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Kansas Roundabout Guide

A supplement to FHWA's
Roundabouts: An Informational Guide

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION PLANNING/TRAFFIC ENGINEERING

TRANSYSTEMS CORPORATION

Foreword

"Modern roundabouts are being constructed more and more in the state of Kansas, in the U.S. and around the world. The benefits range from increased safety, increased capacity and improved aesthetics over other types of intersections.

This guide is a supplement to the Federal Highway Administration (FHWA) document "Roundabouts: An Informational Guide" (Publication No. FHWA-RD-00-067). This guide is intended to provide some consistent information regarding the planning, design, construction and operation of roundabouts in Kansas. Roundabout design is not a specific science, but more of an art form within the context of State and Federal guidelines. The use of sound engineering principles and common sense is vital to the proper planning, design and construction of modern roundabouts. In the event that there are any conflicts between the content of this guide and the Manual on Uniform Traffic Control Devices (MUTCD), the MUTCD will govern.

This guide is not intended to take the place of having an in-depth review of a modern roundabout project plan. We encourage municipalities and state Departments of Transportation to have their roundabout designs (especially multilane roundabouts) reviewed by someone who has years of roundabout design experience and who is knowledgeable in all aspects of modern roundabout planning, design, construction and operation".

David Church, P.E.
Bureau Chief
KDOT, Traffic Engineering

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List of Exhibits

Photo Credits

Armor-Tile Tactile Systems, Website: http://www.armor-tile.com/photos.htm: Exhibit 6-27

Werner Brilon: Exhibit 1-12, Exhibit 6-11, and Exhibit 6-25

City of Grand Junction, Colorado: Exhibit 6-35 (photo at right)

Aimee Flannery: Exhibit 1-9

Kansas State University Website http://www.ksu.edu/roundabouts/ada/photos/manhattantrafficcircle.htm: Exhibit 1-7 (upper left, upper right)

New York State Department of Transportation: Exhibit 1-6

Oregon Department of Transportation: Exhibit 6-26 (top, bottom)

Lee Rodegerdts: Cover (all), Exhibit 1-7 (lower left, lower right), Exhibit 1-8 (all), Exhibit 1-11, Exhibit 2-3 (all), Exhibit 2-4, Exhibit 6-9, Exhibit 6-26 (middle), Exhibit 6-33, Exhibit 6-42 (all), Exhibit 6-44 (all), Exhibit 8-1, Exhibit 8-2, and Exhibit 8-4

Yolanda Takesian: Exhibit 6-34

Chapter 1 - Introduction

1.1 Roundabout Elements

Although roundabouts have been in widespread use in other countries for many years, they have only recently been used within the United States. Roundabouts can offer several advantages over signalized and stop controlled alternatives, including better overall safety performance, lower delays, and shorter queues (particularly during off-peak periods), better management of speeds, and opportunities for community enhancement features. In some cases, roundabouts can avoid or delay the need for expensive widening of an intersection approach (such as an overpass or underpass structure) that would otherwise be necessary for signalization.

Many of the guidelines in this document are based on the FHWA publication, *Roundabouts: An Informational Guide* (hereafter referred to as the FHWA Roundabout Guide). For more discussion and details related to roundabouts, readers are encouraged to review the FHWA Roundabout Guide.

A *roundabout* is a generally circular intersection with the following specific geometric and traffic control characteristics:

- Yield control at all entries, and
- Appropriate geometric features to promote slow and consistent speeds for all movements.

The key features of a roundabout are displayed in Exhibit 1-1 and defined in Exhibit 1-2. Exhibit 1-3 illustrates key dimensions of a roundabout. Refer to Chapter 6 of this guide for further discussion related to each of the design features and dimensions.

Exhibit 1-1
Roundabout Design Features

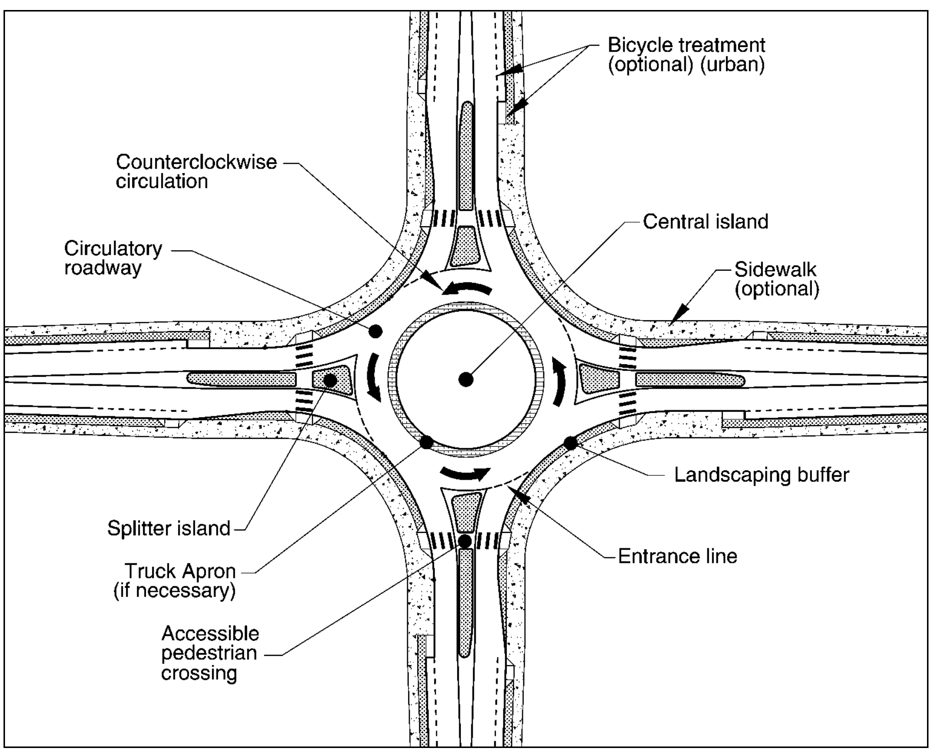
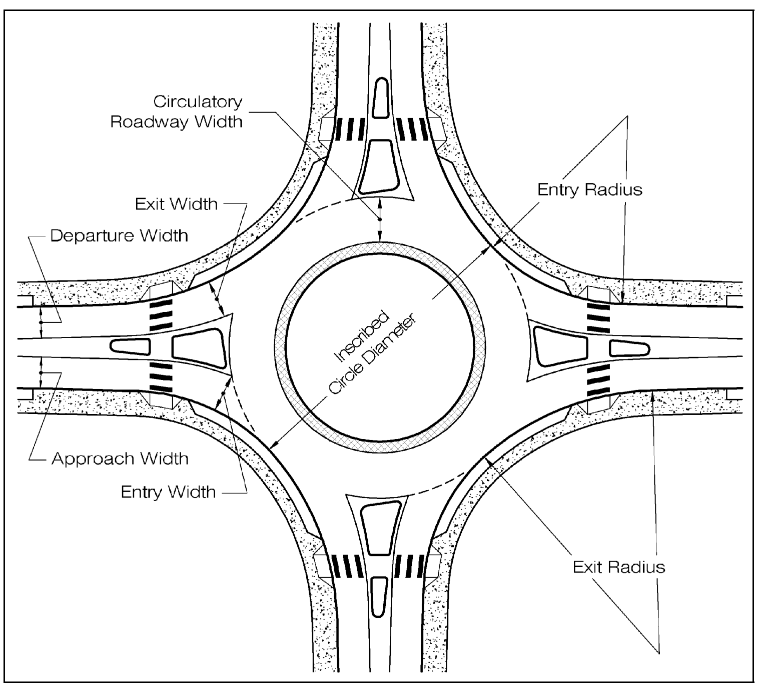


Exhibit 1-2
Key Roundabout Features

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 counterclockwise fashion around the central island
Truck Apron	If required to accommodate the wheel tracking of large vehicles, a truck apron is the mountable portion of the central island adjacent to the circulatory roadway. Truck aprons are not necessary at all roundabouts.
Entrance Line	An entrance 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 considered at all roundabouts. Striped crossings may be omitted at rural roundabouts where pedestrian activity is nonexistent, and not anticipated. Where used, the crossing location is set back from the entrance 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
Key Dimensions



1.2 Categories of Roundabouts

Roundabouts have been categorized according to size and environment to differentiate their design and operational characteristics within different contexts. There are six basic categories based on site environment, number of lanes, and size:

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

A brief description of each of these basic roundabout categories follows.

Mini Roundabouts

Mini-roundabouts are small roundabouts used in built-up urban environments. Because of their small size, the central island is fully mountable, and larger vehicles may cross over the central island, but not to the left of it. However, the mini-roundabout is designed to accommodate passenger cars without requiring them to drive over the central island, and speed control should be provided by requiring vehicles to negotiate around the mountable central island.

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. Capacity for this type of roundabout is expected to be similar to that of the compact urban roundabout.

Urban Compact Roundabouts

Urban compact roundabouts are characterized by their relatively small inscribed circle diameter (typically 100 to 120 ft [30 to 37 m]), a non-mountable central island, and nearly perpendicular entry geometry. These 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. 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 when considering a roundabout of this type. The geometric design includes raised splitter islands, incorporating at-grade pedestrian storage areas, and a non-mountable central island. Being compact, there is usually an apron surrounding the non-mountable part of the central island to accommodate large vehicles.

Urban Single-Lane Roundabouts

This type of roundabout is characterized as having a single-lane entry at all legs and one circulatory lane. They are distinguished from urban compact roundabouts by their larger inscribed circle diameters (typically 120 to 150 ft [37 to 45 m]) and more tangential entries and exits, resulting in higher capacities. Their design allows slightly higher speeds at the entry, on the circulatory roadway, and at the exit. The roundabout design is focused on achieving consistent entering and circulating vehicle speeds. The geometric design includes raised splitter islands, a non-mountable central island, and may include an apron.

Urban Double-Lane Roundabouts

Urban double-lane roundabouts include all roundabouts in urban areas that have at least one entry with two lanes. These roundabouts require wider circulatory roadways to accommodate more vehicles traveling side-by-side. 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, a non-mountable central island, and may include an apron.

Rural Single-Lane Roundabouts

Rural roundabouts may have larger diameters than urban roundabouts to allow slightly higher speeds at the entries, on the circulatory roadway, and at the exits. This is possible if few pedestrians are expected at these intersections, currently and in the future. There is preferably no apron because their larger diameters should accommodate larger vehicles. Supplemental geometric design elements include extended and raised splitter islands, a non-mountable central island, and adequate horizontal deflection. Because they are often located in high-speed environments, they may require supplementary geometric and traffic control device treatments on approaches to encourage drivers to slow to an appropriate speed before entering the roundabout.

Rural Double-Lane Roundabouts

Rural double-lane roundabouts have similar speed characteristics to rural single-lane roundabouts. 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 slightly higher entry speeds and larger diameters, and recommended supplementary approach treatments.

Rural roundabouts that may become part of an urbanized area within the design year should be designed with geometric features that will allow for easy conversion to an urban roundabout, with slower speeds and 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. At rural roundabouts, where installation of pedestrian crossings are deferred, sufficient splitter island width should be provided at to accommodate the easy addition of a pedestrian refuge in conjunction with the installation of the pedestrian crossings.

1.3 Roundabout Design Do's and Don'ts

The following is some general advice for planners and designers considering roundabouts. This list has been prepared in the form of "do's" and "don'ts" with respect to evaluating and designing roundabouts. These "do's" and "don'ts" are based on the authors' real-world experience and may not reflect every situation a planner or designer may encounter. More detailed information regarding each of these topics can be found in later chapters of this guide as well as the FHWA Roundabout Guide.

Do:

- Be sure you know the problem (operations and safety) before you create the solution.
- Be aware of any constraints (including right-of-way, utilities, structures, environmental, etc.) that may impact the space available for a roundabout. Roundabouts often require more property at the corners of existing intersections; however, they can result in less widening of approach roadways than signalized intersections.
- Understand the types of vehicles that will be using the roundabout and select the design vehicle based upon the intersection location, surrounding land uses, roadway facility type, and other considerations. The choice of design vehicle is often the biggest determinant of a roundabout's inscribed diameter and entry/exit width dimensions, particularly for single-lane roundabouts.
- Provide accommodations for the largest motorized vehicle likely to use the intersection. Roundabouts not properly designed for trucks can receive premature wear with maintenance concerns due to trucks driving over the top of curbs and tracking through the central island.
- Consider whether local drivers are familiar with roundabouts. It may be helpful to start small when introducing roundabouts in a new geographic area. A single-lane roundabout will be more easily understood than multilane roundabouts and will help the driving population become more comfortable with navigating a roundabout.
- Consider the roundabout location and user population. Is the intersection in a rural or urban environment? Will the roundabout have frequent pedestrian and/or bicycle activity? The roundabout design should provide reasonable consideration to both auto and non-auto users.
- Check roundabout designs to ensure that the proposed geometry provides appropriate fastest path speeds. It is important that speeds are checked in preliminary and final designs alike to ensure that adequate operating speeds are maintained throughout the design process and into the field.
- Check multilane roundabout designs to ensure that appropriate natural vehicle paths can be achieved. Vehicle paths through the roundabout should not "overlap" each other. Designs with overlapping natural paths may experience a high number of vehicle collisions.
- Start the planning process by creating sketches in pencil over an aerial photograph or scaled drawing. This allows the designer to quickly create several different design concepts, capable of being altered significantly with little effort.

Don't:

- Don't approach intersection improvement projects with a preconceived solution. In other words, perform "intersection design studies," versus "roundabout design studies." This allows the designer to show the public that other alternatives have been examined, and the best solution is the one being proposed.
- Don't assume a roundabout design that works at one intersection location will work at another. Roundabouts are based on sound design PRINCIPLES, not standards—one size does not fit all.
- Don't begin detailed design until other design options or intersection configurations have been explored. A sketch layout will be sufficient at the beginning of the process to select an intersection configuration.
- Don't underestimate the time needed for public awareness. Roundabouts introduced into new areas may require additional effort to inform the general public about roundabouts and the proper way to use them. Public education efforts such as public awareness announcements, pamphlets, and other materials for public distribution may assist the public in becoming more comfortable in using roundabouts.
- Don't take risks with roundabouts in locations where you would not normally take risks for more traditional (signals, stop control, etc.) roadway solutions. Intersections having issues that make it difficult for other types of traffic control will also be difficult with a roundabout.
- Don't use a roundabout that is too small for the operating conditions in an attempt to stay within the existing right of way.
- Don't over-design the roundabout to accommodate a vehicle size that is unlikely to traverse the intersection (i.e. don't design to accommodate a WB-67 [WB-20m] in a residential neighborhood if the largest likely motorized vehicle is a delivery truck or a bus). Designing a roundabout with geometry larger than necessary for its intended use can create operational and safety issues due to a lack of speed control, in addition to needing more right-of-way and costing more to construct.

1.4 Roundabouts vs. Other Circular Intersections

The general public often draws a common association between roundabouts, traffic circles, and other circular intersections. This lack of distinction in the eyes of the public can, and has, lead to public opposition to roundabouts in areas where traffic calming circles have been unfavorably received. It is important to be able to distinguish the critical differences in the intersection treatments, not only to be able to choose the most applicable treatment but to also be able to defend the use of the chosen treatment under public scrutiny. The FHWA Roundabout Guide provides additional comparisons in the fundamental differences between roundabouts and other circular intersections.

Roundabouts are a subset in the category of circular intersections, shown graphically in Exhibit 1-4. Although roundabouts, rotaries, and traffic circles are all considered circular intersections, they have key differences that distinguish each from the other. Exhibit 1-5 presents five key elements distinguish roundabouts from traffic circles and other circular intersections.

Exhibit 1-4
Categories of Circular Intersections

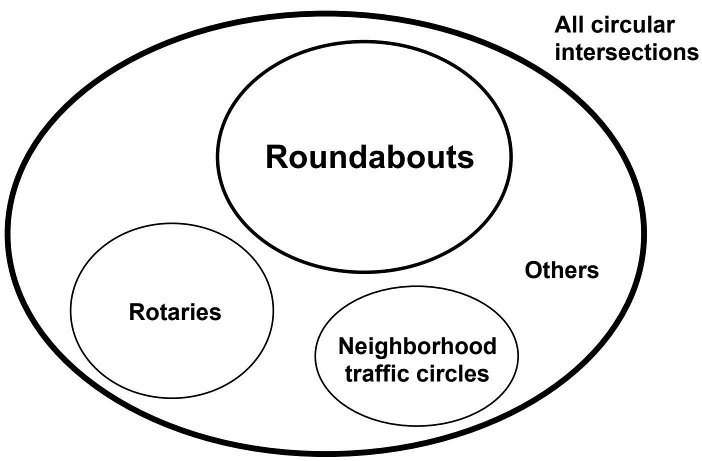


Exhibit 1-5
Key Elements of Roundabouts and Traffic Circles

Key Element	Roundabout	Traffic Circle
Control on entry	YIELD control on entry.	Some use a signal, stop control, or no control on one or more entries.
Priority to circulating vehicles	Circulating vehicles have the right of way.	Some require circulating traffic to yield to entering traffic.
Pedestrian access & crossing	Allowed only across the approaches to the roundabout, behind the entrance line.	Some allow pedestrians to cross to the central island.
Parking	No parking allowed within the circulatory roadway or at the entries.	Some allow parking within the circulatory roadway.
Direction of circulation	Counterclockwise direction to the right of the central island.	Some allow left-turning vehicles to pass to left of the central island.

Rotaries, an old-style circular intersection common in the United States prior to the 1960's, are characterized by a large diameter (often greater than 300 ft [90 m]). Construction of rotaries has fallen out of favor, not only for the large amounts of right-of-way they require, but also due to their lack of speed control and the additional weaving conflicts created on the entries and exits. Rotaries typically provide little or no deflection of the paths of through traffic in which to control speeds. Some may even operate with circulating traffic yielding to entering traffic, which can create congestion on the circulatory roadway. Exhibit 1-6 illustrates the conversion of a rotary (outer ring roadway) to a roundabout (center of photo).

Exhibit 1-6
Conversion From Rotary to Roundabout (Kingston, NY)

The purpose of a traffic circle is generally to provide traffic calming and/or an aesthetic treatment. While a roundabout can accomplish these things, a roundabout is primarily designed for the safe and efficient movement of vehicular and non-vehicular traffic through the intersection. To accomplish this task, roundabouts are generally larger than a neighborhood traffic circle constructed for the purpose of traffic calming. The difference in the purpose of each of the respective intersection treatments is reflected in the control of the intersection. Roundabouts always use yield control to keep traffic flowing, while traffic circles are typically uncontrolled or stop controlled on one or more approaches.

Traffic circles can be an appropriate intersection treatment in areas with low traffic volumes, such as in residential neighborhoods where the primary objective is traffic calming. The implementation of a traffic circle does not necessarily imply a change in the operating characteristics of an intersection, only a change in the physical appearance of the intersection. Often, neighborhood traffic circles can be implemented within an existing intersection without modification to the existing curb line. This allows for a low cost improvement that does not require additional right-of-way. The traffic island creates a physical impediment that must be negotiated around, thus slowing vehicles.

The implementation of a roundabout on the other hand creates a change in the operating characteristics of the intersection by introducing yield control on all movements and reverting right of way to those vehicles within the intersection traveling on the circulatory roadway. Roundabouts are typically much larger than the standard neighborhood traffic circle and utilize geometric features that deflect the path of vehicles, thus requiring motorists to travel at reduced speeds. Roundabouts are designed to provide adequate capacity to the intersection, minimize delay and queuing on the approaches, maintain reduced travel speeds, and reduce the number and severity of collisions at the intersection. Exhibit 1-7 presents examples of traffic circles and roundabouts in Kansas.

Exhibit 1-7
Example Traffic Circles and Roundabouts in Kansas

Traffic Circles, *Manhattan, Kansas*

Roundabout, *Olathe, Kansas*

Roundabout, *Hutchinson, Kansas*

Common Issues Associated with Neighborhood Traffic Circles

Traffic circles can be an effective treatment for traffic calming measures, especially in residential neighborhoods on local streets. However, there are limitations to the locations in which traffic circles may be appropriate. In many instances roundabouts can accomplish the same traffic calming goals as traffic circles, but typically require more right of way and are more costly than the traffic circle alternative. The list below identifies some common issues associated with traffic circles, which are eliminated through the implementation of a roundabout.

- Small traffic circles often are not designed to accommodate trucks. Many neighborhood traffic circles with raised central islands will not accommodate a delivery truck or bus, and may inhibit the ease of movement of emergency vehicles. Vehicles of this size must usually pass in front of the central island to make a left turn, forcing them to drive on the wrong side of the road.
- Some traffic circles are designed without adequate horizontal deflection on the entry to the intersection, preventing speed control objectives from being achieved. While the island provides a physical obstruction to get the motorists attention, the physical characteristics of the intersection itself does not prevent motorists from speeding, especially once familiar with navigating the intersection.
- Stop control, or no control, typical at traffic circles may cause confusion to drivers regarding right of way around the central island. Yield control, typical at roundabouts, provides consistency and helps to maintain efficient traffic operations.
- The lack of priority for circulating vehicles can cause congestion within a traffic circle if high enough traffic volumes are present.

Examples of Neighborhood Traffic Circles

Traffic circles can take on a variety of shapes and sizes. Some forms are easily distinguishable from roundabouts, while others may have many of the features associated with roundabouts but are deficient in one or more critical areas. Exhibit 1-8 presents the characteristics of traffic circles.

Exhibit 1-8
Characteristics of Traffic Circles

Traffic Calming Circles

Perhaps the simplest form of traffic circle, these intersection treatments have gained popularity for use in calming traffic on residential streets. These traffic circles are generally characterized by the use of a small raised island (often landscaped) placed in the center of an existing unsignalized intersection. The original configuration of the intersection approaches often remains in place after the conversion, with stop control, or no control, on one or more entries to the intersection.

Chicanes, curb extensions, or other traffic calming treatments may also be introduced in conjunction with the traffic circle. The treatment shown in the picture at left helps to provide additional deflection and define on-street parking locations in the vicinity of the intersection.

Control of a traffic circle is typically uncontrolled or stop controlled (as shown at left).

Some traffic circles allow parking within the circular roadway of the intersection. Parking is prohibited within the circulatory roadway and approaches to a roundabout.

Roundabouts

Like traffic circles, roundabouts can be developed in a variety of shapes and sizes. However, unlike traffic circles, modern roundabouts utilize key design elements to ensure that each will have similar operating characteristics. Exhibit 1-9 shows an example of some of the geometric features in a typical roundabout.

The use of splitter islands in combination with a central island and an appropriately sized circulatory roadway creates a deflected path that provides reduced operating speeds and helps to maintain speed consistency for all vehicles. Truck aprons are provided around the central island of small and medium-sized roundabouts to accommodate larger vehicles such as trucks and emergency vehicles. A good roundabout design will allow trucks to track on the provided apron, but not over the central island.

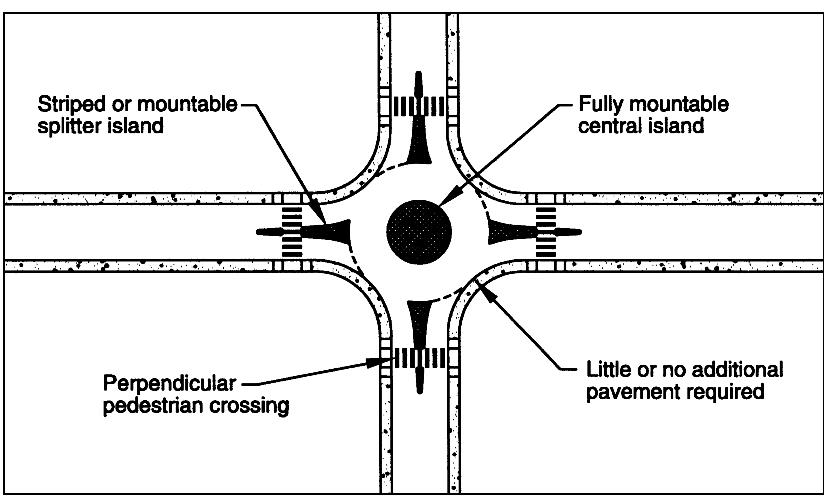
A fundamental element of all roundabouts is the use of yield control on all approaches to the intersection. Vehicles entering the roundabout yield right-of-way to those vehicles already traveling upon the circulatory roadway. Additionally, all vehicles are required to travel in a counterclockwise direction, to the right of the central island.

Exhibit 1-9
Elements of a Roundabout

Mini-roundabouts

Mini-roundabouts, shown in Exhibit 1-10, are small roundabouts used in low speed urban environments. Mini-roundabouts are mostly recommended when there is insufficient right-of-way available for an urban compact roundabout. The use of a mini-roundabout may be an appropriate intersection treatment in lieu of a traffic circle. In retrofit applications, such as in established neighborhoods where there may be right-of-way constraints, mini-roundabouts are relatively inexpensive because they require minimal additional pavement at the intersecting roadways. The main differences in the form of the mini-roundabout versus the standard roundabout are the relatively small size of the inscribed circle, a fully mountable central island, and striped or mountable splitter islands.

Exhibit 1-10
Elements of a Mini-Roundabout



Care should be taken when designing mini-roundabouts to ensure that the same principles are being achieved as would be found in roundabout designs. Designers attempting to retrofit a roundabout into a constrained location sometimes blur the line between a properly designed roundabout and a traffic circle. Often, mini-roundabouts are improperly designed with a non-mountable central and splitter islands and with little regard to providing proper entry and exit geometry for achieving appropriate speeds.

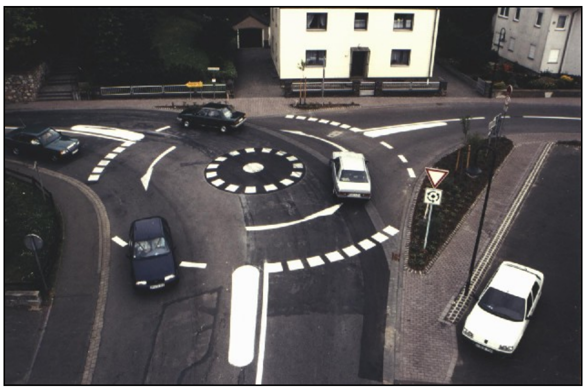
The use of a mountable central island is important for accommodating trucks, emergency vehicles, and other large motorized vehicles through the intersection. Large vehicles may track over the top of the mountable central island, but not to the left of it. Mountable or striped splitter islands are typically required to accommodate the design vehicle; however, raised splitter islands should be used where possible. Additionally, the center of a mini-roundabout should remain free of any objects, including trees and signs. Horizontal deflection on the entry provides speed control around the mountable central island. Achieving proper deflection in the entry geometry may require acquisition of additional right of way at the corners of the intersection.

Mini Roundabout Examples

The photos below in Exhibit 1-11 and Exhibit 1-12 show various examples of mini-roundabout in the United States and Germany, respectively. Note that the size of the roundabout is relatively small, however each of the mini-roundabouts incorporate all of the necessary design features that make up a roundabout such as yield signs and entrance lines, splitter islands, perpendicular crosswalks, and a central island. Even though the central island is fully mountable, each of the examples shows it to be slightly raised with distinct markings or materials that distinguish it from the circulatory roadway.

Exhibit 1-11
Mini-Roundabout, Dimondale, Michigan

Exhibit 1-12
Mini-Roundabouts, Germany



Chapter 2 - Public Involvement Considerations

2.1 Public Meetings Guidance

Public meetings can be an important tool for gaining acceptance of a roundabout in a community as well as providing a forum for educating the public on the new form of traffic control. This forum allows the public to become involved in the design process to identify problems and preferred alternatives. This step in the design process may be especially important for the introduction of a roundabout into a new area exhibiting public opposition. The public meeting provides an opportunity to dispel any misnomers about roundabout design and operation, as well as to showcase the operational and safety benefits.

To gain the most benefit from a public meeting it may be helpful to think about who are advocates and who are the opponents of a roundabout project? Why are people opposing roundabout implementation? What information does the public need to know to understand why a roundabout is being proposed? What role can the public play in providing input and guidance?

Traffic Circles vs. Roundabouts

Misconceptions and opposition regarding roundabouts may be found in communities due to the general association drawn between roundabouts and traffic circles. Although the two intersection treatments are different in some critical features, the circular shape common in both helps to create the association in the minds of the public. Traffic circles have received negative reviews in some communities, creating the opposition to circular shaped intersections. It is important that the public understand the distinction between a roundabout and traffic circle if they are to accept the construction of a roundabout in their community.

Other Public Opposition

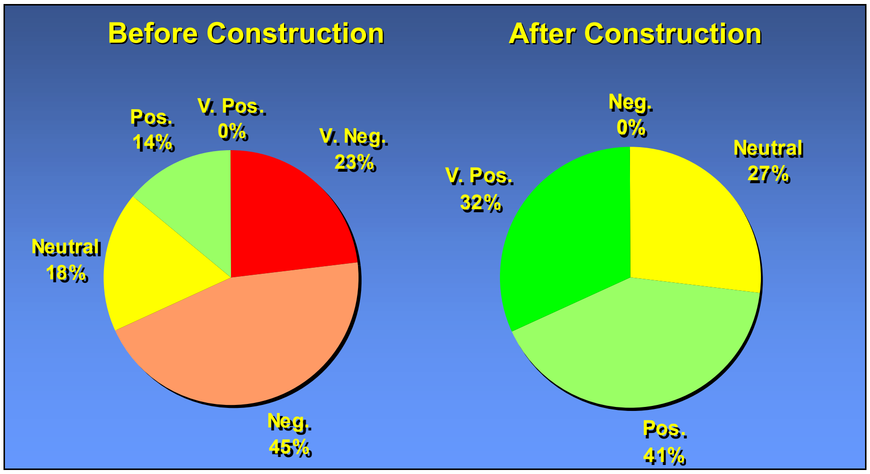
Recent surveys conducted in Kansas, Maryland, and Nevada (Ref. 1) indicates common reasons given for opposing roundabout installation "were that drivers would rather have traffic signals (22 percent) or that roundabouts would make the intersection unsafe (21 percent) or confusing (21 percent)." This opposition may be best overcome through educational programs that familiarize drivers with the basic physical features and operating characteristics of a roundabout. Education on the proper procedure for driving, biking, and walking at a roundabout will help reduce confusion and safety concerns as drivers become more comfortable with how to navigate the intersection. It may be helpful to begin this educational program by producing informational brochures for distribution to the community prior to the first public meeting. This will allow drivers to enter the forum with refined questions and concerns that may help to improve the overall design and help to gain overall acceptance of the project.

Public Acceptance of Roundabouts – Before and After Studies

Recent studies conducted to examine public reaction in the periods before and after the construction of a roundabout have shown a significant improvement in public attitude after construction. This may prove helpful in illustrating to the public that other areas have shown negative reactions toward the construction of a roundabout, but later changed their opinion to generally favorable.

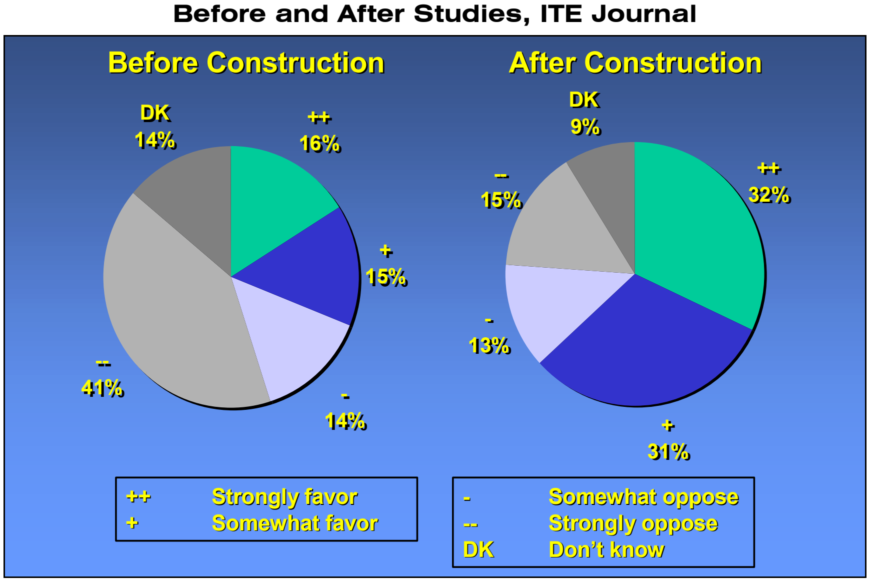
A study published in 1998 (Ref. 2), reported a considerable negative attitude towards roundabouts in the period prior to construction as shown in Exhibit 2-1. A significant improvement in the attitude towards the roundabout was reported following construction with 73 percent of the responses positive or very positive. When compared to the 68 percent negative response prior to construction, the post construction response showing zero percent negative illustrates the possibility for a change in public opinion, even among the strongest opponents.

Exhibit 2-1
Before and After Studies, NCHRP Synthesis 264



More recent data published in the September 2002 issue of the ITE Journal shows similar trends in improvement of responses to roundabouts for surveys conducted in Kansas, Maryland, and Nevada. While responses after construction showed greatly improved responses, this survey found less improvement than the previous study. Retting, et al. (Ref. 1) used a slightly different approach for their study, compiling responses in terms of people in favor or in opposition to the construction of the roundabout. The study, summarized in Exhibit 2-2, found that opposition to a roundabout reduced from 55 percent prior to construction to 24 percent following construction. Similarly, the 31 percent favorable responses prior to construction was improved to 63 percent in favor of the roundabout after construction.

Exhibit 2-2
Before and After Studies, ITE Journal



Alternatives Under Consideration

When examining an intersection for improvements, it may be necessary to look at a variety of design alternatives. Solutions to traffic and safety problems can be preconceived, therefore limiting the focus of the individual(s) performing a particular study. It is advised that "intersection design studies" be performed rather than "roundabout design studies." While this may broaden the scope of the project, it can also be helpful to both the designer and general public. In performing an intersection design study, an alternative improvement may be found that is more appropriate than a roundabout for the traffic or environmental conditions. The designer should analyze an intersection under a variety of treatments (roundabouts, signal, all-way stop, etc.). This allows the designer to demonstrate to the public that other alternatives have been examined, and the best solution is the one being proposed.

Intersection Improvement/Beautification

While the concept of a roundabout may not be immediately appealing to all people, some may take comfort in the aesthetic qualities that can be introduced with a roundabout. The space provided within the central island affords the opportunity to provide landscaping or other features to enhance the intersection. Many communities have recognized this benefit and are using landscaped roundabouts to not only improve intersection performance but to also provide a "gateway" into their community.

Intersection Safety

Many studies have found that roundabouts improve the overall safety performance of an intersection by eliminating conflicts, decreasing speeds, and decreasing speed differentials. Crash experience in the United States has generally shown reductions in both crash frequency and injury crashes with the conversion to a roundabout from other forms of intersection control (signal, stop, unsignalized). More detailed information related to roundabout safety is provided in Chapter 5 of this guide. The reasons for increased safety at roundabouts include:

- Roundabouts have fewer conflict points in comparison to conventional intersections.
- Low operating speeds associated with roundabouts provide drivers more time to react to a situation and reduce the severity of crashes if they occur.
- Pedestrians need only cross one direction of traffic at a time at each approach, with the splitter islands providing refuge to pedestrians in the center of the approach.

2.2 Frequently Asked Questions

Q1: *Roundabouts, rotaries, and traffic circles – they're all the same, aren't they?*

> **A1**: No. Other than sharing a circular shape, a modern roundabout operates much differently than other traffic circles, including rotaries. A modern roundabout requires entering traffic to yield the right–of–way to traffic already in the roundabout. This keeps the traffic in the roundabout constantly moving and prevents much of the gridlock that plagues rotaries, for example. Modern roundabouts are also much smaller than rotaries and thus operate at safer, slower speeds. The design of a modern roundabout allows capacities comparable to signals but with generally a higher degree of safety.

Q2: *Why do roundabouts need to be so big?*

A2: The size of a roundabout is determined by capacity needs, the size of the largest vehicle, the need to achieve appropriate speeds throughout the roundabout, and other factors. To handle typical trucks with overall wheelbases of 50 ft (15 m) or more, a single–lane roundabout needs to be at least 100 ft (30 m) in diameter and is typically 120 to 140 ft (37 to 43 m) in diameter.

Q3: *Why is Kansas installing roundabouts?*

A3: Roundabouts can offer a good solution to safety and capacity problems at intersections. For example, at intersections in Maryland where roundabouts have replaced conventional intersections, crashes of all types have been reduced by over 60 percent, and injury crashes have been reduced by over 75 percent. Roundabouts can also offer high capacity at intersections without requiring the expense of constructing and maintaining a traffic signal.

Q4: *Aren't traffic signals safer than roundabouts for pedestrians?*

A4: It depends on the amount of pedestrians and vehicles. In many cases a roundabout can offer a safer environment for pedestrians than a traffic signal because the pedestrian crossing at a roundabout is reduced to two simple crossings of one–way traffic moving at slow speeds. A pedestrian crossing at a traffic signal still needs to contend with vehicles turning right or left on green, vehicles turning right on red, and vehicles running the red light. The latter of these potential conflicts occur at high speeds and often result in injuries or fatalities to pedestrians. On the other hand, pedestrians (particularly those with visual impairments) may have more difficulty crossing the unsignalized crosswalks at a high-volume, multilane roundabout than at a signalized intersection.

Q5: *Are roundabouts safe near schools?*

A5: Several roundabouts have been installed near schools in the United States, including one location in Lawrence, Kansas. Other locations include Montpelier, Vermont; Howard, Wisconsin; University Place, Washington; and Kennewick, Washington. None has reported any significant problems. For the Howard, Wisconsin, location, prior to the opening of the roundabout, the school required all school children to arrive by bicycle or car because it was unsafe to cross the street. Since the roundabout opened, children now have a safe crossing location, aided by a crossing guard.

Q6: *Are roundabouts appropriate everywhere?*

A6: No. The choice of using a roundabout versus a traffic signal or unsignalized control is a case–by–case decision. The Kansas Department of Transportation evaluates each candidate intersection individually to determine whether a roundabout or a traffic signal, two-way stop, or all way stop control is more effective.

Q7: *I drive a big truck, and that roundabout looks awfully tight. Will I fit?*

A7: Yes. The roundabout has been designed specifically to accommodate large vehicles such as yours. As you approach the roundabout, stay close to the left side of the entry. As you pass through the roundabout, your trailer may drag over the special apron around the central island – it was designed specifically for this purpose. As you exit, again stay close to the left side of the exit.

At a multilane roundabout, you may need to occupy the entire circulatory roadway to make the turn. Signal your intention in advance and claim both lanes on approach to the roundabout.

Q8: *I'm driving in a multilane roundabout. How do I choose which lane to enter and exit?*

A8: In general, approach a multilane roundabout the same way you would approach any other intersection. If you want to turn left, use the left-most lane and signal that you intend to turn left. If you want to turn right, use the right-most lane and signal that you intend to turn right. To go straight through the intersection you can generally use either lane unless signs and/or pavement markings indicate otherwise. In all cases, pass counterclockwise around the central island. When preparing to exit, turn on your right turn signal as you pass the exit before the one you want to use.

Q9: *What should I do when I'm in a roundabout when an emergency vehicle arrives?*

A9: If the roadway in the roundabout is wide enough, you may be able to pull as far to the right as possible and allow the emergency vehicle to pass. However, it is generally better to completely clear the intersection and pull off to the side past the roundabout.

Q10: *How about riding a bicycle through a roundabout?*

A10: A bicyclist has a number of options at a roundabout, and your choice will depend on your degree of comfort and experience level with riding in traffic. You can choose to either circulate as a vehicle or use the sidewalk around the roundabout. When circulating as a vehicle, be sure to ride near the middle of the lane so that drivers can see you and will not attempt to pass you.

Q11: *Should the circulatory roadway of a multilane roundabout be striped?*

A11: There is no international consensus on this question. In the United Kingdom, the general practice is to not stripe, although they will stripe some complicated multilane roundabouts where it improves operations. In Australia, the general practice is to stripe the circulatory roadway. In Kansas, lane lines within the circulatory roadway should generally be striped. Section 7.2 provides guidance on pavement markings within the circulatory roadway where considered.

Q12: *What about snow removal at roundabouts?*

A12: A number of communities in snowy areas have installed roundabouts, including Howard (Green Bay), Wisconsin; Montpelier, Vermont; and Vail, Colorado. All have indicated that while there is some initial adjustment in procedures for snowplow crews, roundabouts generally present no major problems for snow removal. In Howard, Wisconsin, for example, one truck will start on the truck apron and plow around the roundabout to the outside, while another truck will plow each entry and exit, pushing the snow to the outside. Roundabouts make it easier to turn snowplows as well.

2.3 Roundabout Education

An important component in educating the public about roundabouts is the simple task of providing guidance on how to navigate a roundabout. While the yield form of traffic control is not a new concept, surveys have shown that drivers tend to oppose roundabouts because they are perceived as "confusing" or "unsafe", both of which could be attributed to a lack of familiarity with navigating a roundabout. This section provides guidance on the procedures in navigating a roundabout for the various modes of users. Brochures, videos, web-based guidance, or other presentation types may also be useful medium for distributing this information.

Approaching a roundabout

When approaching a modern roundabout, a sign similar to those shown in Exhibit 2-3 will indicate the presence of a roundabout ahead. Motorists should begin to slow down and be prepared to yield. Allow bicyclists to enter the roadway from any bicycle lane. Bicyclists are vehicles and will need to share the travel lane at the intersection. Yield to any pedestrians waiting to cross or in the process of crossing an approach.

Exhibit 2-3
Roundabout Ahead Warning Signs.

When approaching a roundabout with two or more entries, decide as early as possible which exit you need to take and get into the correct lane. Many multilane roundabouts will have a lane usage sign (as shown on the right edge of the photo in Exhibit 2-4) in advance of the roundabout to indicate the proper lane to enter the roundabout from. 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.

Additional instructions for turning at a roundabout are provided later in this chapter.

Exhibit 2-4
Approaching a Multilane Roundabout.

Entering and Exiting the roundabout

At the entrance line, yield to all vehicles and bicycles within the circulatory roadway. Look to your left to see if there is an appropriate gap in traffic. If one is not available, you may need to stop. Always enter the roundabout to the right and proceed on the right side of the central island.

Within the roundabout, proceed slowly (generally 15 to 25 mph [25 to 40 km/h]) and don't pass bicyclists within the roundabout. Continue until you near your exit, at which time you should put on your turn signal to tell drivers that you intend to exit. On a multilane roundabout, do not overtake or pass any vehicles. You should not need to change lanes within the roundabout.

Maintain slow speeds through the exit of the roundabout. Do not accelerate until you are beyond the pedestrian crossing point on the exit. Watch for pedestrians in or approaching the crosswalk upon the exit and stop for them.

Bicycling

Well-designed, low-speed, single-lane roundabouts should not present much difficulty to bicyclists. On the approach to the entry, signal your intentions and merge into traffic. It is generally safest for bicyclists to claim the lane. Keep in mind that drivers should be traveling at about 15 to 20 mph [25 to 32 km/h]—close to the speed you ride your bicycle.

Most roundabouts will give you three options:

1. **Ride like a car:** If you are comfortable riding in traffic, ride on the circulatory roadway of the roundabout like a car. Obey all of the same driving instructions as for cars. 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.
2. **Walk like a pedestrian:** If you are uncomfortable riding in traffic and no special separate facility is provided, 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.

3. **Use a shared bicycle-pedestrian path:** 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. Be courteous to pedestrians and yield to them.

Walking

In Kansas, pedestrians have the right-of-way within crosswalks at all intersections, including roundabouts. 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.

1. **Walk around the perimeter of the roundabout.** Do not cross the circulatory roadway to the central island.

2. **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 from the circulatory roadway of the roundabout.

3. **Look and listen for approaching traffic.** Choose a safe time to cross from the curb ramp to the median opening. Although you have the right-of-way, if approaching vehicles are present, it is best to first satisfy yourself that vehicles have recognized your presence and right to cross. When crossing an entry or exit with more than one lane, be sure that conflicting vehicles in adjacent lanes are coming to a complete stop before proceeding.

4. **Use the splitter island.** It allows you to cross one direction of traffic at a time.

Large Vehicles

When car drivers approach a roundabout, do not overtake large vehicles (trucks and buses). Large vehicles 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.

Emergency Vehicles

Do not enter a modern roundabout when an emergency vehicle is approaching on another leg. This will enable traffic already in the roundabout to clear in front of the emergency vehicle. When an emergency vehicle is approaching, in order to provide a clear path to turn through the roundabout, proceed to beyond the splitter island of your leg before pulling over.

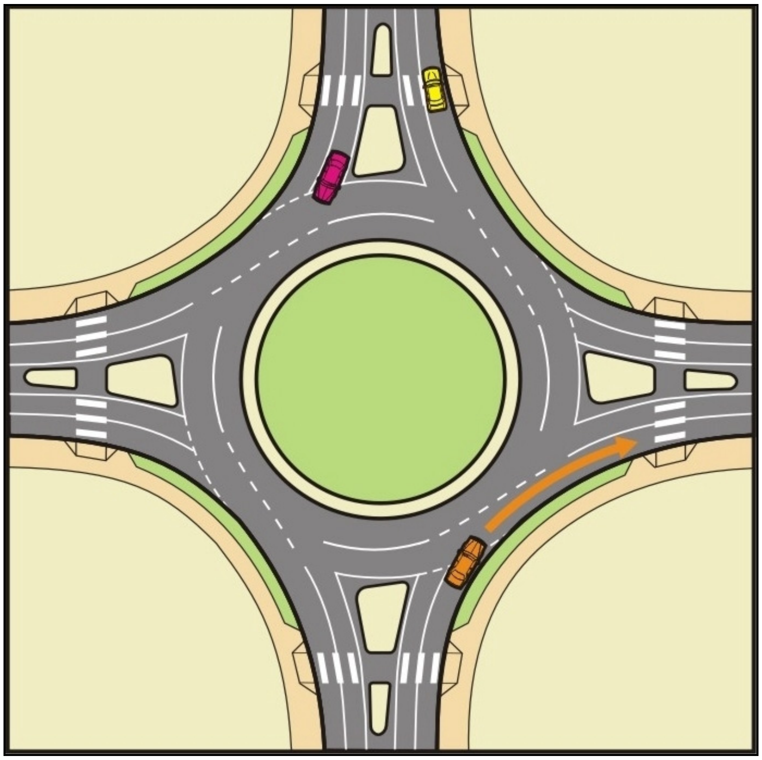
Driving a truck

To negotiate a roundabout in a truck, you may need to use the full width of the roadway, including mountable aprons if provided. Be mindful of the location of all other users of the roundabouts. Prior to entering the roundabout, you may need to occupy both lanes. Signal your intentions well in advance and satisfy yourself that other users are aware of you and are giving you consideration.

Turning at Roundabouts

Turning Right (i.e., exiting at the first exit around the roundabout):

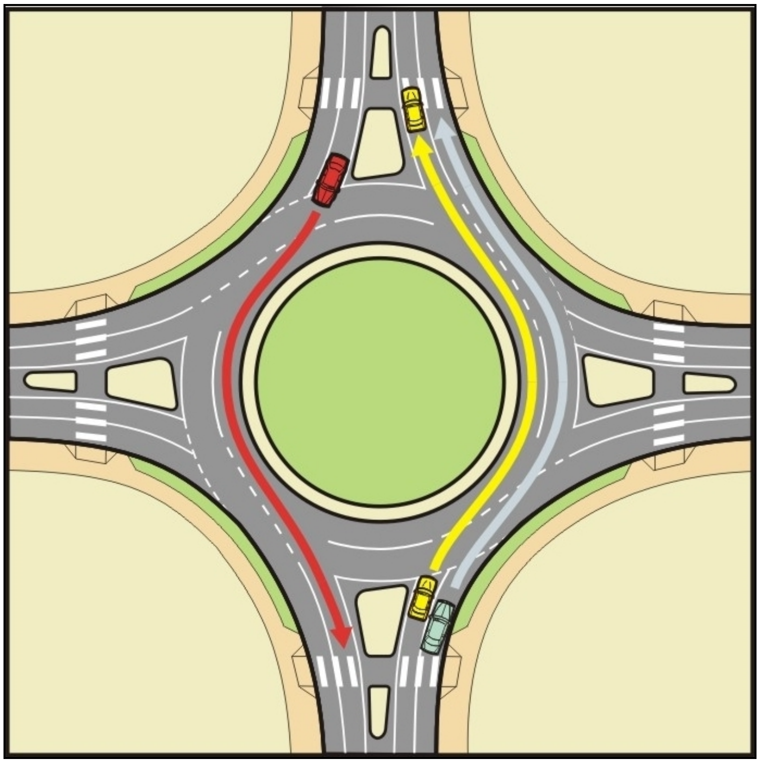
Exhibit 2-5
Turning Right at a Roundabout.



1. Unless posted otherwise, use only the right-hand lane if there are multiple approach lanes. Use your right-turn signal.
2. Reduce your speed.
3. Keep to the right of the splitter island.
4. Watch for bicyclists and allow them to enter the roadway in front of you.
5. Watch for and yield to pedestrians in the crosswalk or waiting to cross.
6. Move up to the entrance line and wait for an acceptable gap in traffic. Do not enter next to someone already in the roundabout, as that vehicle may be exiting at the next exit.
7. Within the 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.
8. Keep to the outside of the circulatory roadway within the roundabout and continue to use your right-turn signal through your exit.
9. If there are multiple exit lanes, use the right-hand lane. Maintain a slow speed.
10. Watch for and yield to pedestrians in the crosswalk or waiting to cross.

Going Straight Ahead (i.e., exiting halfway around the roundabout):

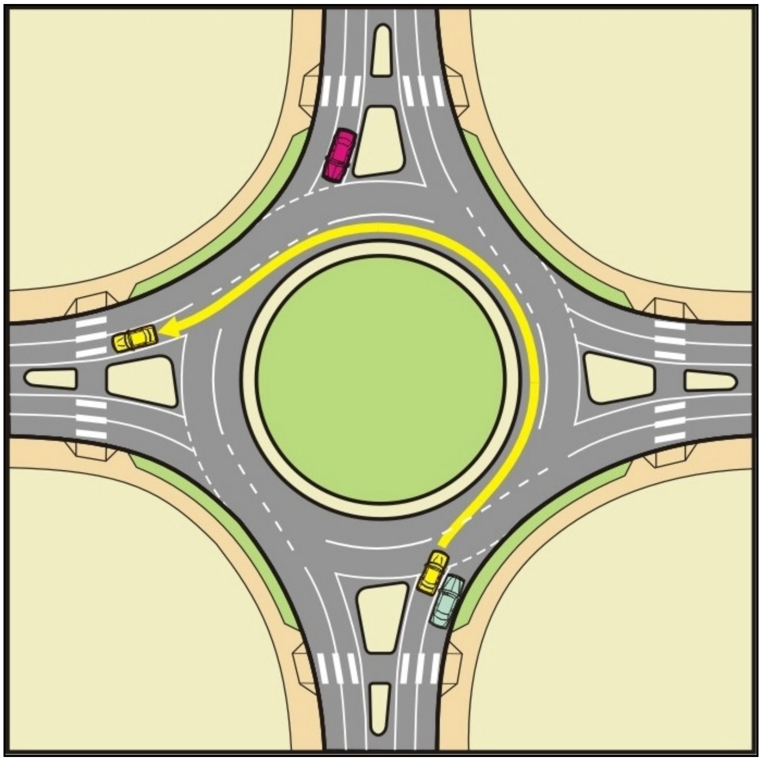
Exhibit 2-6
Driving Straight Through a Roundabout.



1. Unless posted otherwise, use either lane if there are two approach lanes. Do not use any turn signals on approach.
2. Reduce your speed.
3. Keep to the right of the splitter island.
4. Watch for bicyclists and allow them to enter the roadway in front of you.
5. Watch for and yield to pedestrians in the crosswalk or waiting to cross.
6. Move up to the entrance line and wait for an acceptable gap in traffic. Do not enter next to someone already in the roundabout, as that vehicle may be exiting at the next exit.
7. Within the 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.
8. Maintain your position relative to other vehicles. Stay to the inside if you entered from the left lane, or stay to the outside if you entered from the right lane.
9. *Do not overtake other vehicles or bicyclists when in the roundabout.*
10. When you have passed the last exit before the one you want, use your right-turn signal and continue to use your right-turn signal through your exit. Maintain a slow speed.
11. When exiting from the inside lane, watch out for leading or adjacent vehicles on the outside that continue to circulate around the roundabout. At multilane roundabouts with proper striping in the circulatory roadway, the striping will guide you from the inside lane to your exit. However, some drivers in the outside lane may elect to illegally cross your path without yielding (in effect, changing lanes without yielding).
12. Watch for and yield to pedestrians in the crosswalk or waiting to cross.

Turning Left or Making a U-Turn (i.e., exiting more than halfway around the roundabout):

Exhibit 2-7
Turning Left at a Roundabout.



1. Unless posted otherwise, use the left-hand lane if there are two approach lanes. Use your left-turn signal.
2. Reduce your speed.
3. Keep to the right of the splitter island.
4. Watch for bicyclists and allow them to enter the roadway in front of you.
5. Watch for and yield to pedestrians in the crosswalk or waiting to cross.
6. Move up to the entrance line and wait for an acceptable gap in traffic. Do not enter next to someone already in the roundabout, as that vehicle may be exiting at the next exit.
7. Within the 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.
8. Maintain your position relative to other vehicles. Stay to the inside. Do not change lanes until you are ready to exit.
9. *Do not overtake other vehicles or bicyclists when in the roundabout.*
10. When you have passed the last exit before the one you want, use your right-turn signal and continue to use your right-turn signal through your exit. Maintain a slow speed.
11. When exiting from the inside lane, watch out for leading or adjacent vehicles on the outside that continue to circulate around the roundabout. At multilane roundabouts with proper striping in the circulatory roadway, the striping will guide you from the inside lane to your exit. However, some drivers in the outside lane may elect to illegally cross your path without yielding (in effect, changing lanes without yielding).
12. Watch for and yield to pedestrians in the crosswalk or waiting to cross.

2.4 Roundabout Media

Roundabout Videos

Several states and other public and private entities have developed roundabout videos to introduce roundabouts to the public. These informational videos typically describe the safety and operational benefits of a roundabout, the typical roundabout features, and most importantly - how to navigate a roundabout. Kansas is currently one of just a few states that have created these educational videos. Listed below are names of several roundabout educational videos, including the one developed by KDOT, and contact information for obtaining a copy.

"Kansas Roundabout Video" (Kansas DOT, 2003)
"The East Topeka Roundabouts" (Kansas DOT, 2000)
"I-70/Vail Road" (Ourston & Doctors)
"Modern Roundabouts" (Maryland SHA)
"Nonconforming Traffic Circle Becomes Modern Roundabout" (Ourston & Doctors)
"Snow at Roundabouts" (Ourston & Doctors)
"A User's Guide to Roundabouts" (Oregon DOT, 1999)
"Driving Modern Roundabouts" (Washington State DOT; City of Olympia, WA; and City of Lacey, WA)
"The Case for Roundabouts" (Federal Highway Administration)

Exhibit 2-8
Video Contact Information

Kansas DOT: Kansas Department of Transportation Bureau of Traffic Engineering 700 S.W. Harrison Street, 6th Floor Topeka, KS 66603-3754 (785) 296-3618 (phone) (785) 296-3619 (fax)	**Ourston Roundabout Engineering, Inc.** 806 Fawn Place Santa Barbara, CA 93105 (805) 563-1400 More information available at: http://www.ourston.com/
Federal Highway Administration: Marketing Specialist FHWA Resource Center 19900 Governors Drive, Suite 300 Olympia Fields, IL 60461 (708) 283-3500	**Maryland SHA:** Maryland State Highway Administration Office of Traffic and Safety 7491 Connelley Dr Hanover, MD 21076 (410) 787-5879
Oregon DOT: Oregon Department of Transportation Photo & Video Services Support Service Branch 355 Capitol Street NE #14-A Salem, OR 97301-3871	**Washington State DOT:** Washington State Department of Transportation PO Box 47344 Olympia WA 98504 (360) 705-7297

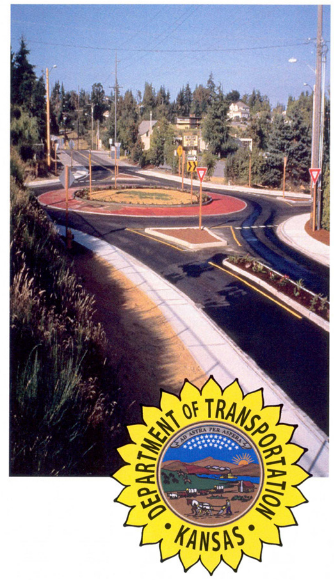
Roundabout Brochures

KDOT has produced brochures and informational cards aimed at providing information to a variety of audiences. Exhibits 2-9 through 2-11 illustrate three of these educational brochures. The first is a general informational brochure describing some key features of roundabouts and their benefits. The other brochures provide information on how to navigate a roundabout from the perspective of a motorist, and from the perspective of a pedestrian and bicyclist. For information in obtaining a copy of any of these brochures, contact the KDOT Bureau of Traffic Safety at 785-296-3756 or the Bureau of Traffic Engineering at 785-296-3618.

Exhibit 2-9
KDOT Roundabout Brochure – General Information

“This information is available in alternative accessible formats. To obtain an alternative format, contact the Kansas Department of Transportation, Office of Public and Employee Information, 7th Floor, Docking State Office Building, Topeka, Kansas, 66612-1568 or phone (785) 296-3585 (Voice)/(TTY).”

Roundabouts



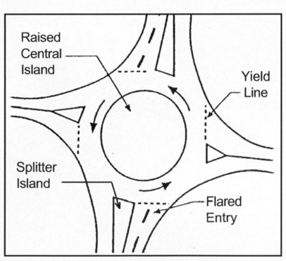
KANSAS DEPARTMENT OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING

ROUNDABOUTS

Roundabouts are used throughout the world in countries such as England, Australia and in recent years here in the United States to reduce injury accidents, traffic delays, fuel consumption, air pollution and construction costs, while moving more traffic and enhancing intersection beauty. They have also successfully been used to control traffic speeds in residential neighborhoods and are accepted as one of the safest types of intersection design.

A roundabout is a circular intersection but very different than the traffic circle used previously in this country. The major differences between a traffic circle and a roundabout are:

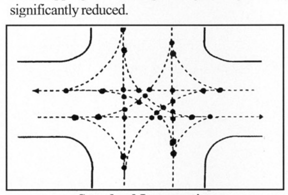
- **Yield at Entry**
  At roundabouts the entering traffic yields the right-of-way to the circulating traffic. This yield-at-entry rule keeps traffic from locking-up and allows free flow movement.
- **Deflection**
  The splitter and center island of a roundabout deflects entering traffic and reinforces the yielding process.
- **Flare**
  The entry to a roundabout often flares out from one or two lanes to two or three lanes at the yield line to provide increased capacity (ability to move traffic).



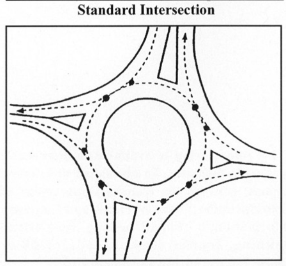
Conventional Roundabout
Figure 1

WHY USE A ROUNDABOUT?

1. **Safety** – Roundabouts have been shown to reduce fatal and injury accidents as much as 75%. The reduction in accidents is attributed to slower speeds and reduced number of conflict points. (*See Figure 2*)
2. **Low Maintenance** – Eliminates maintenance costs associated with traffic signals which amount to approximately $3,500 per year per intersection. In addition, electricity costs are reduced with a savings of approximately $1,500 per year per intersection.
3. **Reduced Delay** – By yielding at the entry rather than stopping and waiting for a green light, delay is significantly reduced.



Standard Intersection



Roundabout Intersection
● = Conflict Point
Figure 2

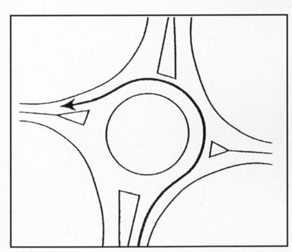
4. **Capacity** – Intersections with a high volume of left turns are better handled by a roundabout than a multi-phased traffic signal.
5. **Environmental** – A reduction in delay corresponds to a decrease in fuel consumption and air pollution.
6. **Aesthetics** – The central island provides an opportunity to beautify the intersection with landscaping.

HOW TO DRIVE A ROUNDABOUT

As you approach a roundabout there will be a YIELD sign and dashed yield line. Slow down, watch for pedestrians and bicyclists, and be prepared to stop if necessary. When you enter, yield to circulating traffic on the left, but do not stop if it is clear.

A conventional roundabout will have ONE-WAY signs mounted in the center island. They help guide traffic and indicate that you must drive to the right of the center island. Upon passing the street prior to your exit, turn on your right turn signal and watch for pedestrians and bicyclists as you exit.

Left turns are completed by traveling around the center island. (*See Figure 3*)



Left Turn
Figure 3

Exhibit 2-10
KDOT Roundabout Brochure – Driving Roundabouts

Roundabouts/Driving

The right way to go in circles.

They're as common in Australia as wheat is in Kansas. And they may soon be coming to an intersection near you! Roundabouts are relative newcomers to the Midwest, so don't be surprised if you've never seen one. And don't be surprised when you do!

Roundabout Realities

Roundabouts are being constructed as a safer and more efficient alternative to traditional intersections, the most common sites of traffic crashes.

Traffic flows in only one direction—counter-clockwise—around a large central island.

Vehicles in the roundabout always have the right-of-way because all vehicles entering the roundabout must yield to traffic already in the roundabout.

Some great news about roundabouts: No traffic signals. No stop signs. No left turn lanes. No parked cars. So, there's less congestion because traffic keeps moving.

(over)

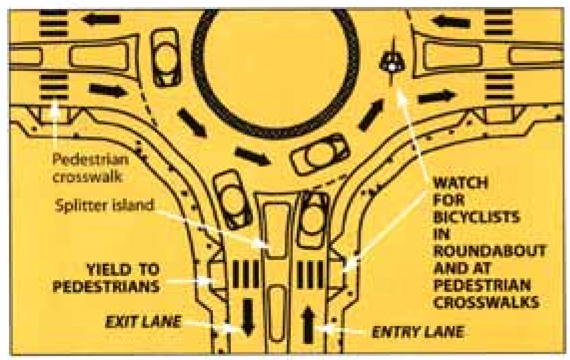
Tips for a Safe Roundabout Rendezvous

Approach

When you see these signs, you know you're approaching a roundabout.

Enter

As you approach, slow down to 15 mph and be prepared to yield. Watch for pedestrians or bicyclists and give them a break. Let pedestrians cross and cyclists merge. Then, look to the left and wait—or enter—if there's a gap in the circulating traffic. Remember, traffic in the roundabout has the right-of-way.



Navigate

Once in the roundabout, drive with the counter-clockwise flow of traffic. Now you have the right-of-way. If you're driving straight through, approach the roundabout from the right lane and stay in the right lane. If you want to go left or even return from the direction you came, it's OK to use the left lane (if there is one), but you'll need to change to the right prior to exiting the roundabout. Remember to use your turn signal. Do not stop in the roundabout! As you approach your exit point, turn on your right signal, watch for cyclists and pedestrians, then exit.

That's it. You're done.

Remember...when it comes to roundabouts, use courtesy and common sense. That's...

Kansas Driving Safe℠ not sorry

A program of the Kansas Department of Transportation

For more information contact the KDOT Bureau of Traffic Safety at 785-296-3756 or on the Web at www.kanroad.org

Exhibit 2-11
KDOT Roundabout Brochure – Walking and Riding at Roundabouts

Roundabouts/Walking & Riding

Roundabouts are becoming a reality.

They're as common in Australia as wheat is in Kansas. And they may soon be coming to an intersection near you! They're roundabouts...a safer and more efficient alternative to traditional intersections, the most common sites of traffic congestion.

Traffic goes round 'n' round

In roundabouts, traffic flows in only one direction—counter-clockwise—around a large central island. Vehicles in the roundabout always have the right-of-way, because all vehicles entering the roundabout must yield.

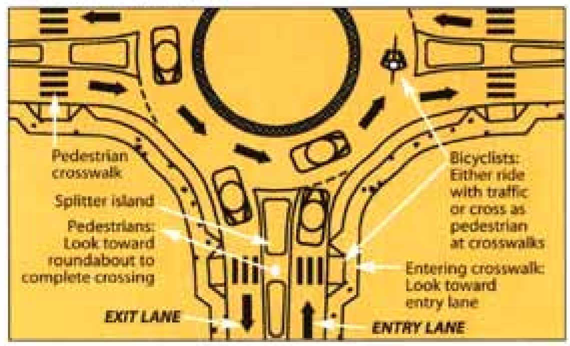
For drivers, roundabouts offer many advantages: No traffic signals. No stop signs. No left turn lanes. No parked cars. Traffic is always moving. But for pedestrians and bicyclists, roundabouts pose some special challenges.

(over)

Steppin' Out: Tips for Pedestrians

Since there are no traffic signals or stop signs to pause traffic, pedestrians should take extra care when crossing.

- Always use the sidewalk and designated crosswalks. Never walk in the roundabout or to the central island.
- Cross one lane at a time to the "splitter island," a safe stopping place.
- Watch traffic coming toward you. Even though you have the right-of-way when you're in a crosswalk, be careful and make sure drivers see you and stop.



Rollin' Out: Tips for Bicyclists

- Ride as if you were driving a car. Vehicles in roundabouts travel around 15-25 mph, close to your cycling speed.
- If you're riding on the shoulder, merge into the travel lane before the shoulder ends. Signal your intent to move into traffic.
- Don't hug the curb. Ride close to the middle of the lane to keep vehicles from passing and cutting you off. Watch for vehicles waiting to enter the roundabout, as they may not see you.
- If you don't want to ride in the roundabout, enter the crosswalk and proceed as a pedestrian.

Remember... when it comes to roundabouts, use caution and common sense. That's...

Kansas Driving Safe℠ not sorry

A program of the Kansas Department of Transportation

For more information contact the KDOT Bureau of Traffic Safety at 785-296-3756 or on the Web at www.kanroad.org

2.5 References

1. Retting, R.A., G. Luttrell, E.R. Russel, "Public Opinion and Traffic Flow Impacts of Newly Installed Modern Roundabouts in the United States," ITE Journal, September 2002, pp.30-32, 37.

2. 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.

3. Traveling Maryland's Roundabouts. Maryland State Highway Administration. http://www.sha.state.md.us/safety/oots/roundabouts/index.asp

Chapter 3 - Planning

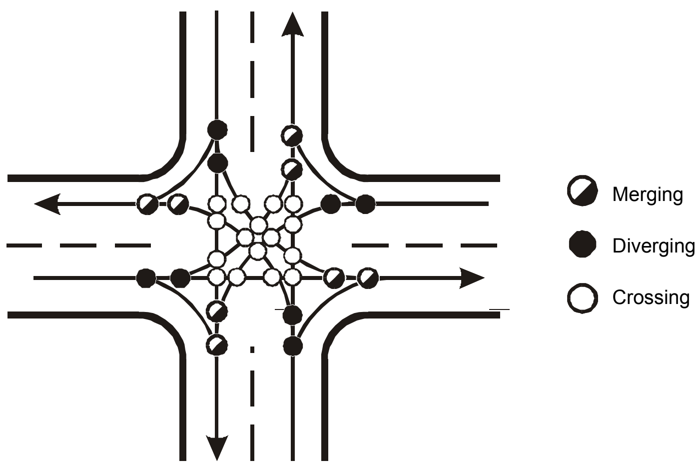
3.1 Roundabout Selection Guidance

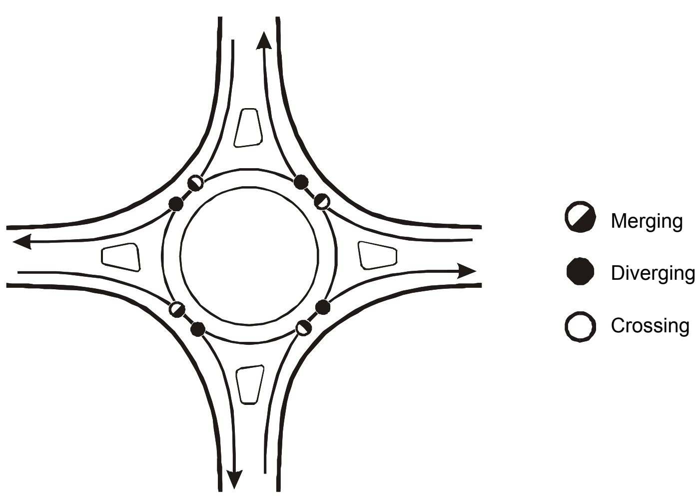
Safety and Capacity Benefits of Roundabouts

When planning for intersection improvements, a variety of improvement alternatives should be evaluated, in addition to roundabouts, to determine whether a roundabout is the most appropriate alternative. This section highlights several benefits of roundabouts with respect to safety and capacity that may make them a viable improvement alternative over typical two-way, all-way, and signalized intersections.

With respect to safety, roundabouts provide a number of advantages over other intersection types, including a reduction in the total number of conflict points, which generally results in a reduction in total observed crashes. By removing the majority of the turning conflicts, left-turn and right- angle type collisions are virtually eliminated. Thus, a roundabout may be a viable option for improving an intersection that has a high crash history associated with these types of crashes. Exhibit 3-1 illustrates the number of motor vehicle conflict points at a conventional four-leg intersection (32 conflict points) and roundabout (8 conflict points) respectively.

Exhibit 3-1
Intersection Motor Vehicle Conflict Points:
Conventional and Roundabout Intersections





Crash severity at roundabouts is also dramatically reduced since vehicles are required to operate at lower speeds with a small relative speed differential between conflicting flows. This means that the chance for injury and fatality crashes is greatly reduced. Other safety features at roundabouts include the use of splitter islands and other geometric features that increase the conspicuity of the roundabout, providing advanced warning to drivers of the impending intersection. Pedestrians may also be more safely accommodated due to the presence of low vehicle speeds and the pedestrian refuge within the splitter island, which allows pedestrians to cross the approach in two phases and minimizes exposure time to motorized vehicles.

A roundabout may be considered a logical choice if its estimated operational performance is better than that of the other alternative control types. Roundabouts may be implemented to provide an operational improvement at an intersection to reduce delay and/or increase the capacity of an intersection. Typically roundabouts are only limited by the number of adequate gaps available for vehicles to enter the intersection. In many cases, delay at a roundabout will be lower in comparison to other intersection forms, which allow only one alternating traffic stream at a time to proceed through the intersection. Roundabouts allow multiple vehicles to enter simultaneously from different approaches, which may provide additional capacity benefits and delay reductions over some intersection forms, especially in the presence of relatively high left-turn volumes on the minor street approaches. The FHWA Roundabout Guide offers the following planning level guidance for comparisons of control modes:

1. A roundabout will always provide a higher capacity and lower delays than all-way stop control operating with the same traffic volumes and right-of-way limitations.
2. A roundabout is unlikely to offer better performance in terms of lower overall delays than two-way stop control (TWSC) at intersections with minor movements (including cross street entry and major street left turns) that are not experiencing, nor predicted to experience, operational problems under TWSC.
3. A single-lane roundabout may be assumed to operate within its capacity at any intersection that does not exceed the peak-hour volume warrant for signals.
4. A roundabout that operates within its capacity will generally produce lower delays than a comparably sized signalized intersection operating with the same traffic volumes.

While the guidance provided above is adequate at the planning level for estimating the validity of multiple alternatives, more detailed analysis is required to closely approximate the actual intersection operations for each alternative. The FHWA Roundabout Guide provides further guidance on predicting roundabout performance at the planning level for comparing roundabouts to TWSC, all-way stop control, and signalized intersection control types.

Site Selection Guidance

This section identifies locations and conditions at which roundabouts often provide advantages over other traffic control forms. Planners and designers are encouraged to consider and evaluate roundabouts as alternatives to conventional intersection forms at these locations. This section also identifies locations and conditions that can make a roundabout complicated or difficult. At these locations, planners and designers are encouraged to use caution when considering roundabouts.

Sites Where Roundabouts Are Often Advantageous

Roundabouts are often advantageous over other traffic control at the following locations and conditions:

- Intersections with historical safety problems.
- Intersections with relatively balanced traffic volumes.
- Intersections with a high percentage of turning movements.
- Intersections with high traffic volumes at peak hours but relatively low traffic volumes during non-peak hours.
- Existing two-way stop-controlled intersections with high side-street delays (particularly those that do not meet signal warrants).
- Intersections that must accommodate U-turns.
- Intersections at a gateway or entry point to a campus, neighborhood, commercial development, or urban area.
- Intersections where a community enhancement may be desirable.
- Intersections or corridors where traffic calming is a desired outcome of the project.
- Intersections where widening one or more approach may be difficult or cost-prohibitive, such as at bridge terminals.
- Intersections where traffic growth is expected to be high and future traffic patterns are uncertain.
- Locations where the speed environment of the road changes (for instance, at the fringe of an urban environment).
- Locations with a need to provide a transition between land use environments (such as between residential and commercial uses).
- Roads with a historical problem of excessive speeds.

Sites At Which Caution Should Be Exercised With Roundabouts

There are a number of locations and site conditions that often present complications or difficulties for installing roundabouts. Some of these locations can also be difficult or problematic for other intersection alternatives as well. Therefore, these site conditions should not necessarily preclude a roundabout from consideration. However, extra caution should be exercised when considering roundabouts at these locations:

- Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.
- Intersections located within a coordinated arterial signal system.
- Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.
- Intersections with physical or geometric complications.

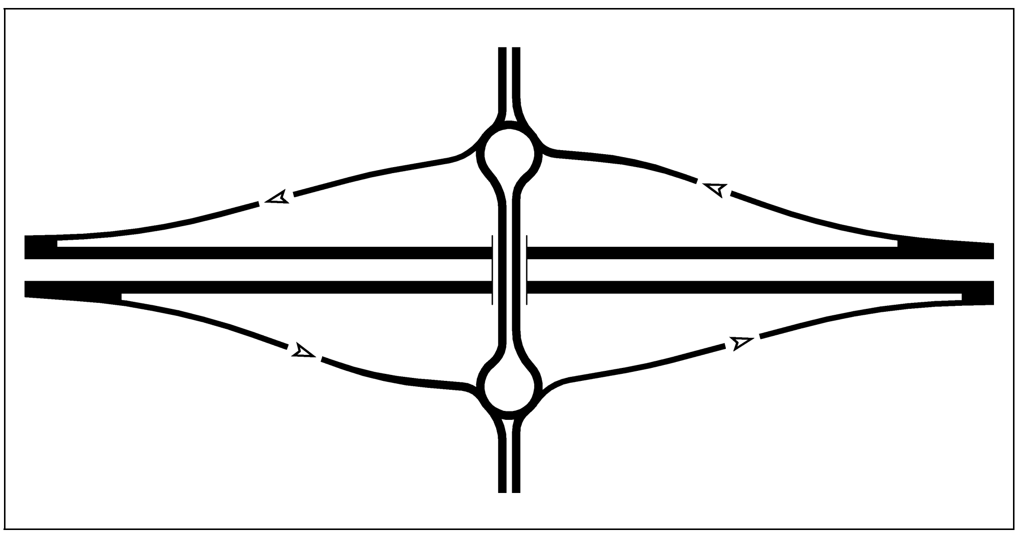
- Locations with steep grades and unfavorable topography that may limit visibility and complicate construction.
- Intersections with heavy bicycle volumes.
- Intersections with heavy pedestrian volumes.

Roundabouts at Interchanges

Roundabouts can be acceptable and, in some locations, advantageous solutions for ramp terminal intersections within freeway service interchanges. Using a roundabout in an interchange does not represent a new or unique interchange form. Rather, the roundabout can be used within a variety of conventional interchange forms as the means of controlling traffic at the ramp terminal intersections. Most commonly, roundabouts are used at diamond interchanges. They may also be used within partial cloverleaf interchanges at the termini of loop ramps or diagonal ramps.

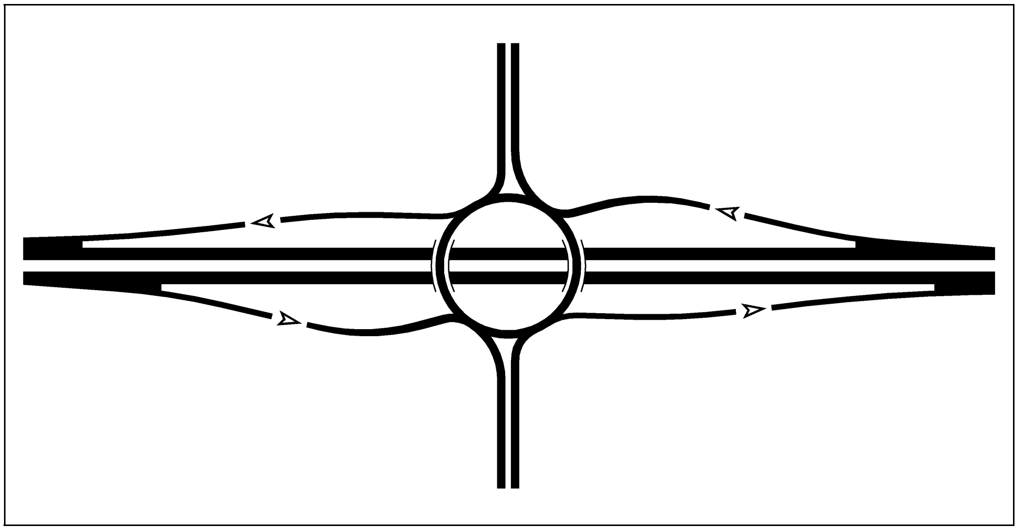
There are two variations of diamond interchanges that can be used with roundabouts. The more common form, shown in Exhibit 3-2, consists of two roundabouts, one on each side of the freeway. There is typically a single bridge structure (or, in some cases, two structures if the freeway crosses over the cross street) between roundabouts. For these interchanges, it is best if the ramp terminal intersections are spread far enough apart to avoid the need for widening of the bridge structure and prevent queues from spilling back between intersections. In some cases, the central islands may be raindrop-shaped with no yielding required for traffic between the two roundabouts. If the intersections consist of frontage roads or need to accommodate U-turns, however, raindrop-shaped central islands should not be used.

Exhibit 3-2
Typical Diamond Interchange with Roundabouts at Ramp Terminal Intersections



Another variation of the diamond interchange with roundabouts consists of a single, large-diameter roundabout centered over or under the freeway. Exhibit 3-3 illustrates this interchange form. As shown in the figure, the interchange requires two overpass or underpass structures. This interchange form can be likened to a typical single-point diamond interchange, where turning traffic from the freeway interchanges with arterial traffic at a single (albeit large) intersection. Due to the large size of this roundabout, care should be taken to ensure adequate entry curvature is achieved to control speeds.

Exhibit 3-3
Diamond Interchange with Roundabout at Single Ramp Terminal Intersection



3.2 Use of Single- and Multilane Roundabouts

Among the first steps in examining the feasibility of a roundabout is determining the preliminary configuration needs. The roundabout configuration is specified in terms of the number of entry and exit lanes needed on each approach to serve the design year traffic volumes. Future year design volumes should be used to determine the ultimate configuration of the roundabout to serve traffic on a twenty-year planning horizon.

Typically, roundabouts are identified in terms of the number of circulating lanes (i.e. single-lane, double-lane, etc.). The number of circulating lanes required for a particular roundabout is usually equal to the number of entering lanes required on the largest approach. Planning-level guidance is provided in Exhibit 3-4 to estimate the number of lanes required based upon the context of the intersection location. This planning level analysis is intended to aid in the decision making process to select or reject a roundabout as a viable improvement option prior to proceeding in to detailed analysis and design.

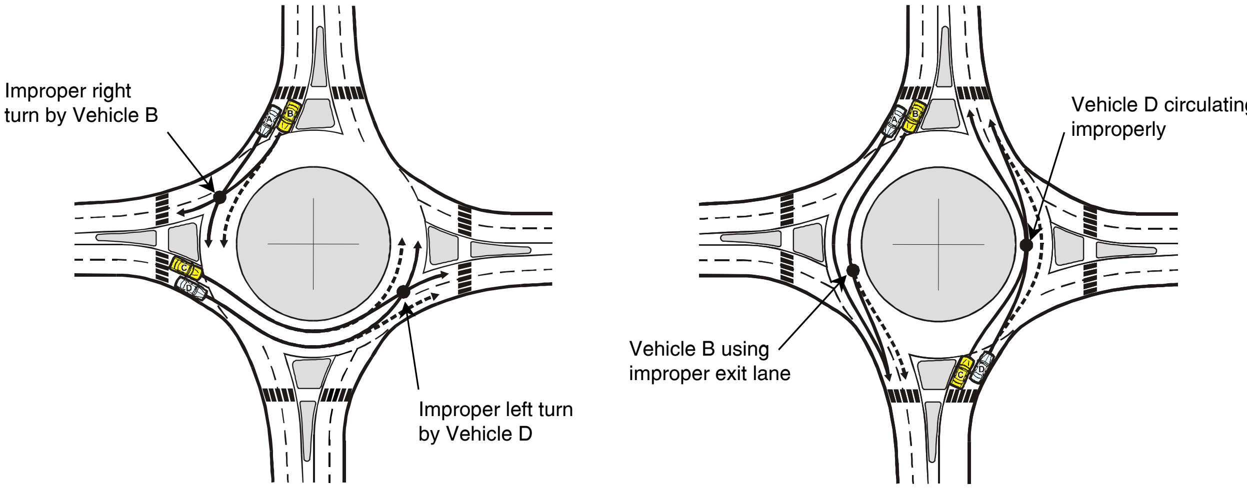
Exhibit 3-4
Roundabout Categories and Design Characteristics

Design Element	Mini-Roundabout	Urban Compact	Urban Single-lane	Urban Double-lane	Rural Single-lane	Rural Double-Lane
Recommended maximum entry design speed	15 mph (25 km/h)	15 mph (25 km/h)	20 mph (35 km/h)	25 mph (40 km/h)	25 mph (40 km/h)	30 mph (50 km/h)
Maximum number of entering lanes per approach	1	1	1	2	1	2
Typical inscribed circle diameter	50 to 90 ft (15 to 27 m)	100 to 120 ft (30 to 37 m)	120 to 150 ft (37 to 45 m)	150 to 220 ft (45 to 67 m)	120 to 200 ft (37 to 60 m)	175 to 250 ft (55 to 75 m)
Splitter island treatment	Raised if possible, crosswalk cut if raised	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised and extended, with crosswalk cut	Raised and extended, with crosswalk cut
Typical daily service volume on 4-leg roundabout (veh/day)	10,000	15,000	20,000	Approximately 40,000 – 50,000 Refer to FHWA publication: "Roundabouts: An Informational Guide"	20,000	Approximately 40,000 – 50,000 Refer to FHWA publication: "Roundabouts: An Informational Guide"

Exhibit 3-4 also provides a range of inscribed circle diameters for each category to assist in estimating the size of the roundabout footprint and aid in creating a preliminary assessment of right-of-way impacts. Information is provided in later sections regarding more detailed operational evaluations and specific geometric design considerations.

Multilane roundabouts produce increased capacity. They also introduce additional conflict points that may prevent a multilane roundabout from achieving the same level of crash reduction as their single-lane counterparts. However, even with an expected lower overall crash reduction, multilane roundabouts should still result in fewer serious injuries and fatalities as compared to the alternative intersection control. Exhibit 3-5 illustrates two examples of additional vehicle conflicts possible at multilane roundabouts.

Exhibit 3-5
Additional Vehicle Conflicts at Multilane Roundabouts



When projected traffic volumes indicate that a multilane roundabout is required for future year conditions, designers should evaluate the duration of time that a single-lane roundabout would operate acceptably before requiring additional lanes. Where a single-lane roundabout will be sufficient for much of its design life, designers should evaluate whether it is best to first construct a single lane roundabout until traffic volumes dictate the need for ultimate expansion to a multilane roundabout.

Single-lane roundabouts are generally simpler for motorists to learn and are more easily accepted in new locations. This, combined with fewer vehicle conflicts, should result in a better overall crash experience and allow for a smooth transition into the ultimate multilane build-out of the intersection. Single-lane roundabouts introduce fewer conflicts to pedestrians and bicycles and provide increased safety benefits to pedestrians by minimizing the crossing distance and limiting exposure time to vehicles while crossing an approach.

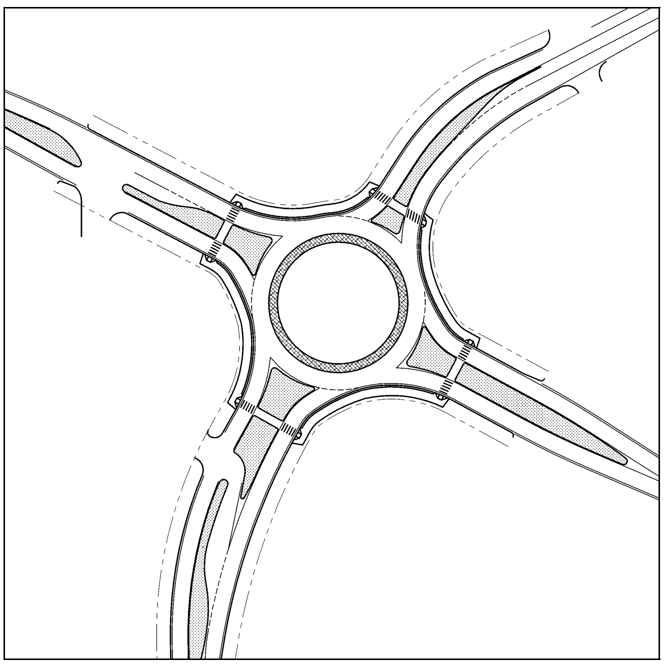
When considering an interim single lane roundabout, the designer should evaluate the right-of-way and geometric needs for both the single and multilane configurations. Consideration should also be given to the future construction staging for the additional lanes. There are generally two ways to expand from a single-lane to a double-lane roundabout:

1) **Construct additional entering, circulating, and exiting lanes on the outside of the single-lane roundabout.** Under this option, it may be easier for construction to occur while maintaining traffic flow. However, when using this option, care should be taken to provide adequate geometric features including entry and splitter island design to ensure that speed reduction and adequate natural paths will be provided at ultimate build-out. In preparing for this type of construction staging, it may be appropriate to initially design the roundabout for the ultimate-double lane condition to ensure adequate geometry and then remove the outside lanes from the design to form the initial single-lane roundabout. It is also helpful to evaluate the ultimate roundabout footprint to reserve right-of-way to accommodate the future widening.

2) **Construct the additional entering, circulating, and exiting lanes on the inside of the single-lane roundabout.** Under this option, the initial single-lane roundabout is designed to occupy the same inscribed circle diameter as the ultimate double-lane roundabout. This allows the designer to set the outer limits of the intersection during the initial construction. This limits the future construction impacts to surrounding properties during widening, as sidewalks and outer curb lines will not typically require adjustment. In this case, the roundabout is again initially designed for the ultimate multilane configuration. However, the modification to a single-lane design is done by providing wide splitter islands and an enlarged central island that occupy the space required for the inside travel lanes. Future expansion to the multilane roundabout is accomplished by reducing the width of the splitter islands and widening on the inside of the existing travel lanes. Typically, the splitter islands, central island curbing, and truck apron would require replacement. This type of expansion is illustrated in Exhibit 3-6.

Exhibit 3-6
Example – Staged Multilane Roundabout Construction

Interim Design – Single-Lane Roundabout



Ultimate Design - Double-Lane Roundabout

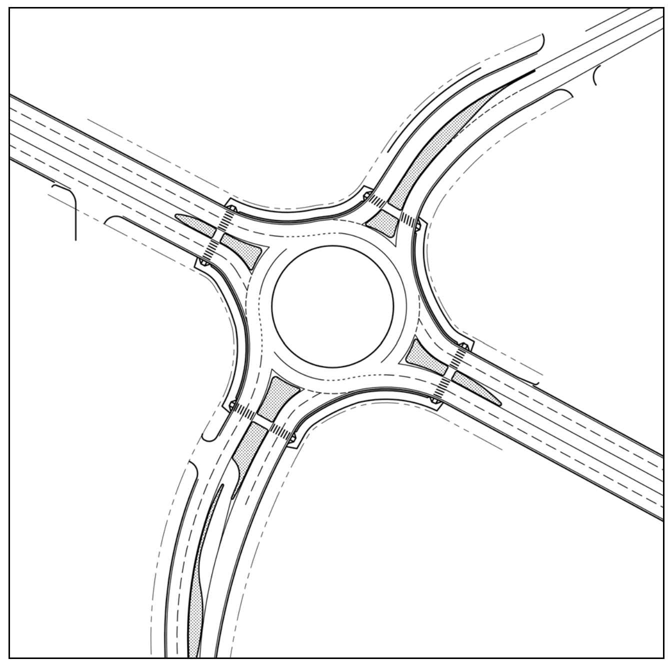


Exhibit 3-6 shows a sample multilane roundabout design where staged construction was utilized to provide a single-lane roundabout in the interim years until traffic volumes dictate the need for additional lanes. Note that the footprint of the roundabout and the approaches does not change between the interim and the ultimate design. Narrowing the splitter islands and reducing the diameter of the central island to accommodate the additional travel lanes accomplish the conversion to a multilane roundabout. It is also important to note that the ultimate roundabout design was established and refined *first*. Then, the interim design was produced by modifying the ultimate design to provide single entering, circulating, and exiting lanes, as shown in Exhibit 3-6. This ensures that the ultimate double-lane design will have the appropriate geometric features at the time it is constructed.

3.3 Typical Construction Costs

The cost of a roundabout varies greatly depending on a wide variety of factors. Some factors include the setting (urban/suburban/rural), the complexity of the improvements, in particular the amount of reconstruction necessary on the approach, and the methodology for maintenance of traffic. Some specific issues to consider when a roundabout is under consideration for intersection improvements include:

- Construction costs for roundabouts vary from one location to another, similar to other types of intersection control. The costs can vary at a roundabout due to several factors. Costs can be lower when there is minimal approach work necessary, there is no change in grades, and there is not a need to add a significant amount of pavement for the footprint of the roundabout. Costs can significantly increase in urban settings and other areas where there are substantial utility relocations, significant right-of-way needs, or urban design and streetscape elements are a considerable portion of the project.
- Roundabouts are typically, but not always more expensive than relatively simple signal design projects. A signal will be less expensive than a roundabout if the signal project only requires installation of the signal equipment with minimal roadway widening or reconstruction. However, if the intersection improvement requires a change in the vertical alignment or the addition of left-turn or right-turn lanes, the costs are often comparable.
- Maintenance of traffic can be a much higher percentage of the construction cost of a roundabout when compared to other intersection treatments, often comprising as much as a third of the total construction cost. This is related to the difficulty associated with the construction of the central island while maintaining traffic in all directions. Savings are possible if all approaches to the intersection can be detoured, or if two of the approaches to the intersection can be detoured.
- When developing costs for a project, future maintenance costs should be considered. For example, the maintenance of the central island can have a significant annual cost. Also, state maintenance crews typically do not have this type of maintenance included in their budget and often are not capable of, or interested in, landscape maintenance. If a high maintenance landscape is proposed, agreements with local municipalities, garden clubs, or civic organizations should be considered.
- Roundabouts in interchanges can often reduce the number of lanes necessary across the interchange structure. This will reduce the initial construction cost as well as the future maintenance costs.
- Costs for a roundabout constructed as part of a new facility or new development are typically comparable to other intersection treatments.

Chapter 4 - Operations

4.1 Operational Analysis Tools

An operational analysis is required for each proposed roundabout configuration to estimate the capacity and operational characteristics. The maximum flow rate that can be accommodated at a roundabout entry depends on two factors: the circulating flow in the roundabout that conflicts with the entry flow, and the geometric elements of the roundabout. The capacity is computed at each entry and compared with the demand traffic volume. **For design purposes, the maximum volume-to-capacity ratio (v/c ratio) threshold for a roundabout entry should be 0.85.** Higher degrees of saturation can lead to unstable operation in which high delays and lengthy queues may occur at the roundabout approach.

The operational methodology presented in Chapter 4 of the FHWA Roundabout Guide should be used as the initial method for evaluating a roundabout's capacity. The FHWA Roundabout Guide provides basic capacity models for urban compact roundabouts, typical single-lane roundabouts, and typical double-lane roundabouts. The only input to these models is the circulatory traffic volume. The resulting capacity forecasts were developed based on typical geometric parameters and simplified regression relationships from the British and German models. Capacity estimates may require adjustment to reflect the use of short lanes at flared entries and the level of pedestrian activity. In addition, delay and queue estimates should also be calculated based upon the procedures provided in section 4.4 of the FHWA Roundabout Guide.

For most applications where the degree of saturation is below 0.85, the FHWA procedures for determining operational characteristics are sufficient. However, as volumes approach capacity, control delay increases exponentially with small changes in volume, having large effects on delay. An accurate analysis under conditions near or over capacity should also consider such factors as the effect of residual queues and the metering effect of upstream oversaturated entries, which are not accounted for in the FHWA procedure.

For cases involving single lane roundabouts with volume-to-capacity ratios exceeding 0.70 and for all multilane roundabouts, use of a second analysis tool is recommended for comparison purposes and to provide a more detailed modeling. At this time, there are several acceptable methods for conducting performance analysis at roundabouts in addition to the FHWA procedure:

- aaSIDRA software package (Australia; gap acceptance);
- RODEL and ARCADY software packages (UK; empirical regression);
- Traffic simulation software packages.

These different methodologies generally yield similar results for roundabouts with moderate traffic volumes (moderate entry flows and/or moderate circulating flows). However, in cases with high entry flows opposed by low circulatory flow and vice versa, (i.e. highly directional/unbalanced flows), the models can yield significantly different results. Because there is little performance data on record for roundabouts in the United States, the worst-case capacity prediction should be chosen to produce a more conservative design.

FHWA Analysis Procedure

The FHWA Roundabout Guide provides basic capacity models for urban compact roundabouts, typical single-lane roundabouts, and typical double-lane roundabouts. For background discussion and more detailed information on this capacity model, please refer to the Chapter 4 of the FHWA Roundabout Guide.

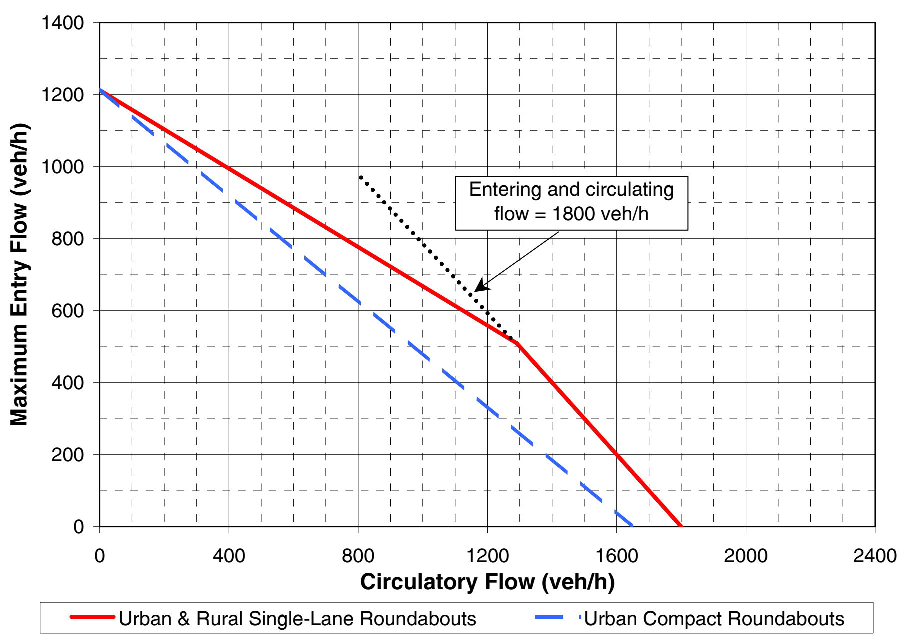
Traffic Volumes

The analysis method requires the specification of traffic volumes for each approach to the roundabout, including the hourly flow rate for each directional movement. Hourly volumes must be converted to *passenger car equivalents* (pce), using the standard conversion factors and methodology from the *Highway Capacity Manual*. Intersection turning movement flows must then be converted to roundabout flows. This process will result in an *entry volume* and a *circulatory volume* at each entry to the roundabout. For more details on how to convert intersection turning movement volumes to roundabout flows, please refer to the Chapter 4 of the FHWA Roundabout Guide.

Single-lane Roundabout Capacity

Exhibit 4-1 shows the expected capacity of a single-lane roundabout for both the urban compact and typical single-lane designs.

Exhibit 4-1
Entry Capacity of a Single-Lane Roundabout



The equations for entry capacity at single-lane roundabouts and urban compact roundabouts, respectively, are expressed below:

Single-lane Roundabouts: $Q_E = Min\{(1212 - 0.5447Q_C),(1800 - Q_C)\}$

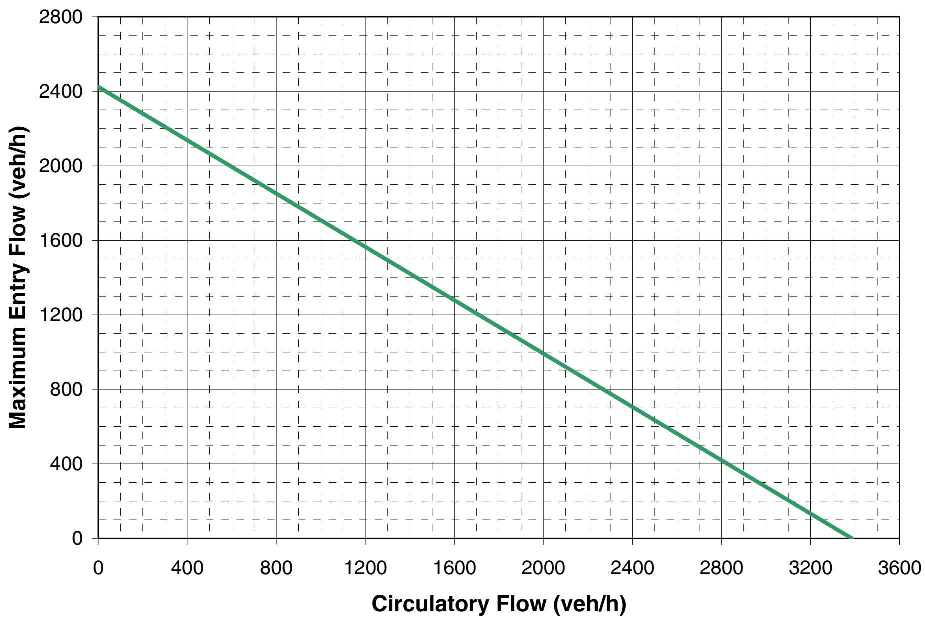
Urban Compact Roundabouts: $Q_E = 1218 - 0.74Q_C$

where:
Q_E = entry capacity, pce/h
Q_C = circulating flow, pce/h

Double-lane Roundabout Capacity

Exhibit 4-2 shows the expected capacity of a typical double-lane roundabout.

Exhibit 4-2
Entry Capacity of a Double-Lane Roundabout



The equation for a double-lane roundabout entry is expressed below:

Double-lane Roundabouts: $Q_E = 2424 - 0.7159 Q_C$

where: Q_E = entry capacity, pce/h
Q_C = circulating flow, pce/h

Capacity Effect of Short Lanes or Flared Entries

In some cases, a single-lane approach may be widened (or *flared*) to two lanes at the roundabout entry to improve the performance. This additional entry lane is referred to as a short lane because it is typically only added for a short distance from the entrance line of the roundabout. The amount of additional capacity achieved depends on the length of the short lane.

The capacity of a flared approach is determined by first determining the capacity of a standard double-lane entry, and then applying a reduction factor based on the short lane length. Exhibit 4-3 displays the capacity reduction factors to be applied for various lengths of short lane. It can be assumed that each vehicle space is equivalent to 25 ft (7.5 m).

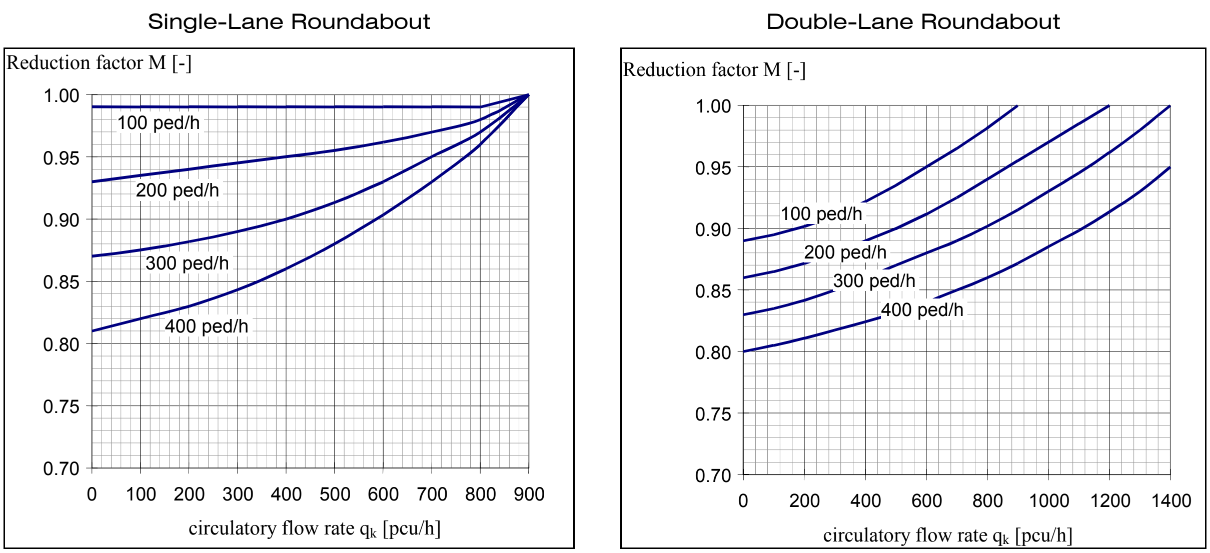
Exhibit 4-3
Capacity Reduction Factors for Short Lanes

Number of vehicle spaces in the short lane, n_f	Factor (applied to double-lane approach capacity)
0	0.500
1	0.707
2	0.794
4	0.871
6	0.906
8	0.926
10	0.939

Pedestrian Effects on Entry Capacity

Pedestrians have priority over entering motor vehicles at all roundabout entries. At intersections with high volumes of pedestrians, the crossings can have a significant effect on entry capacity. In such cases, the vehicular capacity is reduced by the reduction factors (*M*) shown in Exhibit 4-4. Note that the pedestrian impedance decreases as the circulatory flow rate (in front of the subject approach) increases.

Exhibit 4-4
Capacity Reduction Factors Due to Pedestrians

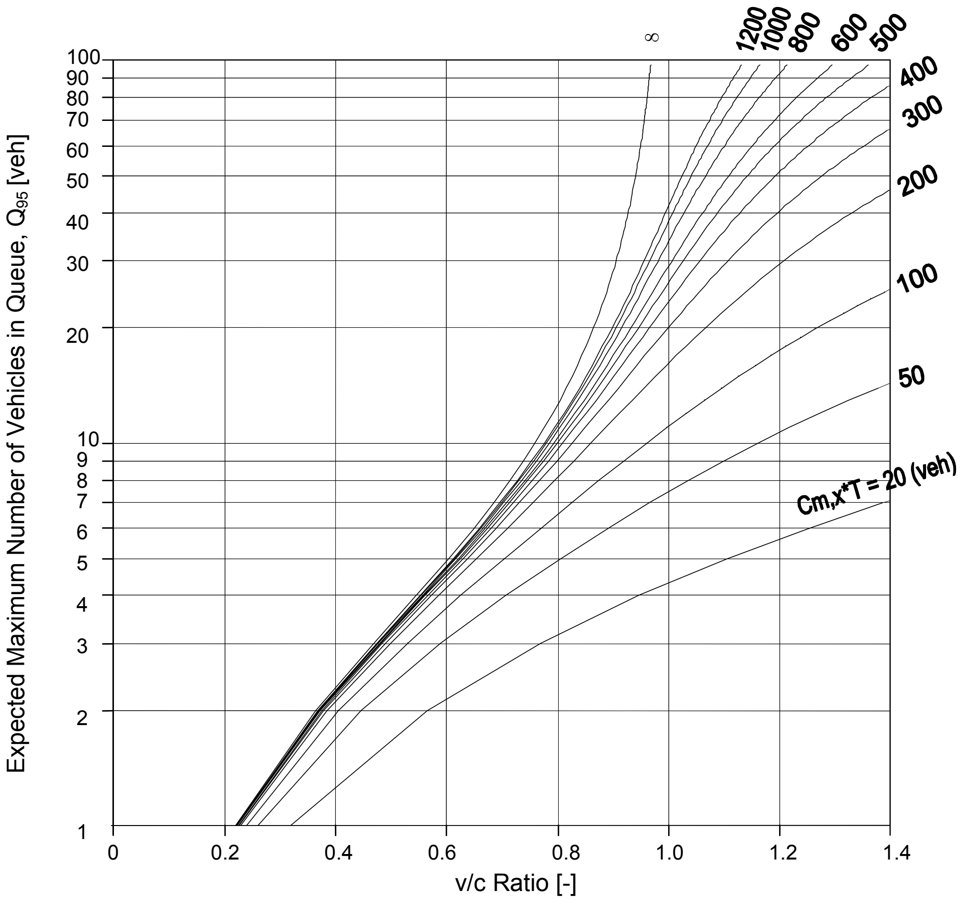


Queues

For design purposes, Figure 4-5 shows how the 95th-percentile queue length varies with the volume-to-capacity ratio of an approach. Individual lines are shown for the product of *T* and entry capacity. To determine the 95th-percentile queue length during time *T*, enter the graph at the computed volume-to-capacity ratio. Move vertically until the computed curve line is reached. Then move horizontally to the left to determine the 95th-percentile queue length.

In most cases, *T* should be 0.25 hours to represent the analysis of the peak 15-minute period. If the analysis has been conducted for the peak 1-hour condition, then *T* should be 1.0.

Exhibit 4-5
95th-Percentile Queue Length Estimation



Delay

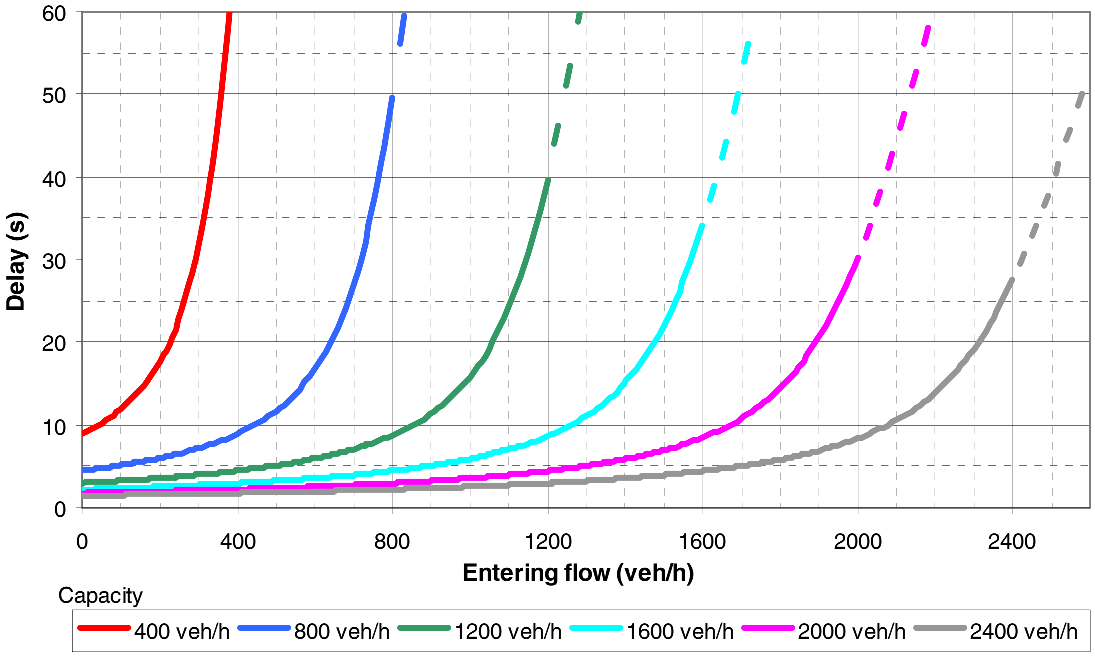
The FHWA procedure cites the use of the Highway Capacity Manual (HCM) delay equation for calculation of delay at roundabouts. Currently, the HCM only includes control delay, the delay attributable to the control device. Geometric delay is the second component of delay, which is the delay experienced by a single vehicle with no conflicting flows due to geometric features encountered when negotiating the intersection. This delay is computed using the following formula:

$$d = \frac{3600}{c_{m,x}} + 900T \times \left[\frac{v_x}{c_{m,x}} - 1 + \sqrt{\left(\frac{v_x}{c_{m,x}} - 1\right)^2 + \frac{\left(\frac{3600}{c_{m,x}}\right)\left(\frac{v_x}{c_{m,x}}\right)}{450T}} \right]$$

where: d = average control delay, sec/veh;
v_x = flow rate for movement x, veh/h;
$c_{m,x}$ = capacity of movement x, veh/h; and
T = analysis time period, h (T = 0.25 for a 15-minute period)

Exhibit 4-6 shows how control delay at an entry varies with entry capacity and circulating flow.

Exhibit 4-6
Control Delay as a Function of Capacity and Entering Flow



4.2 Operational Performance Measures

Three key performance measures should be determined for use in assessing the operating performance for a particular roundabout design:

- Degree of Saturation
- Delay
- Queue Length

Degree of saturation is the ratio of the demand at the roundabout entry to the capacity of the entry. The resulting ratio is typically referred to as the volume-to-capacity ratio (v/c ratio) and provides a direct assessment of the sufficiency of a given design. *For design purposes, the maximum volume-to-capacity ratio should be 0.85 for satisfactory operation*.

Delay is a standard parameter used to measure the performance of an intersection. There are two general components of the total delay at a roundabout: the control delay and the geometric delay. The control delay is the delay attributable to the control device, while the geometric delay is the delay experienced by a single vehicle with no conflicting flows due to geometric features encountered when negotiating the intersection. Calculation of geometric delay requires additional data such as the proportion of vehicles that must stop at the entrance line, as well as knowledge of the roundabout geometry as it affects vehicle speed. *Typically, the control delay is the standard measure used to represent the delay component of a roundabout performance, as it is the same measure used to represent the delay for other types of intersections.* For the FHWA Roundabout Guide procedure, the Highway Capacity Manual delay formula is used, which currently only considers the control delay.

Queue length is important in assessing the adequacy of the geometric design of the roundabout approaches. For design purposes, the 95^{th}-percentile queue length is determined to estimate the maximum resulting queue for a given approach.

For each proposed roundabout, these three performance measures shall be determined for each approach (intersection leg) and summarized in a tabular format such as the example shown in Exhibit 4-7.

Exhibit 4-7
Example Operational Analysis Summary Table

Intersection Parameter	Analysis Method	2020 Weekday AM Peak Hour				2020 Weekday PM Peak Hour			
		NB	WB	SB	EB	NB	WB	SB	EB
Number of entry/exit lanes	-	# / #	# / #	# / #	# / #	# / #	# / #	# / #	# / #
Volume-to-Capacity Ratio (v/c)	FHWA								
	(fill in)[1]								
Average Delay (sec/veh)	FHWA								
	(fill in)[1]								
95th Percentile Queue per Lane (# of Vehicles)	FHWA								
	(fill in)[1]								

[1]If Applicable

Where two or more roundabout configuration options are being considered simultaneously, it may be helpful to compare the two designs in a simplified format. Exhibit 4-8 shows a sample table that may be used to compare two designs based upon the critical roundabout approach (approach with the worst operating parameters).

Exhibit 4-8
Example Option Comparison Table

Intersection Parameter		Option 1		Option 2	
		AM Peak Hour	PM Peak Hour	AM Peak Hour	PM Peak Hour
Critical Approach					
Volume-to-Capacity Ratio (v/c)					
Average Delay (sec)					
95th %tile Queue per Lane	Number of Vehicles				
	Length (ft)				

Chapter 5 - Roundabout Safety

5.1 Roundabout Safety

Typical crash patterns at roundabouts

Exhibits 5-1 and 5-2 identify the most common types of crashes that occur at roundabouts. These crash types are based on data collected outside the United States (principally France but also the United Kingdom and Australia) but are generally transferable to the United States.

Exhibit 5-1 presents a diagram of typical crash types at roundabouts. Exhibit 5-2 presents a summary of the percentage of crashes by collision type as reported in France, Australia, and the United Kingdom to provide guidance on the reported frequencies of each type of crash. The numbered items in the list correspond to the numbers indicated on the diagrams given in Exhibit 5-2 as reported in France. The French data illustrate collision types for a sample of 202 injury crashes from 179 urban and suburban roundabouts in France for the period 1984 to 1988 (CETUR 1992). For comparison purposes, data from Queensland, Australia (Arndt 1998) and the United Kingdom (Maycock and Hall 1984) have been superimposed onto the same classification system.

Exhibit 5-1
Diagram of Crash Types at Roundabouts

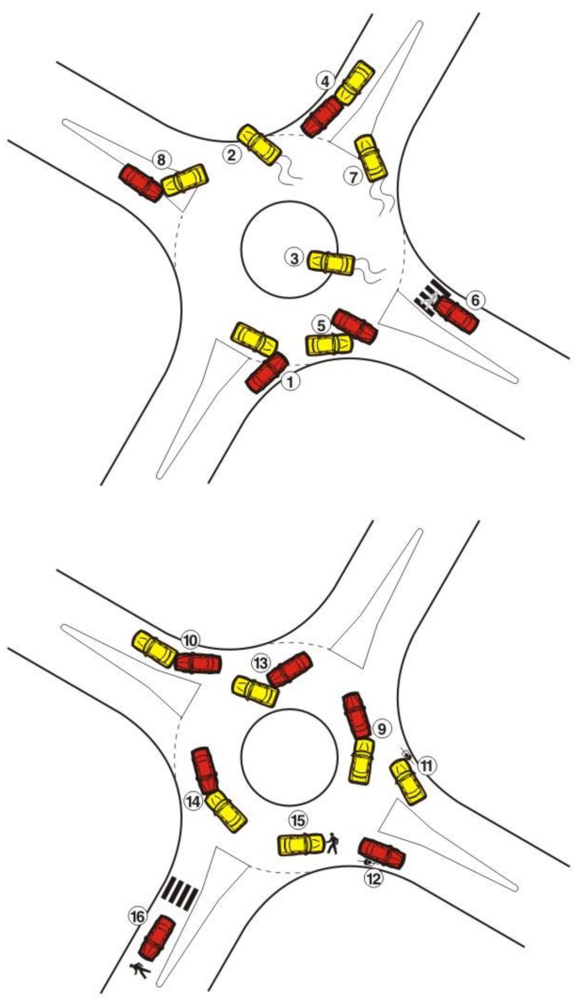


Exhibit 5-2
Comparison of Collision Types at Roundabouts

Collision type	France	Queensland (Australia)	United Kingdom[1]
1. Failure to yield at entry (entering-circulating)	36.6%	50.8%	71.1%
2. Single-vehicle run off the circulatory roadway	16.3%	10.4%	8.2%[2]
3. Single vehicle loss of control at entry	11.4%	5.2%	[2]
4. Rear-end at entry	7.4%	16.9%	7.0%[3]
5. Circulating-exiting	5.9%	6.5%	
6. Pedestrian on crosswalk	5.9%		3.5%[4]
7. Single vehicle loss of control at exit	2.5%	2.6%	[2]
8. Exiting-entering	2.5%		
9. Rear-end in circulatory roadway	0.5%	1.2%	
10. Rear-end at exit	1.0%	0.2%	
11. Passing a bicycle at entry	1.0%		
12. Passing a bicycle at exit	1.0%		
13. Weaving in circulatory roadway	2.5%	2.0%	
14. Wrong direction in circulatory roadway	1.0%		
15. Pedestrian on circulatory roadway	3.5%		[4]
16. Pedestrian at approach outside crosswalk	1.0%		[4]
Other collision types		2.4%	10.2%
Other sideswipe crashes		1.6%	

Notes:

1. Data are for "small" roundabouts (curbed central islands > 4 m [13 ft] diameter, relatively large ratio of inscribed circle diameter to central island size)
2. Reported findings do not distinguish among single-vehicle crashes.
3. Reported findings do not distinguish among approaching crashes.
4. Reported findings do not distinguish among pedestrian crashes.

Sources: France (CETUR 1992), Australia (Arndt 1998), United Kingdom (Maycock and Hall 1984)

Recent Studies

A number of safety studies have been conducted to evaluate the crash experience and safety performance of U.S. roundabouts since the publication of the FHWA Roundabout Guide. These include a study completed by the Insurance Institute for Highway Safety (IIHS) and another by the Maryland State Highway Administration.

Insurance Institute for Highway Safety Study
"Crash Reductions Following Installation of Roundabouts in the United States"

The IIHS study, completed in March 2000, evaluated the changes in motor vehicle crashes following conversion of 24 intersections from stop sign and traffic signal control to modern roundabouts. The settings, located in 8 states, were a mix of urban, suburban, and rural environments. The study categorized the sites into the following categories based on the type of control prior to conversion. The study employed the empirical Bayes methodology to estimate two measures of safety effects of the proposed roundabouts. The first is "index of safety effectiveness", which is approximately equal to the ratio of the number of crashes occurring after conversion to the number expected had conversion not taken place. The second is the more conventional percent reduction in crashes. The results of the analysis are summarized in Exhibit 5-3.

Exhibit 5-3
Estimates of Safety Effect for Groups of Conversions

Group Characteristic Before Conversion/Jurisdiction	Count of Crashes During Period After Conversion		Crashes Expected During After Period Without Conversion (Standard Deviation)		Index of Effectiveness (Standard Deviation)		Percent Reduction in Crashes	
	All	Injury	All	Injury	All	Injury	All	Injury
Single-lane, Urban, Stop Controlled								
9 Intersections	44	4	112.6 (10.2)	16.6 (2.6)	0.39 (0.07)	0.23 (0.12)	61	77
Single-lane, Rural, Stop Controlled								
5 Intersections	44	5	105.2 (8.4)	26.9 (3.4)	0.42 (0.07)	0.18 (0.09)	58	82
Multilane, Urban, Stop Controlled								
7 Intersections	131	*	153.8 (12.4)	(n/a)*	0.85 (0.10)	(n/a)*	15	(n/a)*
Urban, Signalized								
3 Intersections	73	4	106.7 (10.0)	12.0 (2.5)	0.68 (0.10)	0.32 (0.17)	32	68
All conversions	292	14	478.2 (20.7)	57.8 (5.1)	0.61 (0.04)	0.24 (0.07)	39	76

* Injury data unavailable.

Overall, the empirical Bayes procedure estimated a highly significant 39 percent reduction for all crash severities combined for the 24 converted intersections. Because injury data were not available for the period before construction of the 4 roundabouts in Vail, Colorado, overall estimates for changes in injury crashes are based on the other 20 intersections. The empirical Bayes procedure estimated a highly significant 76 percent reduction for injury crashes for these 20 intersections.

Exhibit 5-3 breaks down the crash results according to the above categories. As expected, the crash reductions are greater for the single-lane roundabouts. This can be attributed to fewer conflict points and easier decision-making process for single-lane roundabouts compared to multilane roundabouts.

Two ongoing projects are expected to significantly expand the information presented in the IIHS study, and both involve research team members common to the IIHS study. First, a study is currently nearing completion for the New York State DOT that increases the number of sites documented in the IIHS work by approximately 40 percent. Additionally, further crash information will be investigated under the National Cooperative Highway Research Program (NCHRP) project 3-65 (Applying Roundabouts in the U.S.). Essentially, both studies will use the same methodology to update the crash database initiated with the IIHS study.

Maryland State Highway Administration study
"Maryland's Roundabout Accident Experience and Economic Evaluation"

This study looked at the crash experience at all roundabouts constructed by the Maryland State Highway Administration (SHA) prior to September 2002. As of this date, SHA had in operation more than 30 modern roundabouts. Out of this total, 15 single-lane roundabouts had sufficient post-construction data available for analysis, from which the following conclusions were made:

- The average annual crashes fell from an average of 4.05 crashes per year in the before period, to an average of 1.11 crashes per year in the after period, a 73 percent reduction.
- Crash severity also decreased, as injury crashes have shown a reduction from an annual average of 2.31 injury crashes per year in the before period, to an average of 0.35 injury crashes per year in the after period, a reduction of 85 percent.
- The mean total crash rate for the roundabout in the *before* period was 1.36 reported crashes per million vehicles entering (MVE). The mean total crash rate in the *after* period was 0.27 crashes per MVE.
- The mean injury crash rate in the *before* period was 0.79 crashes per MVE. The mean injury crash rate in the *after* period was 0.09 crashes per MVE.

A benefit/cost analysis was conducted for the fifteen single-lane roundabouts. The findings of this analysis are:

- At locations where roundabouts have been installed there has been a 60-percent decrease in the total crash rate and a 100-percent decrease in the fatal crash rate.
- There was an 82-percent reduction in the injury crash rate and a 27-percent reduction in the property damage only crash rate.
- The benefit/cost effectiveness analysis indicated that for every dollar spent on these projects there is a return of approximately eight dollars to be realized through crash reduction.

5.2 References

1. Maycock G., and Hall R.D. *Crashes at four-arm roundabouts.* TRRL Laboratory Report LR 1120. Crowthorne, England: Transport and Road Research Laboratory, 1984.

2. Centre d'Etude des Transports Urbains (CETUR). "Safety of Roundabouts in Urban and Suburban Areas," Paris, 1992.

3. Arndt, O., "Road Design Incorporating Three Fundamental Safety Parameters", Technology Transfer Forum 5 & 6, Transport Technology Division, Main Roads Department, Queensland, Australia, August 1998.

4. Persaud, B.N., R.A. Retting, P.E. Gardner, and D. Lord. "Crash Reductions Following Installation of Roundabouts in the United States". Arlington, VA: Insurance Institute for Highway Safety. March 2000.

5. Maryland State Highway Administration, Office of Traffic and Safety, Traffic Safety Analysis Division. "Maryland's Roundabout Accident Experience and Economic Evaluation". Maryland, December 2002.

Chapter 6 - Geometric Design

6.1 General Design Guidance

Designing an effective roundabout requires striking a balance between providing sufficient capacity to serve existing and future traffic demand and creating an environment that is going to allow for safe and efficient travel for all users. Finding this balance requires the designer to know the environment that they are working in, the physical constraints, the composition and quantity of expected users, and knowledge of the surrounding roadway system. Each of these factors plays a role in determining the size, shape, and purpose for the roundabout. This section describes the fundamental principles guiding roundabout design and looks at various geometric elements, providing considerations to achieve a balanced design.

Fundamental Design Principles

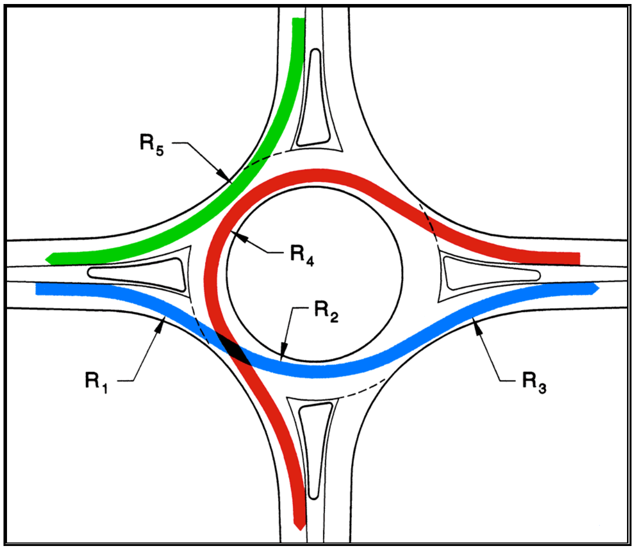
Fundamentally, the principles of roundabout design are no different than other roadways and intersection types. The designer must consider the context of the project and provide suitable geometry and traffic control devices according to established engineering tools and design standards. These considerations include design speed, design vehicle, lane numbers, lane arrangements, user types, and physical environment. However, some of the geometric features and operational objectives are implemented slightly different for roundabouts than for other intersection forms. These fundamental principles are discussed below.

Design Speeds

One of the most critical design objectives is achieving appropriate vehicular speed through the roundabout. Roundabouts operate most safely when their geometry forces traffic to enter, circulate, and exit at slow speeds. Generally, design speeds should be between 15 and 30 miles per hour. The fastest path allowed by the geometry determines the design speed of a roundabout. This is the smoothest, flattest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings. The fastest path is drawn for a vehicle traversing through the entry, around the central island, and out the exit.

The fastest paths must be drawn for all approaches and all movements, including left-turn movements (which generally represent the slowest of the fastest paths) and right-turn movements (which may be faster than the through movement paths at some roundabouts). Exhibit 6-1 illustrates the five critical path radii that must be checked at each approach.

Exhibit 6-1
Vehicle Path Radii at a Roundabout

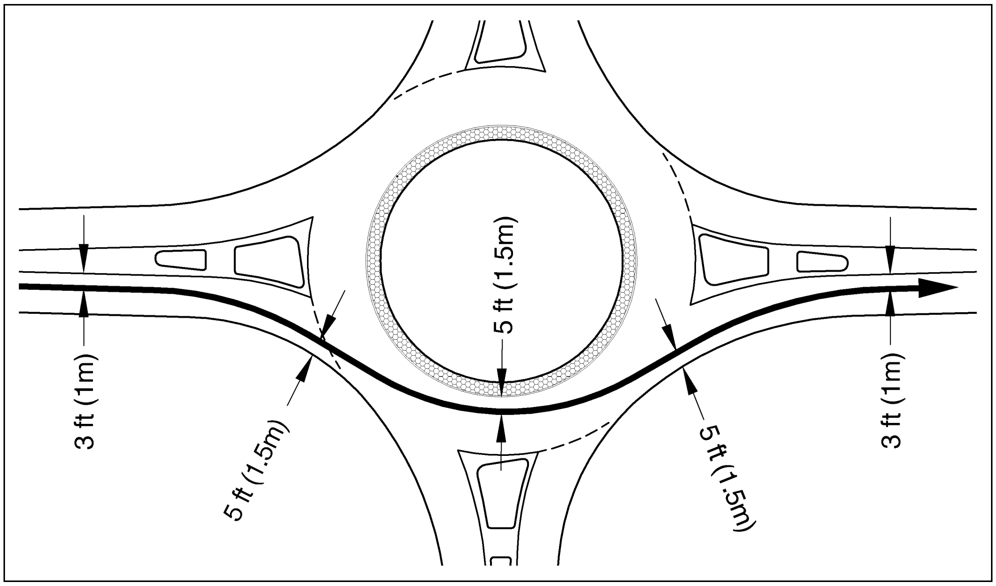


The fastest path is drawn assuming a vehicles starts at the left-hand edge of the approach lane, moves to the right side as it enters the roundabouts, cuts to the left side of the circulatory roadway, then moves back to the right side at the exit, and completes its move at the left-hand side of the departure lane. The centerline of the vehicle path is drawn using the following minimum offset distances:

- 5 ft (1.5 m) from concrete curbs,
- 5 ft (1.5 m) from roadway centerline, and
- 3 ft (1.0 m) from striped edge lines or lane.

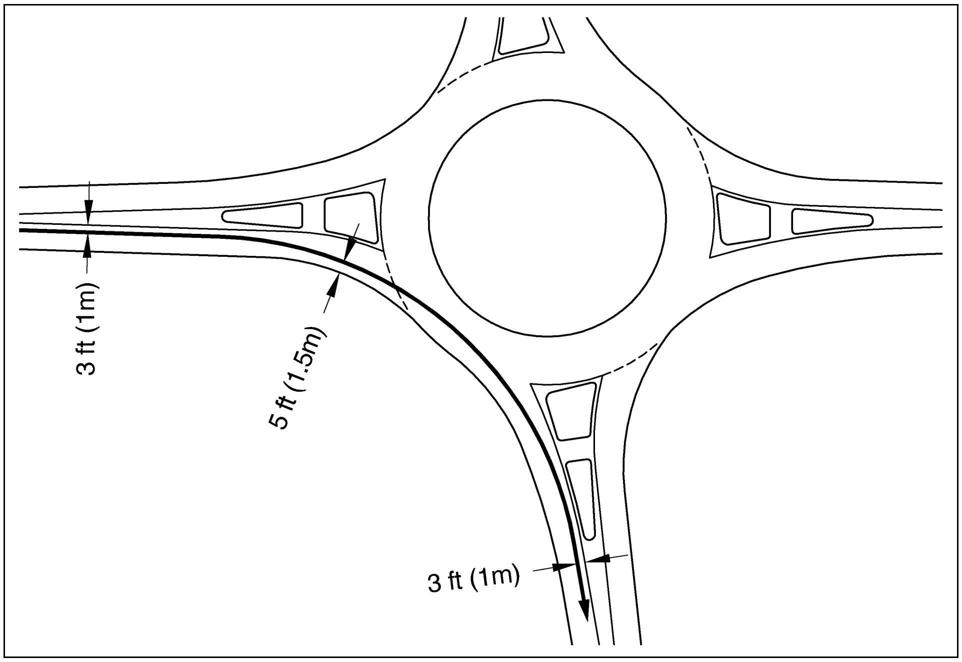
Exhibit 6-2 illustrates the construction of the fastest vehicle path for a through movement at a typical single-lane roundabout.

Exhibit 6-2
Fastest Vehicular Paths at a Single-Lane Roundabout



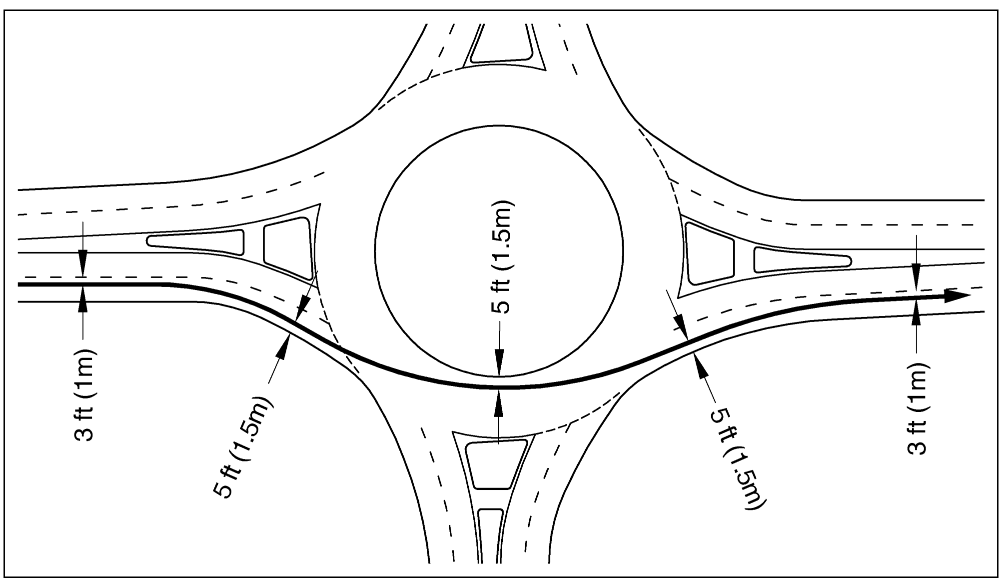
In some cases the right-turn path may be faster than the through movement path. Thus, the right-turn fastest path should be drawn carefully using the same principles and offsets described above. Exhibit 6-3 shows a sample right-turn path.

Exhibit 6-3
Fastest Vehicular Paths for a Critical Right-Turn Movement



At double-lane roundabouts, the fastest path is drawn assuming the vehicle approaches in the right lane, cuts across into the left hand circulatory lane, and then exits into the right lane. Exhibit 6-4 illustrates the fastest path at a typical double-lane roundabout. Note that Exhibit 6-4 is consistent with the guidance in the FHWA Roundabout Guide. However, a potentially faster path can be drawn by assuming that the vehicle changes lanes on approach and/or on exit.

Exhibit 6-4
Fastest Vehicular Paths at a Double-Lane Roundabout



Once the fastest paths are drawn, the minimum radii along these paths are then measured, and the corresponding design speed is calculated according to the methodology in the AASHTO publication *A Policy on Geometric Design of Highways and Streets* (commonly referred to as the "Green Book"). The equation for the design speed with respect to horizontal curve radius is given below (please refer to the FHWA Roundabout Guide for the metric version).

Speed-Radius Relationship: $V = \sqrt{15R(e + f)}$

where: V = Design speed, mph
R = Radius, ft
e = superelevation, ft/ft
f = side friction factor

Superelevation values are usually assumed to be +0.02 for entry and exit curves (R_1, R_3, and R_5) and –0.02 for curves around the central island (R_2 and R_4). More details related to superelevation design are provided later in this chapter.

Values for side friction factor can be determined in accordance with AASHTO standards for curves at intersections (see 2001 AASHTO Exhibit 3-43). The coefficient of friction between a vehicle's tires and the pavement varies with the vehicle's speed. Using the appropriate friction factors corresponding to each speed, Exhibit 6-5 was developed to graphically show the speed-radius relationship for curves on both a +0.02 superelevation and –0.02 superelevation.

Exhibit 6-5
Speed-Radius Relationship

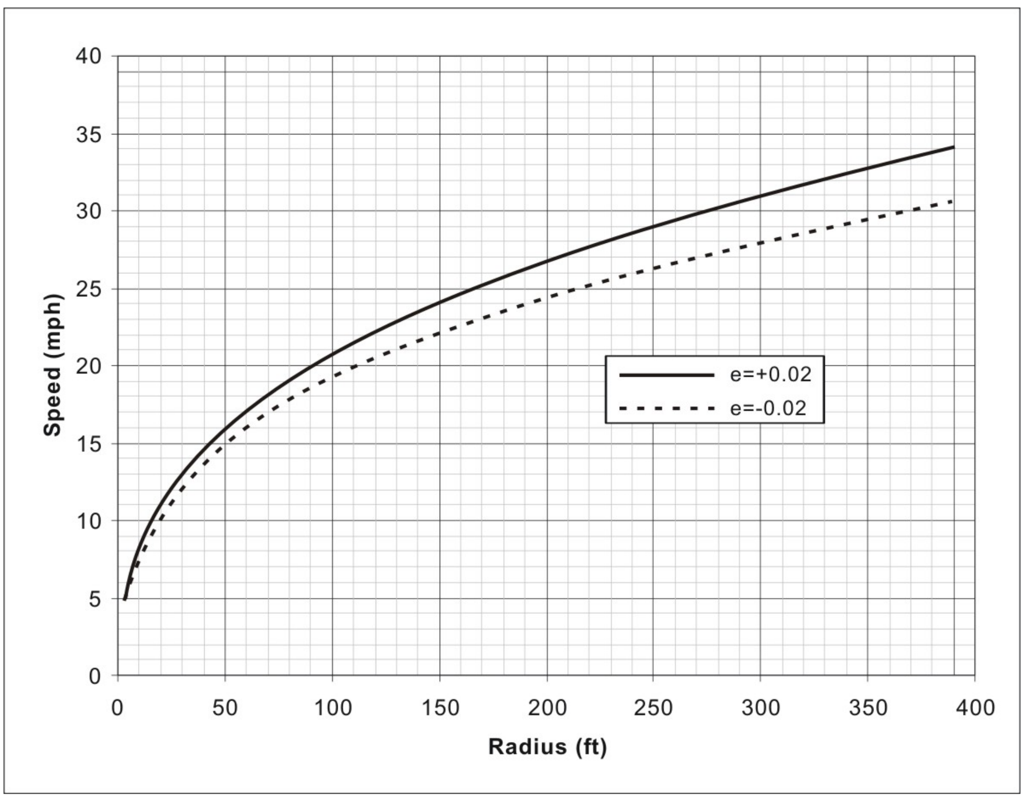


Exhibit 6-6 displays the maximum recommended design speeds for various roundabout categories.

Exhibit 6-6
Roundabout Design Speeds

Site Category	Maximum Entry (R_1) Design Speed
Mini Roundabout	20 mph (32 km/h)
Urban Compact Roundabout	20 mph (32 km/h)
Urban Single-Lane Roundabout	25 mph (40 km/h)
Rural Single-Lane Roundabout	25 mph (40 km/h)
Urban Double-Lane Roundabout	25 mph (40 km/h)
Rural Double-Lane Roundabout	30 mph (48 km/h)

Speed Consistency

In addition to achieving the appropriate design speed for the fastest movements, the relative speeds between consecutive geometric elements should be minimized and the relative speeds between conflicting traffic streams should be minimized. This means that all fastest path radii (R_1, R_2, R_3, R_4, and R_5 from Exhibit 6-1) are determined at each approach and the corresponding design speeds are evaluated. Ideally, the relative differences between all speeds within the roundabout should be no more than 6 mph (10 km/h). However, it is often difficult to achieve this goal, particularly at roundabouts that must accommodate large trucks. In these cases, the maximum speed differential between movements should be no more than 12 mph (20 km/h).

The exit radius, R_3, should not be less than R_1 or R_2 to minimize loss-of-control crashes. At single-lane roundabouts with pedestrian activity, exit radii may still be small (the same or slightly larger than R_2) in order to minimize exit speeds. However, at double-lane roundabouts, additional care must be taken to minimize the likelihood of exiting path overlap. Exit path overlap can occur at the exit when a vehicle on the left side of the circulatory roadway (next to the central island) exits into the right-hand exit lane. More guidance related to path overlap at multilane roundabouts is provided later in this section. At multilane roundabouts and single-lane roundabouts where no pedestrians are expected, it is acceptable for the design speed of the exit radius (R_3) to be slightly higher than 25 mph (40 km/h). Where pedestrians are present, tighter exit curvature may be necessary to ensure sufficiently low speeds at the downstream pedestrian crossing.

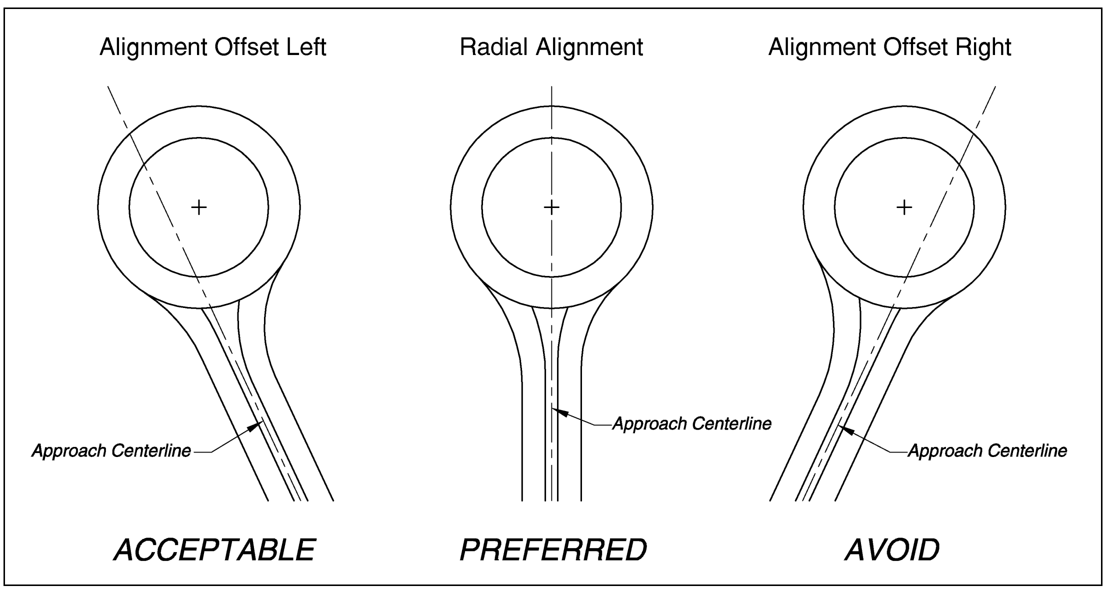
Some recent design philosophies have recommended relaxing the design speed guidelines for roundabout exits. These studies advocate large radii or even tangential geometry at exits to reduce vehicle-to-vehicle conflicts and ease the flow of traffic as it departs from the circulatory roadway. The basic principle behind this argument is that if entry and circulatory speeds are sufficiently low, vehicles will not be able to accelerate significantly on the exit; thus, the safety for pedestrians will not be compromised. However, at this time there is limited data relating pedestrian safety to exit geometry. Exits should therefore be designed with sufficient curvature to ensure even aggressive drivers cannot achieve excessive exits speeds. Overly tight exit geometry should also be avoided, particularly for multilane exits where tight radii can lead to higher frequency of crashes. Thus, the design of exits should be a carefully balanced geometry to maximize safety for all users.

Once a preliminary geometric design for a roundabout has been developed, the fastest path radii and speeds should be summarized in a tabular format (a sample design speed summary table is provided later in Exhibit 6-13). This tabular summary should be provided along with the sketched fastest path diagrams for all conceptual and/or preliminary roundabout design plans submitted to KDOT and/or other governing agencies for review.

Approach Alignment

Ideally, the centerline of the roundabout approaches should align through the center of the roundabout. However, it is acceptable for the approach to be slightly offset to the left of the center point, as this alignment enhances the deflection of the entry path. If it is aligned too far to the left, however, an excessive tangential exit may occur, causing higher exit speeds. If the alignment of the entry is offset to the right, the approach geometry often does not provide enough deflection for the entering vehicles. Therefore, approach alignments offset to the right of the roundabout center should be avoided unless other geometric features are used to provide adequate speed reduction. Exhibit 6-7 illustrates the preferred approach alignment for roundabouts in general.

Exhibit 6-7
Approach Alignment Guidelines

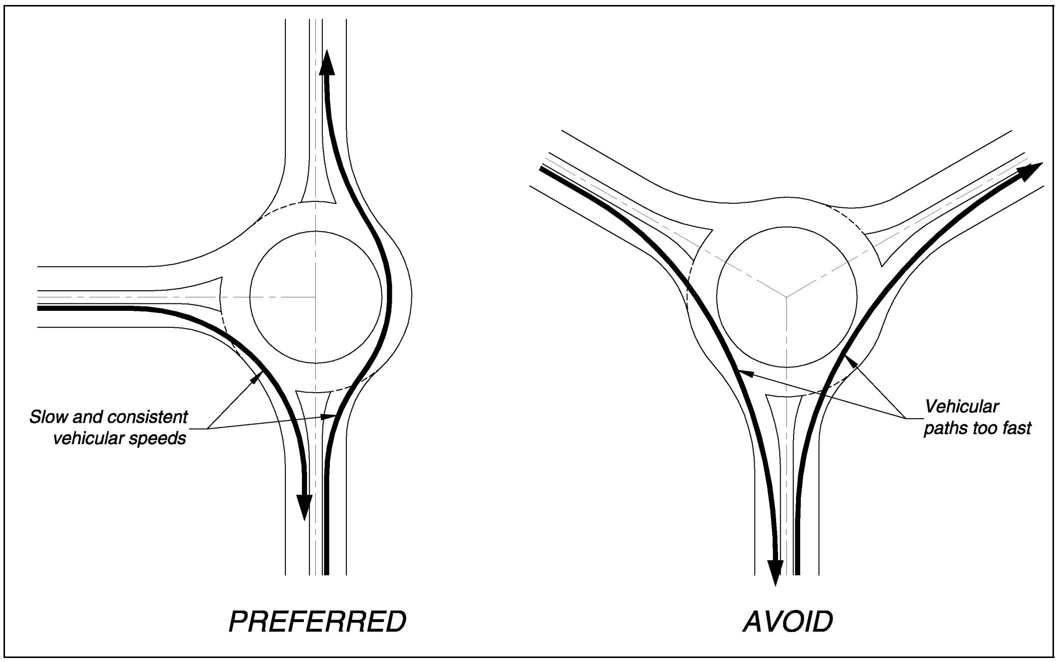


Angles Between Approaches

Similar to signalized and stop-controlled intersections, the angle between approach legs is an important design consideration. Although it is not necessary for opposing legs to align directly opposite one another (as it is for conventional intersections), it is generally preferable for the approaches to intersect at perpendicular or near-perpendicular intersection angles. If two approach legs intersect at an angle significantly less than or greater than 90 degrees, it will often result in excessive speeds for one or more right-turn movements. At the same time, left-turn movements from all approaches will be relatively low, resulting in a higher speed differential than desired. Designing the approaches at perpendicular or near-perpendicular angles generally results in relatively slow and consistent speeds for all movements. Highly skewed intersection angles can often require significantly larger inscribed circle diameters to achieve the speed objectives.

Exhibit 6-8 illustrates the fastest paths at a roundabout with perpendicular approach angles versus a roundabout with obtuse approach angles.

Exhibit 6-8
Perpendicular Approach Angles versus Obtuse Approach Angles



As this figure implies, roundabout T-intersections should intersect as close to 90 degrees as possible. Y-shaped intersection alignments will typically result in higher speeds than desired and should therefore be avoided. Approaches that intersect at angles greater than approximately 105 degrees should generally be realigned by introducing curvature in advance of the roundabout to produce a more perpendicular intersection. For low speed urban roundabouts where large trucks are not present, it may be acceptable to allow larger intersection angles provided the entry curvature is sufficiently tight to ensure low entry speeds.

Design Vehicle

Roundabouts should be designed to accommodate the largest vehicle that can reasonably be anticipated. Because roundabouts are intentionally designed to slow traffic, narrow curb-to-curb widths and tight turning radii are used. However, if the widths and turning requirements are designed too tight, it can create difficulties for oversized vehicles. Large trucks and buses often dictate many of the roundabout's dimensions, particularly for single-lane roundabouts. Therefore, it is very important to determine the design vehicle at the start of the design and investigation process. Exhibit 6-9 illustrates one example roundabout that does not adequately accommodate a truck and one that does.

Exhibit 6-9
Truck Accommodations at Roundabouts

Example of roundabout not properly designed to accommodate large trucks

Example of roundabout designed properly for large trucks

Selecting the design vehicle is determined by considering the types of roadways involved, the area where the intersection is located, and the types and volume of vehicles using the intersection. For intersections in a residential environment, the design vehicle is often a school bus or fire truck. At urban collector or arterial intersections, the design vehicle is often a WB-50 (WB-15m) semi-trailer. For freeway ramp terminals and other intersections on state highway routes, the design vehicle is generally a WB-67 (WB-20m).

Typical design vehicles for various roadway types are given in Exhibit 6-10. The appropriate staff from KDOT and/or the governing local agencies should be consulted early in the design process to identify the design vehicle at each project location. Consideration should be given to the actual vehicle classification mix in addition to the adjacent land uses and facility classifications for the near term and future design years.

Exhibit 6-10
Recommended Design Vehicles

Intersection Type	Design Vehicle
State Highway Routes	WB-67 (WB-20m)
Ramp Terminal	WB-67 (WB-20m)
Other Rural	WB-50 (WB-15m)
Urban Major Streets	WB-50 (WB-15m)
Other Urban	Bus or Single Unit Truck

Vehicle turning path templates or CAD-based vehicle turning path simulation software should be used during the design process to establish the turning path requirements of the design vehicle.

Pedestrian Accommodations

As with any intersection form, providing safe and comfortable accommodations for pedestrians is a fundamental objective. At roundabouts, pedestrian crosswalks are set back from the entrance line approximately one to two vehicle lengths. This distance allows drivers to focus on pedestrians prior to arriving at the entrance line and focusing on other traffic. Refuge areas in the splitter islands enable pedestrians to cross the traffic streams in two stages, by first crossing the entrance lanes and then crossing the exit lanes. Exhibit 6-11 displays pedestrian crossings at an urban single-lane roundabout leg.

Exhibit 6-11
Pedestrian Crossings at a Roundabout

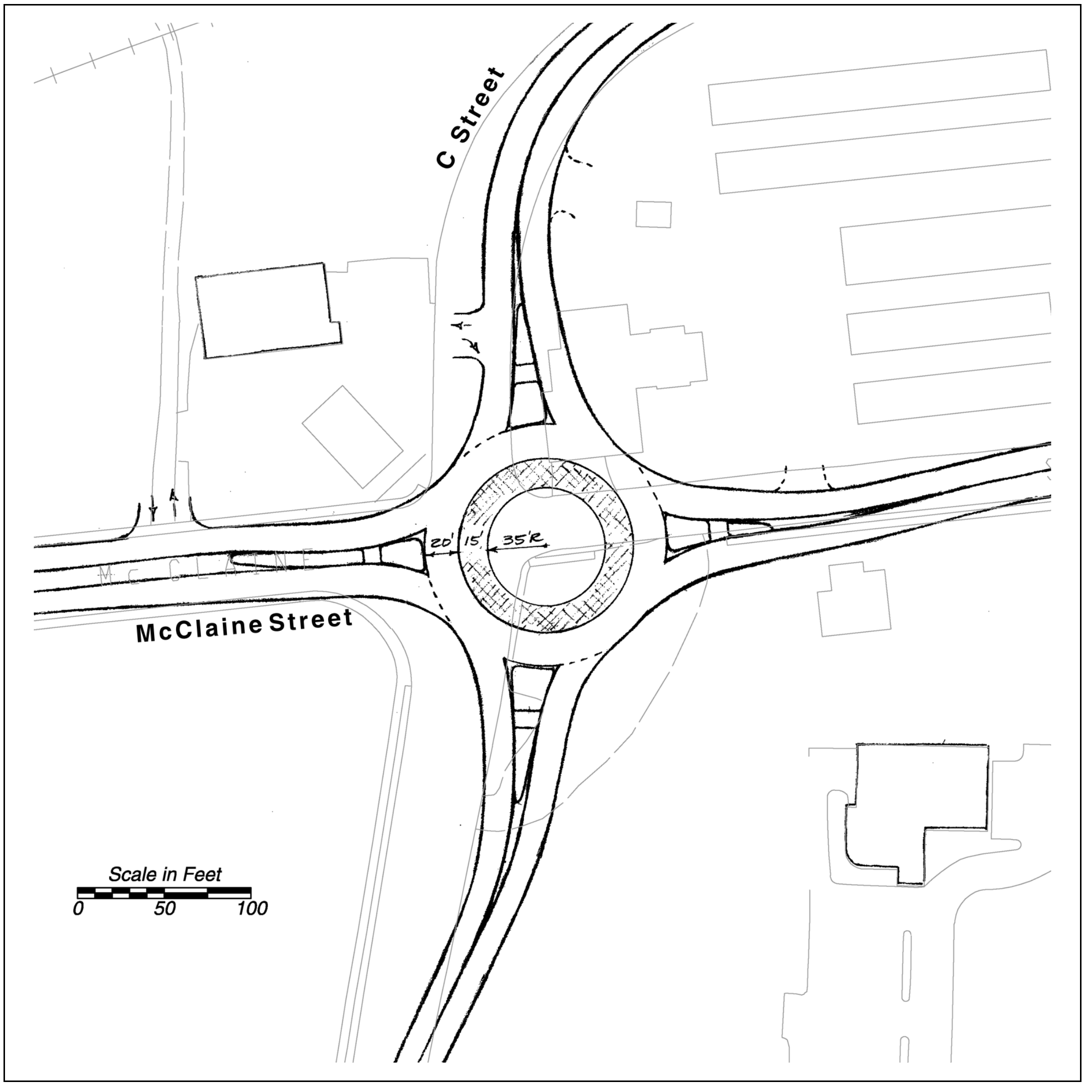
Roundabout Design Process

Roundabout design is an iterative process requiring the designer to consider operational and safety effects of the geometric elements. The recommended process for designing a roundabout is generally as follows:

1. Identify the intersection context and design vehicle. The intersection context includes identifying whether this is the first roundabout in an area and whether the site is new or a retrofit.
2. Perform operational analysis to determine the number of lanes required. In general, the number of entry lanes and exit lanes should be kept to the minimum necessary based on the design year traffic projections. For example, if the designer determines that a two-lane roundabout is required, he/she should then optimize each of the approaches to determine if the demand can be served for any of the approaches with just single-lane entries. It is also important to minimize the number of exit lanes, as exits are the most difficult for pedestrians to cross.

3. Prepare an initial roundabout layout at a sketch level. A scale of 1"=50' (1:500) is generally preferred for this sketch-level design. Exhibit 6-12 shows an example conceptual design sketch.

Exhibit 6-12
Example Roundabout Design Sketch



4. Check the design speeds of all movements at all legs of the roundabout. Watch out for entry speeds greater than 25 mph (40 km/h) or speed differentials of greater than 12 mph (20 km/h). Exhibit 6-13 displays an example design speed summary.

Exhibit 6-13
Sample Roundabout Design Speeds Summary Table

Approach	Curve	Radius (feet)	Speed (mph)	Relative Speed Difference* (mph)
Northbound C Street	R1	140	23	8
	R2	115	20	5
	R3	150	24	9
	R4	55	15	-
	R5	120	22	7
Southbound C Street	R1	150	24	9
	R2	125	21	6
	R3	175	25	10
	R4	55	15	-
	R5	110	21	6
Eastbound McClaine Street	R1	115	22	7
	R2	115	20	5
	R3	150	24	9
	R4	55	15	-
	R5	100	20	5
Westbound McClaine Street	R1	125	22	7
	R2	115	20	5
	R3	165	25	10
	R4	55	15	-
	R5	130	23	8

* Relative difference is from minimum speed within roundabout (typically, R4 speed).

5. If necessary, revise the sketched geometry to meet design speed and speed consistency objectives. Then check the design speeds of the revised design and continue to refine the geometry as necessary.
6. Check the design vehicle turning movement paths at each leg.
7. Revise the sketch if needed to accommodate the design vehicle. It may require using a larger diameter roundabout in order to meet the speed objectives and accommodate the design vehicle.
8. Re-analyze the operational performance if necessary to reflect the geometric parameters. Note that this may not be necessary for intersections with a volume-to-capacity ratio of less than approximately 0.50.
9. Prepare and evaluate alternative roundabout layouts following the same process above. You may test different inscribed diameters or different approach alignments to determine the optimal design.

Elements of Design

Guidelines for designing each element of a roundabout geometry are described in the remainder of this section.

Number of Entering/Exiting/Circulating Lanes

One of the first considerations in the initial design stages of a roundabout project is determining the number of entering/exiting lanes on each approach to the roundabout. Increases in entry width for additional travel lanes on an approach have a direct effect in increasing capacity. However, with an increased number of lanes come additional conflicts that are not present with single-lane roundabouts. International crash models indicate that increasing from a single to a multilane roundabout increases the potential for injury crashes. Additional entering/exiting lanes also increase the number of conflicts for pedestrians, as pedestrians are required to travel a greater distance across an approach and have increased exposure to vehicular traffic. Pedestrians are especially vulnerable on roundabout exits where drivers are beginning to accelerate.

In general, the number of entering/circulating/exiting lanes should be limited to the minimum number required for capacity considerations. It may be possible on multilane roundabouts to provide single lane entries and exits on low volume approaches where additional lanes are not required.

Inscribed Circle Diameter

The inscribed circle diameter is the distance across the circle inscribed by the outer curb (or edge) of the circulatory roadway. It is the sum of the central island diameter and twice the circulatory roadway width. The inscribed circle diameter is determined by a number of design objectives. The designer often has to experiment with varying diameters before determining the optimal size at a given location.

At single-lane roundabouts, the size of the inscribed circle is largely dependent upon the turning requirements of the design vehicle. The diameter must be large enough to accommodate the design vehicle while maintaining adequate deflection curvature to ensure safe travel speeds for smaller vehicles. However, the circulatory roadway width, entry and exit widths, entry and exit radii, and approach angles also play a significant role in accommodating the design vehicle and providing deflection. Careful selection of these geometric elements may allow a smaller inscribed circle diameter to be used in constrained locations.

In general, smaller inscribed diameters are better for overall safety because they help to maintain lower speeds. In high-speed environments, however, the design of the approach geometry is more critical than in low-speed environments. Larger inscribed diameters generally allow for the provision of better approach geometry, which leads to a decrease in vehicle approach speeds. Larger inscribed diameters also reduce the angle formed between entering and circulating vehicle paths, reducing the relative speed between these vehicles and leading to reduced entering-circulating crash rates. Therefore, roundabouts in high-speed environments may require diameters that are somewhat larger than those recommended for low-speed environments.

Exhibit 6-14 provides recommended ranges of inscribed circle diameters for various site locations.

Exhibit 6-14
Recommended Inscribed Circle Diameter Ranges

Site Category	Typical Design Vehicle	Inscribed Circle Diameter Range*
Mini-Roundabout	Single-Unit Truck	50 – 90 ft (15 – 27 m)
Urban Compact	Single-Unit Truck/Bus	90 – 120 ft (27 – 37 m)
Urban Single Lane	WB-50 (WB-15m)	120 – 150 ft (37 – 46 m)
Urban Double Lane	WB-50 (WB-15m)	150 – 220 ft (46 – 67 m)
Rural Single Lane	WB-67 (WB-20m)	130 – 200 ft (40 – 61 m)
Rural Double Lane	WB-67 (WB-20m)	175 – 250 ft (53 – 76 m)

* Assumes approximately 90-degree angles between entries and no more than four legs.

Entry Design

One of the primary ingredients in the safety performance of a roundabout is the low operating speed associated with roundabout operation. Low operating speeds provide drivers the opportunity to react to conflicts and reduce the likelihood of loss of control crashes associated with navigating the geometric elements of the intersection. The entry design is a critical element of the overall design, as the geometric elements of the entry are most often the controlling factor to govern vehicle speeds. However, vehicular speeds are not the only consideration at the entry. At multilane roundabouts, the design must also provide appropriate alignment of vehicles at the entrance line to prevent sideswipe and angle collisions associated with overlapping natural vehicle paths. Other design considerations at the entry include accommodating the design vehicle (typically WB-50 [WB-15m] or WB-67 [WB-20m] trucks) and providing a safe environment for pedestrians.

To maximize the roundabout's safety, entry widths should be kept to a minimum. The capacity requirements and performance objectives will determine the number of entry lanes for each approach. In addition, the turning requirements of the design vehicle may require that the entry be wider still. However, larger entry and circulatory widths increase crash frequency. Therefore, determining the entry width and circulatory roadway width involves balancing between capacity and safety considerations. The design should provide the minimum width necessary for capacity and accommodation of the design vehicle in order to maintain the highest level of safety. Typical entry widths for single-lane entrances range from 14 to 18 ft (4.2 to 5.5 m); however, values slightly higher or lower than this range may be required for site-specific design vehicles and speed requirements for critical vehicle paths.

Entry radii at urban single-lane roundabouts typically range from 35 to 100 ft (10 to 30 m). Larger radii may be used, but it is important that the radii not be so large as to result in excessive entry speeds. At local street roundabouts and traffic circles (typically mini-roundabouts, and urban compact roundabouts), entry radii may be below 35 ft (10 m) if the design vehicle is small.

At multilane roundabouts, the design of entry curves is more complicated due to considerations for side-by-side traffic streams entering the roundabout. Detailed guidelines for multilane entries are provided later in this chapter.

Ideally, the design should accommodate each of these considerations. However, in some circumstances, right-of-way or other constraints may limit the size, shape, or alignment of the roundabout and its approaches. These geometric limitations may make it difficult to provide both ideal speed control and ideal natural vehicle paths. Therefore, the designer may need to try several different alignments to find the one that best balances these design considerations.

Circulatory Roadway

The required width of the circulatory roadway is determined from the width of the entries and the turning requirements of the design vehicle. In general, it should always be at least as wide as the maximum entry width and should remain constant throughout the roundabout.

Single-lane roundabouts

At single-lane roundabouts, the circulatory roadway should just accommodate the design vehicle, exclusive of the trailer for large trucks. Appropriate vehicle-turning templates or a CAD-based computer program should be used to determine the swept path of the design vehicle through each of the turning movements. Usually, the left-turn movement is the critical path for determining circulatory roadway width. A minimum clearance of 2 ft (600 mm) should be provided between the outside edge of the vehicle's tire track and the curb line.

In some cases (particularly where the inscribed diameter is small or the design vehicle is large) the turning requirements of the design vehicle may dictate that the circulatory roadway be so wide that the amount of deflection necessary to slow passenger vehicles is compromised. In such cases, the circulatory roadway width can be reduced and a truck apron, placed behind a mountable curb on the central island, can be used to accommodate larger vehicles. Truck aprons should be used only when there is no other means of providing adequate deflection while accommodating the design vehicle. The width of the truck apron should be determined based upon vehicle-turning templates or a CAD based computer program to accommodate the swept path of the design vehicle for each of the various movements. There is no standard width for a truck apron. However, the designer should re-evaluate the design to ensure that the proper size and geometric features are being provided if an apron is less than 2 ft (600 mm) or greater than 14 ft (4.2 m) in width. In some situations, a very small or very large truck apron may be an indicator that other geometric features are being compromised in the design.

Multilane roundabouts

At multilane roundabouts, the circulatory roadway width is usually not governed by the design vehicle. The width required for two or three vehicles, depending on the number of lanes at the widest entry, to travel simultaneously through the roundabout should be used to establish the circulatory roadway width. The combination of vehicle types to be accommodated side-by-side is dependent upon the specific traffic conditions at each site. In many urban locations, it may be a bus or single-unit truck in combination with a passenger vehicle. If large semi-trailers are relatively infrequent, it is often appropriate to design the circulatory roadway such that these large trucks sweep across both lanes within the circulatory roadway. However, if large trucks are relatively frequent, it may be necessary to accommodate a semi-trailer in combination with a passenger vehicle. The appropriate staff from KDOT and/or other governing agencies should be consulted early in the design process to determine the choice of vehicle types to be accommodated side-by-side.

Exhibit 6-15 displays an example of the swept paths of two vehicles circulating side-by-side through a roundabout geometry. In this case, the roundabout was located on a predominantly recreational route and was designed to accommodate two motor home vehicles with boat trailers circulating side-by-side.

Exhibit 6-15
Example Design: Circulatory Roadway Accommodates Side-by-Side Motorhomes with Boat Trailers.

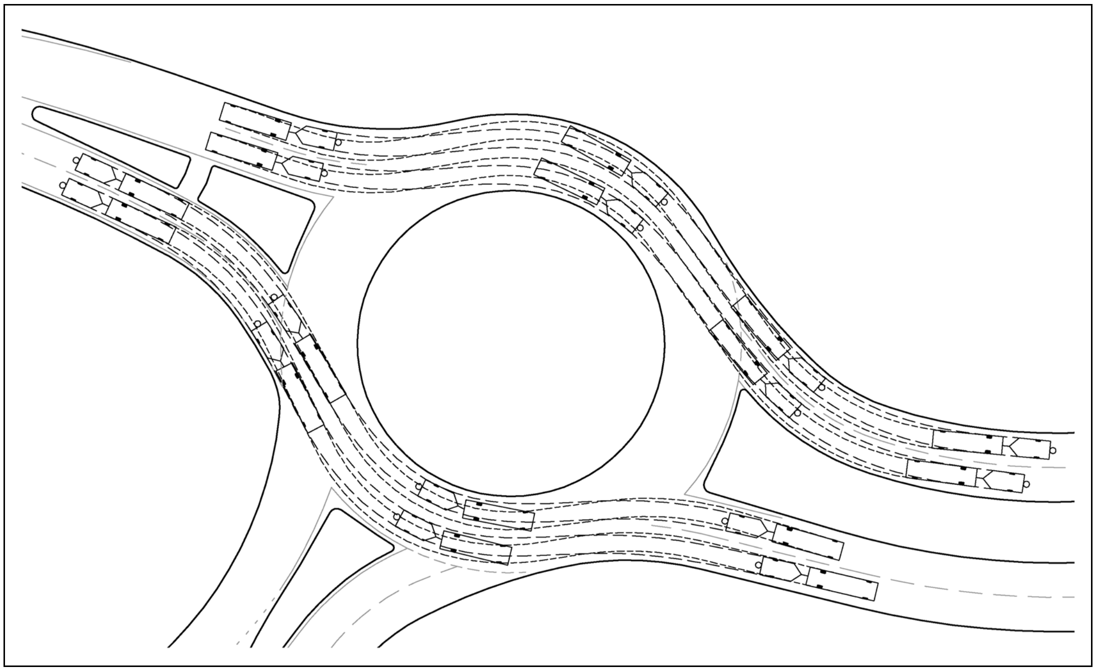


Exhibit 6-16 provides minimum recommended circulatory roadway widths for two-lane roundabouts where semi-trailer traffic is relatively infrequent.

Exhibit 6-16
Minimum Circulatory Lane Widths for Two-Lane Roundabouts.

Inscribed Circle Diameter	Minimum Circulatory Lane Width*	Central Island Diameter
150 ft (45 m)	32 ft (9.8 m)	86 ft (25.4 m)
165 ft (50 m)	31 ft (9.3 m)	103 ft (31.4 m)
180 ft (55 m)	30 ft (9.1 m)	120 ft (36.8 m)
200 ft (60 m)	30 ft (9.1 m)	140 ft (41.8 m)
215 ft (65 m)	29 ft (8.7 m)	157 ft (47.6 m)
230 ft (70 m)	29 ft (8.7 m)	172 ft (52.6 m)

* Based on 2001 AASHTO Exhibit 3-55, Case III(A). Assumes infrequent semi-trailer use.

Exits

Exit curves usually have larger radii than entry curves to minimize the likelihood of congestion at the exits. This, however, is balanced by the need to maintain low speeds at the pedestrian crossing on exit. The exit curve should produce an exit *path* radius (R_3 in Figure 6-1) no smaller than the circulating path radius (R_2). If the exit path radius is smaller than the circulating path radius, vehicles will be traveling too fast to negotiate the exit geometry and may crash into the splitter island or into oncoming traffic in the adjacent approach lane. Likewise, the exit path radius should not be significantly greater than the circulating path radius to ensure low speeds are maintained at the pedestrian crossing.

Right-Turn Bypass Lanes

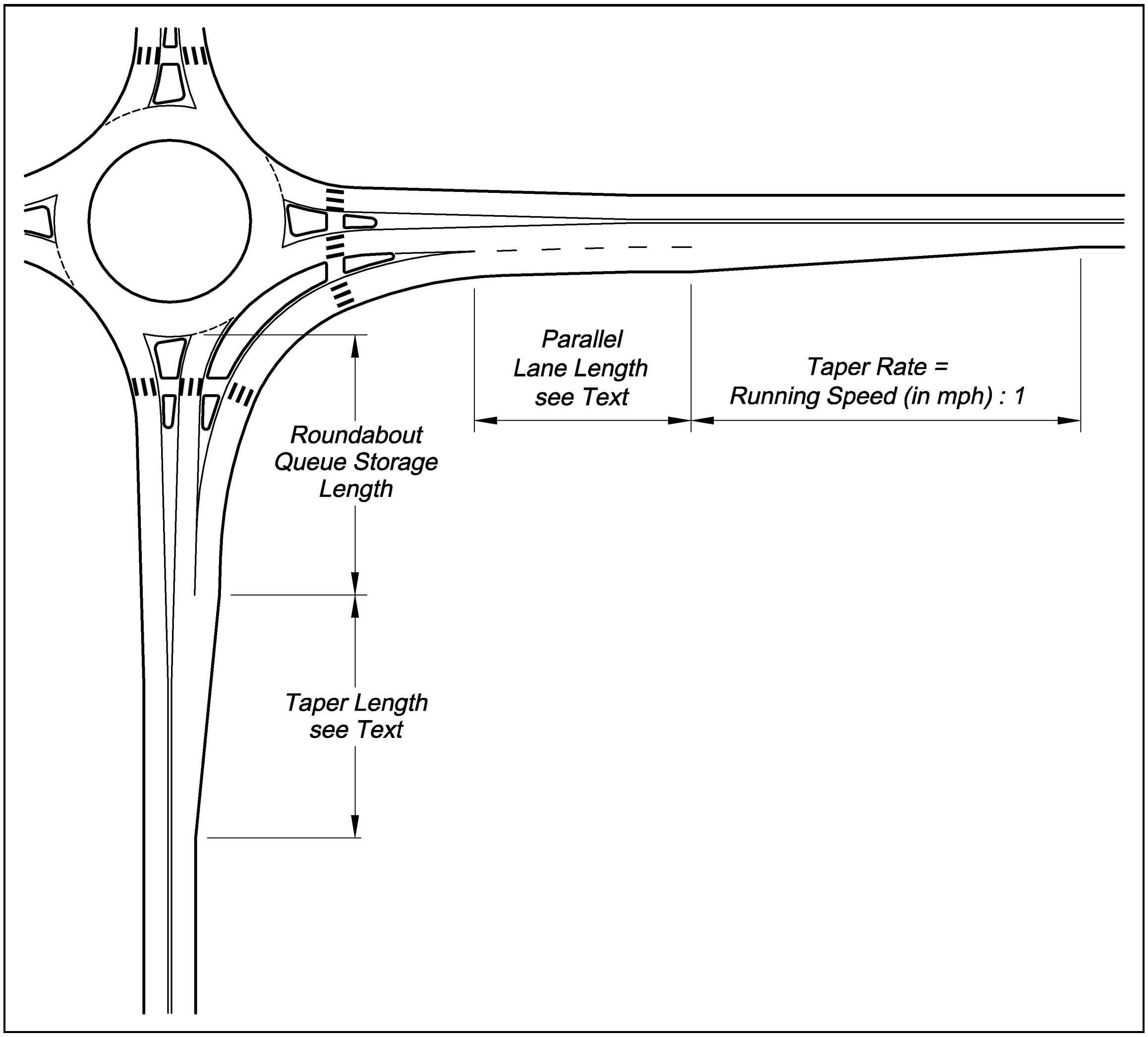
Right-turn bypass lanes (or *right-turn slip lanes*) are useful in providing additional capacity on approaches with high right-turn vehicular volumes. These lanes can effectively remove right turning vehicles from entering the roundabout, thus increasing the capacity of the intersection as a whole. However, right-turn bypass lanes should be used with caution and implemented only where applicable due to capacity or operational considerations. Bypass lanes introduce additional vehicular conflicts on the exits from the roundabout due to the required merge. They also further complicate the task of navigating the roundabout for visually impaired pedestrians due to the additional vehicle conflicts and increased exposure due to the longer crossing distance.

In general, right-turn bypass lanes should be carefully evaluated in urban areas with bicycle and pedestrian activity. The entries and exits of bypass lanes can increase conflicts with bicyclists. The generally higher speeds of bypass lanes and the lower expectation of drivers to stop also increase the risk of collisions with pedestrians. However, in some situations, providing a right-turn bypass lane may prevent the need for a multilane roundabout. Thus, the potential adverse safety effects created by the free-flow bypass lane may be offset by the safety benefits of maintaining single-lane entries within the roundabout.

The design speed of the right-turn bypass lanes should be consistent with the design speed of the roundabout. In other words, the speed of vehicles within the right-turn bypass lane should be comparable to the speed of vehicles entering, circulating, and exiting the roundabout. Thus, the fundamental roundabout design speeds shown in Exhibit 6-6 should also govern the design of the right-turn bypass lane.

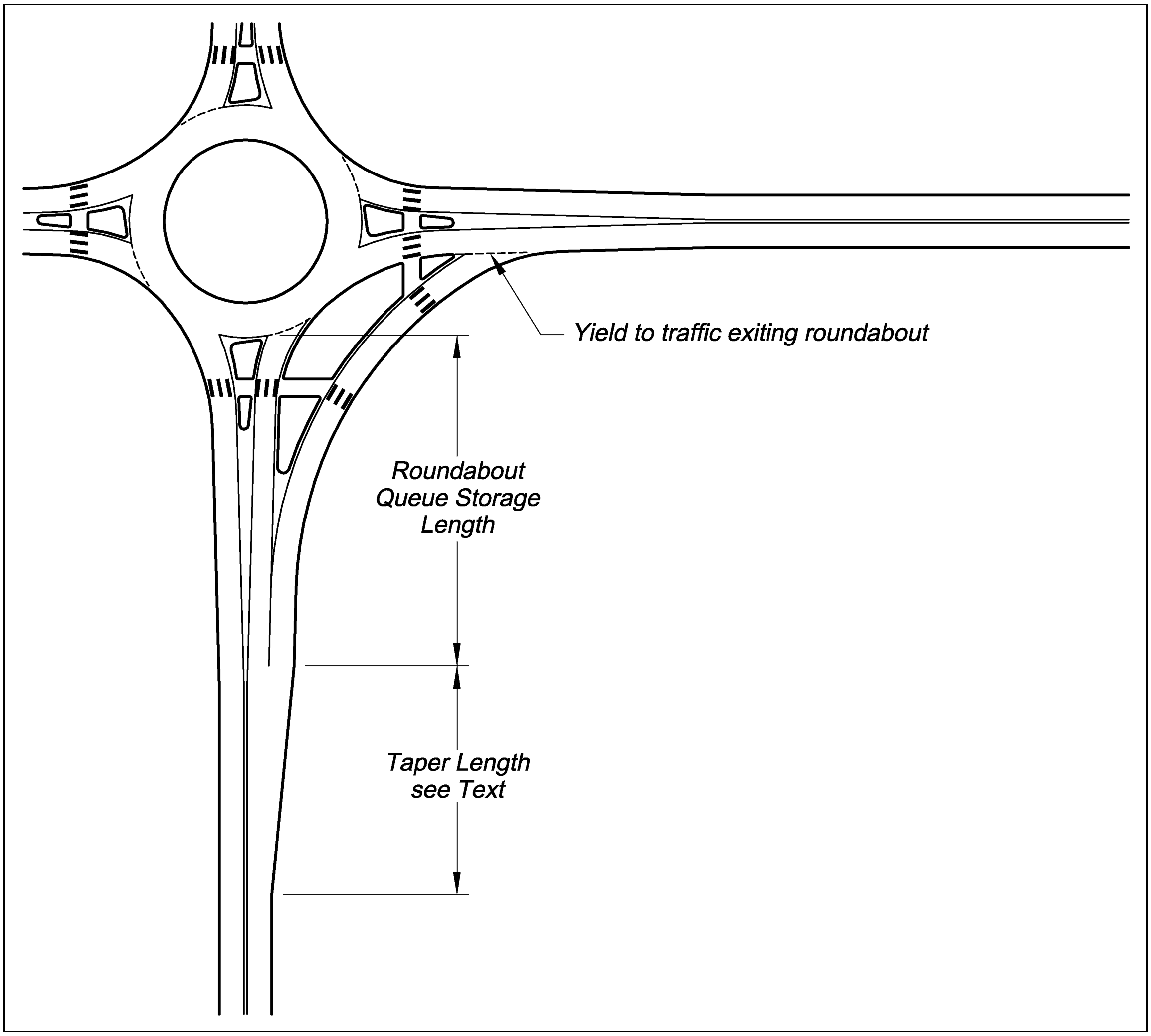
There are two design options for right-turn bypass lanes. The first option, shown in Exhibit 6-17, is to carry the bypass lane parallel to the adjacent exit roadway, and then merge it into the main exit lane from the roundabout. Under this option, the bypass lane should be carried alongside the main roadway for a sufficient distance to allow vehicles in the bypass lane and vehicles exiting the roundabout to achieve similar speeds and safely merge. This distance should be at least long enough to allow proper advance placement of warning signs for a typical lane reduction, based on MUTCD guidelines. The bypass lane is then merged at a taper rate of the design speed (in mph) to one.

Exhibit 6-17
Right-Turn Bypass Configuration



The second design option for a right-turn bypass lane, shown in Exhibit 6-18, is to provide a yield-controlled entrance onto the adjacent exit roadway. This option generally requires less widening and right-of-way downstream of the roundabout than the first. It is also generally more amenable to bicyclists, as they do not have to cross free-flowing traffic from the bypass lane. However, it often requires more right-of-way at the corner with this design option to achieve adequate speed reduction for the right-turn movement while providing pedestrian refuge areas. Consideration should also be given for the intersection angle at the yield point between the bypass traffic stream and traffic stream exiting the roundabout. If the intersection angle at the yield point is too small, it may be difficult for drivers (particularly older drivers) to perceive and react to conflicting vehicles from the roundabout.

Exhibit 6-18
Right-Turn Bypass Configuration



The design of the approach taper for the right-turn bypass lane is developed in a manner similar to right-turn lanes at signalized and stop-controlled intersections. The bay taper, which guides motorists into the right-turn lane, should be developed along the right edge of traveled way. The appropriate length of the taper is per AASHTO, based on KDOT design guidelines for right-turn deceleration lanes at typical intersections (see KDOT Standard Drawings). Shorter taper distances may be acceptable in urban environments or locations with topographic or right-of-way constraints.

The length of the right-turn bypass lane should be designed, at a minimum, to accommodate the 95th-percentile queue at the roundabout entrance without blocking the entrance to the right-turn bypass lane.

6.2 Guidance for Multilane Roundabouts

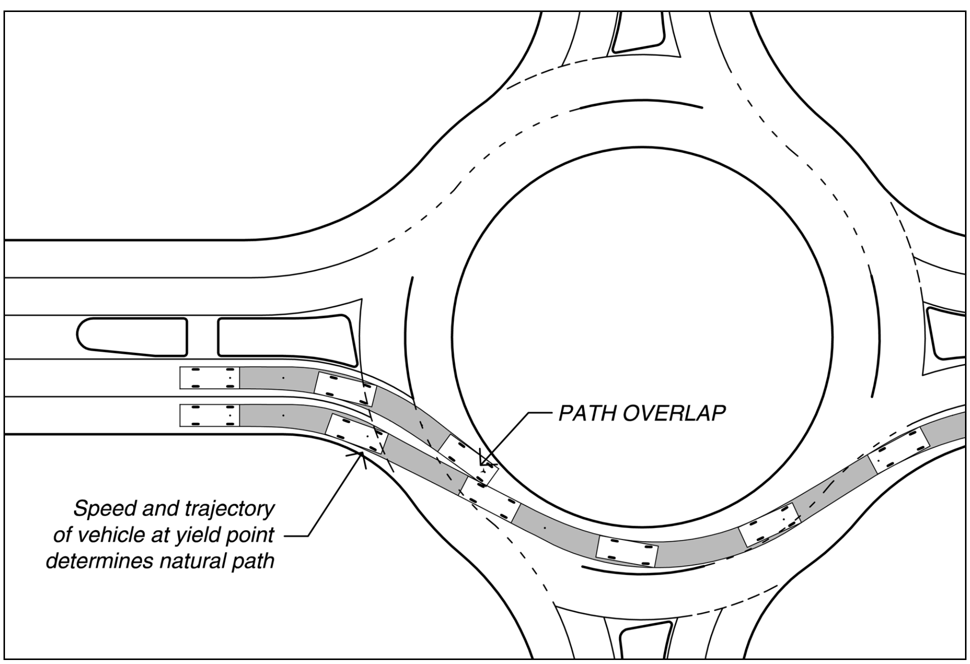
Designing multilane roundabouts is much more complex than single-lane roundabouts due to the additional conflicts present with multiple traffic streams entering, circulating, and exiting the roundabout in adjacent lanes. With single-lane roundabouts, the primary design objective is to ensure the fastest vehicular paths are sufficiently slow and relatively consistent. With multilane roundabouts, the designer must also consider the *natural paths* of vehicles. The natural path is the path a vehicle will naturally follow based on the speed and orientation imposed by the geometry. While the fastest path assumes a vehicle will intentionally cut across the lane markings to maximize speed, the natural path assumes there are other vehicles present and all vehicles will attempt to stay within the proper lane.

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

Path overlap

Path overlap occurs when the natural paths of vehicles in adjacent lanes overlap or cross one another. It occurs most commonly at entries, where the geometry of the right-hand lane tends to lead vehicles into the left-hand circulatory lane. Exhibit 6-19 illustrates an example of path overlap at a multilane roundabout entry.

Exhibit 6-19
Path Overlap

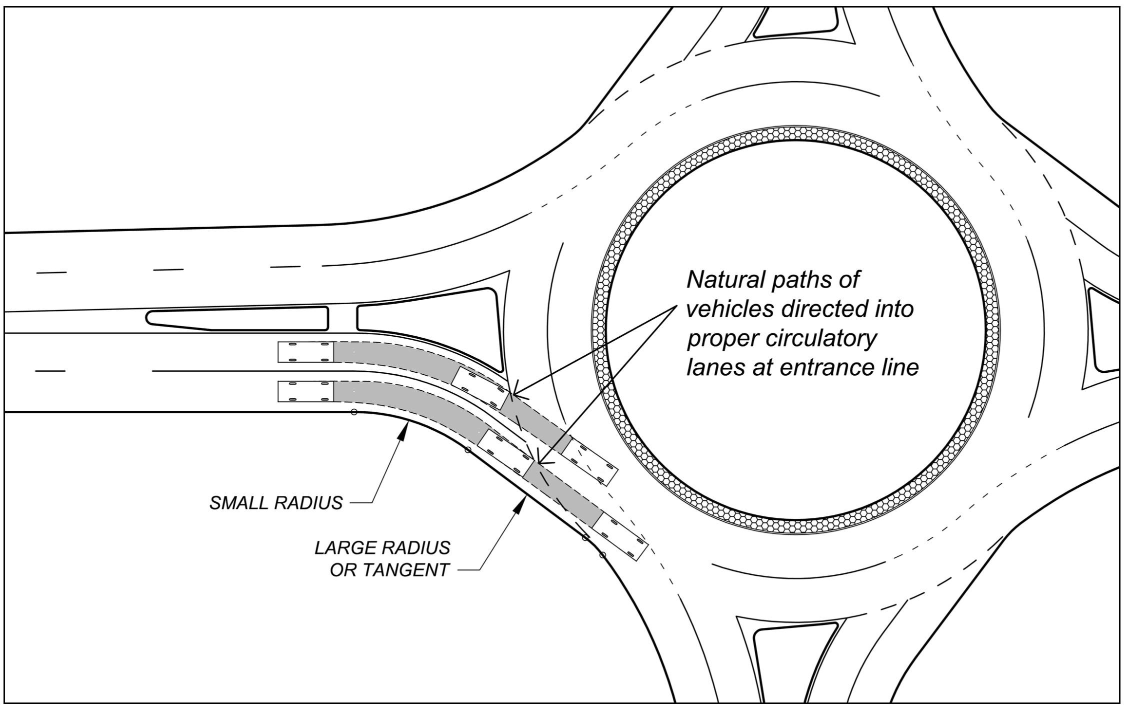


In the design shown in Exhibit 6-19, the geometry consists of a tight-radius entry curve located tangential to the outside edge of the circulatory roadway. At the entrance line, vehicles in the right-hand lane are oriented toward the inside lane of the circulatory roadway. If vehicles follow this natural path, they will cut off vehicles in the left lane, which must make a sharp turn within the circulatory roadway to avoid the central island.

Multilane Entry Design Technique

The preferred design technique for multilane entries is illustrated in Exhibit 6-20.

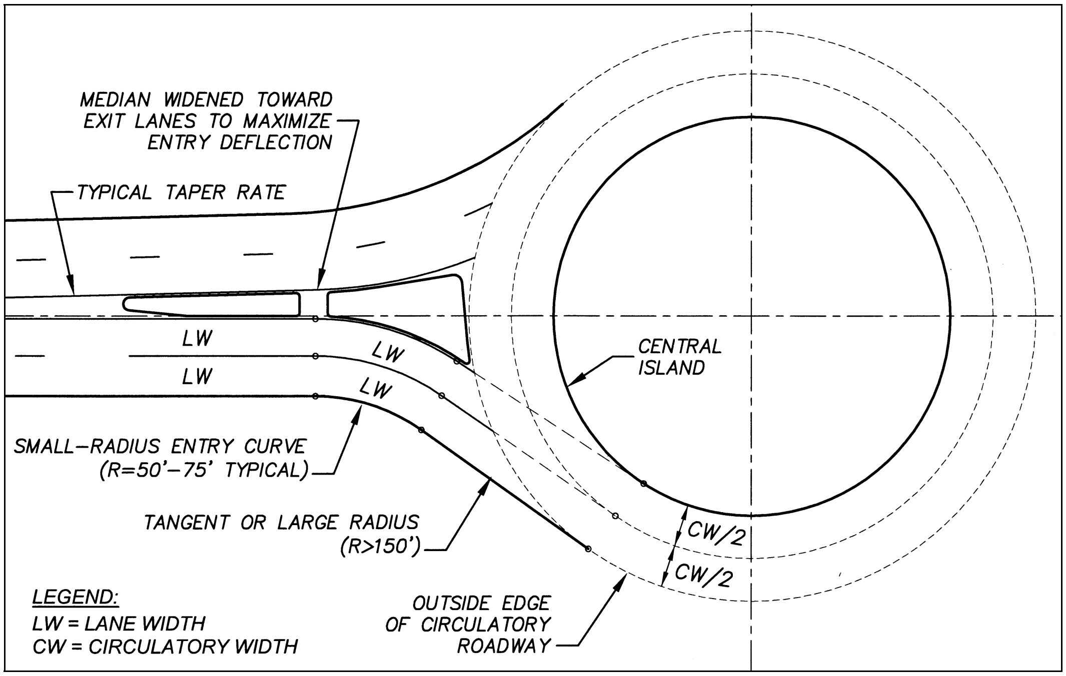
Exhibit 6-20
Design Technique to Avoid Path Overlap at Entry



As shown in Exhibit 6-20, the design consists of small-radius entry curve set back from the edge of the circulatory roadway. A short section of tangent is provided between the entry curve and the circulatory roadway to ensure vehicles are directed into the proper circulatory lane at the entrance line.

Typically, the entry curve radius is approximately 50 to 100 ft (15 to 30 m) and set back approximately 10 to 20 ft (3 to 6 m) from the edge of the circulatory roadway. A tangent or large-radius (greater than 150 ft [45 m]) curve is then fitted between the entry curve and the outside edge of the circulatory roadway. Exhibit 6-21 illustrates the entry design technique in greater detail.

Exhibit 6-21
Multilane Entry Design Details



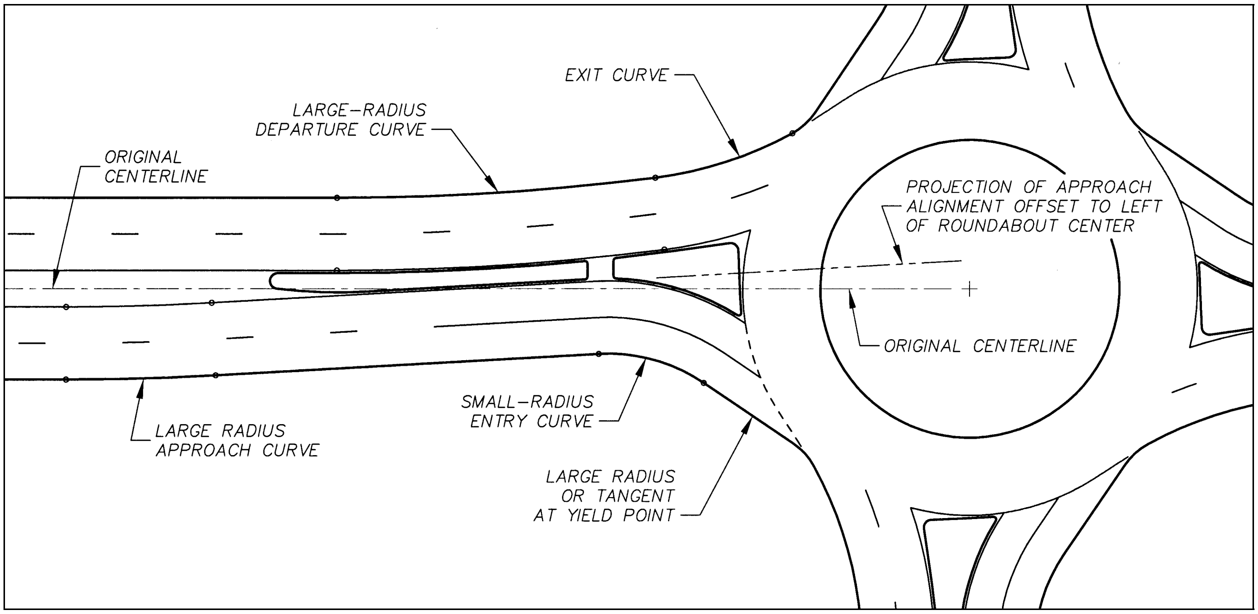
The primary objective of this design technique is to locate the entry curve at the optimal placement so that the projection of the inside entry lane at the entrance line forms a line tangential to the central island, as shown in Exhibit 6-21. Care should be taken in determining the optimal location of the entry curve. If it is located too close to the circulatory roadway, it can result in path overlap issues. However, if it is located too far away from the circulatory roadway, it can result in inadequate deflection (i.e. entry speeds too fast).

Design Techniques to Increase Entry Deflection

Designing multilane roundabouts without path overlap issues while achieving adequate deflection to control entry speeds can be difficult. The same measures that improve path overlap issues generally result in increased fastest path speeds. When the entry speed of a multilane roundabout is too fast, one technique for reducing the entry speed without creating path overlap is to increase the inscribed circle diameter of the roundabout. Often the inscribed circle of a double-lane roundabout must be 175 to 200 ft (53 to 60 m) in diameter, or more, to achieve a satisfactory entry design. However, increasing the diameter will result in slightly faster circulatory speeds. Therefore, care should be exercised to balance the entry speeds and circulatory speeds.

In cases where right-of-way or other physical constraints restrict the size of a multilane roundabout, the technique shown in Exhibit 6-22 may be used.

Exhibit 6-22
Approach Offset to Increase Entry Deflection



In the design shown in Exhibit 6-22, the entry deflection is enhanced by shifting the approach alignment slightly towards the left of the roundabout center. This technique of offsetting the approach alignment left of the roundabout center is effective at increasing entry deflection. However, it also reduces the deflection of the exit on the same leg. In general, it is important to maintain a level of deflection at exits to keep speeds relatively low within the pedestrian crosswalk location. Therefore, the distance of the approach offset from the roundabout center should generally be kept to a minimum to maximize safety for pedestrians.

6.3 Grading and Drainage Considerations

Chapter 6.3.11 of the FHWA publication, *Roundabouts: An Informational Guide*, provides guidance on the development of the vertical profile and location of drainage structures. Roundabouts should be generally designed to slope away from the central island with drainage inlets located on the outer curb line. This will help to raise the elevation of the central island and increase its conspicuity and visibility.

The slope of the circulatory roadway should prevent water from collecting or pooling around the central island. This will help to minimize icing on the circulatory roadway or on the approaches to the roundabout. For large roundabouts, additional drainage inlets may be required within the central island to help minimize the amount of runoff from the central island on to the circulatory roadway. As with any intersection, reasonable care should be taken to avoid low points and inlets placed in the crosswalks.

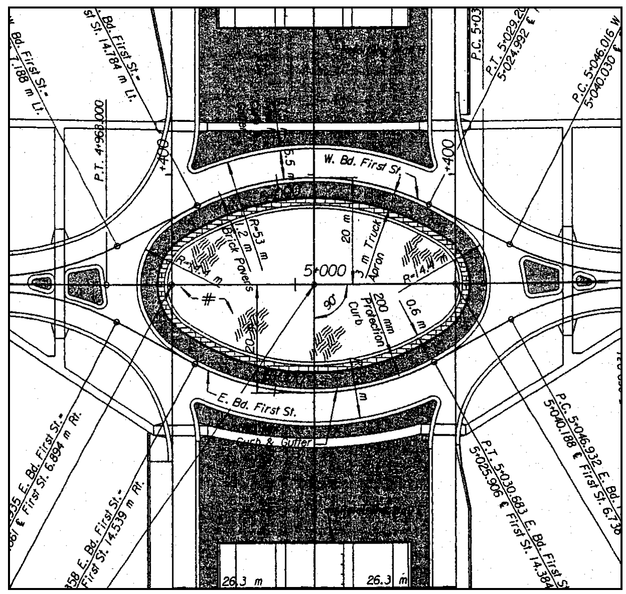
6.4 Curb and Pavement Design

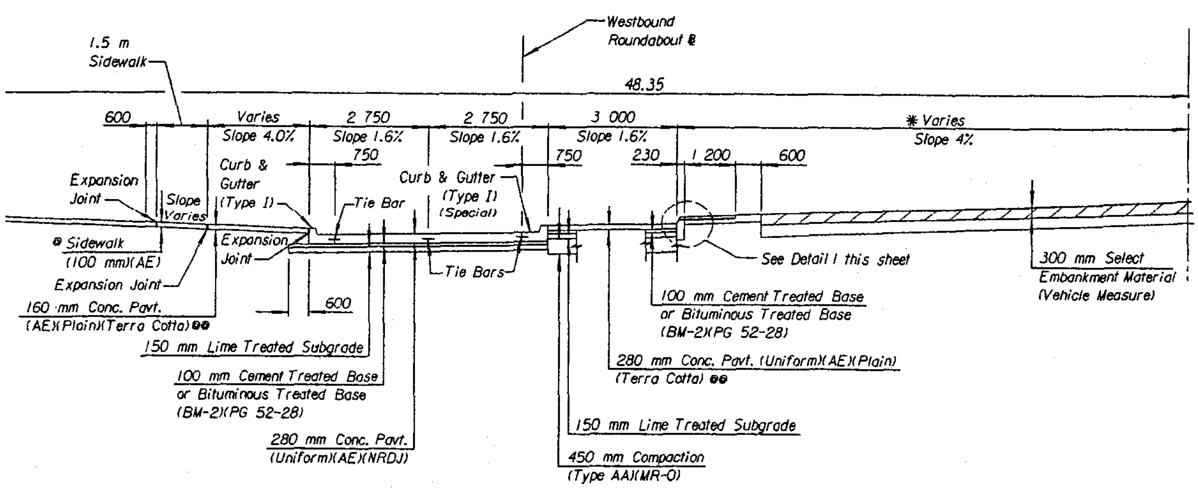
Summary of Current Practices

In order to review current design practices related to curb and pavement design on roundabout projects in Kansas, five projects were reviewed based on plans provided by KDOT and the City of Overland Park. These projects are as follows:

I-135 at Broadway and Main Streets, Newton

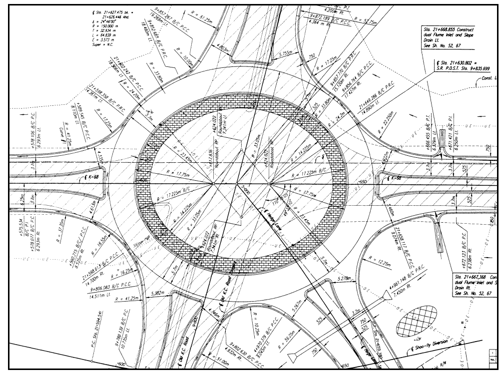
The two roundabouts in Newton are located at adjacent interchanges on I-135. One-way ramps on each side of the highway form four legs of the roundabouts with the cross street forming the other two. Both roundabouts experience significant truck traffic. The elliptical roundabouts are approximately 230 ft (70 m) east/west and 164 ft (50 m) north/south in diameter. All approach lanes and the circulatory roadway are single lane. The circulatory roadway is 16.4 ft (5.0 m) wide plus a 10 ft (3.0 m) truck apron. Pavement is concrete, with KDOT Type I curbs on the outside and inside edges of the circulatory roadway. An additional curb is provided inside the truck apron. Type I curbs are also used around the splitter islands.



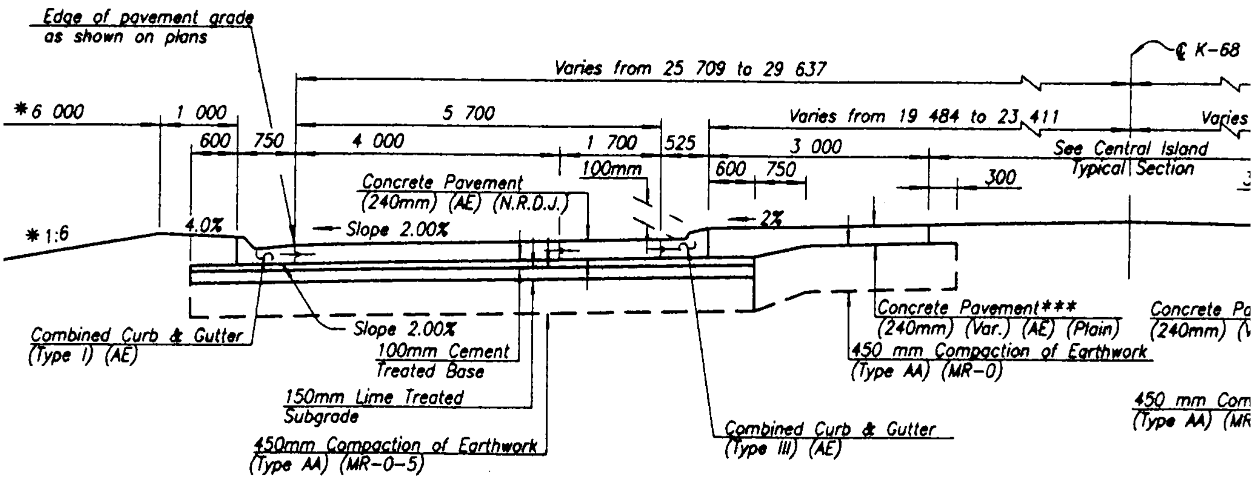


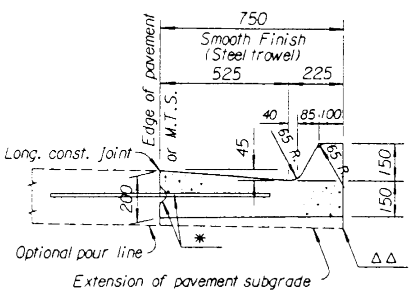
Design by: Burns and McDonnell, 2000.

K-68 & Old Kansas City Road, Miami County



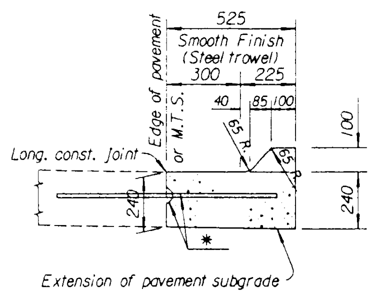
This roundabout is elliptical with five legs and is located in a primarily rural area. The diameter of the roundabout is between 151 ft (46 m) and 190 ft (58 m). All approach lanes are single lane, as is the circulatory roadway. The circulatory roadway is 18.7 ft (5.7 m) wide with a 10 ft (3.0-m) truck apron. Pavement is 9.5 in (240 mm) concrete, with a KDOT Type I curb on the outside edge and a Type III curb around the inner circle and the splitter islands.





TYPICAL SECTION

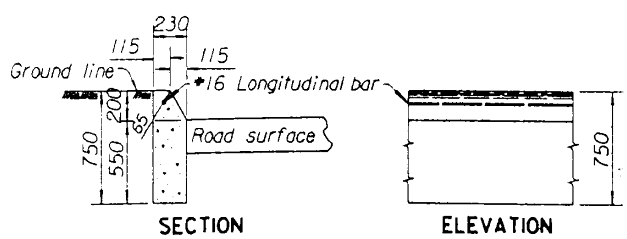
COMBINED CURB & GUTTER - TYPE I (750 mm WIDTH)



TYPICAL SECTION

COMBINED CURB & GUTTER - TYPE III (525 mm WIDTH)

Note: Use Class "A" Concrete (AE) throughout.
All exposed edges shall be finished with an edging tool.
Place a 25 mm premoulded Expansion Joint Filler (nonextruding, Type B) at a spacing not to exceed 75 m.

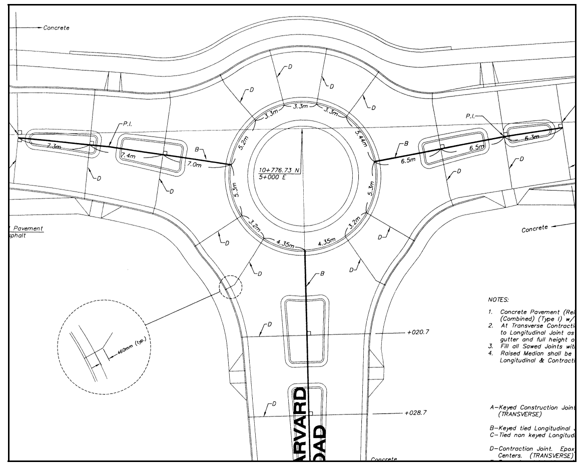


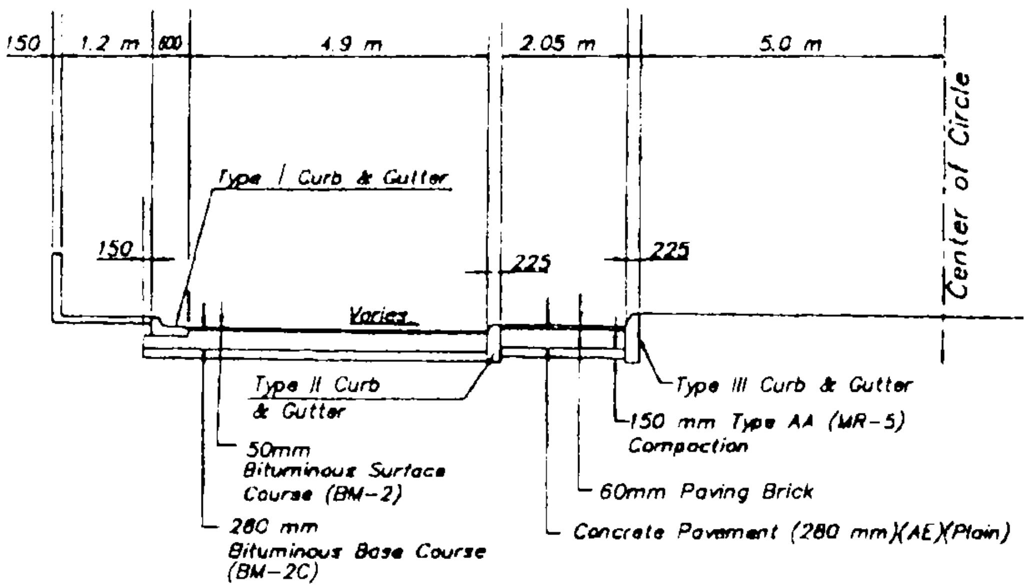
PROTECTION CURB 200 mm

Design by: Professional Engineering Consultants, P.A., 2001.

Harvard Road and Monterey Way, Lawrence

Harvard Road and Monterey Way form a "tee" intersection of two local collector streets in a residential area. The diameter of the roundabout is 85.3 ft (26 m). All approach lanes are single lane, as is the circulatory roadway. The circulatory roadway is 16 ft (4.9 m) wide with an 8.2 ft (2.5 m) truck apron. Contradictory information is provided in the plans about the type of curb and gutter utilized. The pavement in the roundabout is asphalt, with an 11 in (280 mm) base and 2-in (50 mm) surface course.

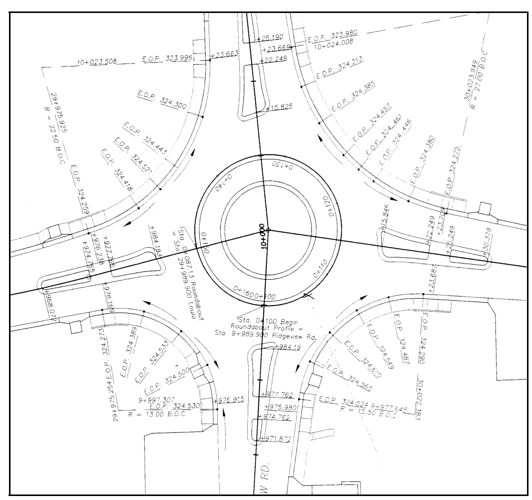


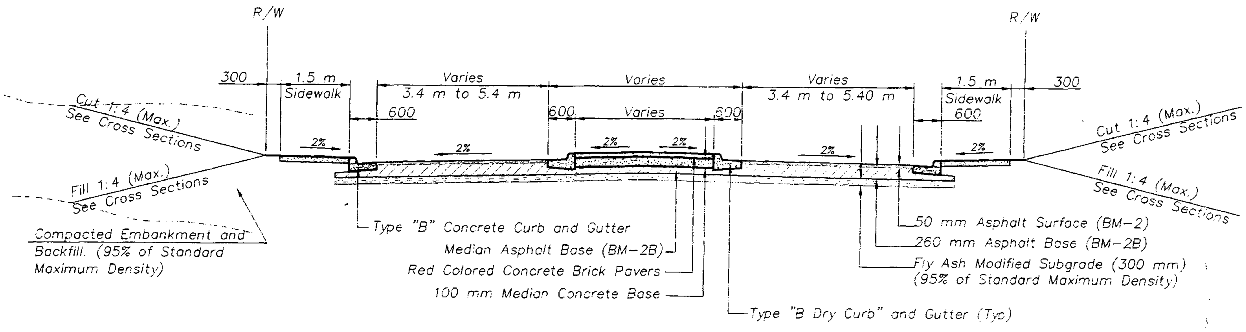


Design by: E.B.H. & Associates, 1998.

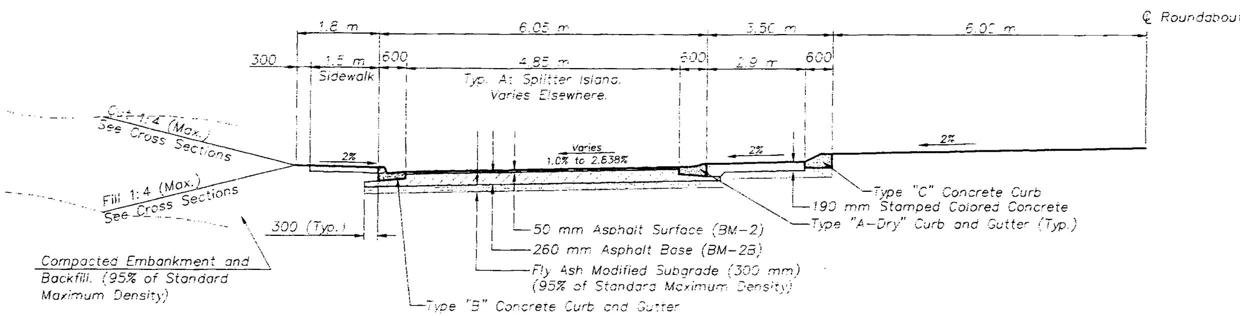
Ridgeview Road and Loula Street, Olathe

The Ridgeview Road and Loula Street roundabout has a circular shape with a 100 ft (30 m) inscribed circle diameter. All approach lanes are single lane, as is the circulatory roadway. The circulatory roadway is 16 ft (4.85 m) wide with a 9.5 ft (2.9 m) truck apron. The design utilizes Type "B" concrete curb and gutter along the outside edge of the approaches and along the outside of the circulatory roadway. Type "B Dry Curb" and gutter are used along edge of the splitter islands, with Type "A-Dry" curb and gutter along the inside edge of the circulatory roadway. The pavement for this roundabout is a 2 in (50 mm) asphalt surface with a 10.25 in (260 mm) asphalt base.





TYPICAL SECTION AT SPLITTER ISLAND
(Not to Scale)



LOULA AND RIDGEVIEW SECTION – ROUNDABOUT
(Not to Scale)

Design by: Olsson Associates, 2002

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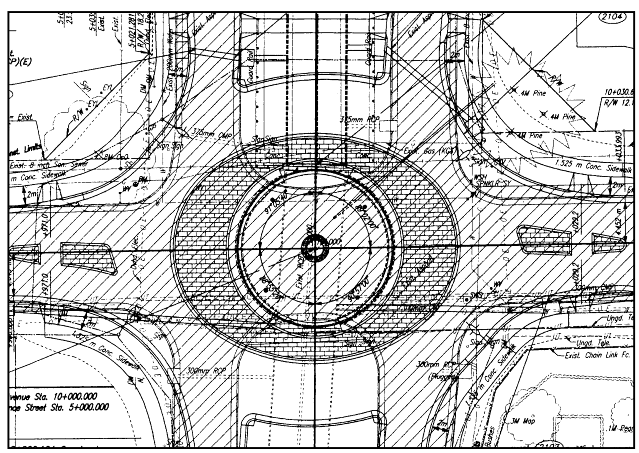
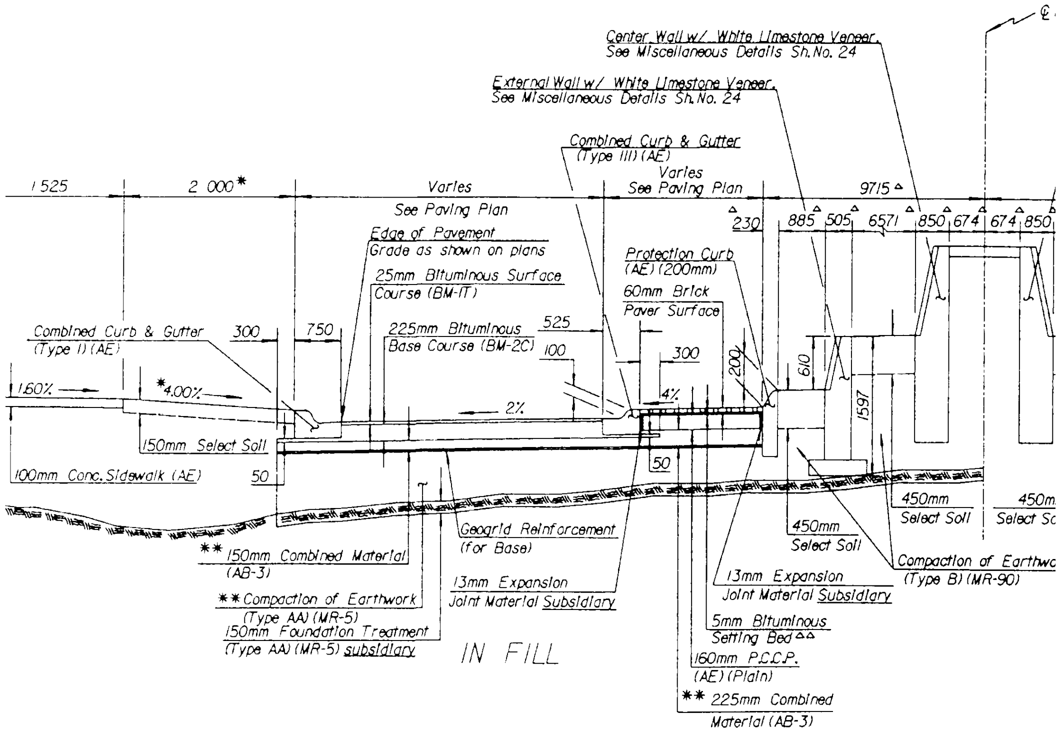
23rd Street and Severance Street, Hutchinson



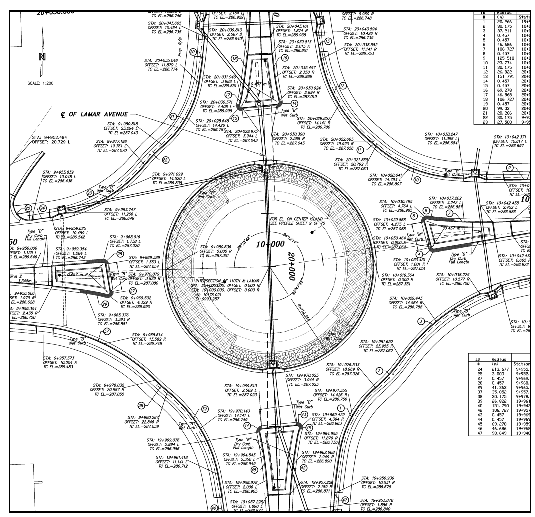
Twenty Third Street and Severance Street are both minor arterial streets. Severance Street has a large drainage channel that runs between the north and southbound lanes, resulting in a median that is approximately 55.8 ft (17 m) wide. The roundabout is elliptical, with a diameter of approximately 145 ft (44 m) east-west and 125 ft (38 m) north-south. All approaches are single lane, as is the circulatory roadway. The circulatory roadway is approximately 23 ft (7 m) in width. A truck apron is provided, varying in width from about 6.5 ft (2 m) to about 16.4 ft (5 m). The outside curb around the roundabout is a KDOT Type I; the inside curb is a KDOT Type III. The curb around the splitter island is a 9-in (230-mm) wide KDOT protection curb, modified to 6 in (150 mm) in height. The pavement in the roundabout is asphalt, with a 9-in (225-mm) base and 1-in (25-mm) surface course.

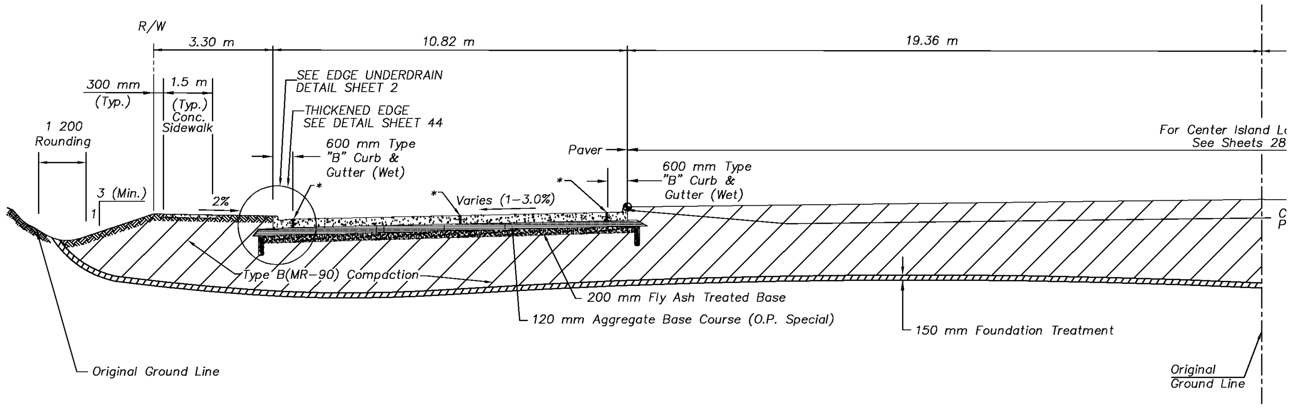


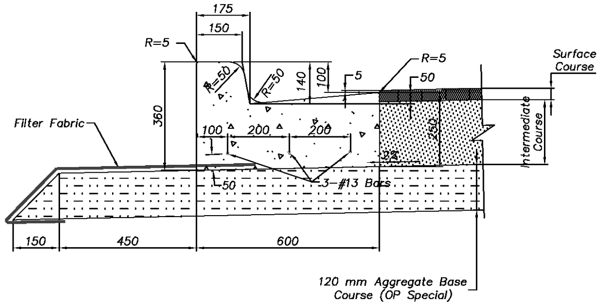
Design by: Professional Engineering Consultants, P.A., 2000.

110th Street and Lamar Avenue, Overland Park

Lamar Avenue is a collector street, while 110th Street serves an adjacent business park and the Overland Park convention center. All approaches are two lanes, with a two lane circulatory roadway. The roundabout is 197 ft (60 m) in diameter with a 36-ft (11-m) circulating roadway. The roundabout was designed to be constructed as either 9.5-in (240-mm) concrete pavement or asphalt with an 8-in (205-mm) base course and a 2-in (50-mm) surface course. Ultimately the roundabout was constructed as concrete. The inner and outer curbs around the roundabout as well as around the splitter islands are Overland Park Type B curbs. The Type B curb has a curb height of 5.5 in (140 mm).

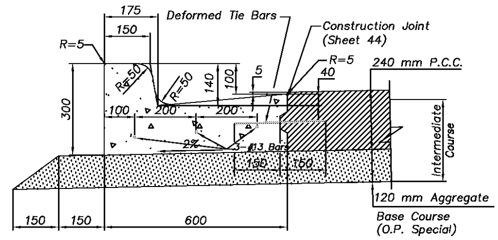




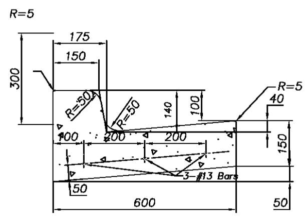


Type "B" Curb with O.P. Special Base Course

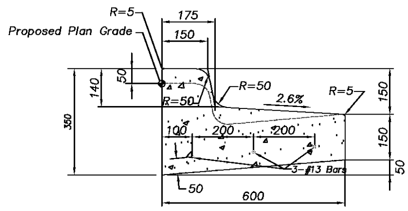
See Sheet 3 for Edge Drain Details



Type "B" Modified Curb with Concrete Pavement O.P. Special Base Course

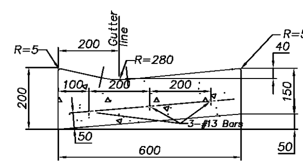


Standard Type "B" Curb



Type "B – Dry" Curb

NOTE: In transitions, water shall flow from the gutter of Type "B" curb to the lip of Type "B–Dry" curb at 0.5% min. slope.



Standard Type "C" Curb*

Design by: Olsson Associates, 2001.

Discussion

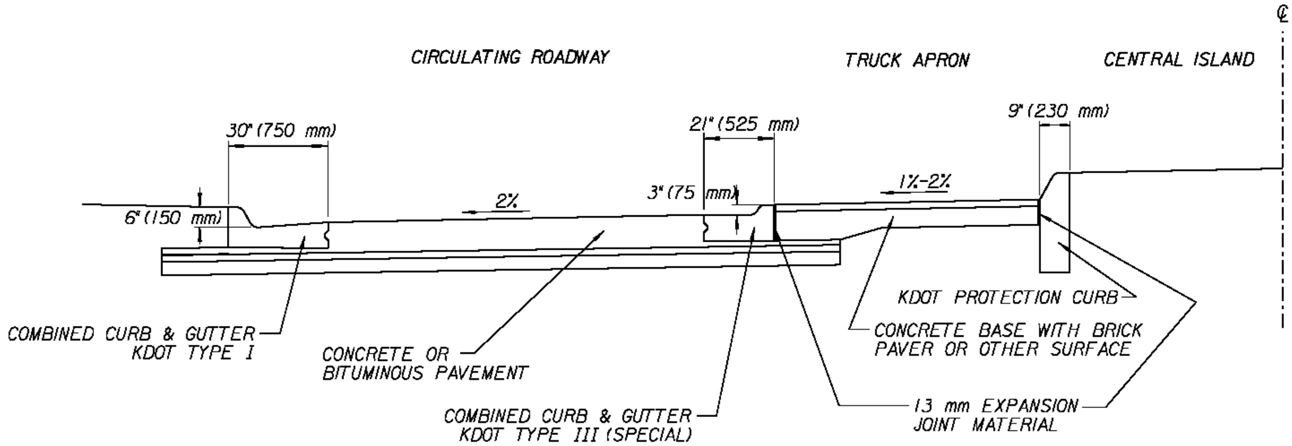
Curb Types

Generally, the curb and gutter type around the outside edges of all of the roundabouts are a KDOT Type I or similar. This type has a curb height of 6 in (150 mm). Around the central island the majority of the designs either used the Type I or Type III curb and gutter. The Type III is similar to Type I, but is 1.75 ft (525 mm) wide, as opposed to 2.5 ft (750 mm). Generally, this was a "dry" type curb, with the exception of the Overland Park roundabout, where a "wet" type curb was used to capture runoff from the central island. Heights of these curbs varied from 4 to 6 in (100 to 150 mm). Around the splitter islands, the KDOT Type III or Protection curb were utilized which generally have a curb height of 6 to 8 in (150 to 200 mm). In those cases where a curb was provided on the inside of the truck apron, generally an 8-in (200-mm) protection curb was utilized.

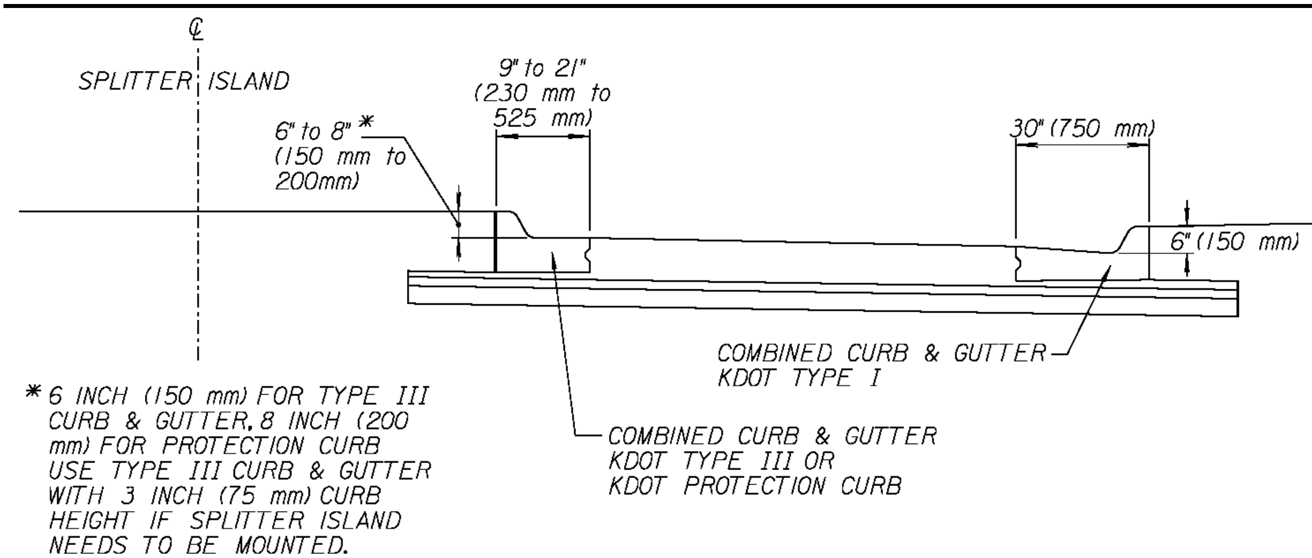
It is generally recommended that a 6-in (150-mm) high curb be used around the outside of the roundabout, the central island and the splitter islands, as one of the important elements of these features is to force deflection in vehicles traveling through the roundabout. If the curb is considered to be mountable by drivers, this effect is lessened. The barrier curb on the approach and in the splitter island also provides better protection for the pedestrian. However, most roundabouts must also be designed to accommodate large trucks. In this case, it is recommended that a 3-in (75-mm) curb height be used, as necessary, on the splitter islands, truck apron, or central islands. On occasion, trucks may also need to mount the outside curb; curb height will also need to be a consideration in these cases. Cross slopes on the circulating roadway are recommended to be 2 percent. On the truck apron, it is recommended that the cross slope be 1 to 2 percent to help prevent load shifting in trucks.

Exhibit 6-23 illustrates the recommended typical sections through the roundabout and the approach lanes.

Exhibit 6-23
Circulatory Roadway and Approach Typical Sections



TYPICAL SECTION - ROUNDABOUT CIRCULATING ROADWAY



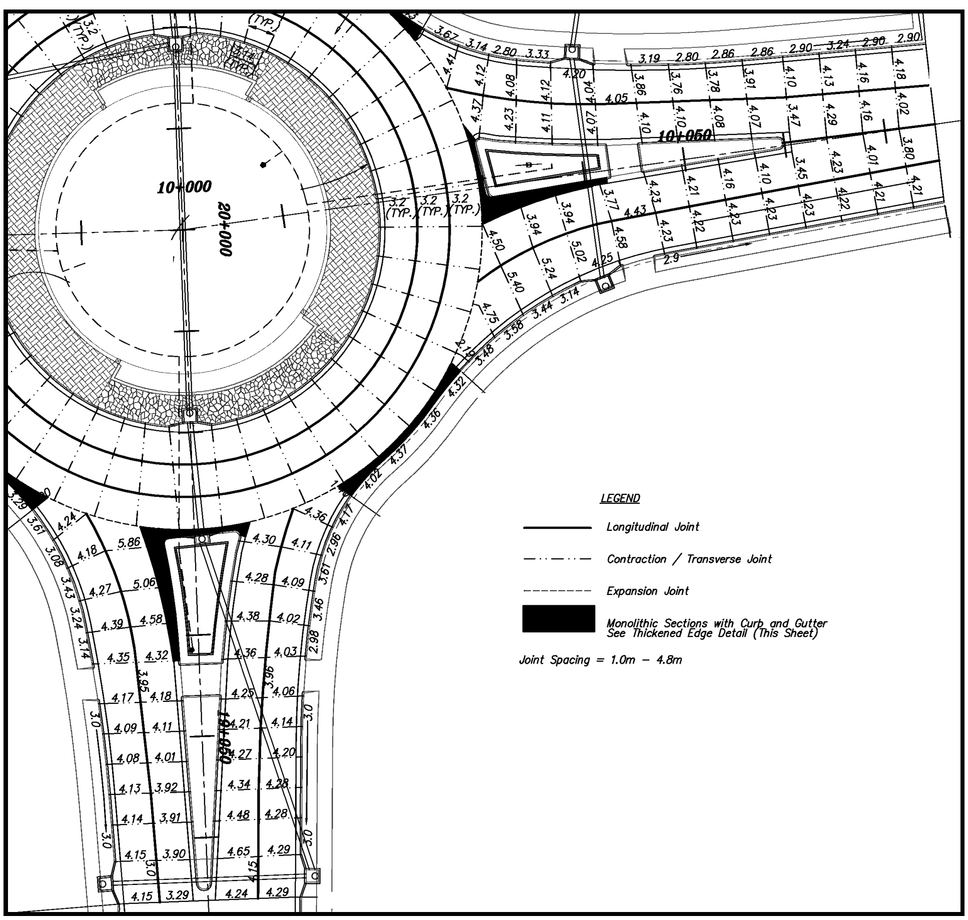
TYPICAL SECTION - ROUNDABOUT APPROACH

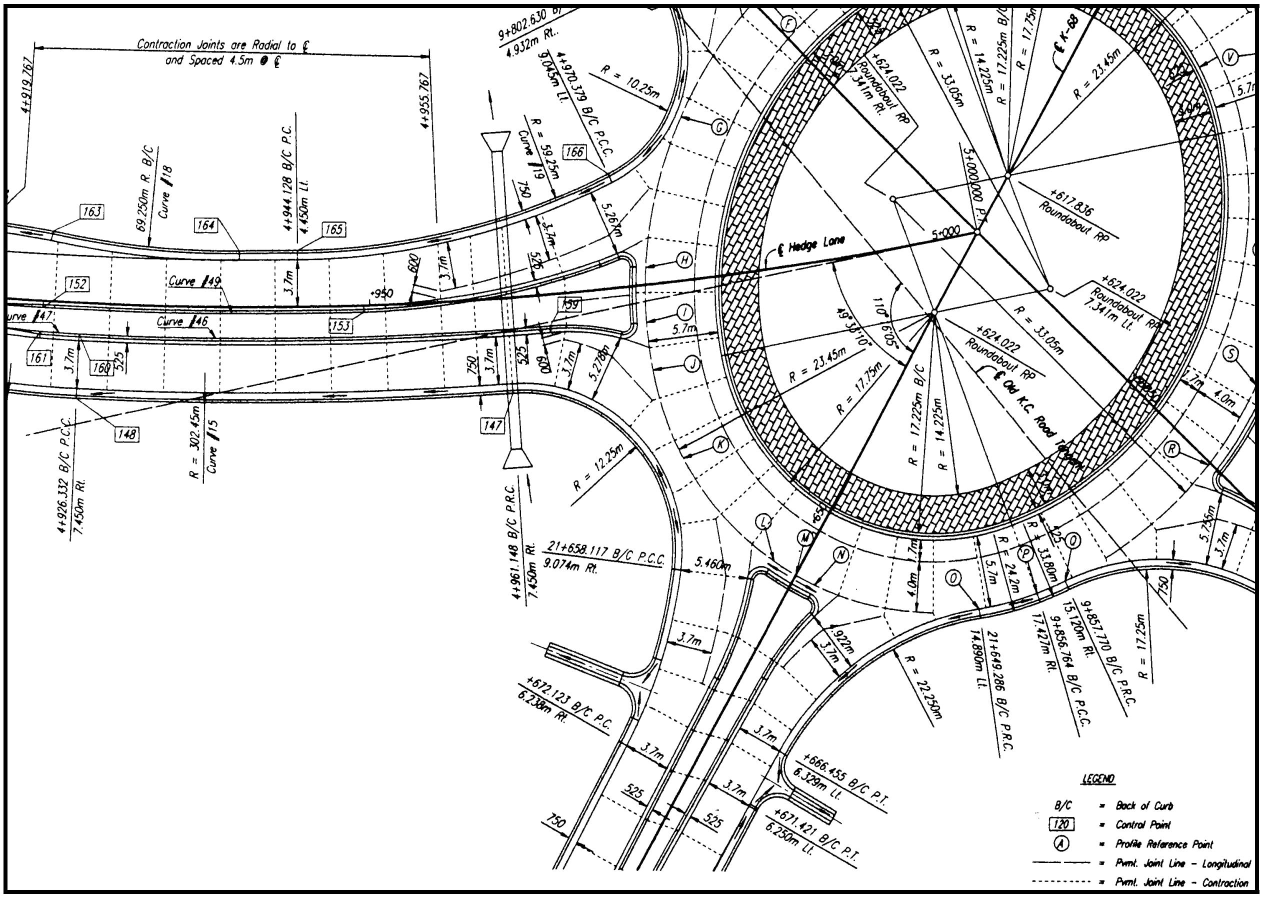
Pavement Type

Both asphalt and concrete pavements were used in the roundabouts reviewed. This is unusual nationally and internationally, where the vast majority of roundabouts are constructed using asphalt. The decision whether to utilize asphalt or concrete will depend on local preferences and the pavement type of the approach roadways. Concrete generally has a longer design life and holds up better under truck traffic. However, national experience has been that rutting has not been a problem with well-constructed asphalt pavement. Constructability is also a consideration in choosing pavement type. Generally, if the roundabout is to be constructed under traffic, asphalt pavement will need to be used. For the truck apron, all of the projects utilized concrete pavement, generally 11 in (280 mm) in depth, or concrete pavement with a brick paver surface. Other options for the truck apron would include using large (4 in [100 mm]) river rocks embedded in concrete that can be traversed by trucks but are uncomfortable for smaller vehicles or pedestrians. A geogrid type material can also be used to provide a more landscaped type appearance but hold up to occasional encroachment by large trucks. The material used for the truck apron should be selected so as to not look like the sidewalk. This will help to keep pedestrians off the truck apron and central island. If the truck apron is constructed under traffic, high early strength concrete should be used to minimize the amount of down time for the intersection.

If concrete pavement is used, joint patterns should be concentric and radial to the circulating roadway within the roundabout. Ideally the joints should not conflict with pavement markings within the roundabout, although concrete panel sizes may control this. On multilane roundabouts, circumferential joints within the circulating roadway should follow the lane edges. Jointing and dowel details should generally utilize KDOT standards RD651 and RD682. Additional information and publications regarding jointing is available from the American Concrete Paving Association (www.pavement.com). Examples of jointing plans are shown below in Exhibit 6-24.

Exhibit 6-24
Example Jointing Plans





Cracking has been found to be a problem in some roundabouts, particularly around the outside of the circulating roadway in the vicinity of the outside curbs and splitter islands, so special care needs to be taken to provide the necessary relief. In the top example above, the City of Overland Park, based on their research of existing roundabouts, isolated the circulating roadway with an expansion joint and constructed special monolithic sections in key areas.

6.5 Pedestrian and Bicycle Considerations

As discussed in the FHWA publication, *Roundabouts: An Informational Guide*, pedestrian crossings at roundabouts should balance pedestrian convenience, pedestrian safety, and roundabout operations. To strike this balance, several geometric elements should be considered when designing pedestrian facilities at a roundabout as described below.

General Design Considerations for Pedestrian Crossings:

- Location of the pedestrian crossing
- Crossing alignment
- Splitter islands / pedestrian refuge design
- Providing for visually impaired pedestrians
- Discouraging pedestrians from crossing to the central island
- Multi-modal sidewalk usage

Exhibit 6-25
Roundabout Pedestrian Accommodations

Selection of the Pedestrian Crossing Location

The FHWA Roundabout Guide provides detailed discussion on considerations in the selection of the pedestrian crossing location. These considerations include minimizing the crossing distance, taking advantage of the splitter island as a pedestrian refuge, minimizing out of direction travel for pedestrians, and minimizing impacts to the roundabout operations. Crossings should be located behind the entrance line in increments of approximate vehicle lengths to reduce the chance of a vehicle being queued across the crosswalk. The crossing should be oriented perpendicular to the direction of traffic to minimize pedestrian exposure time and reduce uncertainty for visually impaired pedestrians regarding crossing alignment.

It is recommended that pedestrian crossings be located one vehicle length, 25 ft (7.5 m) away from the entrance line at both single-lane and multilane roundabouts. This distance is thought to provide the optimal balance of pedestrian safety and convenience by minimizing out of direction travel and utilizing the geometric features of the roundabout to provide slow vehicle speeds in the crossing areas. As the distance from the entrance line increases, the slowing effects of the roundabout geometry may be diminished resulting in greater vehicle speeds, especially upon the exit. This crossing location also provides a greater degree of consistency with other intersection forms, by keeping the crosswalk close to the intersection, which may increase the conspicuity of the crossing to motorists that are not familiar with driving at roundabouts.

Pedestrian crossings should be marked using a series of lines parallel to the flow of traffic (also known as a "zebra crosswalk") to identify the location of pedestrian activity.

Curb Ramps and Crossing Alignment

Curb ramps should be provided at each end of the crosswalk to connect the crosswalk to the sidewalk and other crosswalks around the roundabout. Curb ramps should be aligned with the crossing to guide pedestrians in the proper direction. Pedestrian crossings should be provided in a straight continuous alignment across the entire intersection approach. Crossings that curve or change alignment at the pedestrian refuge should be avoided. A straight alignment allows a visually impaired pedestrian to cross the approach and find the opposite curb ramp without the need to change direction.

Pedestrian refuge areas within the splitter island should be designed at street level, rather than elevated to the height of the splitter island. This eliminates the need for ramps within the refuge area, which may be cumbersome for wheelchairs. However, detectable warning surfaces should be used to indicate when the pedestrian reaches and exits the splitter island.

Exhibit 6-26
Pedestrian Crossing Illustrations

At a single lane roundabout, pedestrian crossings should be placed one vehicle length away from the entrance line as shown in the photo at left.

Pedestrian crossings should be provided in a straight alignment with the surface of the pedestrian refuge at street level.

Place curb ramps in line with the pedestrian crossing to properly guide pedestrians across the approach. A curb ramp such as the one shown in the photo *should be avoided*, as it directs pedestrians into the path of vehicles traveling on the circulatory roadway instead of in the direction of the striped crossing.

Curvilinear pedestrian crossings should also be avoided.

Curb ramps should be centered on the pedestrian crossing.

Avoid placing drainage structures in the crossing area. Drainage inlets such as the one shown in the photo at left may pose a potential hazard for visually impaired pedestrians. In this case the curb ramp had to be offset to the right side of the crossing to avoid the inlet.

Provisions for Visually Impaired Pedestrians

At roundabouts and other intersections, pedestrians with visual impairments are presented with travel challenges that are not experienced by sighted pedestrians. These challenges can be broken down into two general categories: way-finding and gap detection. The following section discusses design treatments and current requirements for assisting visually impaired pedestrians with detecting and navigating the crossing. Additional research is needed to adequately address the issue of the ability for visually impaired pedestrians to detect acceptable gaps in traffic, which is beyond the scope of this guide.

The crossing of a roundabout for visually impaired pedestrians consists of the following tasks (Ref. 1):

1. Finding the beginning of the crosswalk;
2. Establishing directional alignment for the crossing;
3. Deciding when to initiate the crossing;
4. Maintaining proper direction and monitoring traffic movements while crossing;
5. Finding the beginning of the splitter island;
6. Finding the end of the splitter island;
7. Finding the end of the crosswalk.

Each of the above tasks can be aided through the geometric design of the roundabout with exception to Task 3: Deciding when to initiate the crossing. Tactile surfaces placed at the ramps, crosswalks, and splitter islands can be used to help a blind pedestrian to identify each of the geometric elements associated with accomplishing Tasks 1, and 5 through 7. Maintaining a consistent alignment of the pedestrian ramp and the crosswalk across the entire approach can help visually impaired pedestrians with Tasks 2 and 4.

The 3rd task, deciding when to initiate the crossing, is much more complex, as it requires a visually impaired pedestrian to distinguish between the circulating traffic and entering/exiting vehicles. Current research efforts are in progress attempting to address this issue.

The National Institute of Health/National Eye Institute is sponsoring a research effort headed by Western Michigan University. This study is designed to improve the mobility of blind, or otherwise visually impaired, individuals by making intersections more accessible. Roundabout research is being conducted to examine the ability of a blind person to judge sufficient gaps in traffic in comparison to sighted individuals. The study also evaluates the response of drivers at roundabouts to the presence of pedestrians with and without mobility devices.

Other forthcoming NCHRP research is planned to examine the navigational issues of visually impaired pedestrians at roundabouts and identify geometric design issues to help optimize the location of pedestrian facilities. This research may also identify ITS or technology issues related to the use of such devices as pedestrian signals.

Title II of the Americans with Disabilities Act (ADA) requires that new and altered facilities constructed by, on behalf of, or for the use of state and local government entities be designed and constructed to be readily accessible to and usable by individuals with disabilities (28 CFR 35.151). The Americans with Disabilities Act Accessibility Guidelines (ADAAG, 1991) were developed under the umbrella of the ADA to provide guidelines for making facilities accessible to people with disabilities. The ADAAG require that a detectable warning surface be applied to the surface of the curb ramps and within the refuge of a splitter island (defined in the ADAAG as "hazardous vehicle areas") to provide tactile cues to individuals with visual impairments.

Detectible warnings consist of a surface of truncated domes built in or applied to walking surfaces that provides a distinctive surface detectable by cane or underfoot. This surface works to alert visually impaired pedestrians of the presence of the vehicular travel way, and provides physical cues to assist pedestrians in detecting the boundary from sidewalk to street where curb ramps and blended transitions are devoid of other tactile cues typically provided by a curb face. The current ADAAG require the use of detectable warnings on the entire surface of the curb ramp (excluding the side flares).

Exhibit 6-27
Example Pedestrian Crossing with Detectable Warnings

This crosswalk design incorporates the use of truncated dome detectable warning surfaces into the curb ramps and splitter island to facilitate navigation by a visually impaired pedestrian.

Additional tactile devices (distinct from detectable warning surfaces) are also provided along the outside edge and along the center of the crossing to aid the pedestrian in detecting the edges of the crossing and maintaining the proper direction across the intersection.

Within the refuge area of the splitter island, the FHWA Roundabout Guide recommends that a detectable warning surface be applied as shown in Exhibit 6-27. The detectable warning surface shall begin at the curb line and extend into the pedestrian refuge area a distance of 24 in (610 mm). This creates a minimum clear space of 24 in (610 mm) between the detectable warning surfaces for a minimum splitter island width of 6 ft (1.8 m) at the pedestrian crossing. This is consistent with the KDOT standard drawings for *Auxiliary Details For Sidewalks & Steps* and is necessary to enable visually impaired pedestrians to distinguish where the refuge begins and ends from the adjacent roadway where the minimum refuge width of 6 ft (1.8 m) is provided. Exhibit 6-28 provides a summary of the ADAAG requirements for detectable warning surfaces.

Exhibit 6-28
Requirements for Detectable Warning Surfaces*

Legislation	Americans with Disabilities Act Accessibility Guidelines (ADAAG)	*Draft* Guidelines on Accessible Public Rights-of-Way
Applicability	Required under existing regulations	These guidelines are in the rulemaking process and are therefore *not* enforceable. These guidelines are ultimately intended to be incorporated into the ADAAG, however the recommendations listed below are subject to revision prior to the issuance of a final rule.
Type	Raised truncated domes	Raised truncated domes aligned in a square grid pattern
Dome Size	A nominal diameter of 0.9 in (23 mm), A nominal height of 0.2 in (5 mm).	A base diameter of 0.9 in (23 mm) minimum to 1.4 in (36 mm) maximum A top diameter of 50% of the base diameter minimum to 65% of the base diameter maximum A height of 0.2 in (5 mm).
Dome Spacing	A nominal center-to-center spacing of 2.35 in (60 mm).	A center-to-center spacing of 1.6 in (41 mm) minimum and 2.4 in (61 mm) maximum, A base-to-base spacing of 0.65 in (16 mm) minimum, measured between the most adjacent domes on square grid.
Contrast	Detectable warning surfaces shall contrast visually with adjacent walking surfaces either light-on-dark, or dark-on-light. The material used to provide contrast shall be an integral part of the walking surface.	Detectable warning surfaces shall contrast visually with adjacent walking surfaces either light-on-dark, or dark-on-light.
Size	**At curb ramps:** The detectable warning shall extend the full width and depth of the curb ramp. **Within Splitter Island:** boundary between the (curbs) shall be defined by a continuous detectable warning which is 36 in (915 mm) wide, beginning at the curb line.	**At curb ramps, landings, or blended transitions connecting to a crosswalk:** Detectable warning surfaces shall extend 24 in (610 mm) minimum in the direction of travel and the full width of the curb ramp, landing, or blended transition. The detectable warning surface shall be located so that the edge nearest the curb line is 6 in (150 mm) minimum and 8 in (205 mm) maximum from the curb line. **Within Splitter Island:** The detectable warning surface shall begin at the curb line and extend into the pedestrian refuge a minimum of 24 in (600 mm). Detectable warnings shall be separated by a 24 in (610 mm) minimum length of walkway without detectable warnings

*Reflects requirements current as of September 2003

Other recent recommendations offer similar guidance to that of the FHWA Roundabout Guide for detectable surfaces within the refuge area of a splitter island. The *Draft Guidelines on Accessible Public Rights-of-Way* (June 14, 2002), developed by the Access Board, issued a similar recommendation for use of a width of 24 in (610 mm) for detectable warning surfaces. This is consistent with the existing ADAAG requirements for truncated dome detectable warning surfaces at transit platforms. The draft public right-of-way guidelines are based upon the recommendations of the Public Rights of Way Access Advisory Committee as published in the report *Building a True Community.* For detectable warning surfaces, both the U.S. Access Board and FHWA are encouraging the use of the new (recommended) design pattern and application over the original ADAAG requirements (Ref. 5).

Ongoing research is being conducted to improve accessibility for visually impaired pedestrians at roundabouts. This research is required to develop the information necessary for jurisdictions to determine where roundabouts may be appropriate and what design features are required for people with disabilities. Until specific standards or guidelines are adopted, such as the Public Right of Way Accessibility Guidelines, 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.

Non-Typical Pedestrian Treatments

While the detectable warning surfaces required by the ADAAG assist pedestrians in locating the crossing and pedestrian refuge area, blind or other visually impaired pedestrians may require further assistance in navigating a roundabout. For example, a motorized volume that is too heavy at times to provide a sufficient number of gaps acceptable for pedestrians may warrant consideration of an indicator that provides visual or audible cues to assist people with visual disabilities and increase the conspicuity of the crossing to motorists.

Other potential treatments to help reduce the difficulties faced by pedestrians include: narrow entry widths, raised speed tables with detectable warnings, detectable surfaces that direct visually impaired pedestrians to the crossing location, and in-pavement markers with yellow flashing lights to alert drivers of crossing pedestrians (Ref. 6). While not typical, treatments such as these may be implemented if a traffic study identifies the need for additional pedestrian accommodations. At this time there is limited data relating pedestrian safety at roundabouts to implementation of non-typical pedestrian indicators or other treatments. Therefore, implementation of non-typical pedestrian treatments should be evaluated on a case-by-case basis.

Where consideration is given to pedestrian activated indicators near a roundabout, the crossing location should be determined based on an analysis of the interaction between the roundabout and signal to minimize operational impacts and minimize the likelihood of exiting vehicle queues extending into the roundabout.

Speed tables, where considered, should ensure that adequate geometric design is provided to reduce absolute vehicle speeds to less than 12 mph (20 km/h) near the crossing. In addition, speed tables should generally be used only on streets with approach speeds of 35 mph (55 km/h) or less, as the introduction of a raised speed table in higher speed environments may increase the likelihood of single-vehicle crashes.

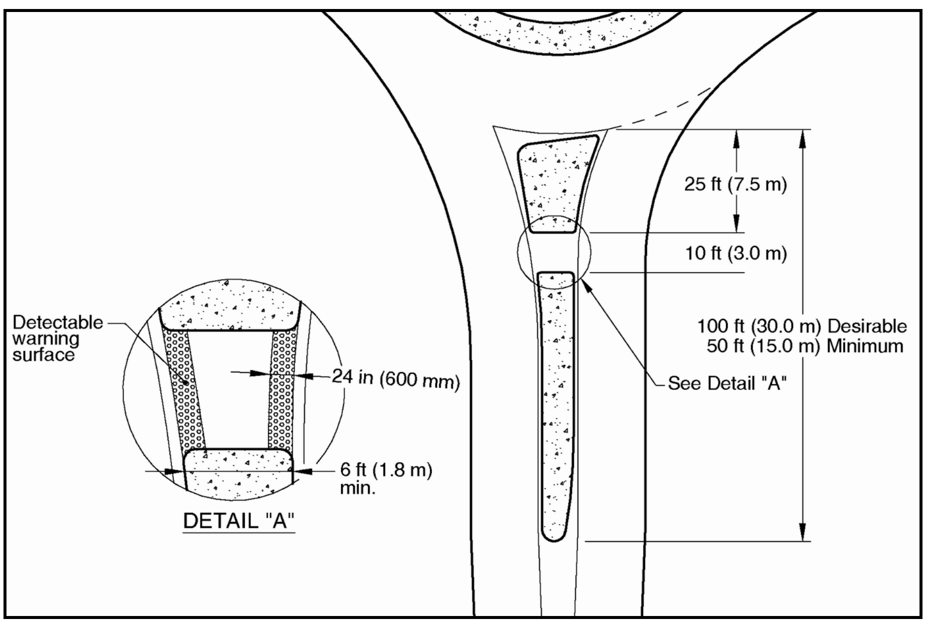
Splitter Islands

Splitter islands should be constructed on all roundabouts, except those with very small diameters at which the splitter island would obstruct the visibility of the central island. Splitter islands serve to separate and guide entering and exiting traffic, provide shelter for pedestrians (including wheelchairs, bicycles, and baby strollers), assist in controlling vehicle speeds, deter wrong way movements, and provide a place to mount signs.

The splitter island envelope is formed by the entry and exit curves on an approach. The extension of these curves should be tangent to the outside edge of the central island. The total length of a splitter island should generally be a minimum of 50 ft (15 m), although 100 ft (30 m) is desirable, to provide sufficient protection for pedestrians and to alert approaching drivers to the roundabout geometry. Additionally, the splitter island should extend beyond the end of the exit curve to prevent exiting traffic from accidentally crossing into the path of approaching traffic. The minimum width of the splitter island is 6 ft (1.8 m), measured at the pedestrian crossing as shown in Exhibit 6-29.

Exhibit 6-29 shows the minimum dimensions for a splitter island at a single lane roundabout, including the location of the pedestrian crossing and location of detectable warning surfaces within the pedestrian refuge area.

Exhibit 6-29
Minimum Splitter Island Dimensions

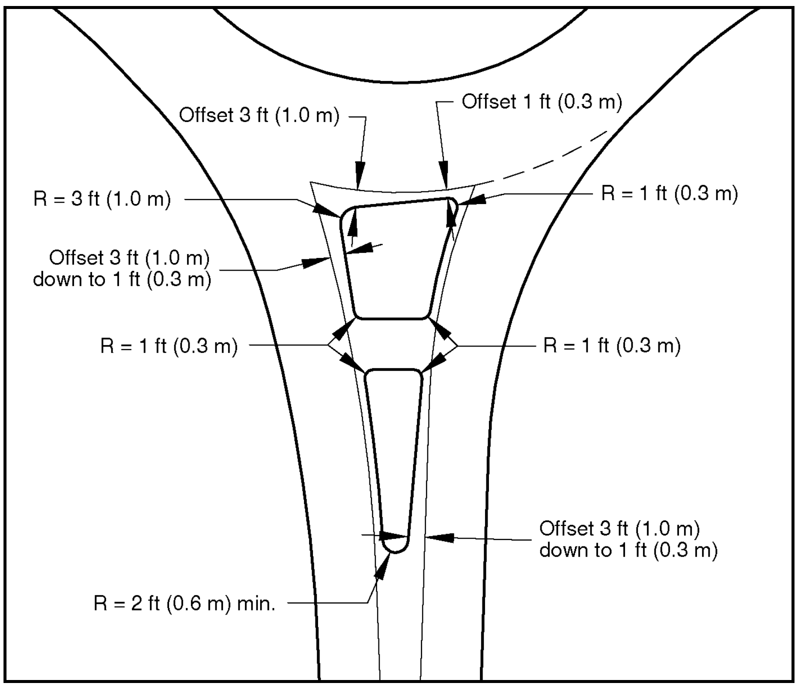


While Exhibit 6-29 provides minimum dimensions for splitter islands, there are benefits to providing larger islands. Longer splitter islands may be appropriate on facilities where vehicle speeds are sufficiently high in relation to the operating speed of the roundabout. The increased splitter island length provides additional warning to drivers of the impending intersection and need for speed reductions.

Increasing the splitter island width results in greater separation between the entering and exiting traffic streams of the same leg and increases the time for approaching drivers to distinguish between exiting and circulating vehicles. In this way larger splitter islands can help reduce confusion for entering motorists. However, care should be taken when designing islands with larger widths to ensure that adequate deflection and speed reduction objectives are being achieved. Increases in the splitter island width generally require increasing the inscribed circle diameter and thus may have higher construction costs and greater land impacts.

Standard AASHTO guidelines for island design should be followed for the splitter island. This includes using larger nose radii at approach corners to maximize island visibility and offsetting curb lines at the approach ends to create a funneling effect. The funneling treatment also aids in reducing speeds as vehicles approach the roundabout. Exhibit 6-30 shows the minimum splitter island nose radii and offset dimensions from the entry and exit traveled way.

Exhibit 6-30
Minimum Splitter Island Nose Radii and Offsets



Sidewalk Considerations

In order to deter pedestrians from crossing to the central island, sidewalks should be set back from the circulatory roadway. A setback distance of 5 ft (1.5 m) is recommended (minimum of 2 ft [0.6 m]) where possible. The area between the sidewalk and circulatory roadway can be planted with grass or low shrubbery to provide a visual barrier. Exhibits 6-31 through 6-33 show examples of this type of treatment.

In areas where sidewalk set back is not possible, bollards, or other barriers may be appropriate to guide pedestrians to the appropriate crossing location and prevent crossing to the central island.

Exhibit 6-31
Sidewalk Treatments

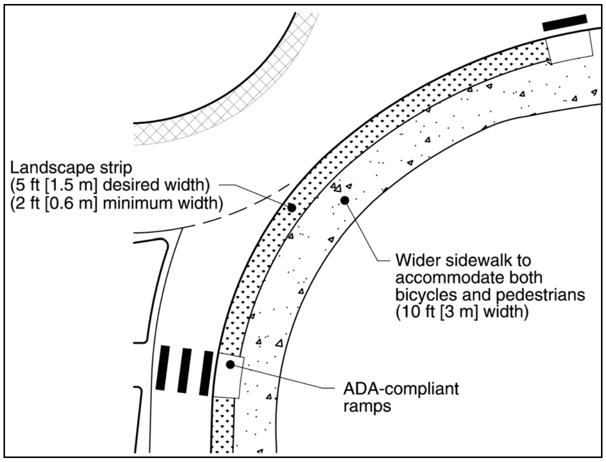


Exhibit 6-32
Alternative Sidewalk Treatment

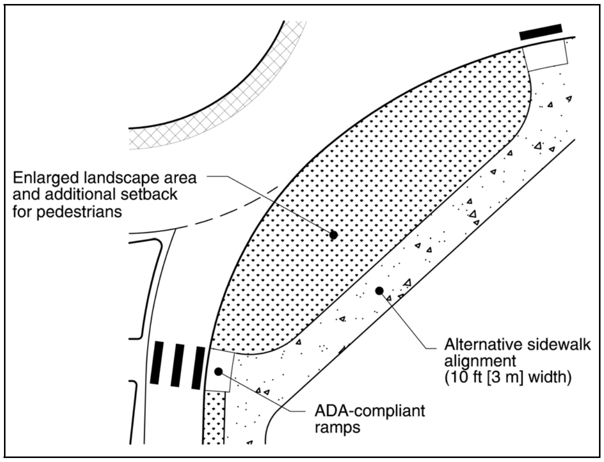


Exhibit 6-33
Example Sidewalk Setback at Roundabouts

Landscaped planter strips set back the sidewalk from the adjacent roadway. This helps to define the sidewalk area and discourage pedestrians from crossing the roadway at locations other than the striped and/or signed crossing.

Providing sidewalk setback may also help visually impaired pedestrians to distinguish the location of the sidewalk and find the appropriate crossing locations.

In this photo, the break in the manicured grass planter strip, combined with the pedestrian crossing sign, help to heighten the conspicuity of the crossing to motorists, especially in the instance where sunlight glare on the concrete road surface may decrease the visibility of the crosswalk striping.

Sidewalk Considerations in Urban Areas

In urban areas, additional consideration may be required for pedestrian facilities, especially sidewalks, to provide for pedestrian mobility and encourage retail activity. The sidewalk width required adjacent to the roundabout is dependent on a number of factors. While, the level of pedestrian activity may be the first consideration, the sidewalk width may also be dependant on the nature of the adjacent business activity in the immediate vicinity of the roundabout. Larger densities of retail stores, restaurants, or entertainment attractions may elicit the need for wider sidewalks. Wider sidewalks accommodate window shoppers, allow for limited outdoor seating at restaurants, and also provide space for public street furniture such as benches or public art.

Exhibit 6-34
Example Pedestrian Features in Urban Areas

In urban areas with high pedestrian activity, consideration may be given to providing additional pedestrian features such as small plazas in the corner areas between the approach legs of the roundabout as shown in the photo. Open space, such as this, allow for increased pedestrian activity without overcrowding. It also allows space for pieces of public art to further accentuate the intersection.

In this example a vertical face of 18 in (450 mm) was provided on the roundabout side of the sidewalk edge and tapered down to match the curb height at the edge of the roadway. This structure was carefully designed to prevent impeding sight distance, but yet to help define the pedestrian space, protect the landscaping, and most importantly to prevent pedestrians from entering the circulatory roadway or crossing to the central island.

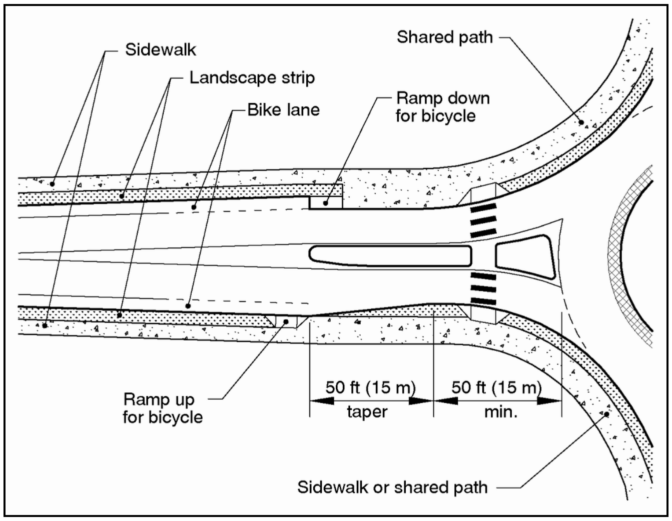
In some locations, where right-of-way is available, additional open space such as shown in Exhibit 6-34 may be provided to enhance the aesthetics of the intersection and increase the freedom of movement for non-motorized users. As with any roundabout, the overall design should ensure that adequate sight distance is provided to make pedestrians visible to motorists. This is especially true in urban areas where the location of landscaping, street furniture, or signs could obstruct the view of pedestrians.

Bicycle Provisions

Bike lanes should be terminated in advance of a roundabout to encourage cyclists to mix with vehicle traffic and navigate the roundabout as a vehicle. Bicycle riders uncomfortable with riding through the roundabout may choose to dismount and circulate around the roundabout as a pedestrian using the provided sidewalks and crossings. It is recommended that bike lanes end 100 ft (30 m) upstream of the entrance line to allow for merging with vehicles.

To accommodate bicyclists who prefer not to use the circulatory roadway, a widened sidewalk or shared bicycle/pedestrian path may be used provided it is physically separated from the circulatory roadway. Ramps or other suitable connections can then be provided between this sidewalk or path and the bike lanes, shoulder, or road surface on the approaching and departing roadways as shown in Exhibit 6-35. Care should be taken when locating and designing bicycle ramps to ensure that they are not misconstrued as an unmarked pedestrian crossing. The AASHTO *Guide for Development of Bicycle Facilities* provides further guidance on the design requirements for bicycle and shared-use path design.

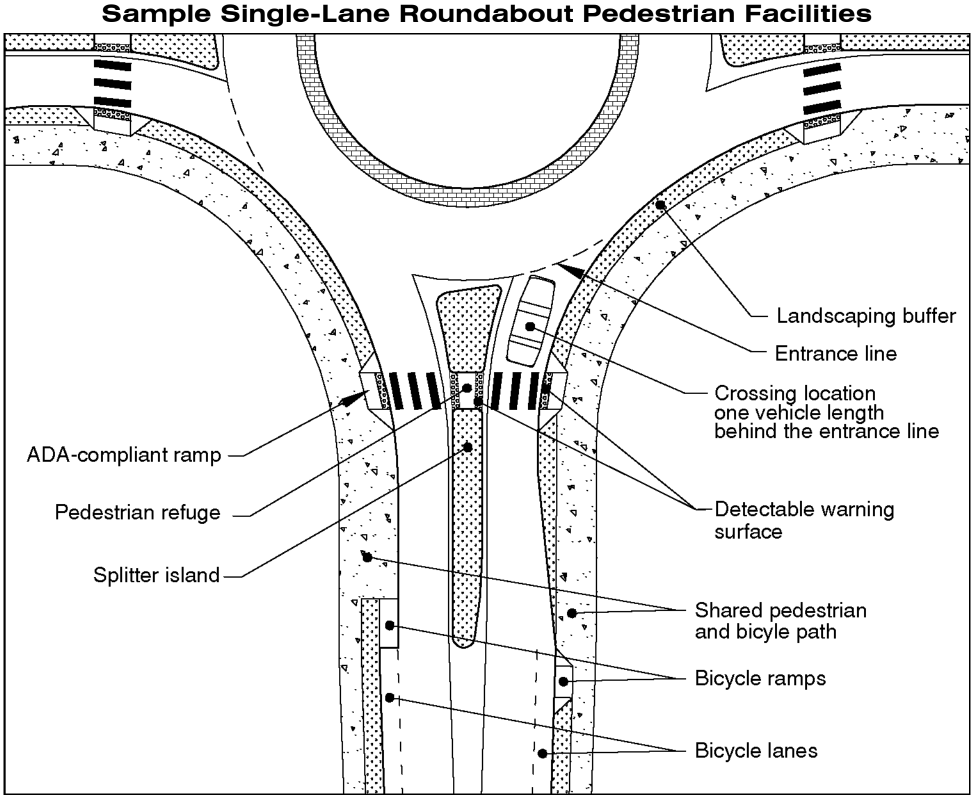
Exhibit 6-35
Possible Provisions for Bicycles



Example Pedestrian Facilities

Exhibit 6-36 provides a sample illustration of pedestrian and bicycle facilities for a single-lane roundabout in an urban or suburban setting. This figure incorporates the various design considerations discussed in Section 6.5. Specific dimensions and design considerations for individual elements are provided throughout Section 6.5 of this guide and in the FHWA publication *Roundabouts: An Informational Guide*.

Exhibit 6-36
Sample Single-Lane Roundabout Pedestrian Facilities



6.6 Sight Distance

As with all roadways, adequate stopping sight distance must be provided at all locations within the roundabout and on the approaches to avoid objects and other vehicles in the road. Intersection sight distance must also be provided at the entries to enable drivers to perceive vehicles from other approaches and safely enter the roundabout. The design speeds from the fastest path evaluation are used in the calculation of stopping sight distance and intersection sight distance requirements.

Stopping Sight Distance

At roundabouts, stopping sight distance should be checked at a minimum of three locations:

- Approach sight distance
- Sight distance on the circulatory roadway
- Sight distance to crosswalk on the immediate downstream exit

Exhibits 6-37 through 6-39 display the stopping sight distance requirements for roundabouts.

Exhibit 6-37
Approach Sight Distance

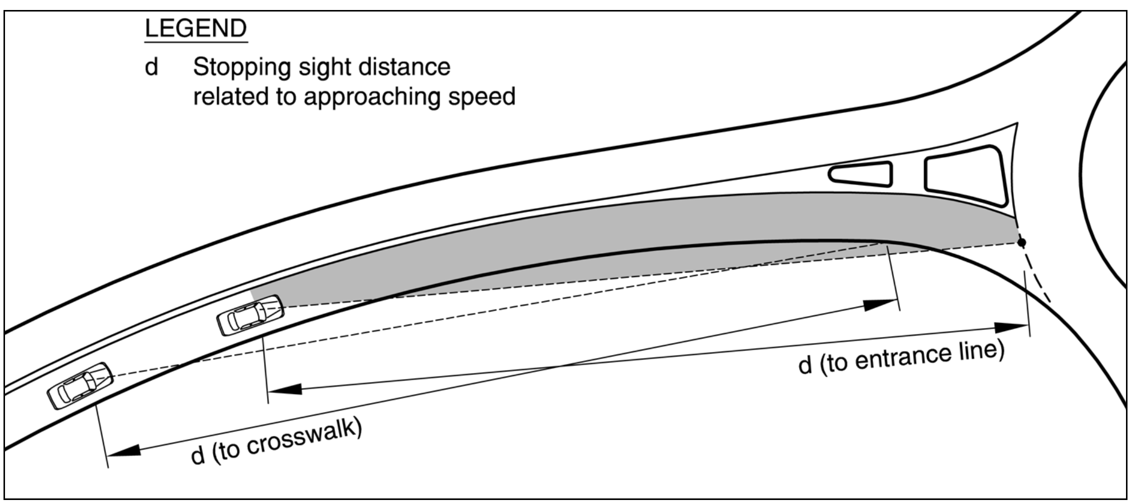


Exhibit 6-38
Sight Distance On Circulatory Roadway

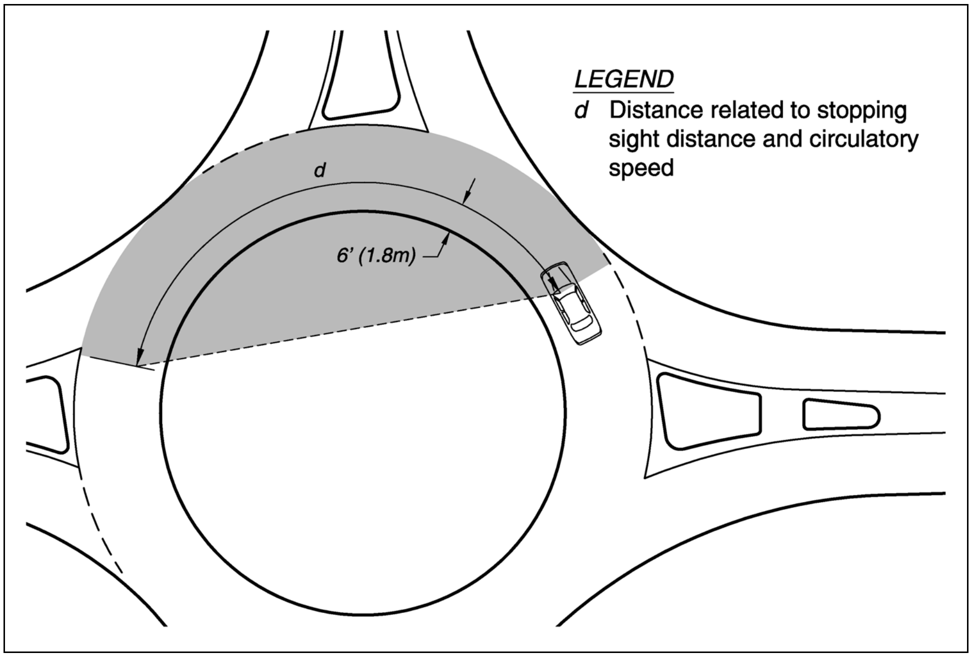
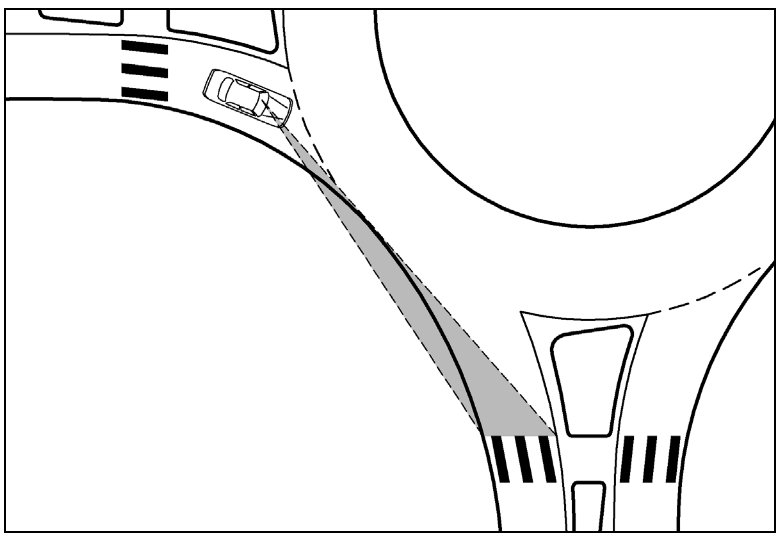


Exhibit 6-39
Sight Distance to Crosswalk on Exit



Stopping sight distance should be measured using an assumed drivers eye height of 3.5 ft (1,080 mm) and an assumed height of object of 2 ft (600 mm) in accordance with the fourth edition of the AASHTO publication, "A Policy on Geometric Design of Highways and Streets" (Green Book).

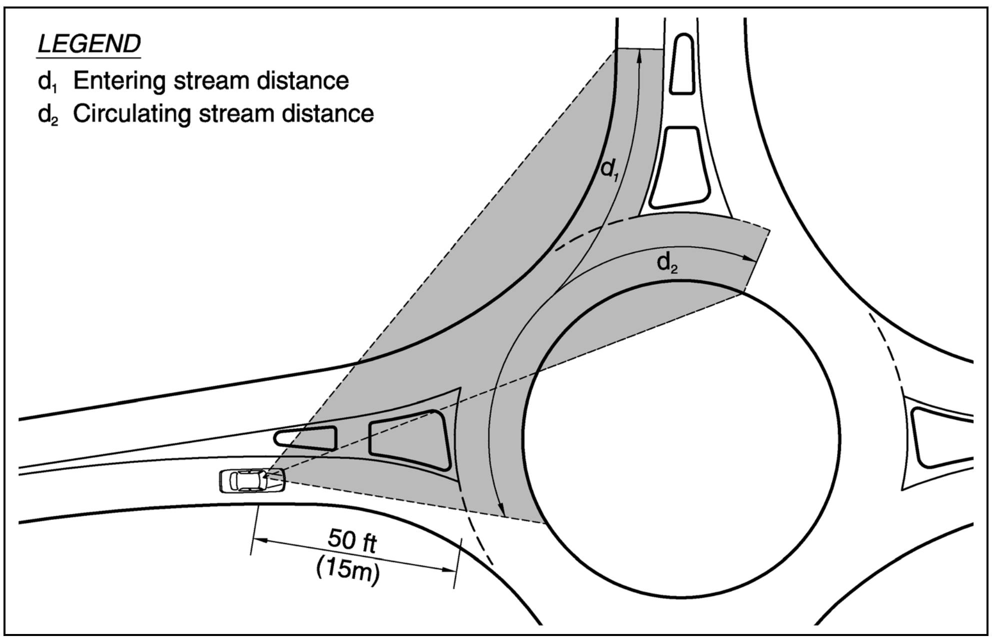
Equations and design values for determining the stopping sight distance required in Exhibit 6-37 through 6-39 are provided in section 6.3.9 of the FHWA publication, *Roundabouts: An Informational Guide*, and in the *Elements of Design* section of the AASHTO "Green Book".

Intersection Sight Distance

Intersection sight distance is the distance required for a driver approaching the roundabout, without the right of way, to perceive and react to the presence of conflicting vehicles on the circulatory roadway and immediate upstream entry. At roundabouts, the only locations requiring evaluation of intersection sight distance are the entries.

The traditional method of using sight triangles to measure intersection sight distance is used. For roundabouts, the limits of the sight triangle are determined through the calculation of sight distance for the two independent conflicting traffic streams: the circulating stream and the entering stream on the immediate upstream entry. The sight distance required for each stream is measured along the curved vehicle path, *not* as a straight line. Exhibit 6-40 presents a diagram showing the method for determining intersection sight distance.

Exhibit 6-40
Intersection Sight Distance

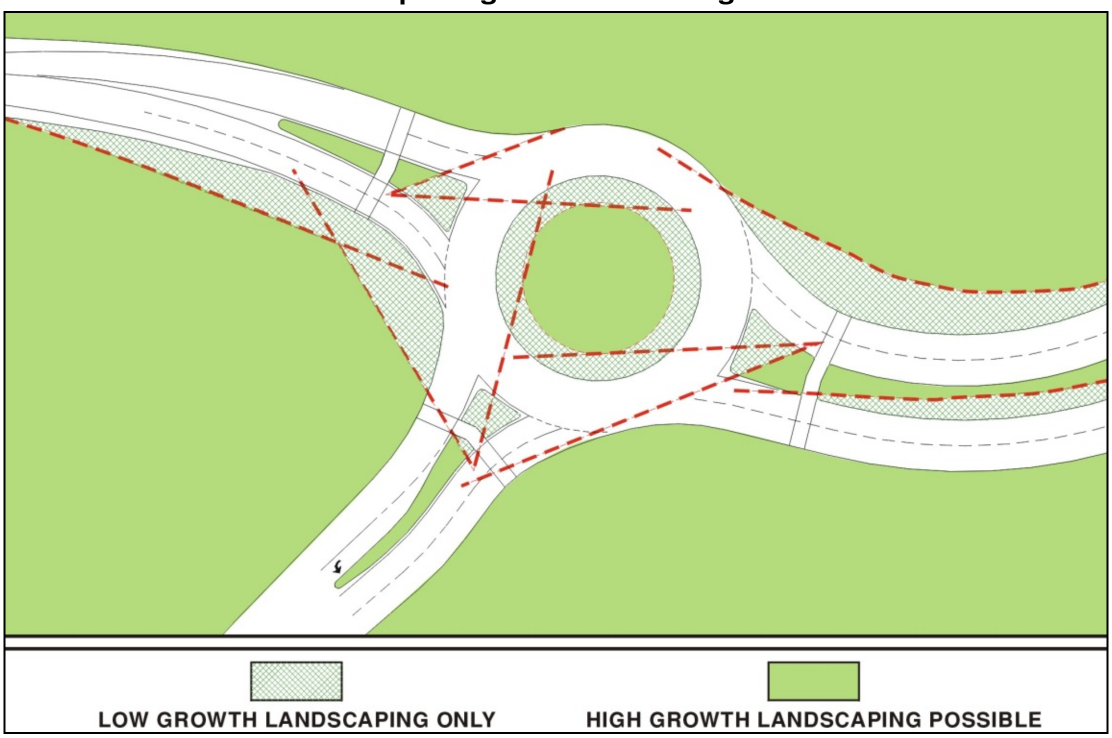


Intersection sight distance should be measured using an assumed drivers eye height of 3.5 ft (1,080 mm) and an assumed height of object of 3.5 ft (1,080 mm) in accordance with the fourth edition of the AASHTO publication, "A Policy on Geometric Design of Highways and Streets" (Green Book).

Equations and design values for determining the intersection sight distance components required in Exhibit 6-40 are provided in section 6.3.10 of the FHWA publication, "Roundabouts: An Informational Guide". The equations are also provided in the *Intersections* section of the AASHTO "Green Book". Calculations for intersection sight distance should assume a critical gap of 6.5 s, based on research of critical gaps at stop-controlled intersections, adjusted for yield-controlled conditions (Ref. 8). However, in locations where site distance may be constrained by adjacent topographic features or buildings, the critical gap may be reduced to 4.6 s. This value is consistent with the lower bound identified for roundabouts in the *Highway Capacity Manual* (HCM 2000). The designer can approximate the speeds for the entering stream by averaging the entry path speed and circulating path speed (paths with radius R_1 and R_2 respectively). Likewise, the designer can approximate the speeds for the circulating stream by taking the speed of left-turning vehicles (path with radius R_4).

During design and review, roundabouts should be checked to ensure that adequate stopping and intersection sight distance is being provided. Checks for each approach should be overlaid onto a single drawing, as shown in Exhibit 6-41, to illustrate for all team members the clear vision areas for the intersection. This provides designers guidance on the appropriate locations for various types of landscaping or other treatments. The compiled drawing should be kept in the project file for future reference in the event landscaping or street furniture is contemplated after the project is completed. In general, it is recommended to provide no more than the minimum required intersection sight distance on each approach, as excessive intersection sight distance can lead to higher speeds that reduce intersection safety. Landscaping can be effective in restricting sight distance to the minimum.

Exhibit 6-41
Example Sight Distance Diagram



The hatched portions in Exhibit 6-41 are areas that should be clear of large obstructions that may hinder driver visibility. Objects such as low growth vegetation, poles, sign posts, and narrow trees may be acceptable within these areas provided that they do not significantly obstruct visibility of other vehicles, the splitter islands, the central island, or other key roundabout components. In the remaining areas (with solid shading), especially within the central island, taller landscaping may be used to break the forward view for through vehicles, thereby contributing to speed reductions and reducing oncoming headlight glare.

6.7 Landscaping Considerations

The use of landscaping at a roundabout is one of the distinguishing features that give roundabouts an aesthetic advantage over traditional intersections. The type and quantity of landscaping plantings or other material incorporated into the roundabout design may be dependant on both the site location and level of care available for maintenance. Exhibit 6-42 illustrates examples of landscaping installed at existing Kansas roundabouts.

Exhibit 6-42
Summary of Landscaping Schemes at Existing Kansas Roundabouts

Lawrence, Kansas – 24th Place at Inverness Drive

Topeka, Kansas – I-70 Ramps at Rice Road and Sycamore Drive

Olathe, Kansas – Sheridan Street at Clairborne Road

Olathe, Kansas – Sheridan Street at Rogers Road

Overland Park, Kansas – 110th Street at Lamar Avenue

Manhattan, Kansas – Kimball Avenue at Grand Mere Parkway
(photo taken from central island)

Manhattan, Kansas – Candlewood Drive at Gary Avenue

Maintenance Considerations

A realistic maintenance program should be developed when designing the landscaping features for any proposed roundabout. For KDOT maintained roundabouts, the landscaping should generally consist of simple, hearty plant materials or hardscape material that have minimal maintenance requirements. Plant selections should be appropriate for the climate to withstand both heat and cold depending on the season.

For roundabouts in urban areas, used as gateway treatments, or any other areas where more complex planting schemes are wanted, it may be desirable to seek out formal agreements with the local government entity, local civic groups, or garden clubs for maintenance where possible.

It is generally necessary for local governments to assume maintenance responsibilities for the roundabout landscaping to provide enhanced streetscapes for their communities. Where cross-jurisdictional or other agreements are formed, liability issues should be considered.

Planting such as grass, trees, and shrubs should be regularly trimmed or pruned to prevent obstruction of the sight triangles and to maintain the aesthetics of the intersection. Landscaping designs that require frequent watering may require installation of sprinkler systems. The design of the sprinkler system should minimize water runoff onto the circulatory roadway. Watering systems with a mist type spray head should be avoided as water spray onto windshields could create safety concerns.

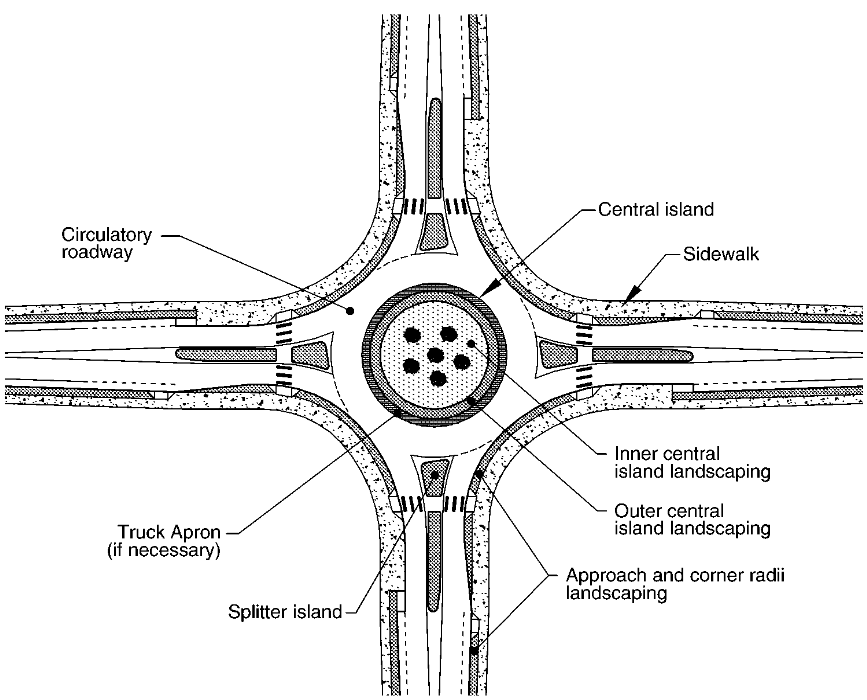
Sight Distance

As discussed in the previous section, sight distance requirements at the intersection dictate the size and types of landscaping materials appropriate for the various areas within and adjacent to the roundabout. Plants or hardscape materials should be placed to avoid obscuring the shape of the roundabout or the signing to the driver. Exhibit 6-41 in the previous section provides an example illustration of a sight distance diagram for a roundabout. Landscaping within the clear vision areas identified for the roundabout should be limited to a height of 2 ft (600 mm) to maintain adequate sight distance. Taller landscaping may be possible within the inner portion of the central island depending on the diameter of the inscribed circle.

Planting Zones

Exhibit 6-43 identifies the various planting areas at a typical roundabout.

Exhibit 6-43
Roundabout Planting Areas



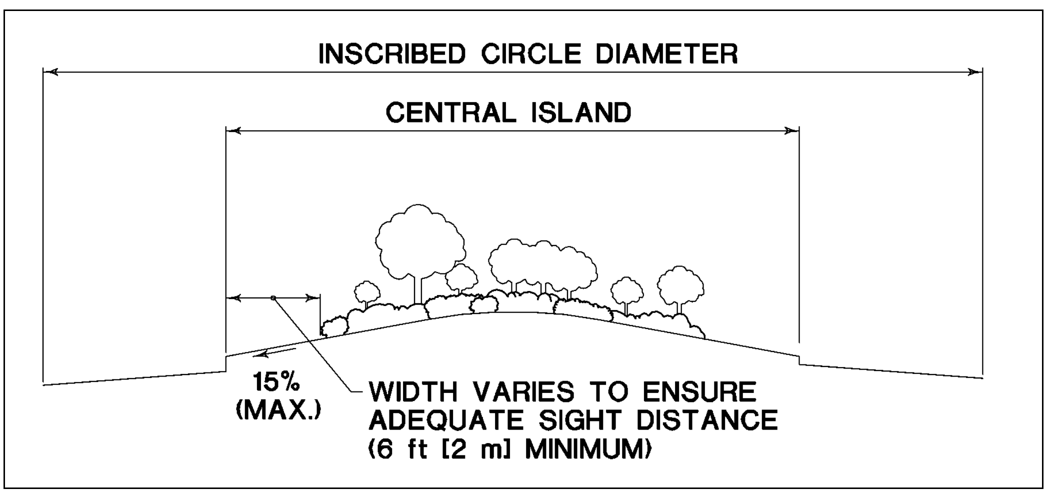
Central island landscaping

Landscaping within the central island provides enhancements to both aesthetics and safety for the intersection. The inner portion of the central island may be planted with trees, bushes and other large items. These plantings help to make the central island more conspicuous by creating a terminal vista in which the line of sight straight through the roundabout is partially obscured. This clearly indicates to the driver that they cannot pass straight through the intersection and helps to make the central island more visible at night with the vehicle headlights illuminating the landscaping.

The perimeter of the central island should be landscaped with low-lying shrubs, grass, or groundcover so that stopping sight distance requirements are maintained for vehicles within the circulatory roadway. This width may vary depending on the size of the roundabout, as shown in Exhibit 6-44. Many of the existing KDOT roundabouts have used bark, small rocks, and low growing plants to provide groundcover around the perimeter of the central island, and maintain sight distance. Large, fixed landscaping objects such as trees, poles, rocks, statues, or walls should be avoided in areas vulnerable to vehicle runoff. Shrubs and columnar growing species of trees may be appropriate within the inner portion of the central island. Consideration should be given to the size and shape of the mature plants. Trees with large canopies should be avoided within the central island. Large objects such as statues, monuments, and other art can often be desirable features and may be allowed in the central island provided that they are located outside the sight triangles and in areas unlikely to be struck by errant vehicles. The slope of the central island should not exceed 6:1 per the requirements of the AASHTO Roadside Design Guide (Ref. 9).

Landscaping within the central island should discourage pedestrian traffic to and through the central island. As such, the design of the central island should avoid use of street furniture such as benches or monuments with small text. Where truck aprons are used, the material or pattern used for the surface of the apron should be different from that used for the sidewalks so that pedestrians are not encouraged to cross the circulatory roadway, or perceive that the truck apron is a sidewalk.

Exhibit 6-44
Central Island Landscaping



Splitter island and approach landscaping

When designing landscaping for the splitter islands and along the outside edges of the approach, care should be taken to avoid obstructing sight distance, as splitter islands are usually located within the critical sight triangles. Landscaping should avoid obscuring the form of the roundabout or the signing to an approaching driver.

At existing Kansas roundabouts, splitter islands have often been constructed with either low-growth plant material or have been devoid of landscaping all together, simply using a patterned concrete or concrete paver surface. The size of the splitter island and location of the roundabout are determining factors in assessing whether or not to provide landscaping within the splitter islands.

Landscaping on the right and left side of the approaches and within the splitter islands (where appropriate) can help to create a funneling effect and induce a decrease in speeds approaching the roundabout. Landscaping on the outer edges of the approach and in the corner radii provide sidewalk setback which helps to channelize pedestrians to the crosswalk areas and discourage pedestrians from crossing to the central island.

For existing Kansas roundabouts, grass has typically been used along the outer edge of the roadway and within the corner radii between adjacent legs of the roundabout. Although other plants species may be used, grass typically blends in well with the surrounding streetscapes and requires little or no watering. The main maintenance requirement for planting grass is mowing, thus consideration may be given to dwarfed varieties such as "buffalo grass" which has a shorter height and requires less frequent maintenance.

Exhibit 6-45
Example Splitter Island Landscaping

Landscaping within the splitter islands and along the outer edge of the approach can help create a funneling effect to help decrease speeds prior to the roundabout.

Landscaping should be carefully placed as to not obstruct the sight distance requirements for the intersection. Trees within the splitter island may not be appropriate in all locations.

Grass or low growth plants can provide improved aesthetics within the splitter island area.

Consider the use of dwarfed plant varieties or horizontally growing ground cover type species to minimize maintenance requirements and preserve sight distance requirements.

Arid plant species may be appropriate within the splitter island to minimize watering requirements.

6.8 References

1. Blind and Sighted Pedestrians at Roundabouts (Guth, Ashmead, Long, Wall, Ponchilla).

2. Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG). 36 CFR Part 1191. As amended through January 1998.

3. Architectural and Transportation Barriers Compliance Board. Draft Guidelines for Public Rights of Way. (June 2002) Washington D.C.: U.S.

4. Building a True Community: Report of the Public Rights of Way Access Advisory Committee. (2001) Washington, D.C.: U.S. Architectural and Transportation Barriers Compliance Board.

5. U.S. Federal Highway Administration. Memorandum Subject, Information: ADAAG Detectable Warnings. 2002. http://www.fhwa.dot.gov/environment/bikeped/dwm.htm

6. Brown, M. TRL State of the Art Review-The Design of Roundabouts. London: HMSO, 1995.

7. American Association of State Highway and Transportation Officials (AASHTO). Guide for Development of Bicycle Facilities. Washington, D.C.: AASHTO, 1991.

8. Harwood, D.W. et al. *NCHRP Report 383: Intersection Sight Distances*. National Cooperative Highway Research Program, Transportation Research Board, National Research Council. Washington D.C.: National Academy Press, 1997.

9. American Association of State Highway and Transportation Officials (AASHTO). Roadside Design Guide. Washington, D.C.: AASHTO, 1989.

Chapter 7 - Traffic Design

7.1 Signing

The signing requirements for roundabouts vary slightly depending on the environment and lane configuration. Exhibits 7-1 and 7-2 show signing for typical roundabouts in urban areas at the intersection of local roadways and at highway junctions, respectively. Signing for typical roundabouts in rural environments are displayed in Exhibit 7-3.

Exhibit 7-1
Typical Signing at Urban Roundabouts on Local Roadways

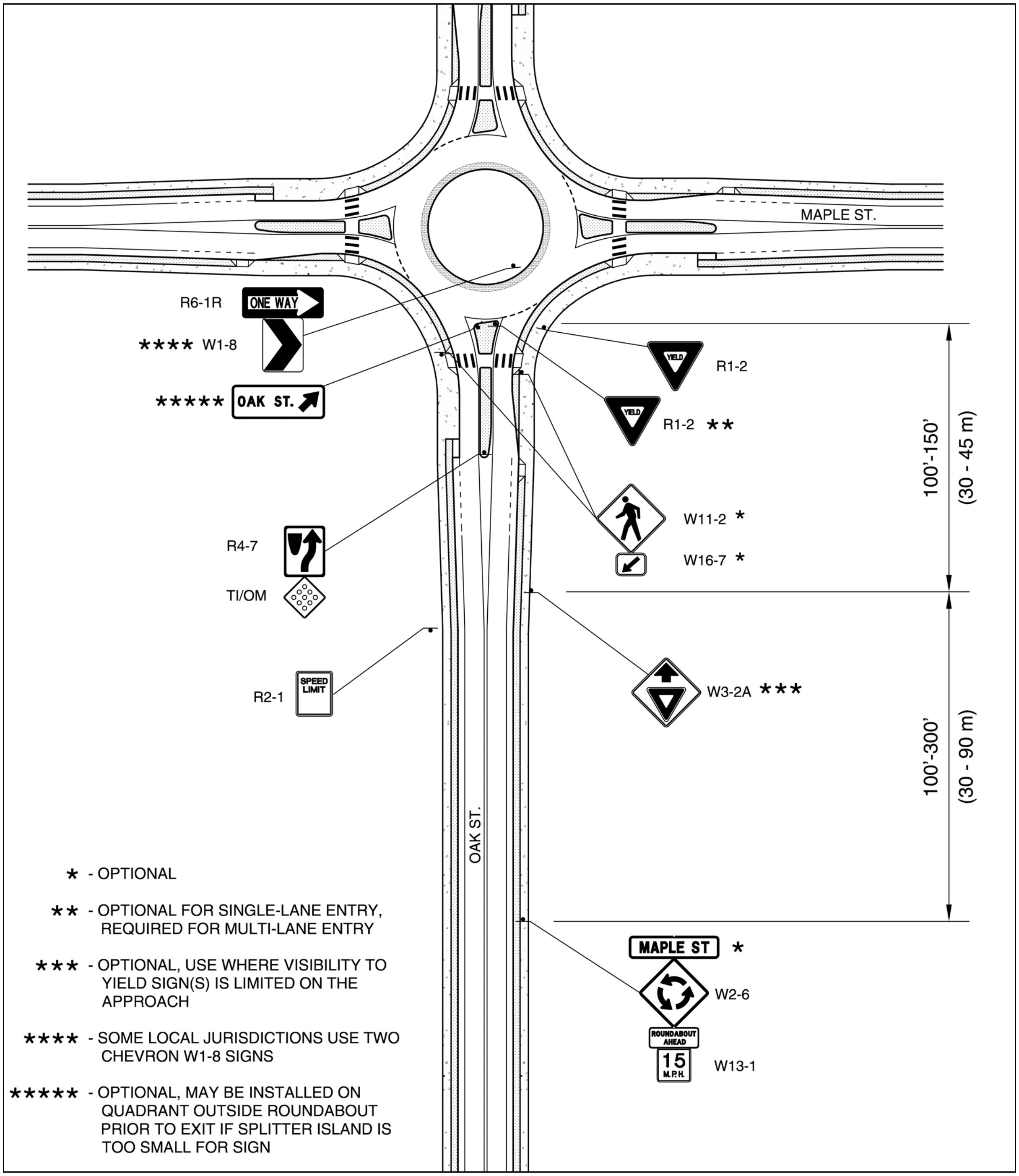
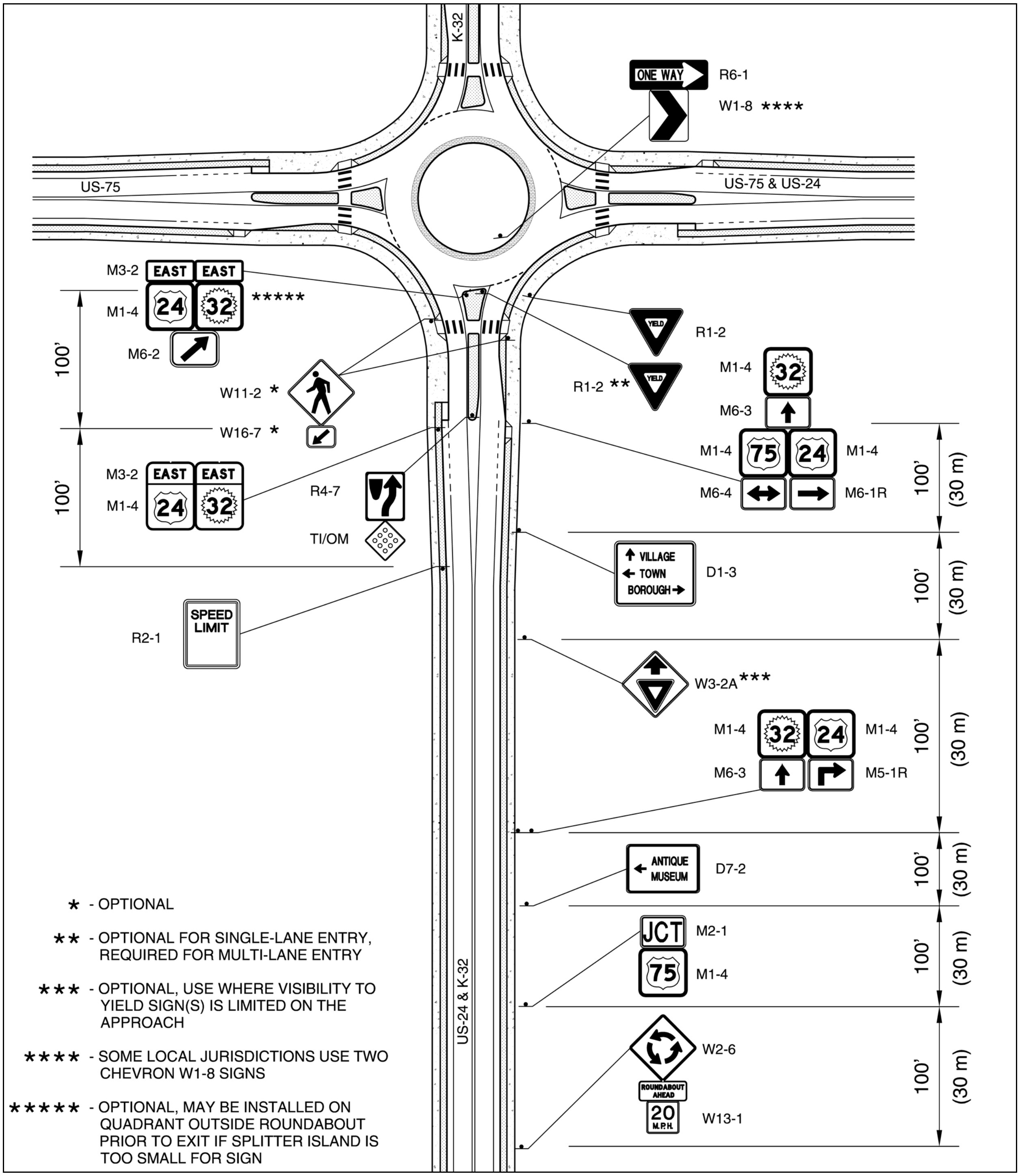


Exhibit 7-2
Typical Signing at Urban Roundabouts on Highway Junctions



* - OPTIONAL

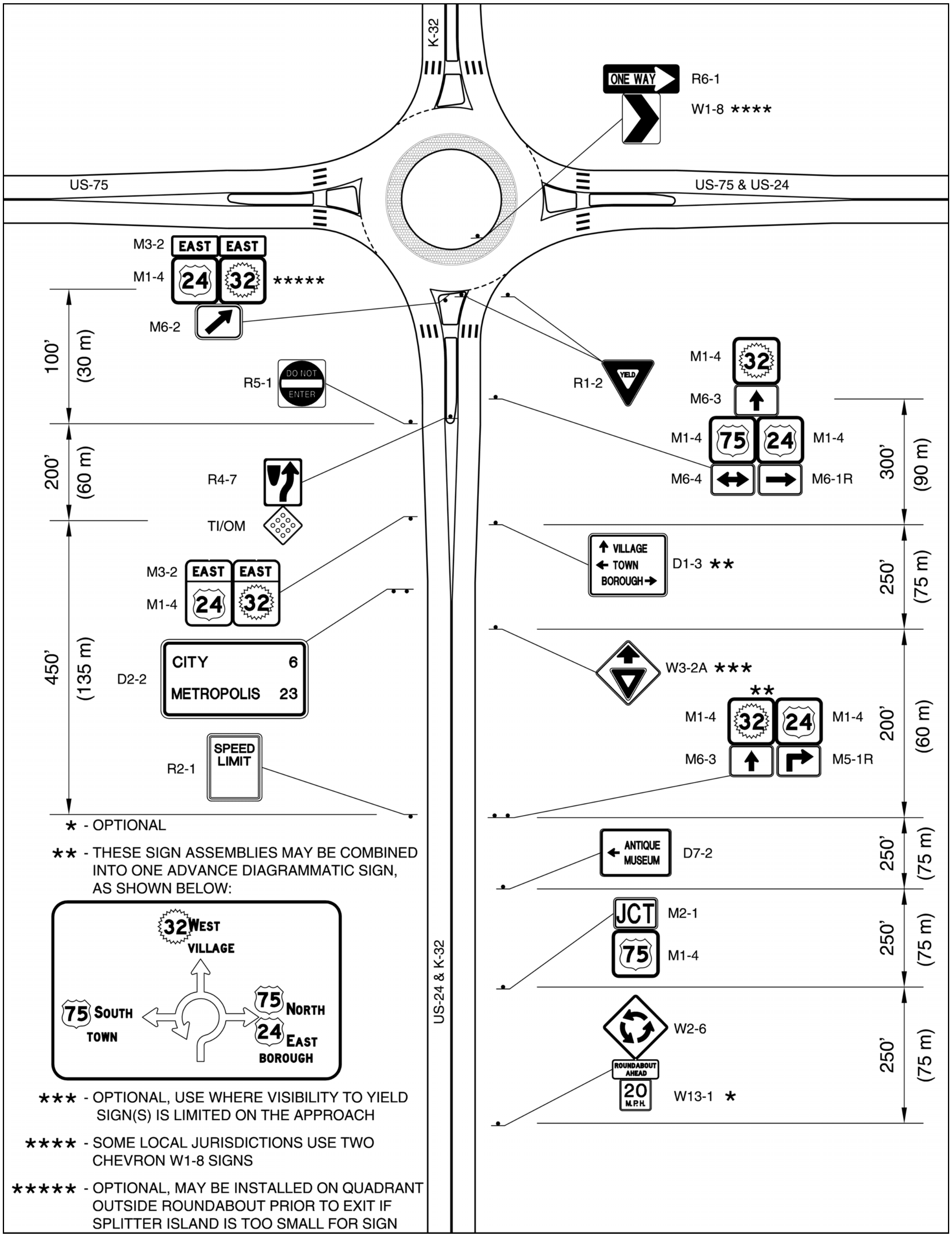
** - OPTIONAL FOR SINGLE-LANE ENTRY, REQUIRED FOR MULTI-LANE ENTRY

*** - OPTIONAL, USE WHERE VISIBILITY TO YIELD SIGN(S) IS LIMITED ON THE APPROACH

**** - SOME LOCAL JURISDICTIONS USE TWO CHEVRON W1-8 SIGNS

***** - OPTIONAL, MAY BE INSTALLED ON QUADRANT OUTSIDE ROUNDABOUT PRIOR TO EXIT IF SPLITTER ISLAND IS TOO SMALL FOR SIGN

Exhibit 7-3
Typical Signing at Rural Roundabouts



As indicated in Exhibit 7-3, diagrammatic guide signs may be used for all rural roundabouts to indicate the upcoming highway junction and to provide directional guidance. In general for urban roundabouts, these large diagrammatic signs are not necessary. However, a diagrammatic sign may be appropriate at an urban intersection with any of the following conditions:

- The intersection is the junction of two major highway routes,
- The signed highway route makes a bend though the roundabout, or
- The intersection layout or signed route configuration is potentially confusing to unfamiliar drivers.

Multilane Considerations

In general, signing at typical multilane roundabouts is essentially the same as at single-lane roundabouts, as shown in Exhibits 7-1 through 7-3. However, supplemental signs may be needed to enhance clarity and guidance for drivers. The primary differences are related to supplemental YIELD signs and lane-use control signs.

YIELD Signs

For roundabout approaches with more than one lane, YIELD signs should be placed on both the left and right side of the approach. The sign on the left side of the approach is located within the splitter island. YIELD signs should be placed to ensure the faces of the signs are not visible to traffic within the circulatory roadway. If the YIELD sign is visible from the circulatory roadway, it may cause circulating vehicles to yield unnecessarily.

For most intersections, the size of the YIELD signs should be 36" x 36" x 36" (914 mm x 914 mm x 914 mm), in accordance with guidelines from the FHWA *Manual on Uniform Traffic Control Devices* (MUTCD). Oversized YIELD signs may be considered in special cases based on MUTCD guidance.

Lane-Use Control Signs

For some multilane roundabouts, lane-use control signs may be needed on one or more approaches. Lane-use controls at roundabouts follow the same general principles as those at conventional intersections. For conventional two-lane approaches, at which through movements can be made from either of the two approach lanes, lane-use control signs are not necessary. This is because the rules of the road at intersections require left-turning traffic to use only the left lane, right-turning traffic to use only the right lane, and through traffic to use both lanes unless official traffic control devices indicate otherwise. However, in cases where the turning movement designations for an approach lane may not meet driver expectancy, lane-use control signs should be used.

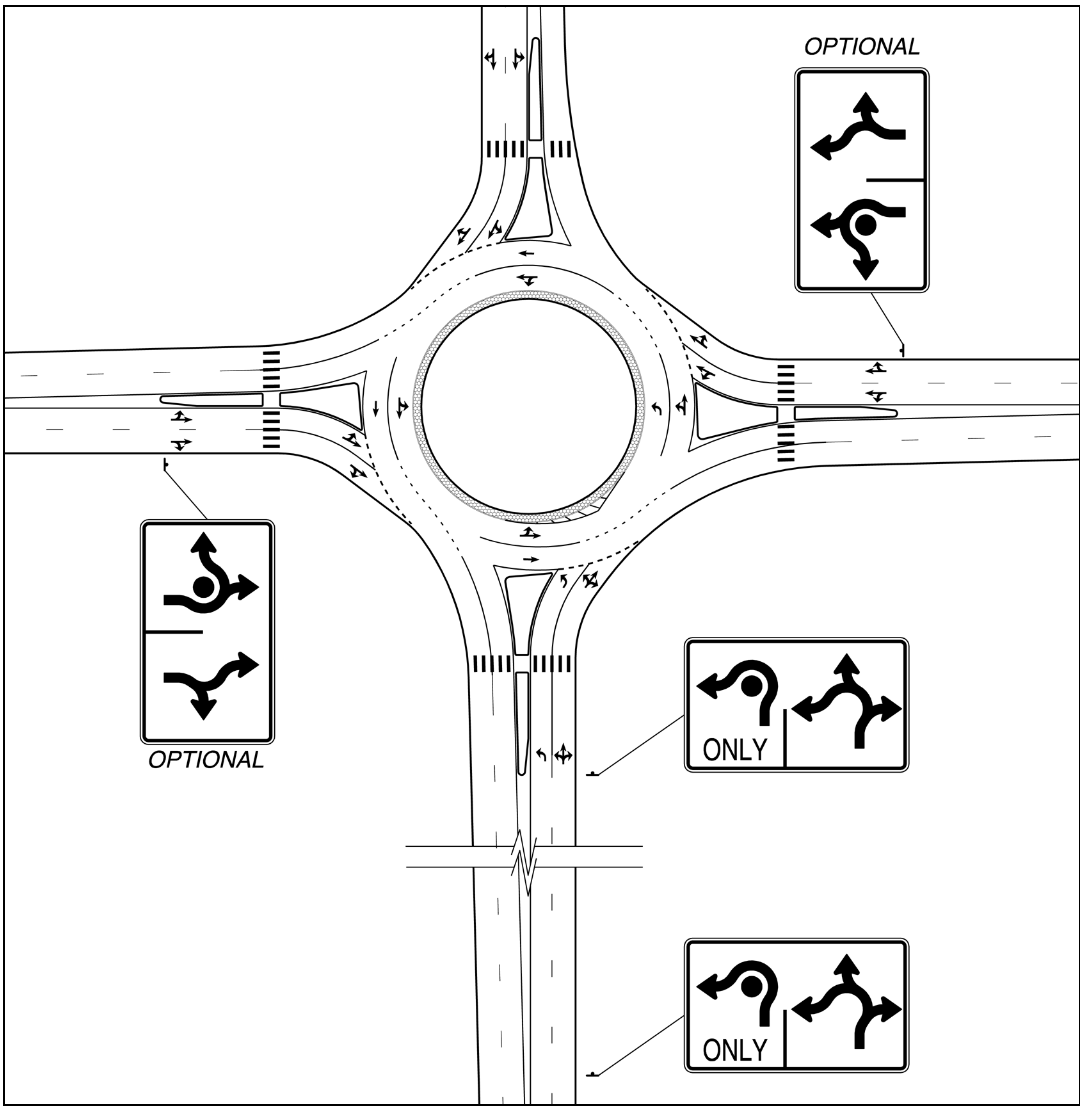
Lane-use control signs should be used for the following conditions:

- Where only a single exit lane is provided opposite two entry lanes, lane use designations should be made to indicate that an entry lane drops as a turning movement.
- Where left- or right- turning traffic demand dictates the need for more than one left turn lane or more than one right turn lane for capacity reasons.

Exhibit 7-4 displays the use of a typical lane-use control sign at a multilane roundabout approach. In the example, the northbound approach consists of two entry lanes, in which left-turns may be made from either lane. The leg directly opposite the northbound entry consists of only one exit lane. Therefore lane-use control signage is necessary to indicate that vehicles in the left-hand entrance lane must exit at the west exit leg (or they may also complete a U-turn), and vehicles in the right-hand entrance lane may exit at the west, north, or east exit legs.

In this example, the eastbound and westbound approaches provide two continuous through lanes (i.e. through movements may be made from either the left-hand or right-hand entrance lanes). Therefore, lane-use control signs are not required on these approaches.

Exhibit 7-4
Example Lane-Use Control Sign at a Multilane Roundabout Approach



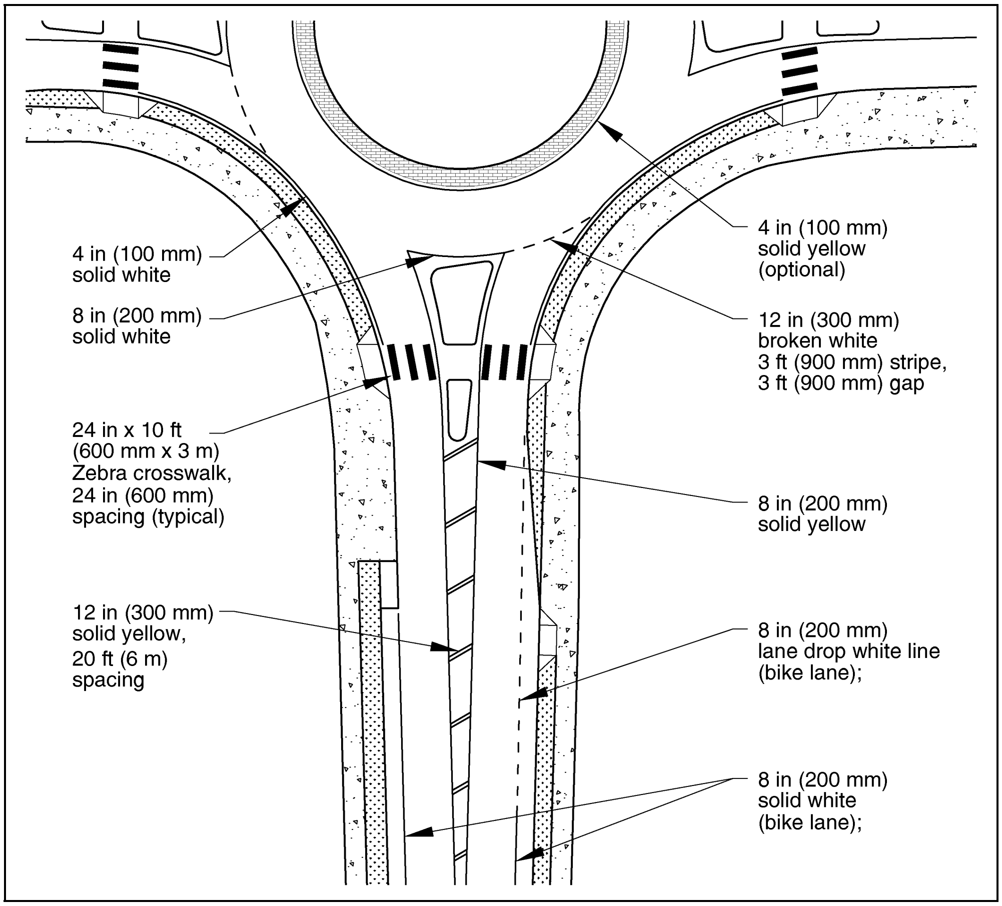
As shown in Exhibit 7-4, the lane-use control signs at roundabouts are similar to lane-use control signs at signalized intersections. However, the arrows are modified to indicate counterclockwise circulation around the central island.

Lane-use control signs should always be used in combination with appropriate circulatory lane striping. Design guidance for circulatory lane striping is provided later in Section 7.2.

7.2 Pavement Markings

Striping and pavement marking specifications for a typical roundabout approach are shown in Exhibit 7-5.

Exhibit 7-5
Pavement Markings at a Typical Roundabout Approach



Note: Standards for cities and other local jurisdictions may vary from KDOT standards.

Multilane Considerations

In general at multilane roundabouts, lane lines should not be striped within the circulatory roadway. This generally promotes more even use of the entry lanes, and it causes entering and circulating drivers to be cognizant of other vehicles in the roundabout. It also encourages large semi-trailers and oversized vehicles to use the entire width of the circulatory, which may reduce the overall width required for the circulatory roadway and truck apron. In some cases, however, providing circulatory lane markings can enhance the capacity or safety of a multilane roundabout.

When circulatory lane markings are considered at a multilane roundabout, two options for the design of these markings are available. These two options are:

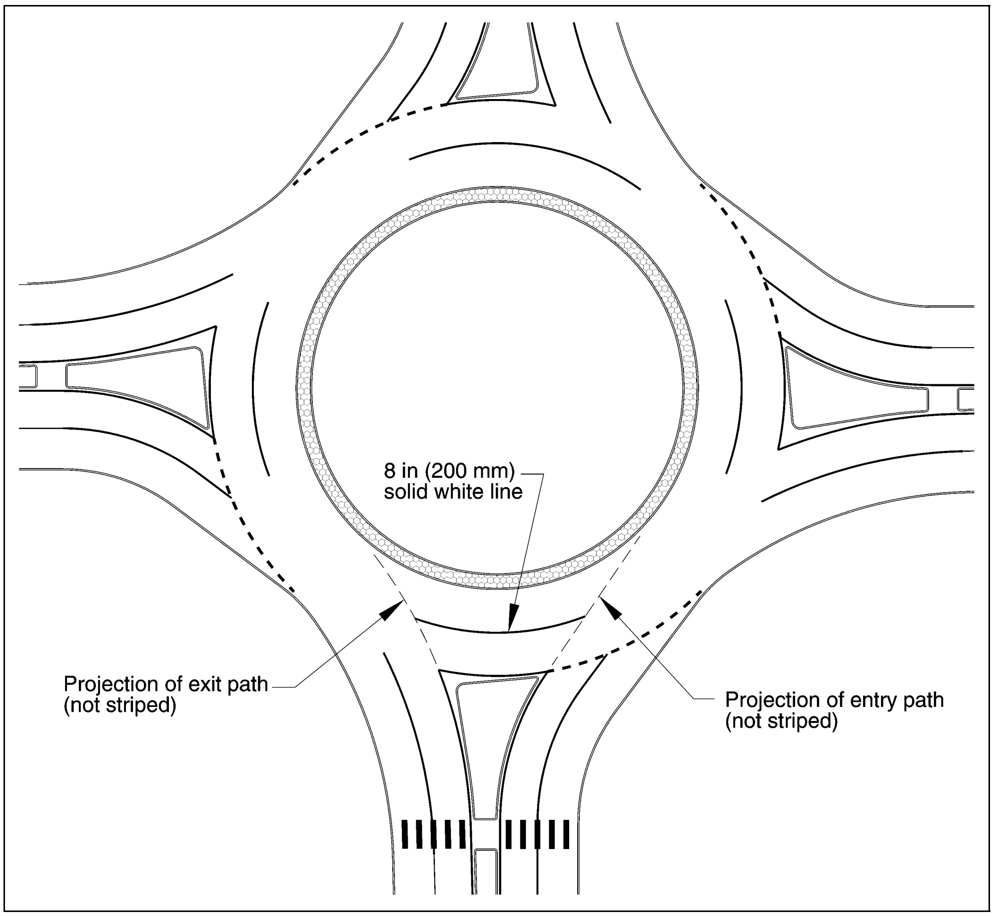
- Partial concentric lane markings, and
- Exit lane markings.

The applications and design details for each of these striping schemes are discussed in the next sections.

Partial Concentric Lane Markings

Partial concentric lane markings consist of a solid white stripe placed at a uniform offset from the central island. The stripe is broken between each entry and the adjacent upstream exit to enable entering and exiting movements. Thus, the lane markings are provided only in front of the splitter islands. Exhibit 7-6 displays an example of partial concentric circulatory lane markings.

Exhibit 7-6
Partial Concentric Circulatory Lane Markings

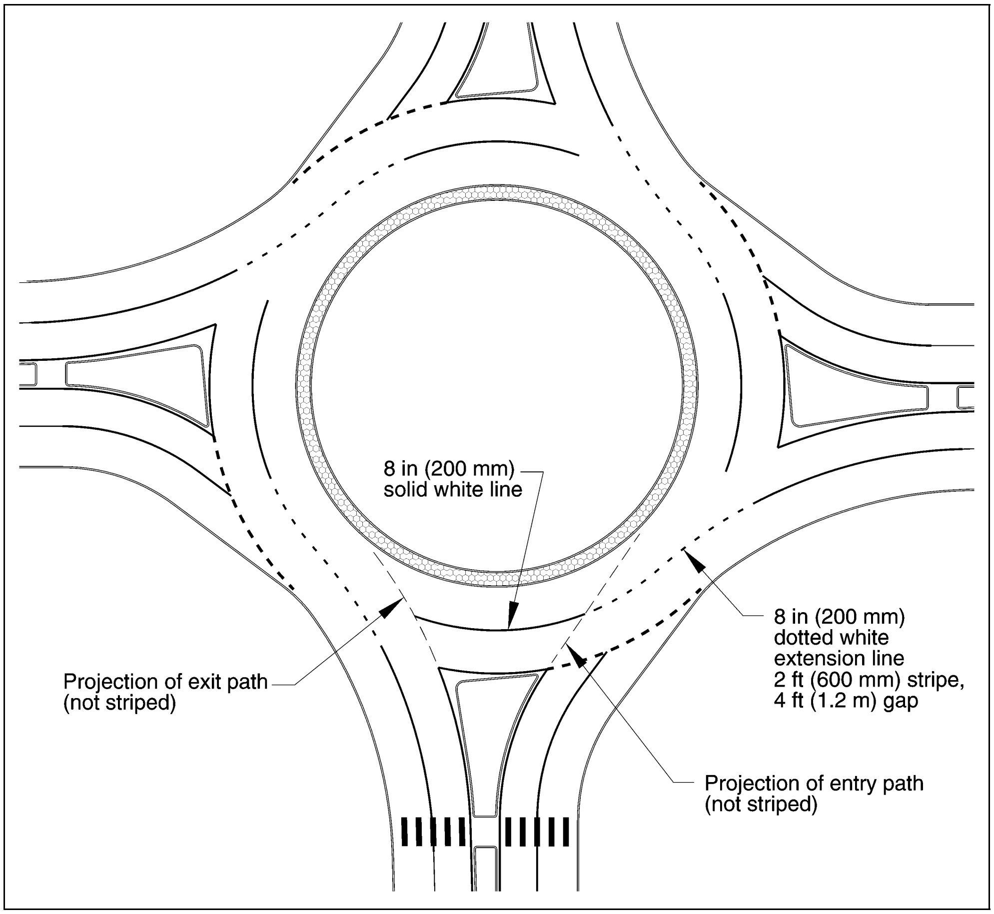


Partial concentric circulatory lane markings can assist drivers in entering into the appropriate circulatory lanes. These markings should be considered at existing roundabouts with a known problem of entering vehicles cutting across the circulatory roadway. In particular, they can be beneficial at roundabouts where vehicles in the right-hand entry lane commonly enter into the inside of the circulatory roadway, cutting in front of vehicles in the left-hand entry lane.

Exit Lane Markings

Exit lane markings (sometimes referred to as “Alberta” markings) consist of solid white lines in front of the splitter islands, as described above for partial concentric lane markings, plus dotted extension lines to direct circulating vehicles into the appropriate exit lane. Similar to the dotted extension line striping within a signalized intersection, the exit extension lines provide clear direction for circulating vehicles but can be crossed by vehicles at the conflicting entrance. Exhibit 7-7 displays an example of a roundabout with exit lane markings.

Exhibit 7-7
Exit Lane Markings



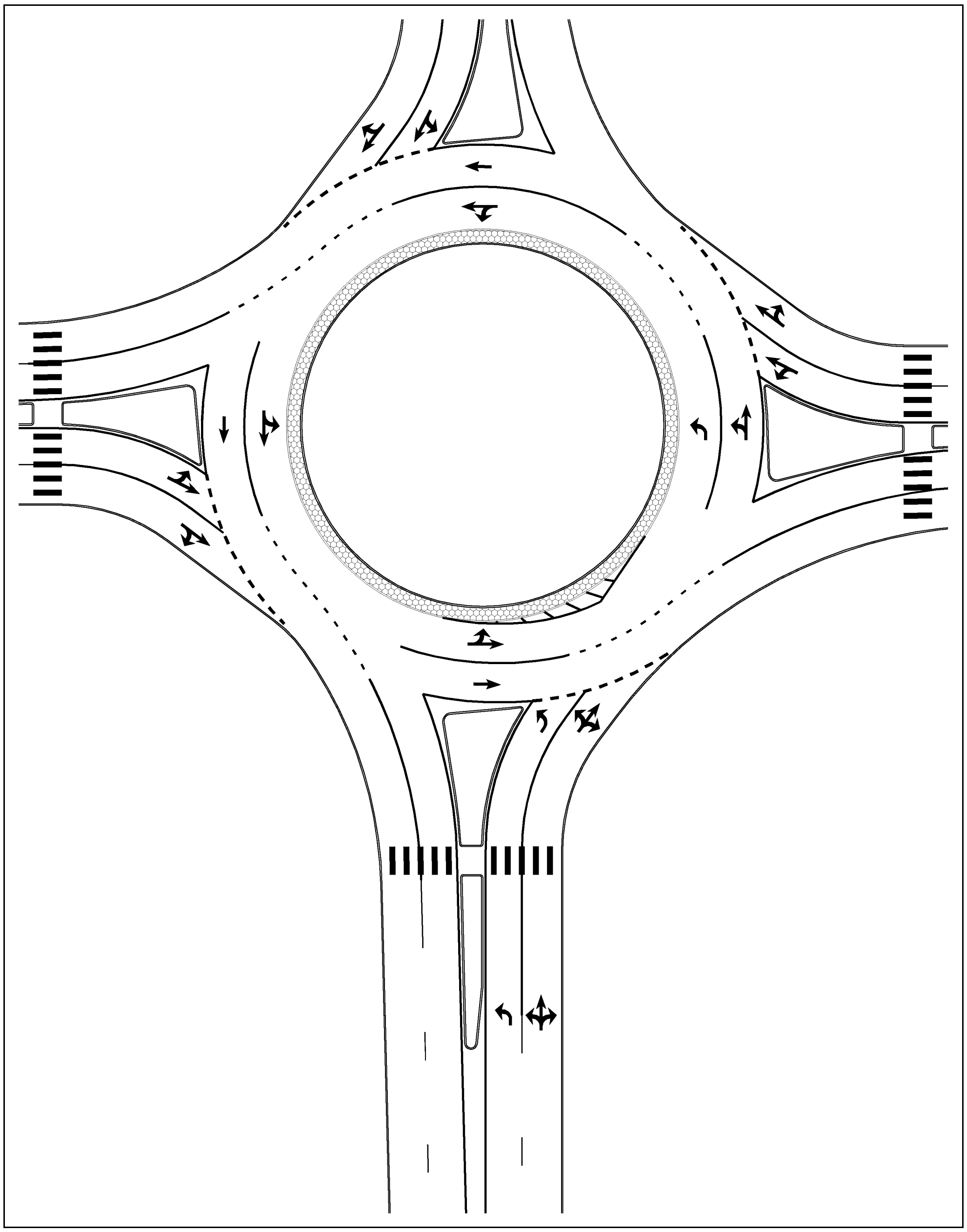
Exit lane markings should be considered at roundabouts with the following conditions:

- A roundabout with a particularly high volume of turning movements at one or more approaches.
- A roundabout with historical safety issues caused by incorrect lane selection at entry or erratic lane changes within the roundabout.
- A roundabout with poor exit geometry that induces vehicle path overlap.

Pavement Marking Arrows

For single-lane roundabouts and conventional double-lane roundabouts, pavement marking arrows are not required. For multilane roundabouts that require lane-use designations (see Section 7.1), pavement marking arrows may be used to denote the designated turning movements of each lane on the approaches and circulatory roadway. Exhibit 7-8 displays a typical use of pavement marking arrows at a double-lane roundabout.

Exhibit 7-8
Pavement Marking Arrows



As shown in Exhibit 7-8, pavement marking arrows are placed on the approach roadway in advance of the roundabout and again immediately behind the entry line (similar to signalized or stop-controlled intersections). Pavement marking arrows may also be used on the circulatory roadway to clarify the designated movements of each circulatory lane. Within the circulatory roadway, a left-turn arrow is used to denote the driver must continue circulating to the left, and a through arrow is used to indicate that the driver must exit at the next exit. A shared left-through arrow is used to indicate the driver may either continue circulating or exit at the next exit.

The use of left-turn arrows for pavement markings is a critically important aspect of properly marking multilane roundabouts. A common concern is that the left turn arrow will induce drivers to turn left into oncoming circulatory traffic. However, a properly designed roundabout has several design elements that make this movement unlikely: (1) an acute turning angle of 120 to 150 degrees; (2) a one-way sign in the central island; (3) a chevron plate in the central island; and (4) pavement arrows on the circulatory roadway. In addition, the presence of circulating vehicles provides a fifth cue of the proper direction of circulation. In the rare event that a vehicle turns left in front of the central island, it almost always happens during times of very low traffic volumes and at low speeds where the consequence of failure is little more than embarrassment to the driver. On the other hand, the failure to include left-turning pavement arrows may result in driver confusion during times of moderate to heavy traffic and more frequent circulating-exit conflicts due to improper lane use (Ref. 4).

In the example design shown in Exhibit 7-8, note that a triangular-shaped hatch pattern is used on the left side of the circulatory roadway opposite the south splitter island to shift the circulatory lanes slightly to the outside. This striping is necessary to guide eastbound left-turn vehicles into the outer circulatory lane (in effect, spiraling them out). Otherwise, they end up being trapped as a U-turn.

7.3 Lighting Guidelines

This section presents recommended guidelines for lighting of roundabouts on facilities within Kansas. The information in this section is based on the following sources:

- FHWA, *Roundabouts: An Informational Guide*, 2000.
- ANSI / IESNA RP-8-00, *American National Standard Practice for Roadway Lighting*, 2000. (Note: The illumination guidance in this document is more current and supercedes the information in FHWA's *Roundabouts: An Informational Guide*.)
- AS/NZS 1158.1.3:1997, *Road lighting*, Australian/New Zealand Standard, 1997.
- Centre d'Etudes sur les Réseaux les Transports, l'Urbanisme et les constructions publiques (CERTU), *L'Éclairage des Carrefours à Sens Giratoire (The Illumination of Roundabout Intersections),* Lyon, France: CERTU, 1991.

General Requirements

Lighting should be provided at all roundabouts, whether in rural or urban settings. The specific lighting requirements for each setting are discussed below. Lighting is required for roundabouts on the Kansas state highway system.

Lighting should be installed and operational before the roundabout is open to traffic. If a portion of the roundabout will be opened to accommodate traffic on a temporary basis, lighting should be provided. If permanent lighting cannot be installed to meet construction schedules, temporary lighting will be allowed, with the approval of the engineer.

Refer to the KDOT *Utility Accommodation Policy* for requirements pertaining to the placement of lighting facilities within the public right-of-way. This policy applies to the location, construction, maintenance, removal and relocation of all private, public and cooperatively owned utilities within the highway rights-of-way under the jurisdiction of the Secretary of the Kansas Department of Transportation (KDOT).

Lighting in Urban and Suburban Areas

The recommended practice for determining proper roadway illumination is provided in ANSI/IESNA RP-8-00, published by the Illuminating Engineering Society of North America. The discussion in this section focuses on the illuminance method, which is commonly used for illumination design at roundabouts. RP-8-00 discusses other methods such as luminance and small target visibility; the reader is encouraged to refer to that document for discussion of those methods, as well as discussion on the proper method to calculate the critical values for each criteria.

The basic principle behind the lighting of roundabouts in urban and suburban areas is that the amount of light on the intersection should be proportional to the classification of the intersecting streets and equal to the sum of the values used for each separate street. In other words, if Street A is illuminated at a level of x and Street B is illuminated at a level of y, the intersection should be illuminated at a level of $x + y$. In addition, RP-8-00 specifies that if an intersecting roadway is illuminated above the recommended value, then the intersection illuminance value should be proportionately increased. Therefore, the illumination design for a roundabout in an urban or suburban area should be designed to properly illuminate the roundabout while being compatible with the illumination levels on approaching roadways.

Exhibit 7-9 presents the recommended illuminance for roundabouts located on continuously illuminated streets. Separate values have been provided for portland cement concrete road surfaces (RP-8-00 Road Surface Classification R1) and typical asphalt road surfaces (RP-8-00 Road Surface Classification R2/R3). Exhibit 7-10 presents the roadway and pedestrian area classifications used for determining the appropriate illuminance levels in Exhibit 7-8. RP-8-00 clarifies that although the definitions given in Exhibit 7-10 may be used and defined differently by other documents, zoning by-laws, and agencies, the area or roadway used for illumination calculations should best fit the descriptions contained in Exhibit 7-10 and not how classified by others (RP-8-00, Section 2.0, p.3). Note that the predominant surface type should be used for illumination calculations; for example, a roundabout with an asphalt concrete circulatory roadway and Portland cement concrete truck apron should be designed using a surface type of R2/R3.

Exhibit 7-9
Recommended Illuminance for the Intersection of Continuously Lighted Urban and Suburban Streets

Pavement Classification[1]	Roadway Classification	Average Maintained Illuminance at Pavement[2] — Pedestrian/Area Classification: High (fc (lux))	Medium (fc (lux))	Low (fc (lux))	Uniformity Ratio (E_{avg}/E_{min})	Veiling Luminance Ratio (L_{vmax}/L_{avg})
R1	Major/Major	2.4 (24.0)	1.8 (18.0)	1.2 (12.0)	3.0	0.3
	Major/Collector	2.0 (20.0)	1.5 (15.0)	1.0 (10.0)	3.0	0.3
	Major/Local	1.8 (18.0)	1.4 (14.0)	0.9 (9.0)	3.0	0.3
	Collector/Collector	1.6 (16.0)	1.2 (12.0)	0.8 (8.0)	4.0	0.4
	Collector/Local	1.4 (14.0)	1.1 (11.0)	0.7 (7.0)	4.0	0.4
	Local/Local	1.2 (12.0)	1.0 (10.0)	0.6 (6.0)	6.0	0.4
R2/R3	Major/Major	3.4 (34.0)	2.6 (26.0)	1.8 (18.0)	3.0	0.3
	Major/Collector	2.9 (29.0)	2.2 (22.0)	1.5 (15.0)	3.0	0.3
	Major/Local	2.6 (26.0)	2.0 (20.0)	1.3 (13.0)	3.0	0.3
	Collector/Collector	2.4 (24.0)	1.8 (18.0)	1.2 (12.0)	4.0	0.4
	Collector/Local	2.1 (21.0)	1.6 (16.0)	1.0 (10.0)	4.0	0.4
	Local/Local	1.8 (18.0)	1.4 (14.0)	0.8 (8.0)	6.0	0.4

Notes: [1] R1 is typical for portland cement concrete surface; R2/R3 is typical for asphalt surface

[2] fc = footcandles

Source: ANSI / IESNA RP-8-00 Table 9 (for R2/R3 values); R1 values adapted from Table 2

Exhibit 7-10
ANSI / IESNA RP-8-00 Guidance for Roadway and Pedestrian/Area Classification for Purposes of Determining Intersection Illumination Levels

Roadway Classification	Description	Daily Vehicular Traffic Volumes[1]
Major	That part of the roadway system that serves as the principal network for through-traffic flow. The routes connect areas of principal traffic generation and important rural roadways leaving the city. Also often known as "arterials," thoroughfares," or "preferentials."	over 3,500 ADT
Collector	Roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial, and industrial areas. They do not handle long, through trips.	1,500 to 3,500 ADT
Local	Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property.	100 to 1,500 ADT
Pedestrian Conflict Area Classification	**Description**	**Guidance on Pedestrian Traffic Volumes[2]**
High	Areas with significant numbers of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals.	over 100 pedestrians/hour
Medium	Areas where lesser numbers of pedestrians use the streets at night. Typical are downtown office areas, blocks with libraries, apartments, neighborhood shopping, industrial, older city areas, and streets with transit lines.	11 to 100 pedestrians/hour
Low	Areas with very low volumes of night pedestrian usage. These can occur in any of the cited roadway classifications but may be typified by suburban single family streets, very low density residential developments, and rural or semi-rural areas.	10 or fewer pedestrians/hour

Notes: [1] For purposes of intersection lighting levels only

[2] Pedestrian volumes during the average annual first hour of darkness (typically 18:00-19:00), representing the total number of pedestrians walking on both sides of the street plus those crossing the street at non-intersection locations in a typical block or 656 ft (200 m) section. RP-8-00 clearly specifies that the pedestrian volume thresholds presented here are a local option and should not be construed as a fixed warrant.

Source: ANSI / IESNA RP-8-00 Sections 2.1, 2.2, and 3.6

Lighting in Rural Areas

Exhibit 7-11 provides recommended illuminance levels for rural isolated intersections with unlit approaches.

Exhibit 7-11
Recommended Illuminance for the Intersection of Unlit Rural Roadways

Pavement Classification[1]	Average Maintained Illuminance at Pavement[2] (fc (lux))	Uniformity Ratio (E_{avg}/E_{min})	Veiling Luminance Ratio (L_{vmax}/L_{avg})
R1	0.6 (6.0)	4.0	0.3
R2/R3	0.9 (9.0)	4.0	0.3

Notes: [1] R1 is typical for Portland cement concrete surface; R2/R3 is typical for asphalt surface
[2] fc = footcandles

Source: ANSI / IESNA RP-8-00 Table D1

Equipment Type and Location

A photometric analysis is required to determine luminaire wattage, mounting height, luminaire arm length, and pole placement at a roundabout. In general, the use of fewer luminaires with higher wattage mounted on traditional luminaire arms ("cobra-style") is preferable to minimize the number of fixed objects in the public right-of-way, provided that the illuminance requirements identified above are met. However, in urban areas where high pedestrian activity is expected or desirable, pedestrian-level illumination at lower mounting heights is often more consistent with urban design goals and should be considered. These types of luminaires may need to be supplemented by strategically located traditional cobra-style luminaires to provide adequate lighting at key conflict areas. Exhibit 7-12 provides a sample of typical types of illumination equipment, including typical wattage levels, distributions, and mounting heights.

Exhibit 7-12
Sample of Typical Illumination Equipment Types Used at Roundabouts

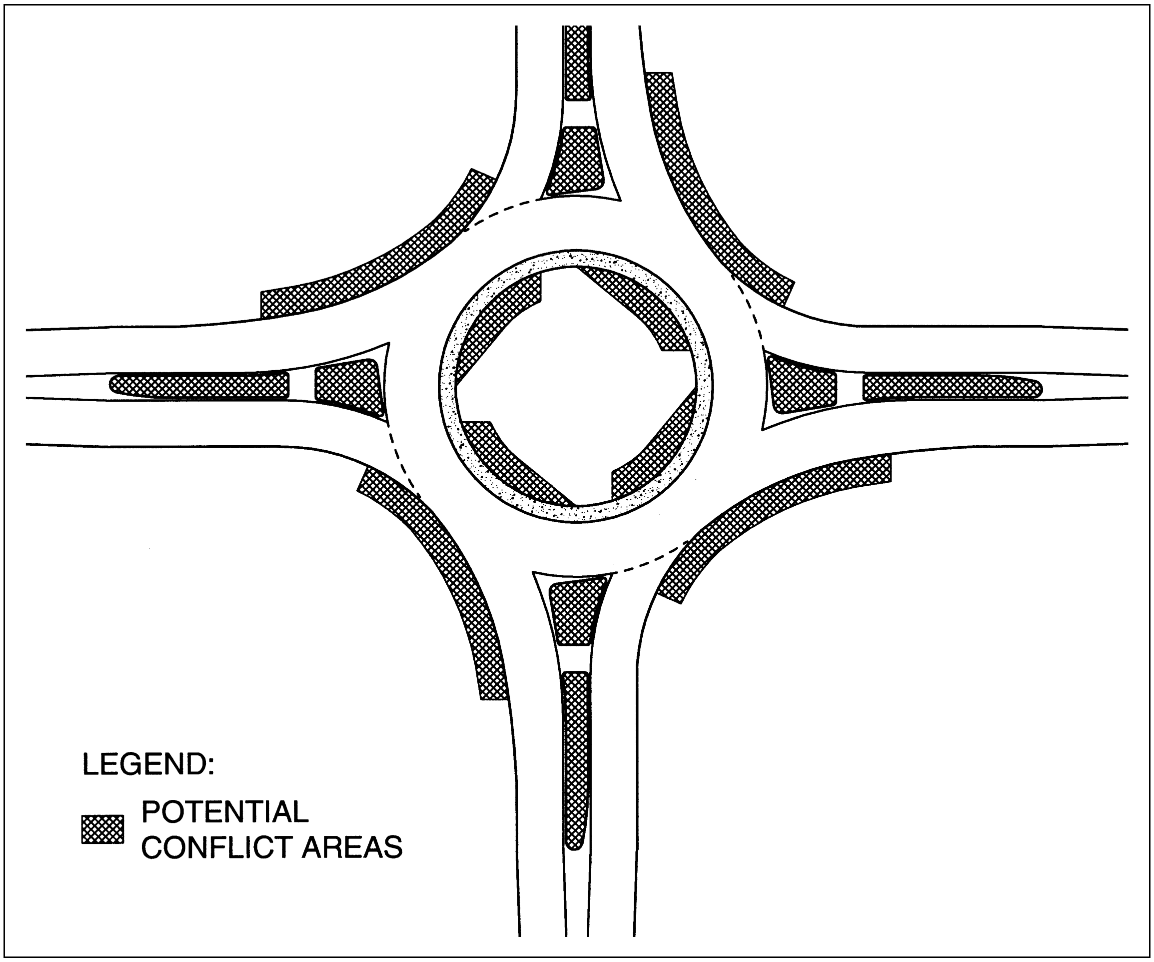
Type	Typical Luminaire	Typical Distribution	Typical Mounting Height
Cobra-style	75 W – 400 W HPS	Type II or III, full or semi cutoff	30 to 50 ft (9 to 15 m)
Pedestrian-level	75 W – 200 W HPS	Type V (360° spread)	14 to 20 ft (4 to 6 m)
High-mast	400 W-1000 W HPS	Type V (360° spread)	50 to 100 ft (15 to 30 m)

Notes: W = watt; HPS = High Pressure Sodium. No representation is made regarding what may be acceptable for a particular project; consult the appropriate agencies and/or power company as appropriate.

The position of lighting poles relative to the curbs at a roundabout is governed in part by the speed environment in which the roundabout is located and the potential speeds of errant vehicles that can be reasonably expected. For installations on rural arterials and high-speed rural collectors, the AASHTO *Roadside Design Guide* should be referenced. For installations on low-speed rural collectors and rural local roads, a minimum clear-zone width of 10 ft (3.0 m) should be provided (AASHTO Green Book, pp. 322-323). For installations on urban arterials, collectors, and local streets where curbs are used, a clearance between curb face and lighting pole of 1.5 ft (0.5 m) should be provided as a minimum, with additional separation desirable. For areas within or on the approach to a roundabout where the overhang of a turning truck could strike a lighting pole, a minimum offset distance of 3 ft (1.0 m) should be provided (AASHTO Green Book, pp. 485-486).

Exhibit 7-13 suggests critical conflict areas where run-off-the-road crashes are most prevalent at roundabouts. In these areas, lighting poles should be placed as far back from the curb face as practical. In rural areas where pedestrian activity is low, breakaway pole bases are required for poles located in these critical areas.

Exhibit 7-13
Critical Conflict Areas Affecting Lighting Pole Placement



Source: Adapted from AS/NZS 1158.1.3:1997, Road lighting, Australian/New Zealand Standard, 1997, Figure 8.2, p. 39.

Roundabouts can be illuminated from a set of luminaires in the middle of the central island, from luminaires arrayed around the periphery of the roundabout, or by a combination of the two. Exhibit 7-14 provides a summary of the key advantages and disadvantages of central and peripheral illumination. In general, illumination from the periphery of the roundabout is recommended due to a greater ability to provide maximum illumination at key conflict areas.

Exhibit 7-14
Summary of Key Advantages and Disadvantages of Central and Peripheral Illumination at Roundabouts

Illumination Type	Advantages	Disadvantages
Central illumination	• Assists in perception of the roundabout at a distance by illuminating the central island • Requires fewer poles to achieve same illumination • Pole in central island is clear of critical conflict areas for all but the smallest of roundabouts • Exit guide signs on the periphery appear in positive contrast (frontlit) and thus are clearly visible	• Illumination is weakest in critical pedestrian and bicycle areas • Signs on the approach are in negative contrast (backlit) • A path is needed to the base of the central pole for maintenance • There is a greater risk of glare • The central pole affects central island landscaping plan • High mast lighting may be inappropriate in urban areas, especially residential areas
Peripheral illumination	• Illumination can be strongest around critical bicycle and pedestrian areas. • Maintains a continuity of poles and luminaires for the illumination of the lanes, as well as good visual guidance on the circulatory roadway • Approach signs appear in positive contrast and thus are clearly visible • Maintenance of luminaires is easier due to curbside location	• Illumination is weakest in central island, which may limit visibility of roundabout from a distance • Requires more poles to achieve same illumination level • Poles may need to be located in critical conflict areas to achieve illumination levels and uniformity

Source: Adapted from: Centre d'Etudes sur les Réseaux les Transports, l'Urbanisme et les constructions publiques (CERTU), *L'Éclairage des Carrefours à Sens Giratoire (The Illumination of Roundabout Intersections),* Lyon, France: CERTU, 1991, with additions by the authors.

Sample Illumination Layouts

The following three exhibits present some sample illumination plans demonstrating layouts using various types of luminaires. Each illumination plan has been customized to the specific geometry of the roundabout, photometric requirements, equipment options, and site constraints. Therefore, the reader is urged to exercise considerable caution if attempting to adapt one or more of these plans to another location.

Exhibit 7-15
Example of Illumination Using Cobra-Style Luminaires

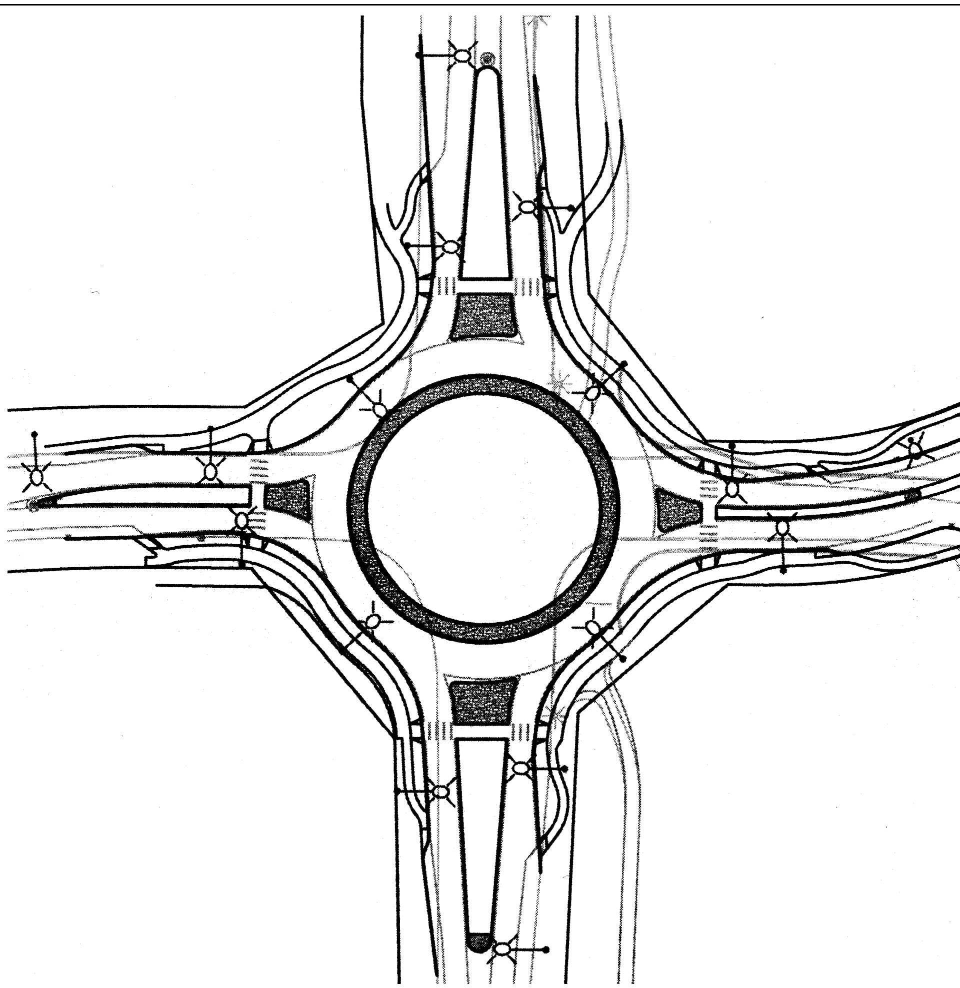
Inscribed Circle Diameter:	190 ft (58 m)
Equipment:	Luminaires over circulatory roadway: 400 W HPS, Type M-C-III, 37 ft (11.2 m) mounting height Remainder: 200 W HPS, Type M-C-III, 35 ft (10.7 m) mounting height
Photometric Requirements:	Avg. illuminance: 2.6 fc (26 lux) Avg./min. uniformity: 3:1
Layout:	

Exhibit 7-16
Example of Illumination Using Pedestrian-Level Luminaires

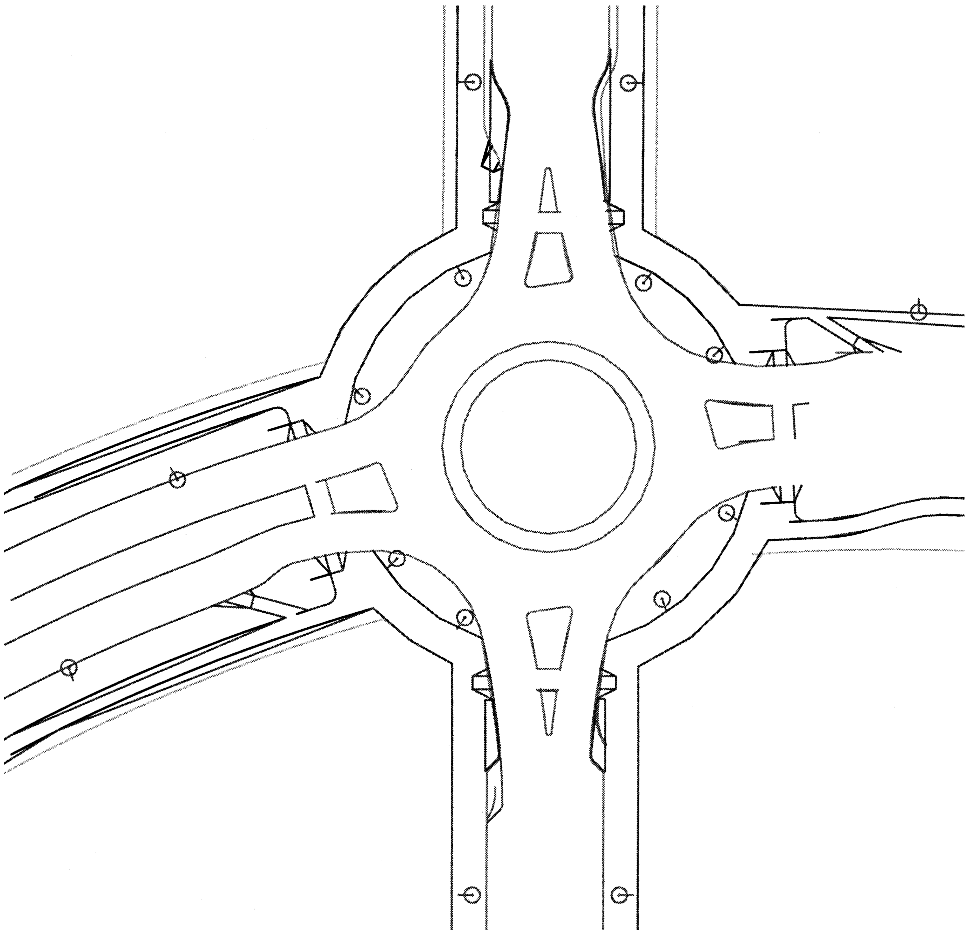
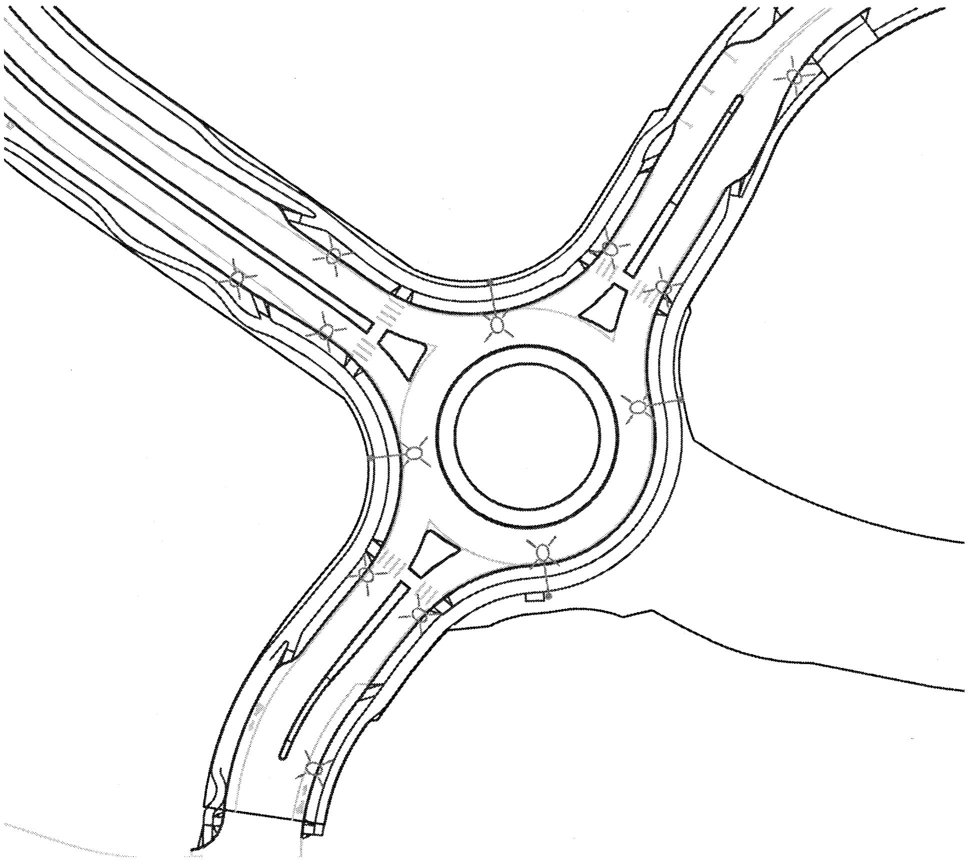
Inscribed Circle Diameter:	120 ft (37 m)
Equipment:	Pedestrian-level luminaires: 250 W HPS, Type V, 18 ft (5.5 m) mounting height
Photometric Requirements:	Avg. illuminance: 2.7 fc (27 lux) Avg./min. uniformity: 3:1
Layout:	

Exhibit 7-17
Example of Illumination Using a Mix of Cobra-Style and Pedestrian-Level Luminaires

Inscribed Circle Diameter:	140 ft (43 m)
Equipment:	Cobras over circulatory roadway: 200 W HPS, Type M-C-III, 30 ft (9.1 m) mounting height Pedestrian-level luminaires: 200 W HPS, Type V,14 ft (4.3 m) mounting height
Photometric Requirements:	Avg. illuminance: 2.0 fc (20 lux) Avg./min. uniformity: 3:1
Layout:	

7.4 References

1. MUTCD Millennium Edition – Proposed Revision No. 2, May 21 2001.

2. The Highways Agency (United Kingdom). Design of Road Markings at Roundabouts. TA 78/97

3. Queensland Department of Main Roads. Traffic Engineering Manual – Pavement Marking Technical Guideline, Section 4.6 Pavement Marking of Multilane Roundabouts. March 1998

4. Adapted from material presented by Barry Crown at meeting of Roundabout Task Force, Markings Technical Committee, National Committee on Uniform Traffic Control Devices, Savannah, GA, June 2003

Chapter 8 - System Considerations

8.1 Proximity to Other Traffic Control Devices

Due to the close spacing of intersections in many urban and suburban areas, roundabouts are often considered for locations near other activities such as unsignalized intersections, signalized intersections, railroad crossings, and parking areas. One of the principle measures to identify this spacing is an estimate of queuing. This section provides a brief discussion of queuing, followed by a discussion of locating roundabouts in each of these locations.

Queuing at Roundabouts

Queuing is an important measure of the performance of a roundabout and how other intersections perform in close proximity to it. A downstream queue that extends into a roundabout impedes circulating flow. As circulating flow is impeded, exits upstream of the impeded exit become blocked, further increasing the queuing within the circulatory roadway. In theory, an entire roundabout could become jammed if an exit is blocked for a sufficient period of time. In addition, queue spillback into a roundabout reduces the overall capacity of each approach that is blocked. Therefore, it is generally preferred to avoid having downstream queues back up into a roundabout for any significant period of time.

The principal measure to determine how close a roundabout should be located to a stop-controlled intersection is the amount of queuing expected at each intersection. The HCM 2000 provides procedures for estimating queues at stop-controlled intersections and should be used to make this assessment. For roundabouts, either the estimation procedures in Chapter 4 of this guide, FHWA's *Roundabouts: An Informational Guide,* or estimates provided by software should be used. In general, it is desirable for the 95th-percentile queue to be completely accommodated within the space between the two intersections. The 95th-percentile queue at an unsignalized intersection represents the percent of time during the peak period being analyzed (typically the peak fifteen minutes of the peak hour) that the queue will be equal to or less than the percentile estimate. For example, a 95th-percentile queue of 8 vehicles during the peak period means that during the peak period the queue will exceed 8 vehicles only 5 percent of the time.

Queuing estimates for a signalized intersection appear to be similar to those for unsignalized intersections but are actually quite different. As noted above, a 95th-percentile queue estimate for an unsignalized intersection represents a queue that will not be exceeded for *95 percent of the time period* being studied. A 95th-percentile queue estimate for a signalized intersection typically represents a queue length that will not be exceeded for *95 percent of the signal cycles* during the time period being studied. Because the maximum back of queue at a signalized intersection only occurs once each signal cycle and because the 95th-percentile queue occurs for only a small fraction of those cycles, it has less of an impact than the 95th-percentile estimate for unsignalized intersections.

Unsignalized intersections

This section discusses the case where the roadway approaching or departing the roundabout is interrupted by a stop sign. A common case is an all-way stop-controlled intersection, although it could be a two-way stop-controlled intersection with a higher-level roadway. Other cases involving two-way stop-controlled intersections where the major roadway is uninterrupted or cases involving other roundabouts are discussed in subsequent sections.

Stop-controlled intersections near a roundabout primarily influence a roundabout through queuing effects. In general, it is best for the 95th-percentile queue between a roundabout and a stop-controlled intersection to be completely contained between the two intersections. It is also best for the 95th-percentile queue from a stop-controlled intersection to end short of the crosswalk area of a roundabout to avoid creating additional potential driver distractions that may compromise pedestrian safety.

Signalized intersections

Signalized intersections can influence a roundabout in several ways:

- *Queuing effects.* For signalized intersections, it is best for the 95th-percentile queue from a signalized intersection to not back up into the roundabout. However, because such backups are infrequent and momentary (as discussed above), it may be acceptable in highly constrained locations to allow these momentary backups into the roundabout. This should only be done in areas where the downstream signal is operating below capacity and can reliably flush out any queue that builds within the signal cycle and where the unblocked capacity of the roundabout is sufficient to accommodate the loss of capacity during these blocked periods.
- *Platooned arrival patterns.* Signalized intersections create platooned arrival patterns at a roundabout. As noted in Section 8.5.1 of *Roundabouts: An Informational Guide*, the platooned arrivals from a nearby signal at a roundabout can increase a roundabout's capacity due to a regular pattern of gaps in traffic that can be used efficiently. The isolated analyses discussed in Chapter 4 will therefore be conservative; simulation could be used to more precisely estimate the effect.
- *Signal preemption and priority.* A roundabout cannot be preempted or give priority to certain vehicles. If a traffic signal is preempted frequently, queues from the signal backing towards the roundabout may be larger than estimated using the above procedures.

Rail crossings

This section discusses the situation where rails cross one of the approaches to a roundabout (see Exhibit 8-2 of *Roundabouts: An Informational Guide*) and crossing gates are warranted. In such cases, the rail crossing itself is typically gated. The question is whether the crossing gates on the affected approach are sufficient (Case (a) in FHWA Exhibit 8-2) or whether each approach to the roundabout needs to be gated (Case (b) in FHWA Exhibit 8-2). The primary issue that affects this question is one of safety: what is the likelihood of a queue from the roundabout extending over the tracks, and what ability is there to clear the tracks before an oncoming train arrives? The secondary issue is one of operations: what is the likelihood that a queue at the rail crossing will back up into the roundabout?

The following items provide guidance on this analysis:

- If the 95th-percentile queues between the rail crossing and roundabout can be completely contained between the two facilities, only the rail crossing needs to be gated. This can occur where the rail crossing is located far enough from the roundabout or where traffic volumes on the affected roadway are low.
- If the 95th-percentile queue on the affected approach entering the roundabout enters the rail crossing area, then the entire roundabout should be considered for gates. Gating all approaches to the roundabout except for the approach with the rail crossing will clear out the circulatory roadway and allow the critical approach to flush out. The advance timing for lowering the gates should be based on the time needed to flush out the circulatory roadway and clear the queue. Alternatively, the circulatory roadway could be gated immediately upstream of the critical approach if it can be demonstrated that it results in better operation.
- If the 95th-percentile queue from the rail crossing backs up into the roundabout, full gating of the roundabout may not be necessary if the queuing is tolerable. This type of queue spillback occurs frequently at other types of intersections near rail crossings and therefore may be generally tolerated by the public.

Parking

Parking maneuvers near a roundabout can create momentary congestion. At a minimum, parallel parking spaces should be located no closer than 30 ft (9.1 m) from the crosswalk to allow parking to take place without affecting pedestrian circulation. If traffic volume on the street is high and/or parking turnover is frequent, an analysis could be conducted to determine how often parking conflicts would occur, how long traffic is disrupted during each parking maneuver, and what length of queue will form. The proximity of parking to the roundabout could then be adjusted further away from the roundabout if closer proximity creates intolerable queuing conditions.

8.2 Access Management

Access management at roundabouts follows many of the principles used for access management at conventional intersections.

For public and private access points near a roundabout, two scenarios commonly occur:

- Access into the roundabout itself
- Access near the roundabout

Access into the Roundabout

In general, it is preferable to avoid locating driveways where they must take direct access to a roundabout. Driveways introduce conflicts into the circulatory roadway, including acceleration and deceleration. Traditional driveway designs do not discourage wrong way movements as a splitter island does.

Nonetheless, site constraints sometimes make it necessary to consider providing direct access into a roundabout. Exhibit 8-1 and 8-2 show examples where one or two residential houses have been provided direct access into a roundabout. These driveways have been designed with traditional curb cuts to provide a clear visual and tactile indication that these are private driveways not to be confused with public roadways.

Exhibit 8-1
Example of Single Residential Driveway into Circulatory Roadway
(Santa Barbara, California)

Exhibit 8-2
Example of Shared Residential Driveway into Circulatory Roadway
(Portland, Oregon)

For a driveway to be located where it takes direct access to the circulatory roadway of a roundabout, it should satisfy the following criteria:

- No alternative access point is reasonable.
- Traffic volumes are sufficiently low to make the likelihood of errant vehicle behavior minimal. Driveways carrying the trip generation associated with a very small number of single-family houses are typically acceptable; driveways with higher traffic volumes should be designed as a regular approach with a splitter island. In addition, if a high proportion of unfamiliar drivers are expected at the driveway, the designer should consider providing more positive guidance.
- The driveway design should enable vehicles to exit facing forward with a hammerhead design or other area on-site where vehicles can turn around. Driveways that only allow backing maneuvers into the roundabout should be discouraged.

Access near the Roundabout

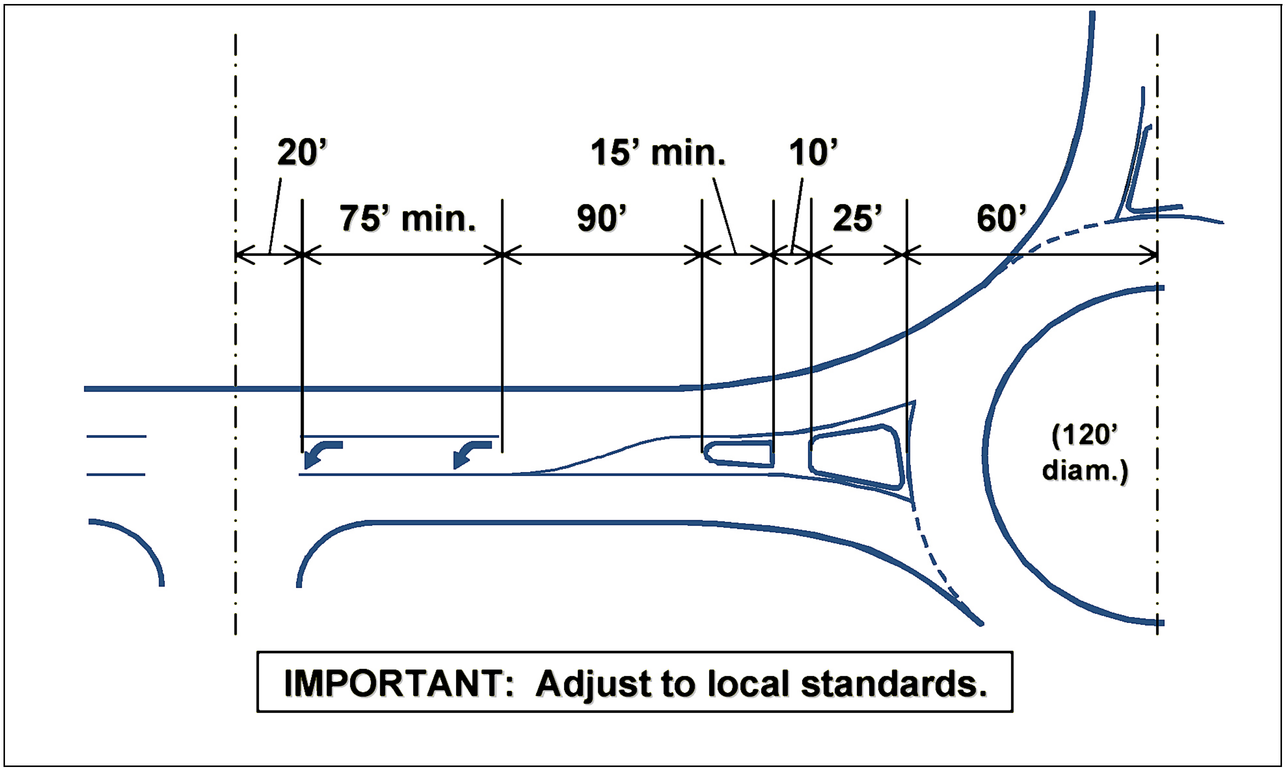
Public and private access points near a roundabout often have restricted operations due to the channelization of the roundabout.

- Driveways between the crosswalk and entrance line should be strongly discouraged. Driveways in this area complicate the pedestrian ramp treatments and introduce conflicts in an area critical to roundabout operations.
- Driveways in the vicinity of the splitter island will be restricted to right-in/right-out operation.

The ability to provide an access point that allows all ingress and egress movements (hereafter referred to as *full access*) is governed by a number of factors:

- *The capacity of the minor movements at the access point.* A standard unsignalized intersection capacity analysis should be performed to assess the operational effectiveness of an access point with full access. Unlike the platooned flow typical downstream of a signalized intersection, traffic passing in front of an access point downstream of a roundabout will be more randomly distributed. As a result, an access point downstream of a roundabout may have less capacity and higher delay than one downstream of a traffic signal.
- *The need to provide left-turn storage on the major street to serve the access point.* It is usually desirable to provide separate left-turn storage for access points downstream of a roundabout to minimize the likelihood that a left-turning vehicle will block the major street traffic flow. If quantification is desired, a probability analysis can be used to determine the likelihood of an impeding left-turning vehicle, and a queuing analysis can be used to determine the length of the queue behind the impeding left-turning vehicle. If the number of left-turning vehicles is sufficiently small and/or the distance between the access point and the roundabout is sufficiently large, a left-turn pocket may not be necessary.
- *The available space between the access point and the roundabout.* Exhibit 8-3 presents a figure showing typical dimensions associated with a roundabout and left-turn storage for a downstream minor street. As the figure demonstrates, a minimum distance is required to provide adequate roundabout splitter island design and left-turn pocket channelization. In addition, access is restricted along the entire length of the splitter island and left-turn pocket channelization.

Exhibit 8-3
Typical Dimensions for Left Turn Access Near Roundabout



8.3 Roundabouts in Series

Roundabouts installed in series can present a variety of opportunities and challenges along a corridor. Exhibit 8-4 presents an example of a corridor in the United States where a series of roundabouts have been employed.

Exhibit 8-4
Roundabouts in Series (Avon, Colorado)

Roundabouts in a series can create a number of opportunities:

- Roundabouts facilitate U-turns between intersections. Driveways with restricted access can often be served more efficiently when located between roundabouts than between traffic signals due to more efficient U-turn movements. This may support an overall access management policy for the corridor.
- Roundabouts may forestall the need to widen the roadway between roundabouts (the "wide nodes, narrow roads" concept).

However, these opportunities come with a number of challenges:

- As noted in the previous section, driveways between roundabouts will generally operate with a lower capacity and higher delay due to the higher degree of randomness in headways along the major street. Downstream of a traffic signal, platooned discharge creates periods between platoons where gaps are more plentiful. Therefore, it may be necessary to restrict some driveway movements and rely on U-turns at the roundabouts to achieve acceptable operations.
- Signal preemption and priority is not possible with a series of roundabouts.
- Delay may be higher for through traffic due to the inability to provide platoon progression as with coordinated traffic signals.

Appendix A – Literature Search and State of the Practice Review

Literature Search and State-of-the-Practice Review

This appendix summarizes current guidelines and policy documents prepared by other states for the analysis, design, and selection of roundabouts. Based on a survey of practitioners conducted by the New York State Department of Transportation and our own database of state-of-the-practice reference materials, the following states had formal guidelines related to roundabouts at the time this document was prepared:

- Maryland
- Florida
- Washington
- Pennsylvania
- New York
- California
- Missouri

The key features and highlights of each state's document are summarized below.

Maryland State Highway Administration (SHA)

The Maryland Department of Transportation State Highway Administration produced a statewide roundabout guide in 1995 as an interim document prior to the FHWA Roundabout Guide being produced. The text of the Maryland guide borrowed most of its information from the Australian Design Guide. The procedures and guidelines were largely the same as those in the Australian guide with all units converted to U.S. standard units and the diagrams inverted to right-side traffic flow. Where necessary, the design guidelines were slightly altered to conform to standard AASHTO and MUTCD practices. Some added details were also included such as examples of landscaping designs, truck apron details, typical signing plans for state route and local street roundabouts, construction staging diagrams, and public education suggestions. The appendix included a sample benefit/cost analysis.

At this time, the Maryland State Highway Administration has adopted the FHWA Roundabout Guide, as its standard. In addition, they have created several supplements with regards to signing and pavement marking guidance.

Florida Department of Transportation (FDOT)

The *Florida Roundabout Guide* was developed by FDOT in March 1996 to assist district offices and local agencies within the state of Florida in identifying appropriate sites for roundabouts and determining their preferred configuration and operational features. The most unique feature of the manual is its "roundabout justification" section. This section contains a discussion of intersection traffic control alternatives and presents a series of categories representing reasons to install a roundabout. An objective "justification procedure" is outlined to provide guidance in the decision to install a roundabout.

The Florida Guide provides a comparison of intersection control alternatives (stop-control, two-phase signal, three-phase signal, and four-phase signal), and presents a graph that shows average delay as a function of volume. The performance analysis section is based upon the Australian methodology (gap-acceptance theory) and also encourages the use of the SIDRA program. Guidelines for geometric design are provided with key dimensions and concepts detailed individually for each design element. A useful figure in the geometric design section displays the recommended minimum dimensions for a typical single-lane roundabout. The manual also provides a number of guidelines for signing, pavement markings, lighting, and landscaping.

The outline of the Florida Roundabout Guide is as follows:

1. *Introduction*
   - Includes discussion of roundabout characteristics and suitable locations for roundabouts.
2. *Roundabout Justification*
   - Provides general guidance to aid in the selection of locations for roundabouts.
   - Outlines a step-by-step approach to document the evaluation and justification for a roundabout as the most appropriate form of traffic control.
3. *Roundabout Performance Analysis*
   - Describes the methodology for the analysis of roundabout performance in terms of capacity and delays, based on the Australian formulas.
4. *Geometric Design of Roundabouts*
   - Establishes design concepts and standards for all major design elements.
5. *Operational Considerations*
   - Provides guidance on traffic design elements such as signing, marking, lighting, and landscaping.

Washington State Department of Transportation (WSDOT)

WSDOT added a section on roundabouts to their *Design Manual* in late 2001. The guidelines are 29 pages in length and primarily based on the principles from the FHWA Roundabout Guide. The outline and notable features of the WSDOT guidelines are as follows:

1. *General*
   - Includes discussion of locations recommended for roundabouts, locations not normally recommended, and locations not recommended.
2. *References*
   - Lists significant reference documents.

3. Definitions

- Consists of approximately three pages of terms and definitions.

4. Roundabout Categories

- Identifies and describes the six categories from the FHWA Roundabout Guide.

5. Capacity Analysis

- Briefly discusses two analysis methods and states that gap acceptance method is preferred.

6. Geometric Design

- Discusses design principles and establishes standard design criteria for each geometric element.

7. Pedestrians

- Discusses pedestrian issues and specifies pedestrian crossing dimensions.

8. Bicycles

- Discusses cyclist issues and design treatments.

9. Signing and Pavement Markings

- Presents standard roundabout signing and pavement markings through figures.

10. Illumination

- Discusses illumination principles and depicts light standard placement.

11. Access, Parking, and Transit Facilities

- Specifies policies and design principles for road approaches, parking, and transit stops.

12. Procedures

- Presents suggested steps for selecting a roundabout for intersection control.
- Identifies and discusses "justification categories" for when roundabouts could be considered.
- Lists the information required for submittal to WSDOT to gain approval of a roundabout on a state highway.

13. Documentation

- Lists the documents to be preserved in the project file.

The entire WSDOT guidelines can be viewed at the following web address:

http://www.wsdot.wa.gov/fasc/engineeringpublications/desEnglish/915-E.pdf

Pennsylvania Department of Transportation (PennDOT)

PennDOT's *Guide To Roundabouts* is a freestanding document completed in May 2001. It is designed as a supplement to the FHWA Roundabout Guide to aid in determining whether a roundabout is a feasible alternative for a specific location. Unlike the other state guides, it does not provide specific guidelines or criteria for design elements. Its primary function is to assist transportation professionals in the planning and study phases of a project to reach a decision regarding the feasibility of installing a roundabout. The guide directs readers to the FHWA Roundabout Guide for further design criteria.

The PennDOT Guide begins with a general description of roundabouts and their benefits. The core of the guide is an eight-page questionnaire with an array of questions and insights to help determine whether a roundabout is the best form of traffic control at a given location. In order to complete the questionnaire, the analyst will be required to obtain a variety of information on the site. An operational analysis and conceptual geometric layout is generally required to answer the questions. The guide provides general insights and discussion throughout the questionnaire to help the analyst understand the probable implications of a roundabout at a given site. The document also includes several appendices including a number of case studies.

The outline of the PennDOT Guide is summarized below.

Introduction

Roundabouts versus Traffic Circles

- Describes roundabout characteristics and distinguishing features from rotaries and neighborhood traffic circles.
- Identifies roundabout categories from FHWA Roundabout Guide.

Benefits of Using Roundabouts

- Discusses safety, capacity, traffic calming, environmental and aesthetic benefits of roundabouts.

Where to Use Roundabouts

- Lists numerous situations where a roundabout could be beneficial.
- Provides the Roundabout Questionnaire, which is intended to help consider all issues and determine whether a roundabout is appropriate at a given site by requiring the analyst to collect a variety of information about the intersection.

Issues Associated with Roundabouts

- Discusses roundabout issues including pedestrians, bicyclists, educating the public, and maintenance.

Appendices

- Includes a glossary of terms, the description of roundabout categories (taken from FHWA Roundabout Guide), and several case studies with completed questionnaires.

The PennDOT Roundabout Guide can be viewed at the following web address:

ftp://ftp.dot.state.pa.us/public/bureaus/design/GuideToRoundabouts.pdf

New York State Department of Transportation (NYSDOT)

Guidelines for the State of New York are contained in the NYSDOT's *Highway Design Manual Chapter 26: Roundabouts*. This chapter is still in draft form and is dated February 28, 2001. It is a total of 73 pages in length and largely based on the FHWA Roundabout Guide. Many of the figures and tables are taken directly from the FHWA Roundabout Guide, although some have been modified slightly to reflect the standards of NYSDOT. The NYSDOT guidelines have also been influenced by British practice. The operation analysis techniques and many of the geometric parameters are based on the British standards.

The outline of the NYSDOT Guide is summarized below along with notable specifications.

1. Introduction

- Discusses background information and defining features of roundabouts
- Summarizes advantages and disadvantages of roundabouts vs. other alternatives.
- Describes roundabout categories (same as FHWA Roundabout Guide).

2. Project Scoping

- Describes appropriate applications for roundabouts, general site requirements, system considerations, and public coordination issues.
- Provides general guidance for where roundabouts are advantageous.
- Specifies RODEL should be used for all capacity analysis.
- Provides typical diameters and services volumes for various site categories.
- Provides some guidance for 3-lane roundabouts.
- Discusses pedestrian and bicycle issues.

3. Preliminary Design: Geometric Standards

- Provides general design principles and dimension ranges for each geometric element, often specifying a "desirable" value.
- Includes discussion and values for entry angle and effective flare length (British-based parameters not included in the FHWA Roundabout Guide).
- Requires a "Design Criteria Table" be prepared for each project summarizing the proposed dimensions of each major roundabout element.
- Presents methods for analyzing roundabout operations. RODEL is to be used for determining capacity, delay, and queue lengths.
- Presents and discusses safety analysis, including U.S. crash data, international crash data, and crash prediction models.

4. Detailed Design Stage

- Provides guidelines for traffic design elements (signing, pavement marking, and illumination), work zone traffic control, and landscaping. It generally replicates the guidelines in the FHWA Roundabout Guide with a few minor modifications.
- Recommends no lane use striping in circulatory roadway (in general).

- Specifies using "Sharks Teeth" markings at yield lines.

5. Construction Stage

- States that the project Engineer in Charge must be alerted to any geometric changes made during construction to prevent adverse impacts on traffic circulation.

6. Monitoring

- Provides guidelines for monitoring roundabouts after construction in effort to better understand roundabout operations and improve design standards.

California Department of Transportation (Caltrans)

Caltrans has no formal design standards for roundabouts but provides guidance in the form of Design Informational Bulletin (DIB) 80. As noted on Caltrans' web site, the purpose of the DIB is "to provide guidance on appropriate applications, site requirements, geometric elements and traffic analysis for use of roundabouts on the State highway system." This document, most recently published in September 1998 (http://www.dot.ca.gov/hq/oppd/dib/dib80.htm), is in the process of being updated to more closely reflect the FHWA Roundabout Guide.

Missouri Department of Transportation (MoDOT)

MoDOT incorporated the first phase of roundabout guidelines into its *Project Development Manual* in early 2002. It is intended to serve as a policy-level document that defines an enforceable set of requirements. The guidelines apply only to single-lane roundabouts. The document specifies that multilane roundabouts may be considered but will require a design exception at this time. MoDOT is currently working on developing guidelines for multilane roundabouts.

The roundabout information consists of five pages of text plus eight figures. It begins with some introductory information, a procedure for selecting a roundabout as the preferred form of traffic control, and basic guidance on operational analysis. The majority of information is focused on geometric and traffic design elements, outlining fundamental principles and identifying dimensions of the primary roundabout features. In most cases, the principles and dimensions are based on the FHWA Roundabout Guide. In some cases modifications were made to reflect MoDOT's standards for intersection design. The document is divided into 17 sections as follows:

1. Introduction and Definitions
2. Justification Procedures
3. Operational/Capacity Analysis
4. Fundamental Design Principles
5. Design Speeds
6. Design Vehicle
7. Sight Distance
8. Central Island
9. Truck Apron
10. Circulatory Roadway
11. Splitter Islands
12. Approach Legs
13. Grades, Cross-Slopes, Superelevation
14. Bicyclists and Pedestrians
15. Signing and Pavement Marking
16. Landscaping, Lighting, and Drainage
17. Traffic Control During Construction

Some of the more notable features of the MoDOT guidelines are as follows:

Justification Procedures

This section establishes a process for selecting a roundabout as the preferred form of traffic control. It includes three stages of evaluation. If a site fails at any of these three stages, a roundabout should not be considered. The three stages are:

(1) Appropriateness – a table specifies conditions for which a roundabout *may* be appropriate, *may not* be appropriate, and *will not* be used.
(2) Operational Feasibility – to determine whether a roundabout can provide acceptable levels of service.
(3) Comparative Performance – to compare its performance to that of other potential forms of control.

Operational Analysis

The guide specifies that the Highway Capacity Manual procedure be used for initial analysis. SIDRA should be used for more detailed analysis. If simulation is used, VISSIM is the preferred model.

Approach Legs

This section provides some guidance for the when right-turn bypass lanes might be considered. It also suggests minimum spacing criteria between adjacent approach legs (a unique concept not developed in other guides).

Bicyclists

The MoDOT Guide introduces a unique option for accommodating bicyclists: a "bicycle platform," which is a raised concrete strip immediately outside the curb (inside the landscape buffer and sidewalk) between the crosswalks of adjacent legs.

The MoDOT *Project Development Manual* can be viewed at the following web address:

http://www.modot.state.mo.us/design/ppdm/ppdm.htm

Appendix B – Guidance for Law Enforcement

Guidance for Law Enforcement

This appendix sets forth guidance for interpretation of the Kansas Motor Vehicle Code, presented in Chapter 8 of the Kansas Statute Articles, as related to the operation of roundabouts within the State of Kansas. This guidance is intended to provide clarification on the intended purpose of the laws, and enforcement of those laws, to ensure the safety and welfare of the public while maneuvering through a roundabout.

Each of the crash types described in Exhibits 5-1 and 5-2, in Chapter 5 of this guide, can generally be linked to specific rules of the road. The following table lists each crash type with the possible corresponding violations of Kansas's statutes.

Exhibit B-1
Traffic violations at roundabouts by collision type

Collision type	Possible violation (Kansas statute number[1])
1. Failure to yield at entry (entering-circulating)	Failure to yield right-of-way (8-1528)
2. Single-vehicle run off the circulatory roadway	Basic rule governing speed of vehicles (8-1557)
3. Single vehicle loss of control at entry	Basic rule governing speed of vehicles (8-1557)
4. Rear-end at entry	Following another vehicle too closely (8-1523)
5. Circulating-exiting	Failure to make turn from proper position (8-1545)
6. Pedestrian on crosswalk	Failure of driver to yield right-of-way to pedestrian (8-1533)
7. Single vehicle loss of control at exit	Basic rule governing speed of vehicles (8-1557)
8. Exiting-entering	Failure to yield right-of-way (8-1528)
9. Rear-end in circulatory roadway	Following another vehicle too closely (8-1523)
10. Rear-end at exit	Following another vehicle too closely (8-1523)
11. Passing a bicycle at entry	---
12. Passing a bicycle at exit	---
13. Weaving in circulatory roadway	---
14. Wrong direction in circulatory roadway	Driving in the wrong direction around the central island of a roundabout (8-1521(c))
15. Pedestrian on circulatory roadway	Illegal diagonal crossing by pedestrian (8-1534(d))
16. Pedestrian at approach outside crosswalk	Pedestrian failing to yield right-if-way outside crosswalk (8-1534(a))

[1] Per Kansas state statutes current through end of 2002 legislative session.

Appendix C – Sample Roundabout Feasibility Study

Appendix D – Sample Roundabout Peer Review Report

Appendix E – Sample Roundabout Design Review Submittal Packet