are typically used on local streets for speed and volume control. They are typically not designed to accommodate large vehicles, and often left-turning traffic is required to turn left in front of the circle. Mini-roundabouts, which are presented, may be an appropriate substitute.
- *Specific legal or policy requirements and language.* The legal information that is provided in this guide is intended only to make the reader aware of potential issues. The reader is encouraged to consult with an attorney on specific legal issues before adopting any of the recommendations contained herein. Similarly, regarding policy information, the guide refers to or encompasses applicable policies, such as those of the American Association of State Highway and Transportation Officials (AASHTO) (4). It does not, however, establish any new policies.
- *Roundabouts with more than two entry lanes on an approach.* While acknowledging the existence and potential of such large roundabouts, the guide does not provide specific guidance on the analysis or design of such roundabouts. However, the design principles contained in this document are also applicable to larger roundabouts. The relative safety advantages of roundabout intersections diminish at high traffic flows, particularly with regard to pedestrians and bicyclists. The advantages of larger roundabouts are their higher capacities that may make them attractive alternatives at sites with high traffic volumes. More intricate design is required to ensure adequate operational and safety performance. Therefore, expert operations and design advice should be sought and roundabout analysis software should be utilized in such circumstances. As users and designers in the United States become more familiar with roundabouts, this experience may then be extended to such applications.

1.2 Organization of the Guide

This guide has been structured to address the needs of a variety of readers including the general public, policy-makers, transportation planners, operations and safety analysts, conceptual and detailed designers. This chapter distinguishes roundabouts from other traffic circles and defines the types of roundabouts addressed in the remainder of the guide. The remaining chapters in this guide generally increase in the level of detail provided.

Chapter 2—Policy Considerations: This chapter provides a broad overview of the performance characteristics of roundabouts. The costs associated with roundabouts versus other forms of intersections, legal issues, and public involvement techniques are discussed.

Chapter 3—Planning: This chapter discusses general guidelines for identifying appropriate intersection control options, given daily traffic volumes, and procedures for evaluating the feasibility of a roundabout at a given location. Chapters 2 and 3 provide sufficient detail to enable a transportation planner to decide under which circumstances roundabouts are likely to be appropriate, and how they compare to alternatives at a specific location.

Chapter 4—Operational Analysis: Methods are presented for analyzing the operational performance of each category of roundabout in terms of capacity, delay, and queuing.

Chapter 5—Safety: This chapter discusses the expected safety performance of roundabouts.

Chapter 6—Geometric Design: Specific geometric design principles for roundabouts are presented. The chapter then discusses each design element in detail, along with appropriate parameters to use for each type of roundabout.

Chapter 7—Traffic Design and Landscaping: This chapter discusses a number of traffic design aspects once the basic geometric design has been established. These include signs, pavement markings, and illumination. In addition, the chapter provides discussion on traffic maintenance during construction and landscaping.

Chapter 8—System Considerations: This chapter discusses specific issues and treatments that may arise from the systems context of a roundabout. The material may be of interest to transportation planners as well as operations and design engineers. Signal control at roundabouts is discussed. The chapter then considers the issue of rail crossings through the roundabout or in close proximity. Roundabouts in series with other roundabouts are discussed, including those at freeway interchanges and those in signalized arterial networks. Finally, the chapter presents simulation models as supplementary operational tools capable of evaluating roundabout performance within an overall roadway system.

Appendices: Three appendices are provided to expand upon topics in certain chapters. Appendix A provides information on the capacity models in Chapter 4. Appendix B provides design templates for each of the categories of roundabout described in Chapter 1, assuming four perpendicular legs. Appendix C provides information on the alternative signing and pavement marking in Chapter 7.

Margin notes have been used to highlight important points.

Several typographical devices have been used to enhance the readability of the guide. Margin notes, such as the note next to this paragraph, highlight important points or identify cross-references to other chapters of the guide. References have been listed at the end of each chapter and have been indicated in the text using numbers in parentheses, such as: (3). New terms are presented in *italics* and are defined in the glossary at the end of the document.

1.3 Defining Physical Features

A roundabout is a type of circular intersection, but not all circular intersections can be classified as roundabouts. In fact, there are at least three distinct types of circular intersections:

Types of circular intersections.

- *Rotaries* are old-style circular intersections common to the United States prior to the 1960's. Rotaries are characterized by a large diameter, often in excess of 100 m (300 ft). This large diameter typically results in travel speeds within the circulatory roadway that exceed 50 km/h (30 mph). They typically provide little or no horizontal deflection of the paths of through traffic and may even operate according to the traditional "yield-to-the-right" rule, i.e., circulating traffic yields to entering traffic.
- *Neighborhood traffic circles* are typically built at the intersections of local streets for reasons of traffic calming and/or aesthetics. The intersection approaches may be uncontrolled or stop-controlled. They do not typically include raised channelization to guide the approaching driver onto the circulatory roadway. At some traffic circles, left-turning movements are allowed to occur to the left of (clockwise around) the central island, potentially conflicting with other circulating traffic.
- *Roundabouts* are circular intersections with specific design and traffic control features. These 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 less than 50 km/h (30 mph). Thus, roundabouts are a subset of a wide range of circular intersection forms.

Key roundabout features include:

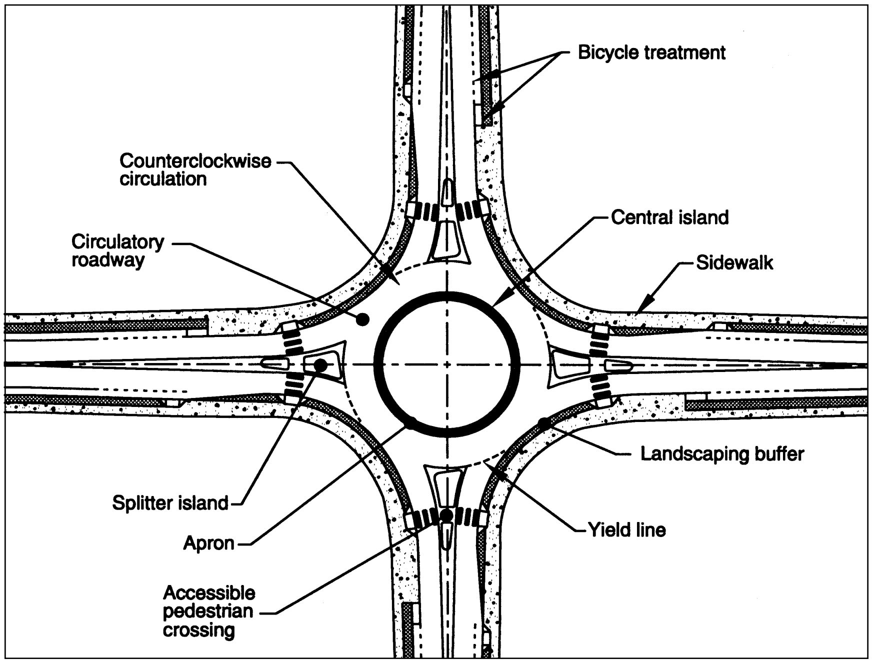
- **Yield control of entering traffic**
- **Channelized approaches**
- **Appropriate geometric curvature to slow speeds**

To more clearly identify the defining characteristics of a roundabout, consistent definitions for each of the key features, dimensions, and terms are used throughout this guide. Exhibit 1-1 is a drawing of a typical roundabout, annotated to identify the key features. Exhibit 1-2 provides a description of each of the key features.

1.4 Key Dimensions

For operational analysis and design purposes, it is useful to define a number of key dimensions. Exhibit 1-3 shows a number of key dimensions that are described in Exhibit 1-4. Note that these exhibits do not present all of the dimensions needed in the detailed analysis and design of roundabouts; these will be presented and defined in later chapters as needed.

Exhibit 1-1. Drawing of key roundabout features.



Splitter islands have multiple roles. They:

- **Separate entering and exiting traffic**
- **Deflect and slow entering traffic**
- **Provide a pedestrian refuge**

Exhibit 1-2. Description of key roundabout features.

Feature	Description
Central island	The *central island* is the raised area in the center of a roundabout around which traffic circulates.
Splitter island	A *splitter island* is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing the road in two stages.
Circulatory roadway	The *circulatory roadway* is the curved path used by vehicles to travel in a counter-clockwise fashion around the central island
Apron	If required on smaller roundabouts to accommodate the wheel tracking of large vehicles, an *apron* is the mountable portion of the central island adjacent to the circulatory roadway.
Yield line	A *yield line* is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.
Accessible pedestrian crossings	*Accessible pedestrian crossings* should be provided at all roundabouts. The crossing location is set back from the yield line, and 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 as a vehicle or as a pedestrian, depending on the bicyclist's level of comfort.
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.

Exhibit 1-3. Drawing of key roundabout dimensions.

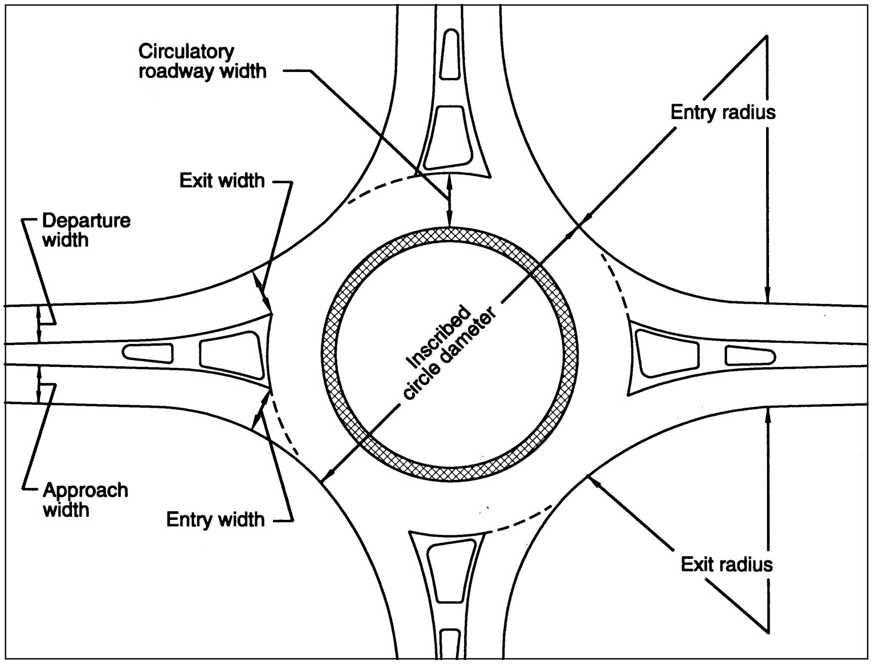


Exhibit 1-4. Description of key roundabout dimensions.

Dimension	Description
Inscribed circle diameter	The *inscribed circle diameter* is the basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.
Circulatory roadway width	The *circulatory roadway width* defines the roadway width for vehicle circulation around the central island. It is measured as the width between the outer edge of this roadway and the central island. It does not include the width of any mountable apron, which is defined to be part of the central island.
Approach width	The *approach width* is the width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The approach width is typically no more than half of the total width of the roadway.
Departure width	The *departure width* is the width of the roadway used by departing traffic downstream of any changes in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the roadway.
Entry width	The *entry width* defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.
Exit width	The *exit width* defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and the inscribed circle.
Entry radius	The *entry radius* is the minimum radius of curvature of the outside curb at the entry.
Exit radius	The *exit radius* is the minimum radius of curvature of the outside curb at the exit.

1.5 Distinguishing Roundabouts from Other Circular Intersections

Circular intersections that do not conform to the characteristics of modern roundabouts are called "traffic circles" in this guide.

Since the purpose of this guide is to assist in the planning, design, and performance evaluation of roundabouts, not other circular intersections, it is important to be able to distinguish between them. Since these distinctions may not always be obvious, the negative aspects of rotaries or neighborhood traffic circles (hereafter referred to as "*traffic circles*") may be mistaken by the public for a roundabout. Therefore, the ability to carefully distinguish roundabouts from traffic circles is important in terms of public understanding.

How then does one distinguish a roundabout from other forms of circular intersection? Exhibit 1-5 identifies some of the major characteristics of roundabouts and contrasts them with other traffic circles. Note that some of the traffic circles shown have many of the features associated with roundabouts but are deficient in one or more critical areas. Note also that these characteristics apply to yield-controlled roundabouts; signalized roundabouts are a special case discussed in Chapter 8.

Exhibit 1-5. Comparison of roundabouts with traffic circles.

Roundabouts must have all of the characteristics listed in the left column.

Chapter 8 discusses signalization at roundabouts.

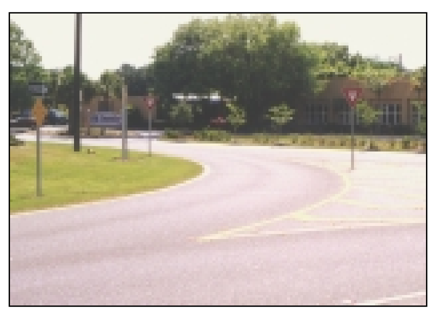
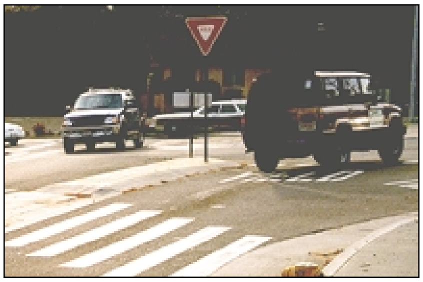
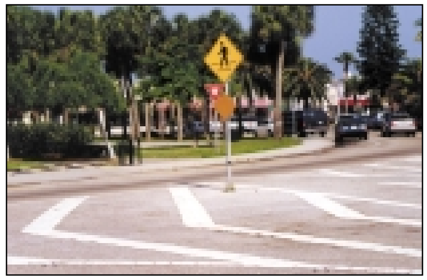
Roundabouts	Traffic Circles
	
(a) Traffic control Yield control is used on all entries. The circulatory roadway has no control. *Santa Barbara, CA*	Some traffic circles use stop control, or no control, on one or more entries. *Hagerstown, MD*
	
(b) Priority to circulating vehicles Circulating vehicles have the right-of-way. *Santa Barbara, CA*	Some traffic circles require circulating traffic to yield to entering traffic. *Sarasota, FL*

Exhibit 1-5. (continued). Comparison of roundabouts with traffic circles.

Roundabouts	Traffic Circles





(c) Pedestrian access
Pedestrian access is allowed only across the legs of the roundabout, behind the yield line. *Santa Barbara, CA*

Some traffic circles allow pedestrian access to the central island. *Sarasota, FL*

(d) Parking
No parking is allowed within the circulatory roadway or at the entries. *Avon, CO*

Some traffic circles allow parking within the circulatory roadway. *Sarasota, FL*

All traffic circulates counter-clockwise around a roundabouts central island.

(e) Direction of circulation
All vehicles circulate counter-clockwise and pass to the right of the central island. *Naples, FL*

Some neighborhood traffic circles allow left-turning vehicles to pass to the left of the central island. *Portland, OR*

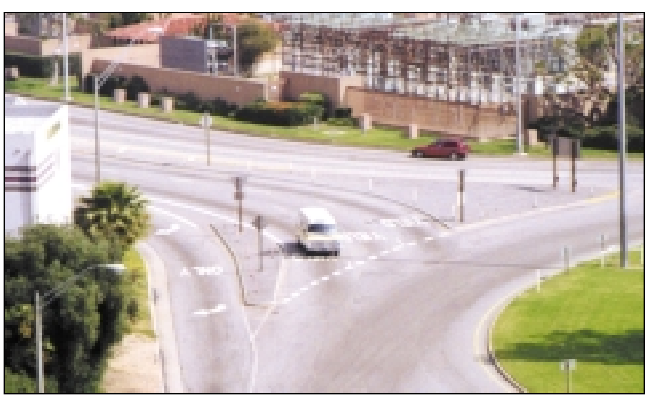
In addition to the design elements identified in Exhibit 1-5, roundabouts often include one or more additional design elements intended to enhance the safety and/or capacity of the intersection. However, their absence does not necessarily preclude an intersection from operating as a roundabout. These additional elements are identified in Exhibit 1-6.

Exhibit 1-6. Common design elements at roundabouts.

Roundabouts may have these additional design features.

Characteristic	Description
(a) Adequate speed reduction	 Good roundabout design requires entering vehicles to negotiate a small enough radius to slow speeds to no greater than 50 km/h (30 mph). Once within the circulatory roadway, vehicles' paths are further deflected by the central island. *West Boca Raton, FL*  Some roundabouts allow high-speed entries for major movements. This increases the risk for more severe collisions for vehicles, bicycles, and pedestrians. *Bradenton Beach, FL*

Exhibit 1-6 (continued). Common design elements at roundabouts.

Characteristic	Description
(b) Design vehicle	 Good roundabout design makes accommodation for the appropriate design vehicle. For small roundabouts, this may require the use of an apron. *Lothian, MD*
	 Some roundabouts are too small to accommodate large vehicles that periodically approach the intersection. *Naples, FL*
(c) Entry flare	 Flare on an entry to a roundabout is the widening of an approach to multiple lanes to provide additional capacity and storage at the yield line. *Long Beach, CA*

Aprons can be used in small roundabouts to accommodate the occasional large vehicle that may use the intersection.

Exhibit 1-6 (continued). Common design elements at roundabouts.

Characteristic	Description
(d) Splitter island	 All except mini-roundabouts have raised splitter islands. These are designed to separate traffic moving in opposite directions, deflect entering traffic, and to provide opportunities for pedestrians to cross in two stages. Mini-roundabouts may have splitter islands defined only by pavement markings. *Tavares, FL*
(e) Pedestrian crossing locations	 Pedestrian crossings are located at least one vehicle length upstream of the yield point. *Fort Pierce, FL*

1.6 Roundabout Categories

For the purposes of this guide, roundabouts have been categorized according to size and environment to facilitate discussion of specific performance or design issues. There are six basic categories based on environment, number of lanes, and size:

This guide uses six basic roundabout categories.

- Mini-roundabouts
- Urban compact roundabouts
- Urban single-lane roundabouts
- Urban double-lane roundabouts
- Rural single-lane roundabouts
- Rural double-lane roundabouts

Multilane roundabouts with more than two approach lanes are possible, but not explicitly covered in this guide.

Multilane roundabouts with more than two approach lanes are possible, but they are not covered explicitly by this guide, although many of the design principles contained in this guide would still apply. For example, the guide provides guidance on the design of flaring approaches from one to two lanes. Although not explicitly discussed, this guidance could be extended to the design of larger roundabout entries.

Note that separate categories have not been explicitly identified for suburban environments. Suburban settings may combine higher approach speeds common in rural areas with multimodal activity that is more similar to urban settings. Therefore, they should generally be designed as urban roundabouts, but with the high-speed approach treatments recommended for rural roundabouts.

Suburban roundabouts incorporate elements of both urban and rural roundabouts.

In most cases, designers should anticipate the needs of pedestrians, bicyclists, and large vehicles. Whenever a raised splitter island is provided, there should also be an at-grade pedestrian refuge. In this case, the pedestrian crossing facilitates two separate moves: curb-to-island and island-to-curb. The exit crossing will typically require more vigilance from the pedestrian and motorist than the entry crossing. Further, it is recommended that all urban crosswalks be marked. Under all urban design categories, special attention should be given to assist pedestrian users who are visually impaired or blind, through design elements. For example, these users typically attempt to maintain their approach alignment to continue across a street in the crosswalk, since the crosswalk is often a direct extension of the sidewalk. A roundabout requires deviation from that alignment, and attention needs to be given to providing appropriate informational cues to pedestrians regarding the location of the sidewalk and the crosswalk, even at mini-roundabouts. For example, appropriate landscaping is one method of providing some information. Another is to align the crosswalk ramps perpendicular to the pedestrian's line of travel through the pedestrian refuge.

Roundabout design should generally accommodate pedestrian, bicycle, and large vehicle use.

1.6.1 Comparison of roundabout categories

Exhibit 1-7 summarizes and compares some fundamental design and operational elements for each of the six roundabout categories developed for this guide. The following sections provide a qualitative discussion of each category.

Exhibit 1-7. Basic design characteristics for each of the six roundabout categories.

Design Element	Mini-Roundabout	Urban Compact	Urban Single-Lane	Urban Double-Lane	Rural Single-Lane	Rural Double-Lane
Recommended maximum entry design speed	25 km/h (15 mph)	25 km/h (15 mph)	35 km/h (20 mph)	40 km/h (25 mph)	40 km/h (25 mph)	50 km/h (30 mph)
Maximum number of entering lanes per approach	1	1	1	2	1	2
Typical inscribed circle diameter[1]	13 m to 25 m (45 ft to 80 ft)	25 to 30 m (80 to 100 ft)	30 to 40 m (100 to 130 ft)	45 to 55 m (150 to 180 ft)	35 to 40 m (115 to 130 ft)	55 to 60 m (180 to 200 ft)
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 volumes on 4-leg roundabout (veh/day)	10,000	15,000	20,000	Refer to Chapter 4 procedures	20,000	Refer to Chapter 4 procedures

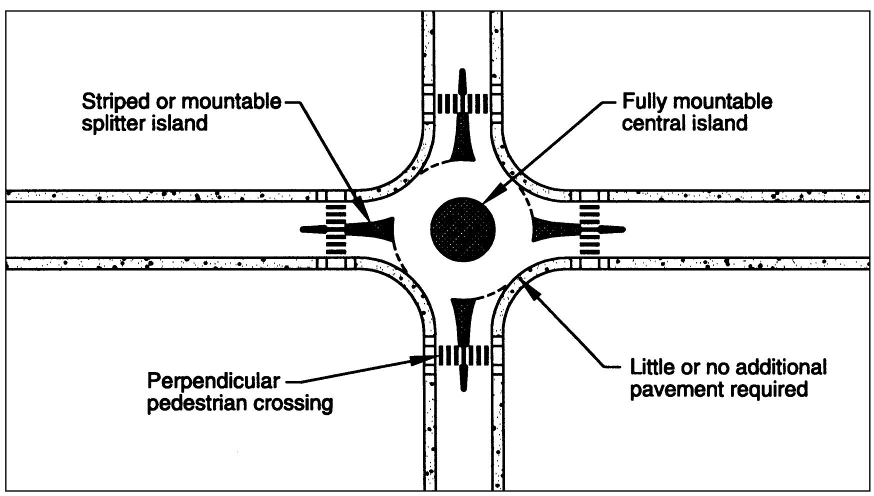
1. Assumes 90-degree entries and no more than four legs.

1.6.2 Mini-roundabouts

Mini-roundabouts can be useful in low-speed urban environments with right-of-way constraints.

Mini-roundabouts are small roundabouts used in low-speed urban environments, with average operating speeds of 60km/h (35mph) or less. Exhibit 1-8 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 right-of-way constraints. In retrofit applications, mini-roundabouts are relatively inexpensive because they typically require minimal additional pavement at the intersecting 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 compact urban roundabout. The recommended design of these roundabouts is based on the German method, with some influence from the United Kingdom.

Exhibit 1-8. Typical mini-roundabout.



1.6.3 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 an apron surrounding the nonmountable part of the compact central island to accommodate large vehicles. The recommended design of these roundabouts is similar to those in Germany and other northern European countries. Exhibit 1-9 provides an example of a typical urban compact roundabout.

Urban compact roundabouts are intended to be pedestrian-friendly; capacity should not be a critical issue when considering this type.

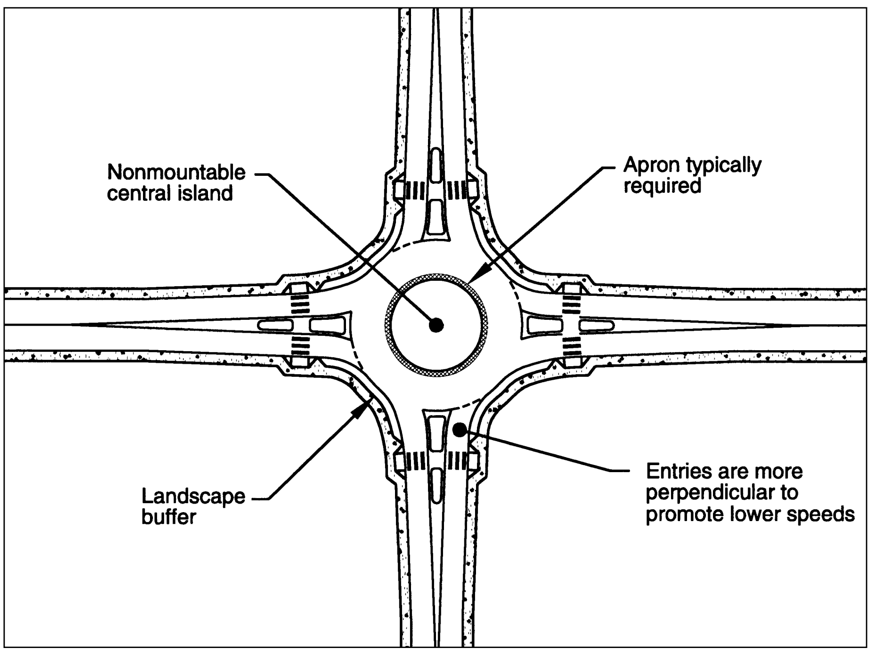


Exhibit 1-9. Typical urban compact roundabout.

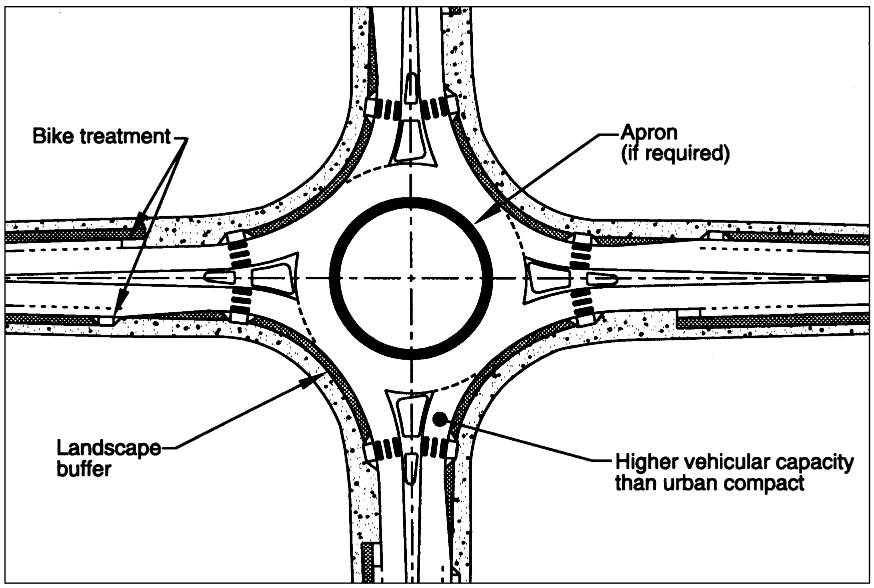
1.6.4 Urban single-lane roundabouts

Urban single-lane roundabouts have slightly higher speeds and capacities than urban compact roundabouts.

This type of roundabout is characterized as having a single lane entry at all legs and one circulatory lane. Exhibit 1-10 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. Notwithstanding the larger inscribed circle diameters than compact roundabouts, the speed ranges recommended in this guide are somewhat lower than those used in other countries, in order to enhance safety for bicycles 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. The design of these roundabouts is similar to those in Australia, France, and the United Kingdom.

The design focuses on consistent entering and exiting speeds.

Exhibit 1-10. Typical urban single-lane roundabout.



1.6.5 Urban double-lane roundabouts

Urban double-lane roundabouts include all roundabouts in urban areas that have at least one entry with two lanes. They include roundabouts with entries 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. Exhibit 1-11 provides an example of a typical urban multilane roundabout. The speeds at the entry, on the circulatory roadway, and at the exit are similar to those for the urban single-lane roundabouts. Again, it is important that the vehicular speeds be consistent throughout the roundabout. The geometric design will include raised splitter islands, no truck apron, a nonmountable central island, and appropriate horizontal deflection.

The urban double-lane roundabout category includes roundabouts with one or more entries that flare from one to two lanes.

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 Chapters 6 and 7. The design of these roundabouts is based on the methods used in the United Kingdom, with influences from Australia and France.

See Chapters 6 and 7 for special design considerations for pedestrians and bicycles.

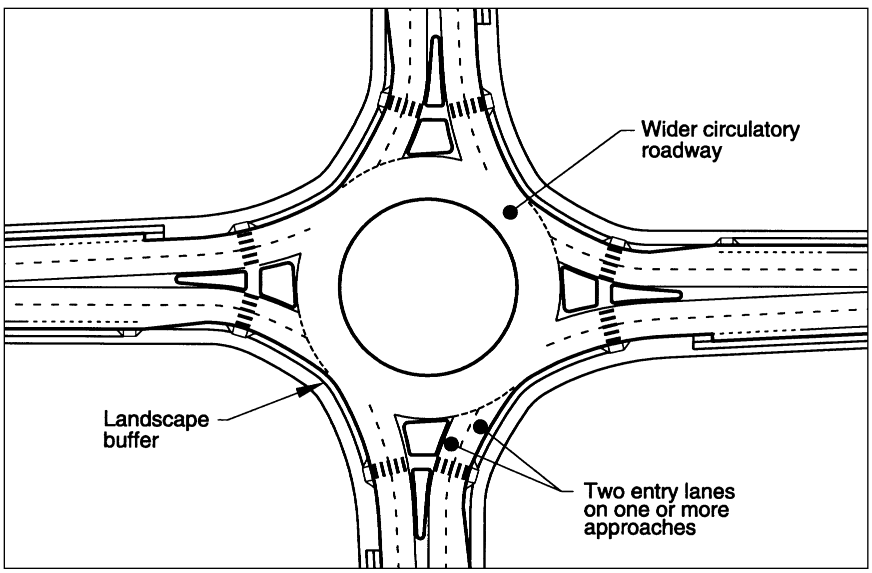


Exhibit 1-11. Typical urban double-lane roundabout.

1.6.6 Rural single-lane roundabouts

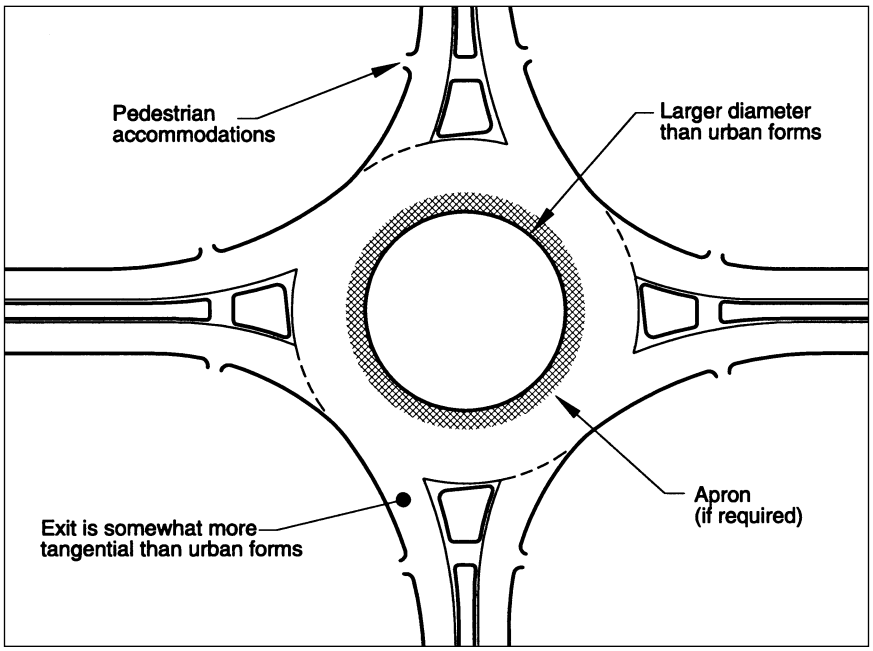
Because of their higher approach speeds, rural single-lane roundabouts require supplementary geometric and traffic control device treatments on the approaches.

Rural single-lane roundabouts generally have high average approach speeds in the range of 80 to 100 km/h (50 to 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 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. The design of these roundabouts is based primarily on the methods used by Australia, France, and the United Kingdom. Exhibit 1-12 provides an example of a typical rural single-lane roundabout.

Rural roundabouts that may become part of an urbanized area should include urban roundabout design features.

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

Exhibit 1-12. Typical rural single-lane roundabout.



1.6.7 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 80 to 100 km/h (50 to 60 mph). They differ in having two entry lanes, or entries flared from one to two 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. The design of these roundabouts is based on the methods used by the United Kingdom, Australia, and France. Exhibit 1-13 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.

Rural double-lane roundabouts have higher entry speeds and larger diameters than their urban counterparts.

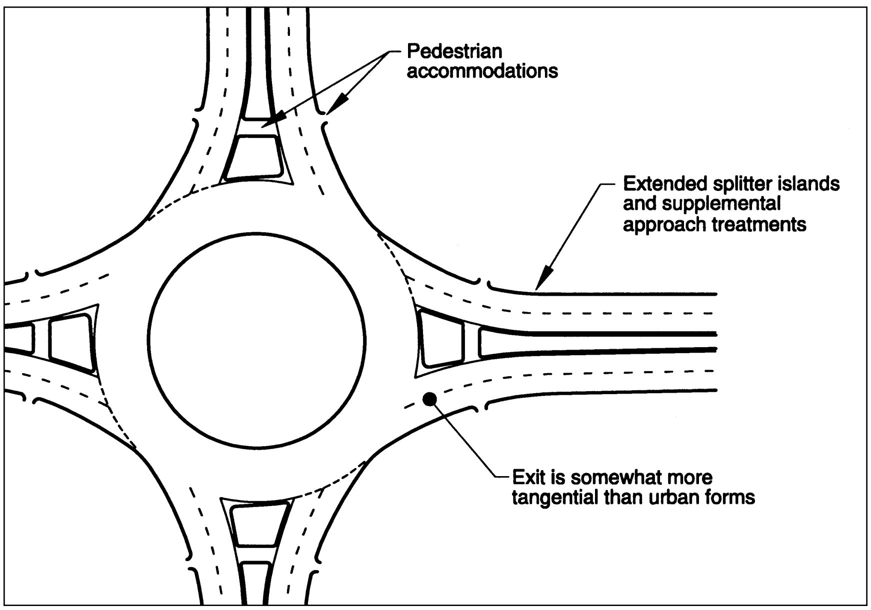


Exhibit 1-13. Typical rural double-lane roundabout.

1.7 References

1. Brown, M. *TRL State of the Art Review—The Design of Roundabouts.* London: HMSO, 1995.

2. Todd, K. "A history of roundabouts in Britain." *Transportation Quarterly,* Vol. 45, No. 1, January 1991.

3. Jacquemart, G. *Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States.* National Cooperative Highway Research Program. Washington, D.C: National Academy Press, 1998.

4. American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets.* Washington, D.C.: AASHTO, 1994.

2

Policy Considerations

Chapter 2 Policy Considerations

Roundabouts have unique characteristics that warrant consideration by developers and managers of the road system. This chapter provides a general overview of the characteristics of roundabouts and policy considerations pertaining to them. The information may be useful to policy makers and the general public. The reader is encouraged to refer to later chapters on the specifics associated with planning, operation, safety, and design of roundabouts.

2.1 Characteristics

The previous chapter described the physical features of a roundabout. This section describes performance characteristics that need to be considered, either at a policy level when introducing roundabouts into a region or at specific locations where a roundabout is one of the alternatives being considered.

2.1.1 Safety

This section provides an overview of the safety performance of roundabouts and then discusses the general characteristics that lead to this performance. It does not attempt to discuss all of the issues related to safety; the reader is encouraged to refer to Chapter 5 for a more detailed discussion.

Roundabouts are generally safer than other forms of intersection in terms of aggregate crash statistics for low and medium traffic capacity conditions (1). Injury crash rates for motor vehicle occupants are generally lower, although the proportion of single-vehicle crashes is typically higher. However, bicyclists and pedestrians are involved in a relatively higher proportion of injury accidents than they are at other intersections (2).

Roundabouts have been demonstrated to be generally safer for motor vehicles and pedestrians than other forms of at-grade intersections.

Exhibit 2-1 presents comparisons of before and after aggregate crash frequencies (average annual crashes per roundabout) involving users of eleven roundabouts constructed in the United States (3). The decrease in severe injury crashes is noteworthy. However, the "before" situation at these intersections required mitigation for safety. Therefore, some other feasible alternatives may also be expected to have resulted in a reduction in the crash frequencies. This study yielded insufficient data to draw conclusions regarding the safety of bicyclists and pedestrians.

Exhibit 2-1. Average annual crash frequencies at 11 U.S. intersections converted to roundabouts.

Type of roundabout	Sites	Before roundabout			Roundabout			Percent change		
		Total	Inj.[3]	PDO[4]	Total	Inj.	PDO	Total	Inj.	PDO
Single-Lane[1]	8	4.8	2.0	2.4	2.4	0.5	1.6	-51%	-73%	-32%
Multilane[2]	3	21.5	5.8	15.7	15.3	4.0	11.3	-29%	-31%	-10%
Total	11	9.3	3.0	6.0	5.9	1.5	4.2	-37%	-51%	-29%

Notes:
1. Mostly single-lane roundabouts with an inscribed circle diameter of 30 to 35 m (100 to 115 ft).
2. Multilane roundabouts with an inscribed circle diameter greater than 50 m (165 ft).
3. Inj. = Injury crashes.
4. PDO = Property Damage Only crashes.

Source: (3)

Good roundabout designs encourage speed reduction and speed consistency.

Good roundabout design places a high priority on speed reduction and speed consistency. Such designs require that vehicles negotiate the roundabout through a series of turning maneuvers at low speeds, generally less than 30 km/h (20 mph). Speed consistency refers to the design objective of slowing vehicles in stages down to the desired negotiating speed to be consistent with the expectations of drivers. Speed control is provided by geometric features, not only by traffic control devices or by the impedance of other traffic. Because of this, speed reduction can be achieved at all times of day. If achieved by good design, then in principle, lower vehicle speeds should provide the following safety benefits:

Potential safety benefits of low vehicle speeds.

- Reduce crash severity for pedestrians and bicyclists, including older pedestrians, children, and impaired persons;
- Provide more time for entering drivers to judge, adjust speed for, and enter a gap in circulating traffic;
- Allow safer merges into circulating traffic;
- Provide more time for all users to detect and correct for their mistakes or mistakes of others;
- Make collisions less frequent and less severe; and
- Make the intersection safer for novice users.

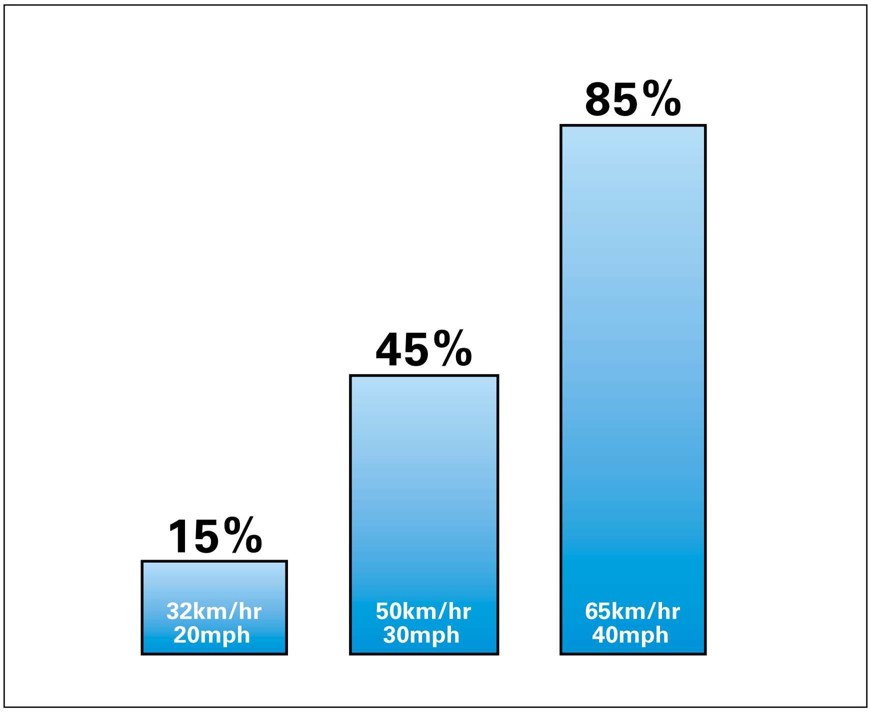
Visually impaired pedestrians are not provided with audible cues from vehicle streams.

For example, Exhibit 2-2 shows that a pedestrian is about three times more likely to die when struck at 50 km/h (30 mph) than at 32 km/h (20 mph), across a range of only 18 km/h (10 mph) difference in speed (4). Typical commuter bicyclist speeds are in the range of 20 to 25 km/h (12 to 15 mph). Therefore, the difference in design speed is critical to all users who are not within the protective body of a motorized vehicle. The minor additional delay or inconvenience to drivers of lower-speed roundabout designs (as compared to higher-speed roundabout designs) is a tradeoff for the substantial safety benefit to pedestrians and bicyclists. Older drivers may benefit from the additional time to perceive, think, react, and correct for errors (as may all users). It should be clarified that there has been no specific research performed on older drivers, older pedestrians, and older bicyclists at roundabouts. It should also be noted that visually impaired pedestrians are not provided the audible cues from vehicle streams that are available at a signal controlled intersection. For example, at roundabout exits, it may be difficult to discern the sound of vehicles which will continue to circulate from those exiting the roundabout. Therefore, information needs to be provided to these users through various appropriate design features to assist them in safely locating and navigating the crossings at roundabouts.

Lower circulating speeds can provide greater capacity.

Furthermore, the operational efficiency (capacity) of roundabouts is probably greater at lower circulating speed, because of these two phenomena:

- The faster the circulating traffic, the larger the gaps that entering traffic will comfortably accept. This translates to fewer acceptable gaps and therefore more instances of entering vehicles stopping at the yield line.
- Entering traffic, which is first stopped at the yield line, requires even larger gaps in the circulating traffic in order to accelerate and merge with the circulating traffic. The faster the circulating traffic, the larger this gap must be. This translates into even fewer acceptable gaps and therefore longer delays for entering traffic.



Source: United Kingdom (4)

Exhibit 2-2. Pedestrian's chances of death if hit by a motor vehicle.

2.1.1.1 Single-lane roundabouts

The safety characteristics of single-lane and multilane roundabouts are somewhat different and are discussed separately. Single-lane roundabouts are the simplest form of roundabout and thus are a good starting point for discussing the safety characteristics of roundabouts relative to other forms of intersections.

Roundabouts bring the simplicity of a "T" intersection to intersections with more than three legs.

The *frequency* of crashes at an intersection is related to the number of *conflict points* at an intersection, as well as the magnitude of conflicting flows at each conflict point. A conflict point is a location where the paths of two vehicles, or a vehicle and a bicycle or pedestrian diverge, merge, or cross each other. For example, Exhibit 2-3 presents a diagram of vehicle-vehicle conflict points for a traditional four-leg intersection and a four-leg roundabout intersection of two-lane roads. The number of vehicle-vehicle conflict points for four-leg intersections drops from thirty-two to eight with roundabouts, a 75 percent decrease. Fewer conflict points means fewer opportunities for collisions. These are not the only conflict points at roundabouts or traditional intersections, but are illustrative of the differences between intersection types. Chapter 5 contains a more detailed comparison of conflicts at more complex intersections and for pedestrians and bicyclists.

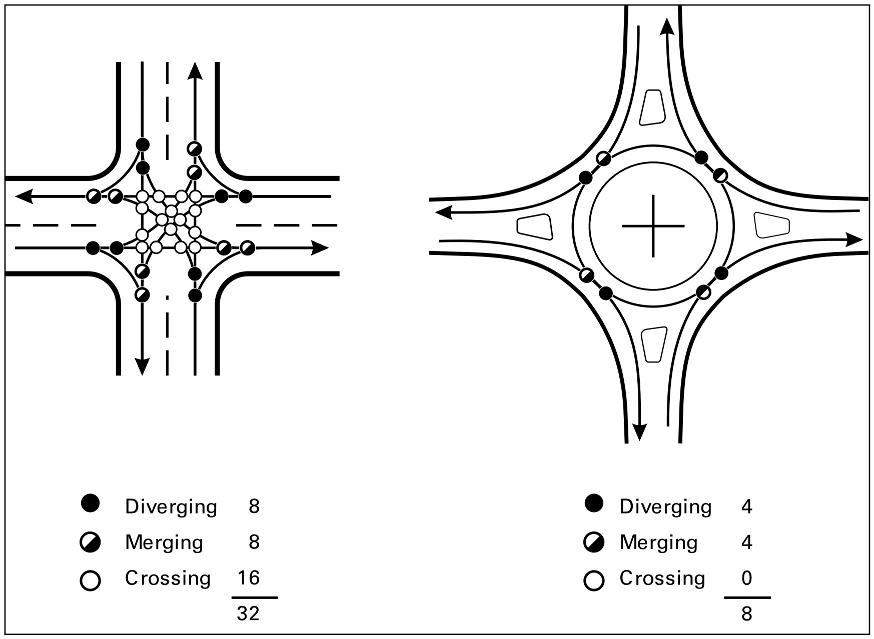
A four-leg intersection has 75 percent fewer conflicts between vehicles and pedestrians and other vehicles, compared to a conventional four-leg intersection.

See Chapter 5 for a comparison of intersection conflicts.

The *severity* of a collision is determined largely by the speed of impact and the angle of impact. The higher the speed, the more severe the collision. The higher the angle of impact, the more severe the collision. Roundabouts reduce in severity or eliminate many severe conflicts that are present in traditional intersections.

Exhibit 2-3. Comparisons of vehicle-vehicle conflict points for intersections with four single-lane approaches.

Types of intersection conflicts.



Roundabouts eliminate crossing conflicts by converting all movements to right turns.

As Exhibit 2-3 shows, a roundabout eliminates vehicle-vehicle crossing conflicts by converting all movements to right turns. Separate turn lanes and traffic control (stop signs or signalization) can often reduce but not eliminate the number of crossing conflicts at a traditional intersection by separating conflicts in space and/or time. However, the most severe crashes at signalized intersections occur when there is a violation of the traffic control device designed to separate conflicts by time (e.g., a right-angle collision due to a motorist running a red light, or vehicle-pedestrian collisions). The ability of roundabouts to reduce conflicts through physical, geometric features has been demonstrated to be more effective than the reliance on driver obedience to traffic control devices. At intersections with more than four legs, a roundabout or pair of roundabouts may sometimes be the most practical alternative to minimize the number of conflicts.

Drivers approaching a single-lane roundabout have five basic decisions regarding other users. First, drivers must be mindful of any bicyclists merging into motor vehicle traffic from the right side of the road or a bicycle lane or shoulder. Then they must yield to any pedestrians crossing at the entry. Third, they must choose an acceptable gap in which to enter the roundabout. Then they must choose the correct exit, and finally, they must yield to any pedestrians crossing the exit lane.

By contrast, a driver making a left turn from the minor leg of a two-way stop-controlled intersection has to yield to pedestrians and bicyclists, and judge gaps in both of the major street through movements from both directions, as well as the major street left and right turns and opposing minor through and right turns.

Signalized intersections have simplified the decision-making process for drivers, especially at locations where protected left-turn phasing is provided, by separating conflicts in time and space. However, the rules and driver decisions for negotiating signalized intersections are still quite complex when all the possible signal phasing schemes are accounted for. For signals with permitted left-turn phasing, the driver must be cognizant of the opposing traffic including pedestrians, and the signal indication (to ensure a legal maneuver). At roundabouts, once at the yield line, the entering driver can focus attention entirely on the circulating traffic stream approaching from the left. A driver behind the entering driver can focus entirely on crossing pedestrians.

2.1.1.2 Double-lane roundabouts

As discussed in Chapter 1, double-lane roundabouts are those with at least one entry that has two lanes. In general, double-lane roundabouts have some of the same safety characteristics for vehicle occupants as their less complicated single-lane counterparts. However, due to the presence of multiple entry lanes and the accompanying need to provide wider circulatory and exit roadways, double-lane roundabouts have complications that result in poorer safety characteristics, particularly for bicyclists and pedestrians, than single-lane roundabouts serving similar traffic demands. This makes it important to use the minimum number of entry, circulating, and exit lanes, subject to capacity considerations.

Increasing the number of lanes increases the number of conflict points.

Due to their typically larger size compared to single-lane roundabouts, double-lane roundabouts often cannot achieve the same levels of speed reduction as their single-lane counterparts. Wider entering, circulating, and exiting roadways enable a vehicle to select a path that crosses multiple lanes, as shown in Exhibit 2-4. Because of the higher-speed geometry, single-vehicle accidents can be more severe. However, design of double-lane roundabouts according to the procedures in Chapter 6, especially the approach and entry, can substantially reduce the speeds of entering vehicles and consequently reduce the severity of conflicts. Even so, speed control cannot occur to the extent possible with single-lane roundabouts.

The design of double-lane roundabouts to control the speed of the fastest vehicle path is covered in Chapter 6.

Pedestrians crossing double-lane roundabouts are exposed for a longer time and to faster vehicles. They can also be obscured from, or not see, approaching vehicles in adjacent lanes if vehicles in the nearest lane yield to them. Children, wheel-

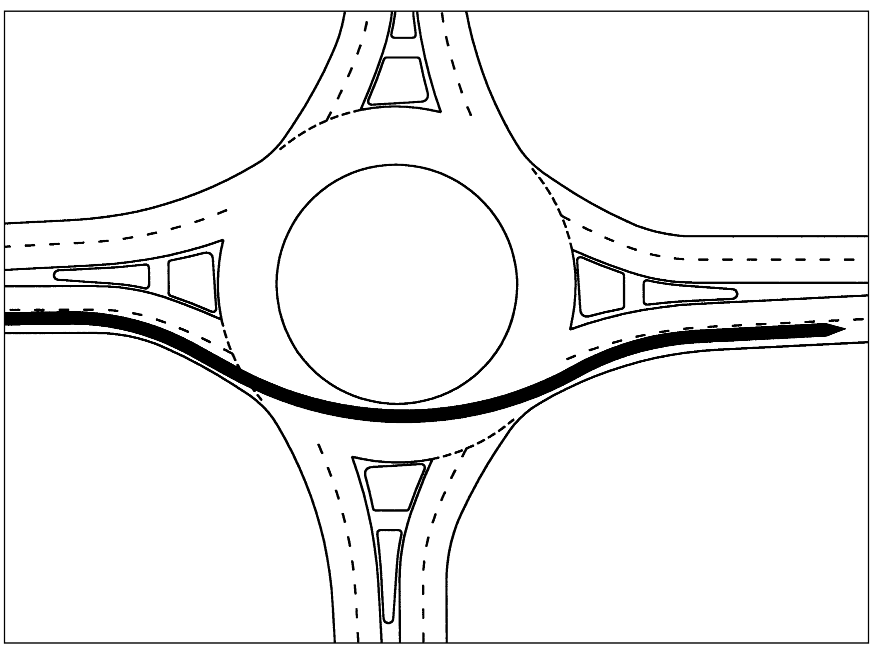


Exhibit 2-4. Fastest vehicle path through a double-lane roundabout.

chair users, and visually impaired pedestrians face particular risks. Bicycles are also more exposed to severe conflicts when choosing to circulate with motor vehicles.

Double-lane roundabouts can be confusing without proper engineering and user education.

Driver decisions are more complex at double-lane roundabouts. The requirement to yield to pedestrians still applies. The primary additional decisions are the choices of the proper lane for entering, lateral position for circulating, and proper lane for exiting the roundabout. Lane choice on approaching a double-lane roundabout is no different from approaching a signalized intersection: to turn left, stay left; to turn right, stay right. However, the decisions for circulating within and especially exiting a double-lane roundabout are unique.

Consider guide signs for roundabouts with skewed approaches or more than four legs.

Sections 2.5 and 2.6 cover user education topics.

Double-lane roundabouts with legs aligned at approximately 90-degree angles allow motorists to determine the appropriate lane choice for their path through the roundabout in a relatively easy manner. Double-lane roundabouts with more than four legs and/or with legs aligned at angles significantly different from 90 degrees make driver decisions more complicated. This occurs because it can be difficult on some legs to determine which movements are left, through, and right. For this reason, it is desirable that multilane roundabouts be limited to a maximum of four legs, with legs aligned at approximately 90-degree angles. If this is not possible, special advance guide signs showing appropriate lane choice should be considered.

When double-lane roundabouts are first introduced to an area, there is a need for adequate user education. Recommendations for user education material specifically related to this issue are presented later in this chapter.

2.1.2 Vehicle delay and queue storage

Techniques for estimating delay are given in Chapter 4.

When operating within their capacity, roundabout intersections typically operate with lower vehicle delays than other intersection forms and control types. With a roundabout, it is unnecessary for traffic to come to a complete stop when no conflicts present themselves, or else deceleration will avoid a conflict. When there are queues on one or more approaches, traffic within the queues usually continues to move, and this is typically more tolerable to drivers than a stopped or standing queue. The performance of roundabouts during off-peak periods is particularly good in contrast to other intersection forms, typically with very low average delays.

2.1.3 Delay of major movements

Since all intersection movements at a roundabout have equal priority, major street movements may be delayed more than desired.

Roundabouts tend to treat all movements at an intersection equally. Each approach is required to yield to circulating traffic, regardless of whether the approach is a local street or major arterial. In other words, all movements are given equal priority. This may result in more delay to the major movements than might otherwise be desired. This problem is most acute at the intersection of high-volume major streets with low- to medium-volume minor streets (e.g., major arterial streets with minor collectors or local streets). Therefore, the overall street classification system and hierarchy should be considered before selecting a roundabout (or stop-controlled) intersection. This limitation should be specifically considered on emergency response routes in comparison with other intersection types and control. The delays depend on the volume of turning movements and should be analyzed individually for each approach, according to the procedures in Chapter 4.

2.1.4 Signal progression

It is common practice to coordinate traffic signals on arterial roads to minimize stops and delay to through traffic on the major road. By requiring coordinated platoons to yield to traffic in the circulatory roadway, the introduction of a roundabout into a coordinated signal system may disperse and rearrange platoons of traffic if other conflicting flows are significant, thereby reducing progressive movement. To minimize overall system delay, it may be beneficial to divide the signal system into subsystems separated by the roundabout, assigning each subsystem its own cycle. The traffic performance of the combination roundabout-signal system should be tested in advance with signal systems and roundabout analysis tools. In some cases, total delay, stops, and queues will be reduced by the roundabout. The number of available gaps for midblock unsignalized intersections and driveways may also be reduced by the introduction of roundabouts, although this may be offset by the reduced speeds near roundabouts. In addition, roundabouts can enable safe and quick U-turns that can substitute for more difficult midblock left turns, especially where there is no left turn lane.

2.1.5 Environmental factors

Roundabouts may provide environmental benefits if they reduce vehicle delay and the number and duration of stops compared with an alternative. Even when there are heavy volumes, vehicles continue to advance slowly in moving queues rather than coming to a complete stop. This may reduce noise and air quality impacts and fuel consumption significantly by reducing the number of acceleration/deceleration cycles and the time spent idling.

In general, if stop or yield control is insufficient, traffic through roundabouts generates less pollution and consumes less fuel than traffic at fixed-time signalized intersections. However, vehicle-actuated signals typically cause less delay, less fuel consumption, and less emissions than roundabouts as long as traffic volumes are low. During busy hours, vehicle-actuated signals tend to operate like fixed-time signals, and the percentage of cars that must stop becomes high (5).

2.1.6 Spatial requirements

Roundabouts usually require more space for the circular roadway and central island than the rectangular space inside traditional intersections. Therefore, roundabouts often have a significant right-of-way impact on the corner properties at the intersection, especially when compared with other forms of unsignalized intersection. The dimensions of a traditional intersection are typically comparable to the envelope formed by the approaching roadways. However, to the extent that a comparable roundabout would outperform a signal in terms of reduced delay and thus shorter queues, it will require less queue storage space on the approach legs. If a signalized intersection requires long or multiple turn lanes to provide sufficient capacity or storage, a roundabout with similar capacity may require less space on the approaches. As a result, roundabouts may reduce the need for additional right-of-way on the links between intersections, at the expense of additional right-of-way requirements at the intersections themselves (refer to Chapters 3 and 8). The right-of-way savings between intersections may make it feasible to accommodate parking, wider sidewalks, planter strips, wider outside lanes, and/or bicycle lanes in order to better accommodate pedestrians and/or bicyclists. Another space-saving strategy is the use of flared approach lanes to provide additional capacity at the intersection while maintaining the benefit of reduced spatial requirements upstream and downstream of an intersection.

At interchange ramp terminals, paired roundabouts have been used to reduce the number of lanes in freeway over- and underpasses. In compact urban areas, there are typically signalized intersections at both ends of overpass bridges, necessitating two additional overpass lanes to provide capacity and storage at the signalized intersections.

2.1.7 Operation and maintenance costs

Compared to signalized intersections, a roundabout does not have signal equipment that requires constant power, periodic light bulb and detection maintenance, and regular signal timing updates. Roundabouts, however, can have higher landscape maintenance costs, depending on the degree of landscaping provided on the central island, splitter islands, and perimeter. Illumination costs for roundabouts and signalized intersections are similar. Drivers sometimes face a confusing situation when they approach a signalized intersection during a power failure, but such failures have minimal temporary effect on roundabouts or any other unsignalized intersections, other than the possible loss of illumination. The service life of a roundabout is significantly longer, approximately 25 years, compared with 10 years for a typical signal (6).

2.1.8 Traffic calming

Series of roundabouts can have secondary, traffic calming effects on streets by reducing vehicle speeds. As discussed previously, speed reduction at roundabouts is caused by geometry rather than by traffic control devices or traffic volume. Consequently, speed reduction can be realized at all times of day and on streets of any traffic volume. It is difficult to speed through an appropriately designed roundabout with raised channelization that forces vehicles to physically change direction. In this way, roundabouts can complement other traffic calming measures.

By reducing speeds, roundabouts complement other traffic calming measures.

Roundabouts have also been used successfully at the interface between rural and urban areas where speed limits change. In these applications, the traffic calming effects of roundabouts force drivers to slow and reinforce the notion of a significant change in the driving environment.

2.1.9 Aesthetics

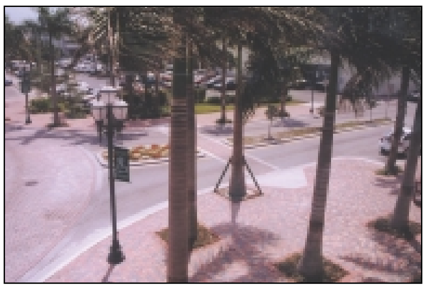
Landscaping issues are discussed in detail in Chapter 7.

Roundabouts offer the opportunity to provide attractive entries or centerpieces to communities. However, hard objects in the central island directly facing the entries are a safety hazard. The portions of the central island and, to a lesser degree, the splitter islands that are not subject to sight-distance requirements offer opportunities for aesthetic landscaping. Pavement textures can be varied on the aprons as well. Exhibit 2-5 presents examples of the aesthetic treatments that have been applied to roundabouts. They can also be used in tourist or shopping areas to facilitate safe U-turns and to demarcate commercial uses from residential areas. They have been justified as a spur to economic development, conveying to developers that the area is favorable for investment in redevelopment. Some are exhibited as a "signature" feature on community postcards, advertisements, and travelogues.

Exhibit 2-5. Examples of aesthetic treatments.

(a) West Boca Raton, FL

(b) Santa Barbara, CA



(c) Fort Pierce, FL

(d) Vail, CO

2.1.10 Design for older drivers

In the United States, there is a trend toward an aging population, as well as individuals, continuing to drive until an older age. This trend has implications for all roadway design, including roundabout design, ranging from operations through geometric and sign design. In this regard, designers should consult available documents such as the Federal Highway Administration (FHWA) *Older Driver Highway Design Handbook* (7):

- The single greatest concern in accommodating older road users, both drivers and pedestrians, is the ability of these persons to safely maneuver through intersections.
- Driving situations involving complex speed-distance judgments under time constraints are more problematic for older drivers and pedestrians than for their younger counterparts.
- Older drivers are much more likely to be involved in crashes where the drivers were driving too fast for the curve or, more significantly, were surprised by the curved alignment.
- Many studies have shown that loss-of-control crashes result from an inability to maintain lateral position through the curve because of excessive speed, with inadequate deceleration in the approach zone. These problems in turn stem from a combination of factors, including poor anticipation of vehicle control requirements, induced by the driver's prior speed, and inadequate perception of the demands of the curve.
- Older drivers have difficulties in allocating attention to the most relevant aspects of novel driving situations.
- Older drivers generally need more time than average drivers to react to events.

While the *Handbook* is not specific to roundabouts, and since no age-related research has been conducted with U.S. roundabouts to date, these findings may apply to older persons encountering roundabouts, as well. The excerpts above all imply that lower, more conservative design speeds are appropriate. Roundabouts designed for low, consistent speeds cater to the preferences of older drivers: slower speeds; time to make decisions, act, and react; uncomplicated situations to interpret; simple decision-making; a reduced need to look over one's shoulder; a reduced need to judge closing speeds of fast traffic accurately; and a reduced need to judge gaps in fast traffic accurately. For example, two-way stop-controlled intersections may be appropriate for replacement with a roundabout when a crash analysis indicates that age-related collisions are prevalent.

2.2 Multimodal Considerations

As with any intersection design, each transportation mode present requires careful consideration. This section presents some of the general issues associated with each mode; additional detail on mode-specific safety and design issues is provided in subsequent chapters.

2.2.1 Pedestrians

Pedestrian crossings should be set back from the yield line by one or more vehicle lengths.

Pedestrians are accommodated by crossings around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The roundabout should be designed to discourage pedestrians from crossing to the central island, e.g., with landscape buffers on the corners. Pedestrian crossings are set back from the yield line by one or more vehicle lengths to:

- Shorten the crossing distance compared to locations adjacent to the inscribed circle;
- Separate vehicle-vehicle and vehicle-pedestrian conflict points; and
- Allow the second entering driver to devote full attention to crossing pedestrians while waiting for the driver ahead to enter the circulatory roadway.

If sidewalks on the intersecting roads are adjacent to the curbs, this setback may require the sidewalks to deviate from a straight path. This is not the case if sidewalks are separated from the curbs by a generous landscape buffer.

Most intersections are two-way stop-controlled, or uncontrolled. Compared to two-way stop-controlled intersections, roundabouts may make it easier and safer for pedestrians to cross the major street. At both roundabouts and two-way stop-controlled intersections, pedestrians have to judge gaps in the major (uncontrolled) stream of traffic. By reducing stopping distance, the low vehicular speeds through a roundabout generally reduce the frequency and severity of incidents involving pedestrians. In addition, when crossing an exit lane on the minor road, the sight angle is smaller than when watching for left-turning vehicles at a conventional intersection.

The comparison between roundabouts and all-way stop-controlled intersections is less clear. All-way stop control is virtually nonexistent in foreign countries that have roundabouts, and so there is little international experience with which to compare. All-way stop-controlled intersections may be preferred by pedestrians with visual impairment because vehicles are required to stop before they enter the intersection. However, crossing the exit leg of an all-way stop-controlled intersection can be intimidating for a pedestrian since traffic may be turning onto the exit from multiple directions. Roundabouts, on the other hand, allow pedestrians to cross one direction of traffic at a time; however, traffic may be moving (albeit at a slow speed), thus making it more challenging to judge gaps, especially for visually impaired users, children, and the elderly.

The biggest difference may be that all-way stop-controlled intersections, like two-way stops, do not provide positive geometric features to slow vehicles and instead rely entirely on the authority of the traffic control device. The roundabout geometry physically slows and deflects vehicles, reducing the likelihood of a high-speed collision due to a traffic control device violation.

Signalized intersections offer positive guidance to pedestrians by providing visual and occasionally audible pedestrian signal indications. In this respect, the decision process for pedestrians requires less judgment at signalized intersections than at roundabouts, particularly for visually impaired and elderly pedestrians. However, pedestrians are still vulnerable at signalized intersections to right-turn and left-turn movements unprotected by a green arrow. In addition, high-speed collisions are still possible if a vehicle runs through a red indication. In this respect, the roundabout provides a speed-constrained environment for through traffic. At two-way and all-way stop intersections, right-turning motorists often look only to the left in order to check for vehicular conflicts, endangering or inconveniencing pedestrians crossing from the right or on the right. This situation is exacerbated by the fact that many of these drivers do not come to a complete stop if they do not perceive any conflicts. With crosswalks located back from the circulatory roadway, roundabouts place pedestrians in a more visible location.

The two populations at opposite ends of the age continuum—children and the elderly—and people with disabilities are particularly at risk at intersections. Children (owing to their lack of traffic experience, impulsiveness, and small size) and the elderly (owing to their age-related physical limitations) present challenges to the designer. In recognition of pedestrians with disabilities, intersections must comply with Americans with Disabilities Act (ADA) mandated accessibility standards discussed in Section 2.4.5 and Chapter 5.

Elderly pedestrians, children, and the disabled find it more difficult to cross unprotected road crossings. These types of pedestrians generally prefer larger gaps in the traffic stream, and walk at slower speeds than other pedestrians. Multilane roadways entering and exiting double-lane roundabouts require additional skills to cross, since pedestrians need assurance that they have been seen by drivers in each lane they are crossing.

When crossing a roundabout, there are several areas of difficulty for the blind and or visually impaired pedestrian. It is expected that a visually impaired pedestrian with good travel skills must be able to arrive at an unfamiliar intersection and cross it with pre-existing skills and without special, intersection-specific training. Roundabouts pose problems at several points of the crossing experience, from the perspective of information access.

When crossing a roundabout, there are several areas of difficulty for the blind and or visually impaired pedestrian.

Unless these issues are addressed by a design, the intersection is "inaccessible" and may not be permissible under the ADA. Chapters 5, 6, and 7 provide specific suggestions to assist in providing the above information. However, more research is required to develop the information jurisdictions need to determine where roundabouts may be appropriate and what design features may be appropriate for the disabled, such as audible signalized crossings. Until specific standards are adopted, engineers and jurisdictions must rely on existing related research and professional judgment to design pedestrian features so that they are usable by pedestrians with disabilities.

2.2.2 Bicycles

Roundabouts may not provide safety benefits to bicyclists (1). Nevertheless, the recommended roundabout designs discourage erratic or undesirable driver behavior. They slow drivers to speeds more compatible with bicycle speeds, while reducing high-speed conflicts and simplifying turn movements for bicyclists. Typical commuter bicyclist speeds are around 25 km/h (15 mph), so entering a roundabout designed for circulating traffic to flow at similar speeds should be safer compared with larger and faster roundabout designs. Bicyclists require particular attention in two-lane roundabout design, especially in areas with moderate to heavy bicycle traffic.

As with pedestrians, one of the difficulties in accommodating bicyclists is their wide range of skills and comfort levels in mixed traffic. On single-lane roundabouts, bicyclists have the option of either mixing with traffic or using the roundabout like a pedestrian. The former option will likely be reasonably comfortable for experienced cyclists; however, less-experienced cyclists (including children) may have difficulty and discomfort mixing with vehicles and are more safely accommodated as pedestrians.

Bike lanes through roundabouts should never be used.

The complexity of vehicle interactions within a roundabout leaves a cyclist vulnerable, and for this reason, bike lanes within the circulatory roadway should never be used. On double-lane roundabouts, a bicycle path separate and distinct from the circulatory roadway is preferable, such as a shared bicycle-pedestrian path of sufficient width and appropriately marked to accommodate both types of users around the perimeter of the roundabout. While this will likely be more comfortable for the casual cyclist, the experienced commuter cyclist will be significantly slowed down by having to cross as a pedestrian at each approach crossing and may choose to continue to traverse a double-lane roundabout as a vehicle. It may sometimes be possible to provide cyclists with an alternative route along another street or path that avoids the roundabout, which should be considered as part of overall network planning. The provision of alternative routes should not be used to justify compromising the safety of bicycle traffic through the roundabout because experienced cyclists and those with immediately adjacent destinations will use it.

2.2.3 Large vehicles

Design roundabouts to accommodate the largest vehicle that can reasonably be expected.

Roundabouts should always be designed for the largest vehicle that can be reasonably anticipated (the "design vehicle"). For single-lane roundabouts, this may require the use of a mountable apron around the perimeter of the central island to provide the additional width needed for tracking the trailer wheels. At double-lane roundabouts, large vehicles may track across the whole width of the circulatory roadway to negotiate the roundabout. In some cases, roundabouts have been designed with aprons or gated roadways through the central island to accommodate oversized trucks, emergency vehicles, or trains.

2.2.4 Transit

Transit considerations at a roundabout are similar to those at a conventional intersection. If the roundabout has been designed using the appropriate design vehicle, a bus should have no physical difficulty negotiating the intersection. To minimize passenger discomfort, if the roundabout is on a bus route, it is preferable that scheduled buses are not required to use a truck apron if present. Bus stops should be located carefully to minimize the probability of vehicle queues spilling back into the circulatory roadway. This typically means that bus stops located on the far side of the intersection need to have pullouts or be further downstream than the splitter island. Pedestrian access routes to transit should be designed for safety, comfort, and convenience. If demand is significant, such as near a station or terminus, pedestrian crossing capacity should be accounted for.

Public transit buses should not be forced to use a truck apron to negotiate a roundabout.

Roundabouts may provide opportunities for giving transit (including rail) and emergency vehicles priority as can be done at signalized intersections. This may be provided using geometry, or signals. For example, these could include an exclusive right-turn bypass lane or signals holding entering traffic while the transit vehicle enters its own right-of-way or mixed traffic. The roundabout can be supplemented by signals activated by a transit, emergency, or rail vehicle. Chapters 6, 7, and 8 provide more detail on transit treatments.

Chapters 6-8 provide more detail on transit treatments.

2.2.5 Emergency vehicles

The passage of large emergency vehicles through a roundabout is the same as for other large vehicles and may require use of a mountable apron. On emergency response routes, the delay for the relevant movements at a planned roundabout should be compared with alternative intersection types and control. Just as they are required to do at conventional intersections, drivers should be educated not to enter a roundabout when an emergency vehicle is approaching on another leg. Once having entered, they should clear out of the circulatory roadway if possible, facilitating queue clearance in front of the emergency vehicle.

Roundabouts provide emergency vehicles the benefit of lower vehicle speeds, which may make roundabouts safer for them to negotiate than signalized crossings. Unlike at signalized intersections, emergency vehicle drivers are not faced with through vehicles unexpectedly running the intersection and hitting them at high speed.

2.2.6 Rail crossings

Rail crossings through or near a roundabout may involve many of the same design challenges as at other intersections and should be avoided if better alternatives exist. In retrofit, the rail track may be designed to pass through the central island, or across one of the legs. Queues spilling back from a rail blockage into the roundabout can fill the circulatory roadway and temporarily prevent movement on any approach. However, to the extent that a roundabout approach capacity exceeds that of a signal at the same location, queues will dissipate faster. Therefore, a case-specific capacity and safety analysis is recommended. Section 8.2 addresses the design of at-grade rail crossings.

See Section 8.2 for information on designing roundabouts located near at-grade rail crossings.

2.3 Costs Associated with Roundabouts

Many factors influence the amount of economic investment justified for any type of intersection. Costs associated with roundabouts include construction costs, engineering and design fees, land acquisition, and maintenance costs. Benefits may include reduced crash rates and severity, reduced delay, stops, fuel consumption, and emissions. Benefit-cost analysis is discussed further in Chapter 3.

When comparing costs, it is often difficult to separate the actual intersection costs from an overall improvement project. Accordingly, the reported costs of installing roundabouts have been shown to vary significantly from site to site. A roundabout may cost more or less than a traffic signal, depending on the amount of new pavement area and the extent of other roadway work required. At some existing unsignalized intersections, a traffic signal can be installed without significant modifications to the pavement area or curbs. In these instances, a roundabout is likely to be more costly to install than a traffic signal, as the roundabout can rarely be constructed without significant pavement and curb modifications.

Roundabouts may require more pavement area at the intersection, compared to a traffic signal, but less on the approaches and exits.

However, at new sites, and at signalized intersections that require widening at one or more approaches to provide additional turn lanes, a roundabout can be a comparable or less expensive alternative. While roundabouts typically require more pavement area at the intersection, they may require less pavement width on the upstream approaches and downstream exits if multiple turn lanes associated with a signalized intersection can be avoided. The cost savings of reduced approach roadway widths is particularly advantageous at interchange ramp terminals and other intersections adjacent to grade separations where wider roads may result in larger bridge structures. In most cases, except potentially for a mini-roundabout, a roundabout is more expensive to construct than the two-way or all-way stop-controlled intersection alternatives.

Recent roundabout projects in the United States have shown a wide range in reported construction costs. Assuming "1998 U.S. Dollars" in the following examples, costs ranged from $10,000 for a retrofit application of an existing traffic circle to $500,000 for a new roundabout at the junction of two State highways. National Cooperative Highway Research Program (NCHRP) Synthesis 264 (3) reports that the average construction cost of 14 U.S. roundabouts, none being part of an interchange, was approximately $250,000. This amount includes all construction elements, but does not include land acquisition.

The cost of maintaining traffic during construction of a roundabout retrofit can be relatively high.

Higher costs are typically incurred when a substantial amount of realignment, grading, or drainage work is required. The cost of maintaining traffic during construction tends to be relatively high for retrofitting roundabouts. This expense is due mainly to the measures required to maintain existing traffic flow through the intersection while rebuilding it in stages. Other factors contributing to high roundabout costs are large amounts of landscaping in the central and splitter islands, extensive signing and lighting, and the provision of curbs on all outside pavement edges.

Operating and maintenance costs of roundabouts are somewhat higher than for other unsignalized intersections, but less than those for signalized intersections. In addition, traffic signals consume electricity and require periodic service (e.g., bulb replacement, detector replacement, and periodic signal retiming). Operating costs for a roundabout are generally limited to the cost of illumination (similar to signalized alternatives, but typically more than is required for other unsignalized intersections).

Maintenance includes regular restriping and repaving as necessary, as well as snow removal and storage in cold climates (these costs are also incurred by conventional intersections). Landscaping may require regular maintenance as well, including such things as pruning, mowing, and irrigation system maintenance. To the extent that roundabouts reduce crashes compared with conventional intersections, they will reduce the number and severity of incidents that disrupt traffic flow and that may require emergency service.

2.4 Legal Considerations

The legal environment in which roundabouts operate is an important area for jurisdictions to consider when developing a roundabout program or set of guidelines. The rules of the road that govern the operation of motor vehicles in a given State can have a significant influence on the way a roundabout operates and on how legal issues such as crashes involving roundabouts are handled. Local jurisdictions that are interested in developing a roundabout program need to be aware of the governing State regulations in effect. The following sections discuss several of the important legal issues that should be considered. These have been based on the provisions of the 1992 Uniform Vehicle Code (UVC) (8), which has been adopted to varying degrees by each State, as well as the rules of the road, and commentaries thereof, from the United Kingdom (9) and Australia (10, 11). Note that the information in the following sections does not constitute specific legal opinion; each jurisdiction should consult with its attorneys on specific legal issues.

2.4.1 Definition of "intersection"

The central legal issue around which all other issues are derived is the fundamental relationship between a roundabout and the legal definition of an "intersection." A roundabout could be legally defined one of two ways:

- As a single intersection; or
- As a series of T-intersections.

The UVC does not provide clear guidance on the appropriate definition of an intersection with respect to roundabouts. The UVC generally defines an "intersection" as the area bounded by the projection of the boundary lines of the approaching roadways (UVC §1-132a). It also specifies that where a highway includes two roadways 9.1 m (30 ft) or more apart, each crossing shall be regarded as a separate intersection (UVC §1-132b). This may imply that most circular intersections should be regarded as a series of T-intersections. This distinction has ramifications in the interpretation of the other elements identified in this section.

This guide recommends that a roundabout be specifically defined as a single intersection, regardless of the size of the roundabout. This intersection should be defined as the area bounded by the limits of the pedestrian crossing areas around the perimeter of a single central island. Closely spaced roundabouts with multiple central islands should be defined as separate intersections, as each roundabout is typically designed to operate independently.

It is recommended that roundabouts be defined as a single intersection: the area bounded by the limits of the pedestrian crossing areas.

2.4.2 Right-of-way between vehicles

Because of yield-to-the-right laws, yield signs and lines must be used on roundabout entries to assign right-of-way to the circulatory roadway.

The UVC specifies that "when two vehicles approach or enter an intersection from different highways at approximately the same time, the driver of the vehicle on the left shall yield the right-of-way to the vehicle on the right" (UVC §11-401). This runs contrary to the default operation of a roundabout, which assigns the right-of-way to the vehicle on the left and any vehicle in front. This requires the use of yield signs and yield lines at all approaches to a roundabout to clearly define right-of-way.

This guide recommends that right-of-way at a roundabout be legally defined such that an entering vehicle shall yield the right-of-way to the vehicle on the left (France passed such a law in 1984). This definition does not change the recommendation for appropriately placed yield signs and yield lines.

2.4.3 Required lane position at intersections

At a typical intersection with multilane approaches, vehicles are required by the UVC to use the right-most lane to turn right and the left-most lane to turn left, unless specifically signed or marked lanes allow otherwise (e.g., double left-turn lanes) (UVC §11-601). Because multilane roundabouts can be used at intersections with more than four legs, the concept of "left turns" and "right turns" becomes more difficult to legally define. The following language (10) is recommended:

Recommended lane assignments: Exit less than halfway, use the right lane. Exit more than halfway, use the left lane. Exit exactly halfway, use either lane.

Unless official traffic control devices indicate otherwise, drivers must make lane choices according to the following rules:

- *If a driver intends to exit the roundabout less than halfway around it, the right lane must be used.*
- *If a driver intends to exit the roundabout more than halfway around it, the left lane must be used.*

The Australian Traffic Act (10) gives no guidance for straight through movements (movements leaving the roundabout exactly halfway), and the general Australian practice is to allow drivers to use either lane unless signed or marked otherwise. On multilane roundabouts where the intersecting roadways are not at 90-degree angles or there are more than four legs to the roundabout, special consideration should be given to assisting driver understanding through advance diagrammatic guide signs or lane markings on approaches showing the appropriate lane choices.

2.4.4 Priority within the circulatory roadway

For multilane roundabouts, the issue of priority within the circulatory roadway is important. Any vehicle on the inner track on the circulatory roadway (e.g., a vehicle making a left turn) will ultimately cross the outer track of the circulatory roadway to exit. This may cause conflicts with other vehicles in the circulatory roadway.

Consistent with its lack of treatment of roundabouts, the UVC does not provide clear guidance on priority within the circulatory roadway of a roundabout. In general, the UVC provides that all overtaking should take place on the left (UVC §11-303). However, the UVC also specifies the following with respect to passing on the right (UVC §11-304a):

The driver of a vehicle may overtake and pass upon the right of another vehicle only under the following conditions.

1. *When the vehicle overtaken is making or about to make a left turn;*
2. *Upon a roadway with unobstructed pavement of sufficient width for two or more lines of vehicles moving lawfully in the direction being traveled by the overtaking vehicle.*

A case could be made that this provision applies to conditions within a circulatory roadway of a multilane roundabout. Under the definition of a roundabout as a single intersection, a vehicle making a left turn could be overtaken on the right, even though the completion of the left turn requires exiting on the right.

International rules of the road vary considerably on this point. The United Kingdom, for example, requires drivers to "watch out for traffic crossing in front of you on the roundabout, especially vehicles intending to leave by the next exit. Show them consideration." (9, §125) This is generally interpreted as meaning that a vehicle at the front of a bunch of vehicles within the circulatory roadway has the right-of-way, regardless of the track it is on, and following vehicles on any track must yield to the front vehicle as it exits. Australia, on the other hand, does not have a similar statement in its legal codes, and this was one of the factors that led Australians to favor striping of the circulatory roadway in recent years. Further research and legal exploration need to be performed to determine the effect of this legal interpretation on driver behavior and the safety and operation of multilane roundabouts.

For clarity, this guide makes the following recommendations:

- Overtaking within the circulatory roadway should be prohibited.
- Exiting vehicles should be given priority over circulating vehicles, provided that the exiting vehicle is in front of the circulating vehicle.

Recommendations: No overtaking within the circulatory roadway, and exiting vehicles in front of other circulating vehicles have priority when exiting.

2.4.5 Pedestrian accessibility

The legal definition of a roundabout as one intersection or a series of intersections also has implications for pedestrians, particularly with respect to marked and unmarked crosswalks. A portion of the UVC definition of a crosswalk is as follows: ". . . and in the absence of a sidewalk on one side of the roadway, that part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline" (UVC §1-112(a)). Under the definition of a roundabout as a series of T-intersections, this portion of the definition could be interpreted to mean that there are unmarked crosswalks between the perimeter and the central island at every approach. The recommended definition of a roundabout as a single intersection simplifies this issue, for the marked or unmarked crosswalks around the perimeter as defined are sufficient and complete.

In all States, drivers are required to either yield or stop for pedestrians in a crosswalk (however, this requirement is often violated, and therefore it is prudent for pedestrians not to assume that this is the case). In addition, the provisions of the ADA also apply to roundabouts in all respects, including the design of sidewalks, crosswalks, and ramps. Under the ADA, accessible information is required to make the existing public right-of-way an accessible program provided by State and local governments (28 CFR 35.150). Any facility or part of a facility that is newly constructed by a State or local government must be designed and constructed so that it is readily accessible to and usable by people with disabilities (28 CFR 35.151(a)). Alterations to existing facilities must include modifications to make altered areas accessible to individuals with disabilities (28 CFR 735.151 (b)).

Current guidelines do not specifically address ways to make roundabouts accessible. Nonetheless, these provisions mean providing information about safely crossing streets in an accessible format, including at roundabouts. At a minimum, design information should provide for:

- Locating the crosswalk;
- Determining the direction of the crosswalk;
- Determining a safe crossing time; and
- Locating the splitter island refuge.

2.4.6 Parking

Many States prohibit parking within a specified distance of an intersection; others allow parking right up to the crosswalk. The degree to which these laws are in place will govern the need to provide supplemental signs and/or curb markings showing parking restrictions. To provide the necessary sight distances for safe crossings to occur, this guide recommends that parking be restricted immediately upstream of the pedestrian crosswalks.

The legal need to mark parking restrictions within the circulatory roadway may be dependent on the definition of a roundabout as a single intersection or as a series of T-intersections. Using the recommended definition of a roundabout as a single intersection, the circulatory roadway would be completely contained within the intersection, and the UVC currently prohibits parking within an intersection (UVC §11-1003).

2.5 Public Involvement

Public acceptance of roundabouts has often been found to be one of the biggest challenges facing a jurisdiction that is planning to install its first roundabout. Without the benefit of explanation or first-hand experience and observation, the public is likely to incorrectly associate roundabouts with older, nonconforming traffic circles that they have either experienced or heard about. Equally likely, without adequate education, the public (and agencies alike) will often have a natural hesitation or resistance against changes in their driving behavior and driving environment.

In such a situation, a proposal to install a roundabout may initially experience a negative public reaction. However, the history of the first few roundabouts installed in the United States also indicates that public attitude toward roundabouts improves significantly after construction. A recent survey conducted of jurisdictions across the United States (3) reported a significant negative public attitude toward roundabouts prior to construction (68 percent of the responses were negative or very negative), but a positive attitude after construction (73 percent of the responses were positive or very positive).

A recent survey found negative public attitudes towards roundabouts before construction, but positive attitudes following construction.

A wide variety of techniques have been used successfully in the United States to inform and educate the public about new roundabouts. Some of these include public meetings, informational brochures and videos, and announcements in the newspaper or on television and radio. A public involvement process should be initiated as soon as practical, preferably early in the planning stages of a project while other intersection forms are also being considered.

Public meetings, videos and brochures, and media announcements are some of the ways to educate the public about new roundabouts.

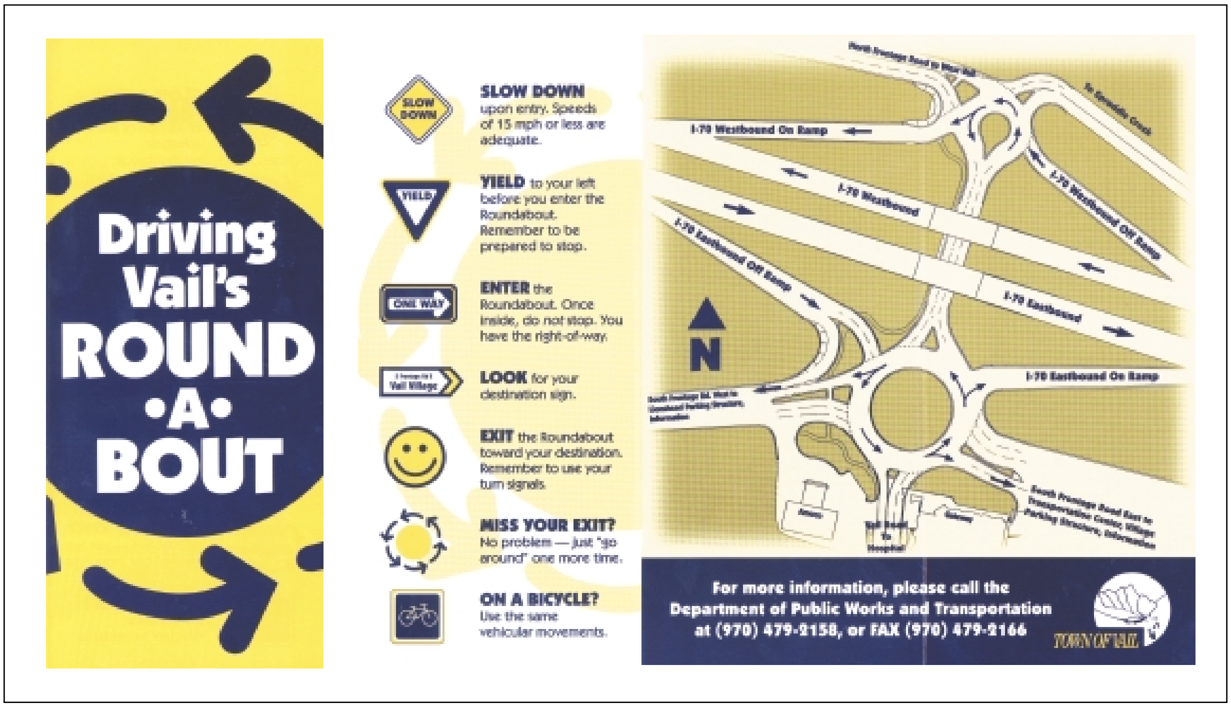
2.5.1 Public meetings

Public meetings can be a good forum for bringing the public into the design process. This allows early identification of potential problems and helps to gain overall acceptance throughout the process. Public input may be useful at various stages in the planning process: data collection, problem definition, generation of design alternatives, selection of preferred alternatives, detailed design, go/no-go decision, construction/opening, and landscape maintenance. Many jurisdictions require or recommend public meetings with the affected neighborhood or businesses prior to approval of the project by elected officials. Even if such meetings are not required, they can be helpful in easing concerns about a new form of intersection for a community.

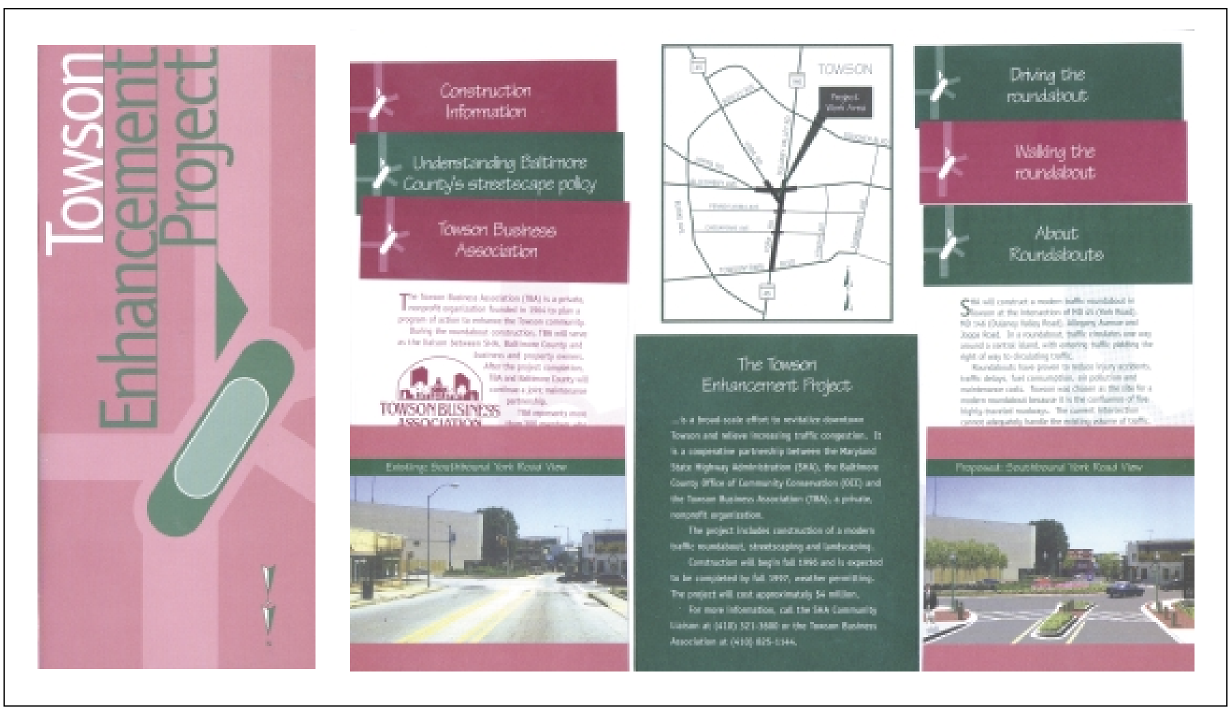
2.5.2 Informational brochures

A number of agencies, including the Maryland State Highway Administration and the City of Montpelier, Vermont, have used informational brochures to educate the public about roundabouts in their communities. Brochures have also been prepared for specific projects. Exhibit 2-6 shows examples from the brochures prepared for the I-70/Vail Road roundabouts in Vail, Colorado, and the Towson Roundabout in Towson, Maryland. These brochures include drawings or photographic simulations of the proposed roundabout. The brochures also typically include general information on roundabouts (what roundabouts are, where they can be found, and the types of benefits that can be expected). Sometimes they also include instructions on how to use the roundabout as a motorist, bicyclist, and pedestrian. The Towson brochure included additional information on the business association in the area, the streetscape policy of the county, and information on the construction phases of the roundabout.

Exhibit 2-6. Examples of informational brochures.



(a) Vail, CO



(b) Towson, MD

2.5.3 Informational videos

A number of agencies and consulting firms have prepared videos to inform the public about roundabouts. These videos are typically 10 to 15 minutes in length and include footage of existing roundabouts and narration about their operational and safety characteristics. These videos have been successfully used at public meetings as an effective means of introducing the public to roundabouts.

2.5.4 Media announcements

Given the new nature of a roundabout in many communities, the local media (newspaper, radio, and television) is likely to become involved. Such interest often occurs early in the process, and then again upon the opening of the roundabout. Radio reading services, telephone information services, and publications intended primarily for individuals with disabilities should be used to communicate with persons who are visually impaired when a roundabout is proposed and when it opens.

2.6 Education

One of the important issues facing a State considering the implementation of roundabouts is the need to provide adequate driver, cyclist, and pedestrian education. To clarify the following tips and instructions, user education should begin by using simple exhibits such as those in Chapter 1 to familiarize them with the basic physical features of a roundabout intersection. Users should also familiarize themselves with the instructions for all other modes so that they understand the expectations of each other. The following sections provide instructional material and model language for drivers, cyclists, and pedestrians that can be adapted to drivers manuals. These have been adapted from similar rules of the road and drivers manuals used for roundabouts in the United Kingdom (9), Australia (10), and the State of Victoria, Australia (11).

The following sample instructions assume that readers have already seen introductory material on roundabouts, such as the brochures depicted in the previous section.

2.6.1 Driver education

2.6.1.1 Approaching the roundabout

On approaching a roundabout, decide as early as possible which exit you need to take and get into the correct lane (refer to the section below on "Turning at roundabouts"). Reduce your speed. Bicyclists are vehicles and need to share the lane at intersections. Therefore, allow bicycles to enter the roadway from any bicycle lane. The law gives pedestrians the right-of-way in a crosswalk. Yield to pedestrians waiting to cross or crossing on the approach. Watch out for and be particularly considerate of people with disabilities, children, and elderly pedestrians. Always keep to the right of the splitter island (either painted or raised) on the approach to the roundabout.

2.6.1.2 Entering the roundabout

Upon reaching the roundabout yield line, yield to traffic circulating from the left unless signs or pavement markings indicate otherwise. Do not enter the roundabout beside a vehicle already circulating within the roundabout, as a vehicle near the central island may be exiting at the next exit. Watch out for traffic already on the roundabout, especially cyclists and motorcyclists. Do not enter a roundabout when an emergency vehicle is approaching on another leg; allow queues to clear in front of the emergency vehicle.

2.6.1.3 Within the roundabout

Within a roundabout, do not stop except to avoid a collision; you have the right-of-way over entering traffic. Always keep to the right of the central island and travel in a counterclockwise direction.

Where the circulatory roadway is wide enough to allow two or more vehicles to travel side-by-side, **do not overtake adjacent vehicles who are slightly ahead of yours as they may wish to exit next.** Watch out for traffic crossing in front of you on the roundabout, especially vehicles intending to leave by the next exit. Do not change lanes within the roundabout except to exit.

When an emergency vehicle is approaching, in order to provide it a clear path to turn through the roundabout, proceed past the splitter island of your exit before pulling over.

2.6.1.4 Exiting the roundabout

Maintain a slow speed upon exiting the roundabout. Always indicate your exit using your right-turn signal. For multilane roundabouts, watch for vehicles to your right, including bicycles that may cross your path while exiting, and ascertain if they intend to yield for you to exit. Watch for and yield to pedestrians waiting to cross, or crossing the exit leg. Watch out for and be particularly considerate of people with disabilities, children, and elderly pedestrians. Do not accelerate until you are beyond the pedestrian crossing point on the exit.

2.6.1.5 Turning at roundabouts

Unless signs or pavement markings indicate otherwise:

- **When turning right or exiting** at the first exit around the roundabout, use the following procedure:
  - Turn on your right-turn signal on the approach.
  - If there are multiple approach lanes, use only the right-hand lane.
  - Keep to the outside of the circulatory roadway within the roundabout and continue to use your right-turn signal through your exit.
  - When there are multiple exit lanes use the right-hand lane.
- **When going straight ahead** (i.e., exiting halfway around the roundabout), use the following procedure (see Exhibit 2-7):
  - **Do not use any turn signals on approach.**
  - If there are two approach lanes, you may use either the left– or right-hand approach lanes.
  - When on the circulatory roadway, turn on your right-turn signal once you have passed the exit before the one you want and continue to use your right-turn signal through your exit.
  - Maintain your inside (left) or outside (right) track throughout the roundabout if the circulatory roadway is wide. This means that if you entered using the inner (left) lane, circulate using the inside track of the circulatory roadway and exit from here by crossing the outside track. Likewise, if you entered using the outer (right) lane, circulate using the outside track of the circulatory roadway and exit directly from here. **Do not change lanes within the roundabout except when crossing the outer circulatory track in the act of exiting.**

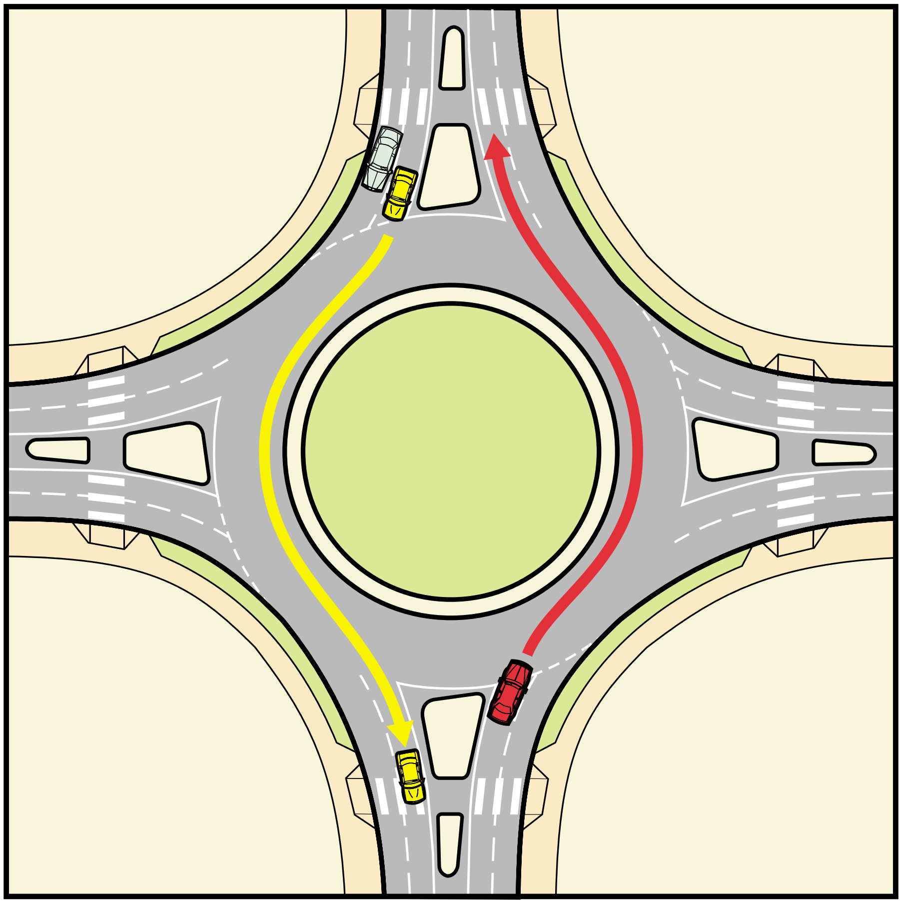


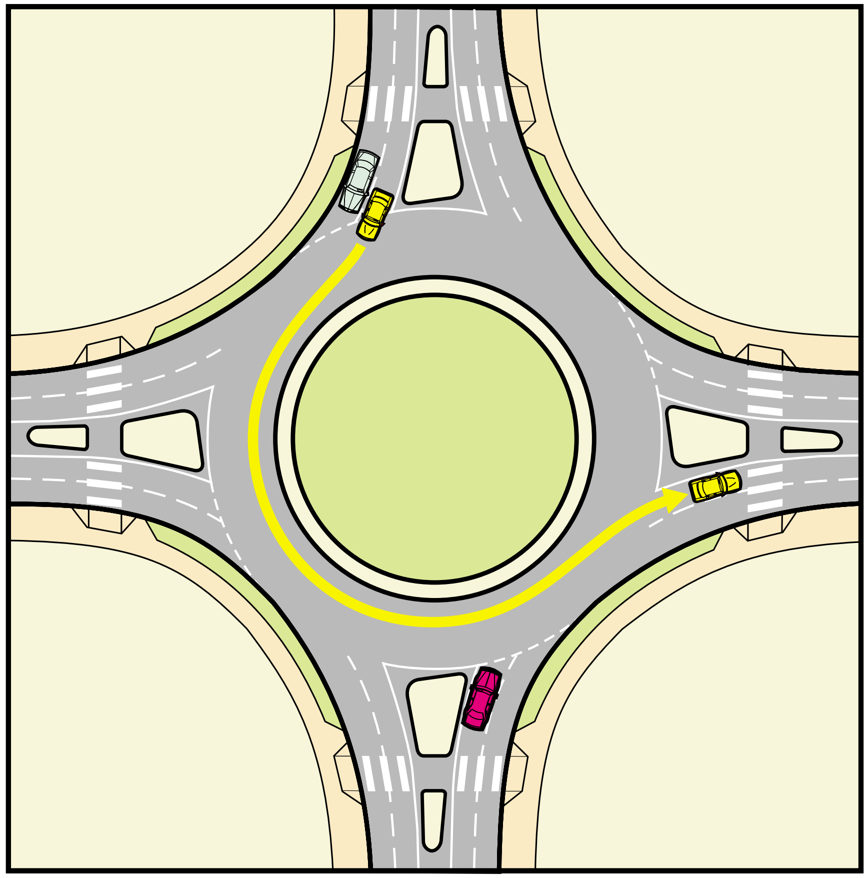
Exhibit 2-7. Driving straight through a roundabout.

Source: *The Highway Code* (UK) (9), converted to right-hand drive

- When exiting the circulatory roadway from the inside track, watch out on the outside track for leading or adjacent vehicles that continue to circulate around the roundabout.
- When exiting the circulatory roadway from the outside track, yield to leading or adjacent vehicles that are exiting into the same lane.

- When turning left or making a U-turn (i.e., exiting more than halfway around the roundabout), use the following procedure (see Exhibit 2-8):
  - Turn on your left turn signal.
  - If there are multiple approach lanes, use only the left-hand lane.
  - Keep to the inner (left) side of the circulatory roadway (nearest the central island).
  - Continue to use your left-turn signal until you have passed the exit before the one you want, and then use your right-turn signal through your exit.
  - When exiting from a multilane roundabout from the inside part of the circulatory roadway, use only the inner lane on the exit (the lane nearest the splitter island). Watch out on the outside part of the circulatory roadway for leading or adjacent vehicles that continue to circulate around the roundabout.

Exhibit 2-8. Turning left at a roundabout.



Source: *The Highway Code* (UK) (9), converted to right-hand drive

- When in doubt about lane choice (especially for roundabouts with legs at angles other than 90½), **use the following general rules to determine which lane you should be in** (unless signs or pavement markings indicate otherwise):
  - If you intend to exit the roundabout less than halfway around it, use the right lane.
  - If you intend to exit the roundabout more than halfway around it, use the left lane.

2.6.1.6 Motorcyclists and bicyclists

Watch out for motorcyclists and bicyclists. Give them plenty of room and show due consideration. Bicyclists may enter the approach roadway from a bicycle lane. Bicyclists will often keep to the right on the roundabout; they may also indicate left to show they are continuing around the roundabout. It is best to treat bicyclists as other vehicles and not pass them while on the circulatory roadway. Motorcyclists should not ride across the mountable truck apron next to the central island, if present.

2.6.1.7 Large vehicles

When car drivers approach a roundabout, do not overtake large vehicles. Large vehicles (for example, trucks and buses) may have to swing wide on the approach or within the roundabout. Watch for their turn signals and give them plenty of room, especially since they may obscure other conflicting users.

To negotiate a roundabout, drivers of large vehicles may need to use the full width of the roadway, including mountable aprons if provided. They should be careful of all other users of the roundabouts and, prior to entering the roundabout, satisfy themselves that other users are aware of them and will yield to them.

2.6.2 Bicyclist education

Bicyclists should likewise be educated about the operating characteristics of roundabouts. Well-designed, low-speed, single-lane roundabouts should not present much difficulty to bicyclists. They should enter these roundabouts just as they enter a stop sign or signal controlled intersection without auxiliary lanes (the bike lane terminates on the approach to these intersections, too). On the approach to the entry, a bicyclist should claim the lane. Right-turning cyclists should keep to the right side of the entry lane; others should be near the center of the lane.

Cyclists have three options upon approaching a roundabout:

- Travel on the circulatory roadway of the roundabout like motorists. When using a double-lane roundabout as a vehicle, obey all rules of the road for vehicles using roundabouts. However, you may feel safer approaching in the right-hand lane and keeping to the right in the roundabout (rather like making two through movements to turn left at a signalized intersection). If you do keep to the right, take extra care when crossing exits and signal left to show you are not leaving. Watch out for vehicles crossing your path to leave or join the roundabout. Watch out for large vehicles on the roundabout, as they need more space to maneuver. It may be safer to wait until they have cleared the roundabout. Or,
- If you are unsure about using the roundabout, dismount and exit the approach lane before the splitter island on the approach, and move to the sidewalk. Once on the sidewalk, walk your bicycle like a pedestrian. Or,
- Some roundabouts may have a ramp that leads to a widened sidewalk or a shared bicycle-pedestrian path that runs around the perimeter of the roundabout. If a ramp access is provided prior to the pedestrian crossing, you may choose to ramp up to curb level and traverse the sidewalk or path while acting courteously to pedestrians. A ramp may also be provided on the exit legs of a roundabout to reenter the roadway, after verifying that it is safe to do so.

2.6.3 Pedestrian education

Pedestrians have the right-of-way within crosswalks at a roundabout; however, pedestrians must not suddenly leave a curb or other safe waiting place and walk into the path of a vehicle if it is so close that it is an immediate hazard. This can be problematic if the design is such that a disabled pedestrian cannot accurately determine the gap. Specific education beyond these general instructions should be provided for disabled pedestrians to use any information provided for them.

- Do not cross the circulatory roadway to the central island. Walk around the perimeter of the roundabout.
- Use the crosswalks on the legs of the roundabout. If there is no crosswalk marked on a leg of the roundabout, cross the leg about one vehicle-length away (7.5 m [25 ft]) from the circulatory roadway of the roundabout. Locate the wheelchair ramps in the curbs. These are built in line with a grade-level opening in the median island. This opening is for pedestrians to wait before crossing the next roadway.

- Roundabouts are typically designed to enable pedestrians to cross one direction of traffic at a time. Look and listen for approaching traffic. Choose a safe time to cross from the curb ramp to the median opening (note that although you have the right-of-way, if approaching vehicles are present, it is prudent to first satisfy yourself that conflicting vehicles have recognized your presence and right to cross, through visual or audible cues such as vehicle deceleration or driver communication). If a vehicle slows for you to cross at a two-lane roundabout, be sure that conflicting vehicles in adjacent lanes have done likewise before accepting the crossing opportunity.
- Most roundabouts provide a raised median island halfway across the roadway; wait in the opening provided and choose a safe time to cross traffic approaching from the other direction.

2.7 References

1. Brown, M. *TRL State of the Art Review—The Design of Roundabouts.* London: HMSO, 1995.
2. Alphand, F., U. Noelle, and B. Guichet. "Roundabouts and Road Safety: State of the Art in France." In *Intersections without Traffic Signals II,* Springer-Verlag, Germany (W. Brilon, ed.), 1991, pp. 107–125.
3. Jacquemart, G. *Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States.* National Cooperative Highway Research Program. Washington, D.C: National Academy Press, 1998.
4. Department of Transport (United Kingdom). "Killing Speed and Saving Lives." As reported in Oregon Department of Transportation, *Oregon Bicycle and Pedestrian Plan,* 1995.
5. Garder, P. *The Modern Roundabouts: The Sensible Alternative for Maine.* Maine Department of Transportation, Bureau of Planning, Research and Community Services, Transportation Research Division, 1998.
6. Niederhauser, M.E., B.A. Collins, and E.J. Myers. "The Use of Roundabouts: Comparison with Alternate Design Solution." *Compendium of Technical Papers,* 67th Annual Meeting, Institute of Transportation Engineers. August 1997.
7. Federal Highway Administration (FHWA). *Older Driver Highway Design Handbook.* Publication No. FHWA-RD-97-135. Washington, D.C.: FHWA, January 1998.
8. National Committee on Uniform Traffic Laws and Ordinances (NCUTLO). Uniform Vehicle Code and Model Traffic Ordinance. Evanston, Illinois: NCUTLO, 1992.
9. Department of Transport (United Kingdom). *The Highway Code.* Department of Transport and the Central Office of Information for Her Majesty's Stationery Office, 1996.
10. Australia. *Traffic Act,* Part 6A, 1962.
11. VicRoads. *Victorian Traffic Handbook,* Fourth Edition. Melbourne, Australia: Roads Corporation, 1998.