<u>Disclaimer</u>: This website and documents are provided for use by persons outside of the Kansas Department of Transportation as information only. The Kansas Department of Transportation, the State of Kansas, nor its officers or employees, by making this website and documents available for use by persons outside of KDOT, does not undertake any duties or responsibilities of any such person or entity who chooses to use this website and documents. This website and documents should not be substituted for the exercise of a person's own professional judgment nor the determination by contractors of the appropriate manner and method of construction on projects under their control. It is the user's obligation to make sure that he/she uses the appropriate practices. Any person using this website and documents agrees that KDOT will not be liable for any commercial loss; inconvenience; loss of use, time, data, goodwill, revenues, profits, or savings; or any other special, incidental, indirect, or consequential damages in any way related to or arising from use of this website and documents.

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

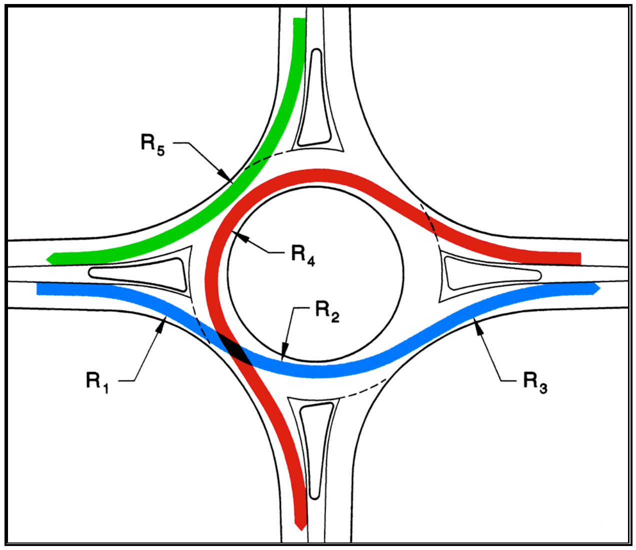
Fundamentally, the principles of roundabout design are no different than other roadways and intersection types. The designer must consider the context of the project and provide suitable geometry and traffic control devices according to established engineering tools and design standards. These considerations 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

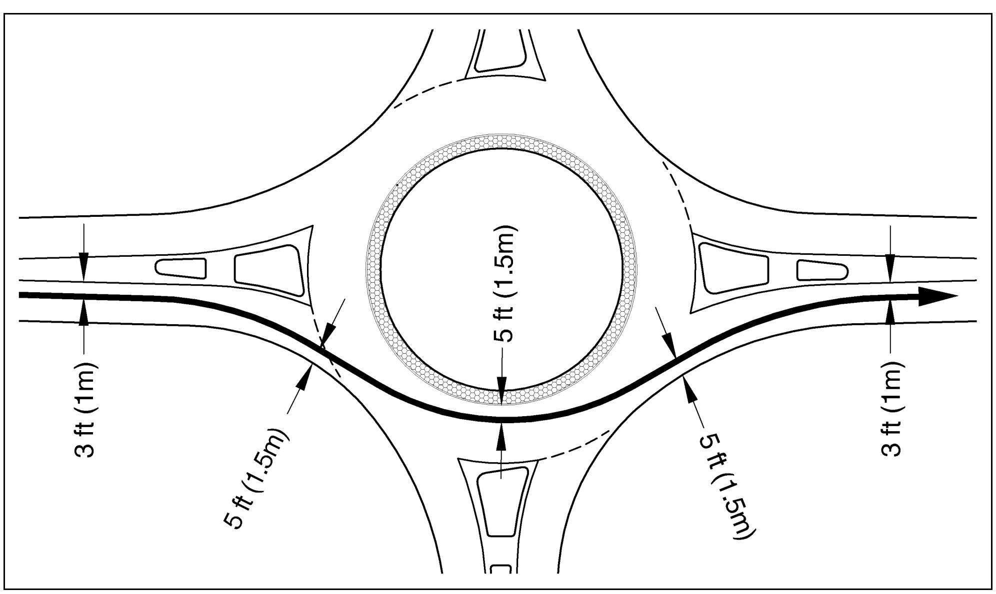


The fastest path is drawn assuming a vehicles starts at the left-hand edge of the approach lane, moves to the right side as it enters the roundabouts, cuts to the left side of the circulatory roadway, then moves back to the right side at the exit, and completes its move at the left-hand side of the departure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

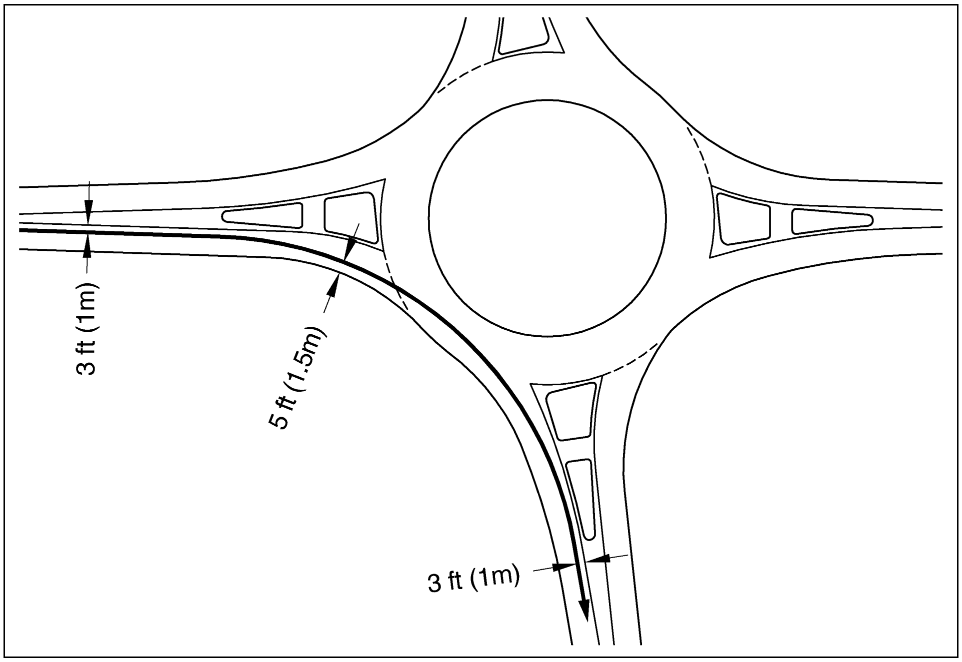
Exhibit 6-2 illustrates the construction of the fastest vehicle path for a through movement at a typical single-lane roundabout.

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



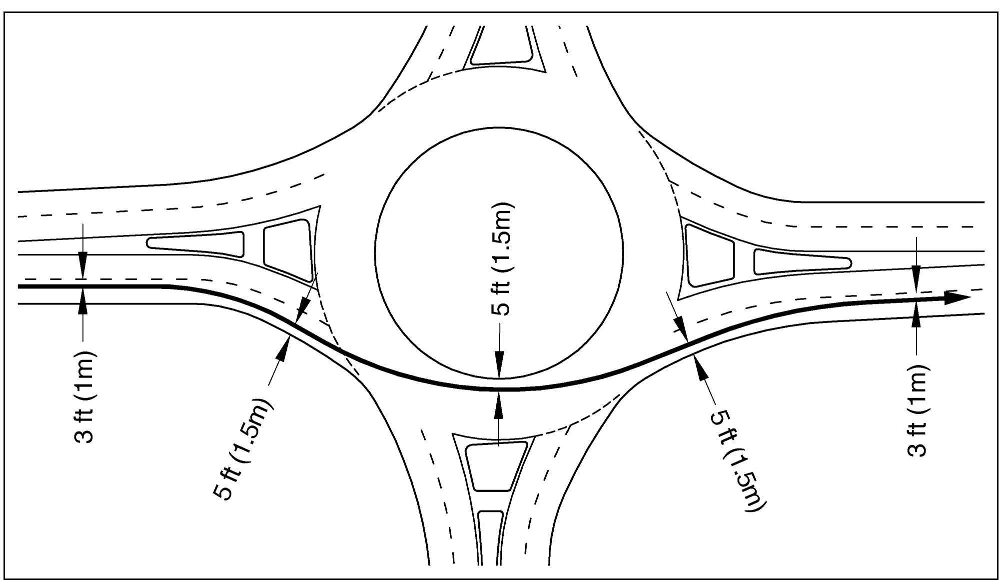
In some cases the right-turn path may be faster than the through movement path. Thus, the right-turn fastest path should be drawn carefully using the same principles and offsets described above. Exhibit 6-3 shows a sample right-turn path.

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

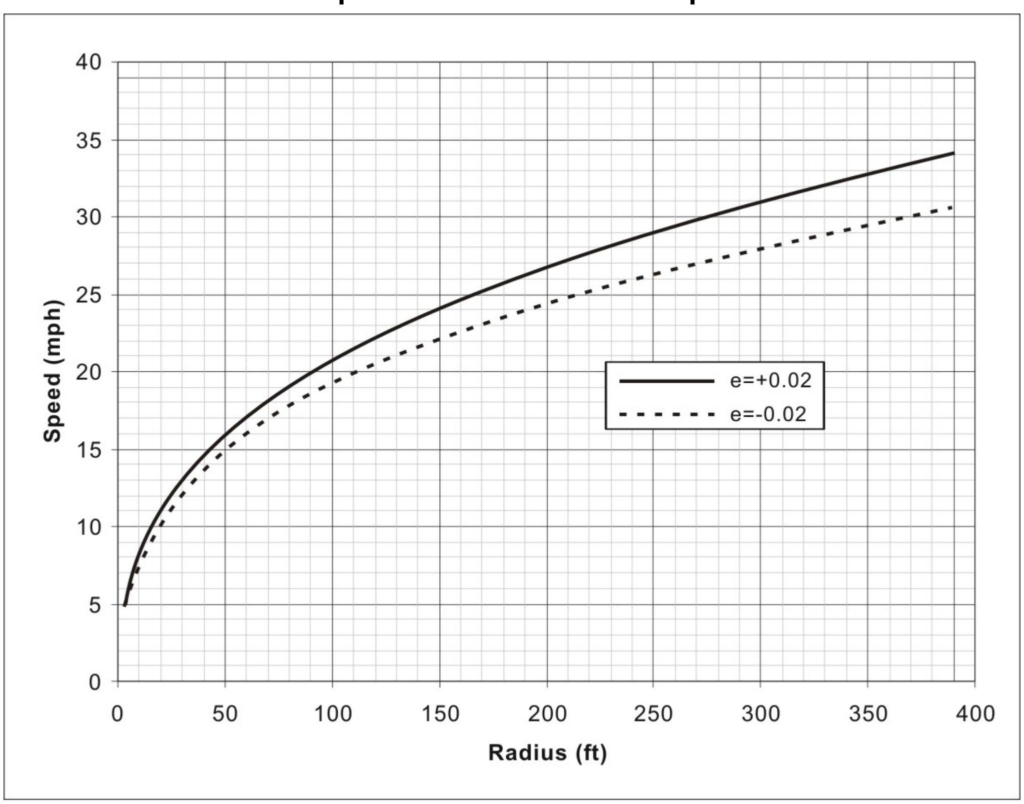


Exhibit 6-6 displays the maximum recommended design speeds for various roundabout categories.

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.

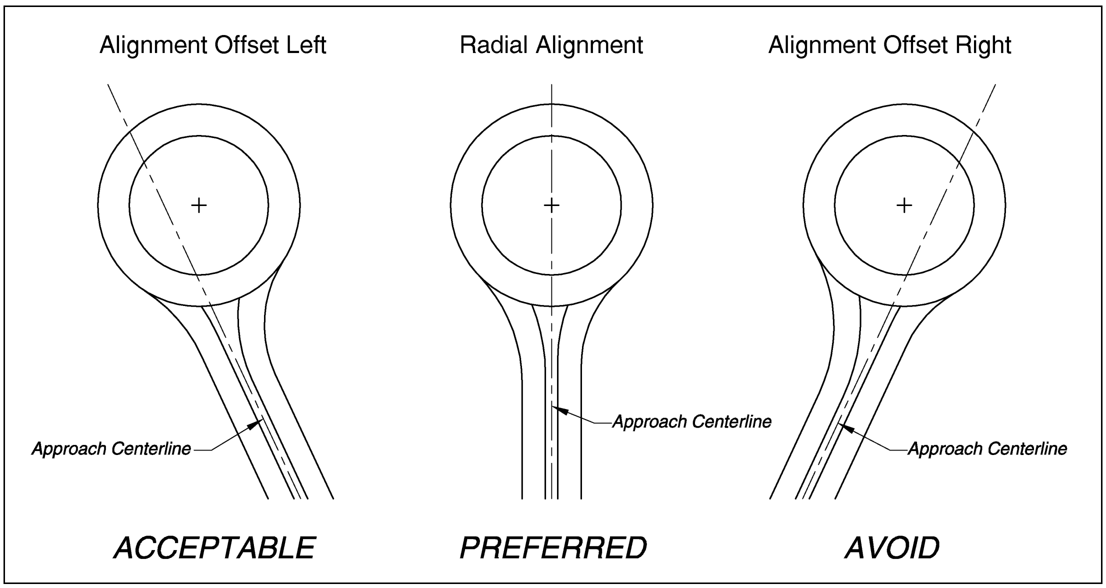
Some recent design philosophies have recommended relaxing the design speed guidelines for roundabout exits. These studies advocate large radii or even tangential geometry at exits to reduce vehicle-to-vehicle conflicts and ease the flow of traffic as it departs from the circulatory roadway. The basic 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

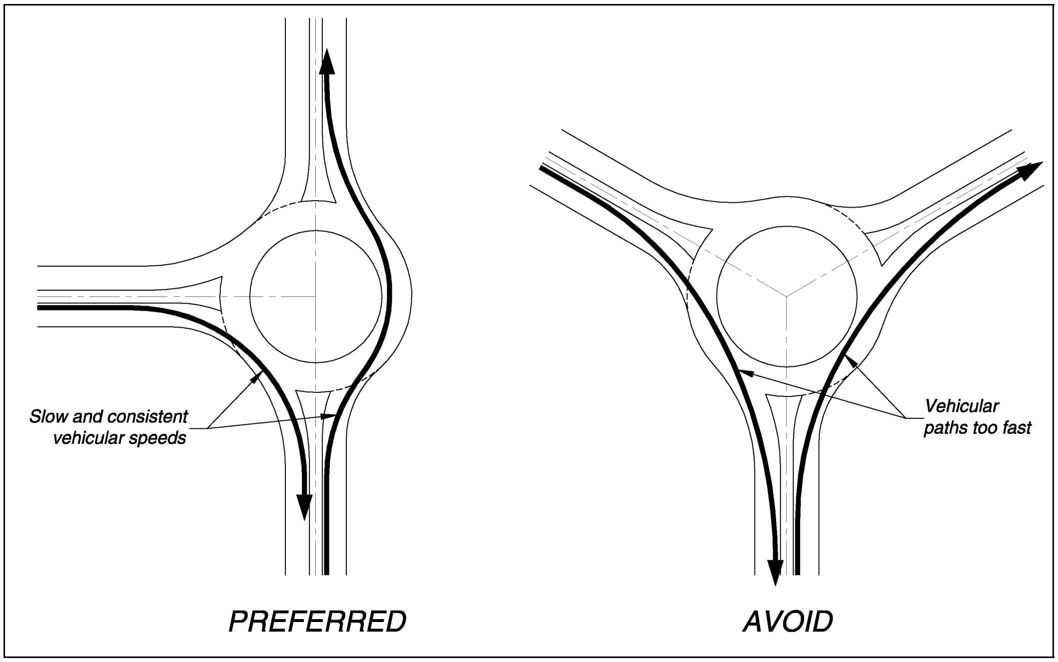


Angles Between Approaches

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

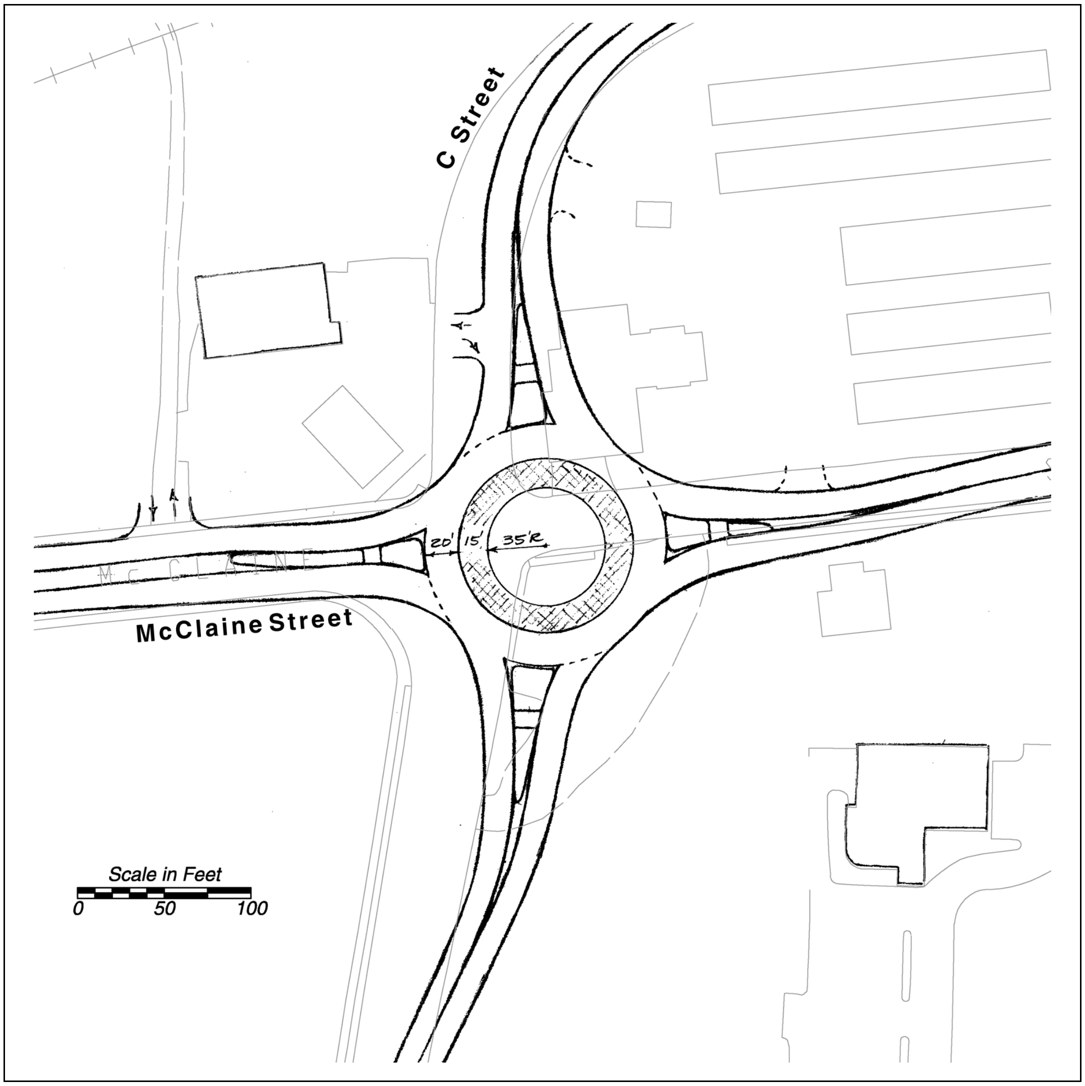
Roundabout Design Process

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.

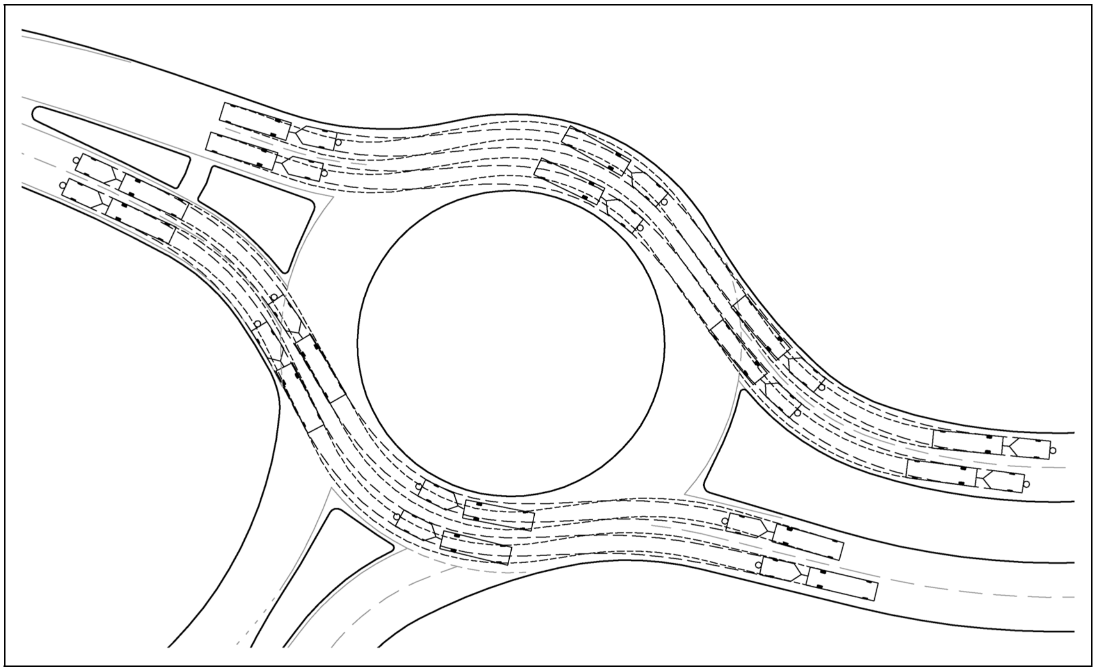


Exhibit 6-16 provides minimum recommended circulatory roadway widths for two-lane roundabouts where semi-trailer traffic is relatively infrequent.

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

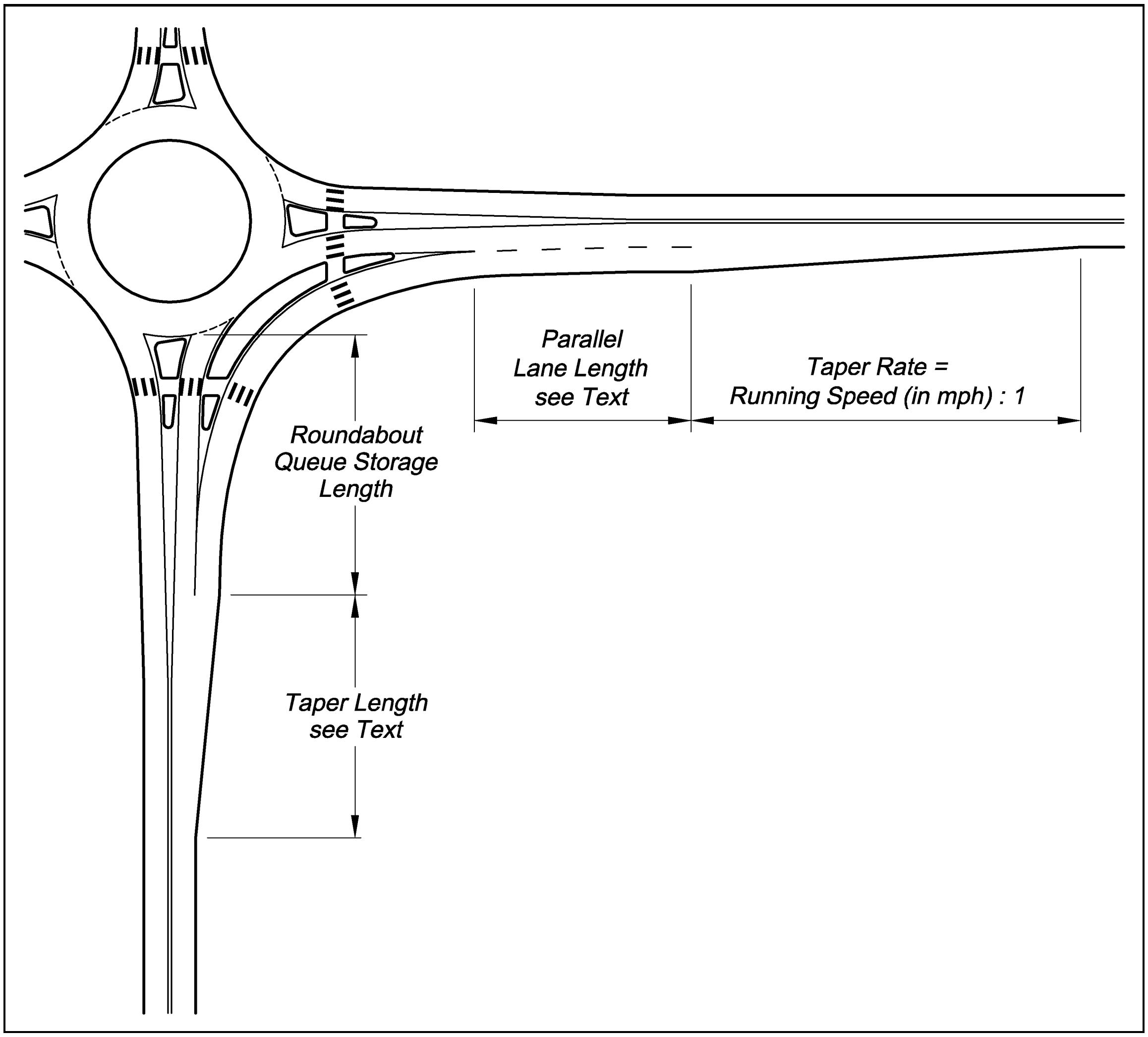
Right-turn bypass lanes (or *right-turn slip lanes*) are useful in providing additional capacity on approaches with high right-turn vehicular volumes. These lanes can effectively remove right turning vehicles from entering the roundabout, thus increasing the capacity of the intersection as a whole. However, 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.

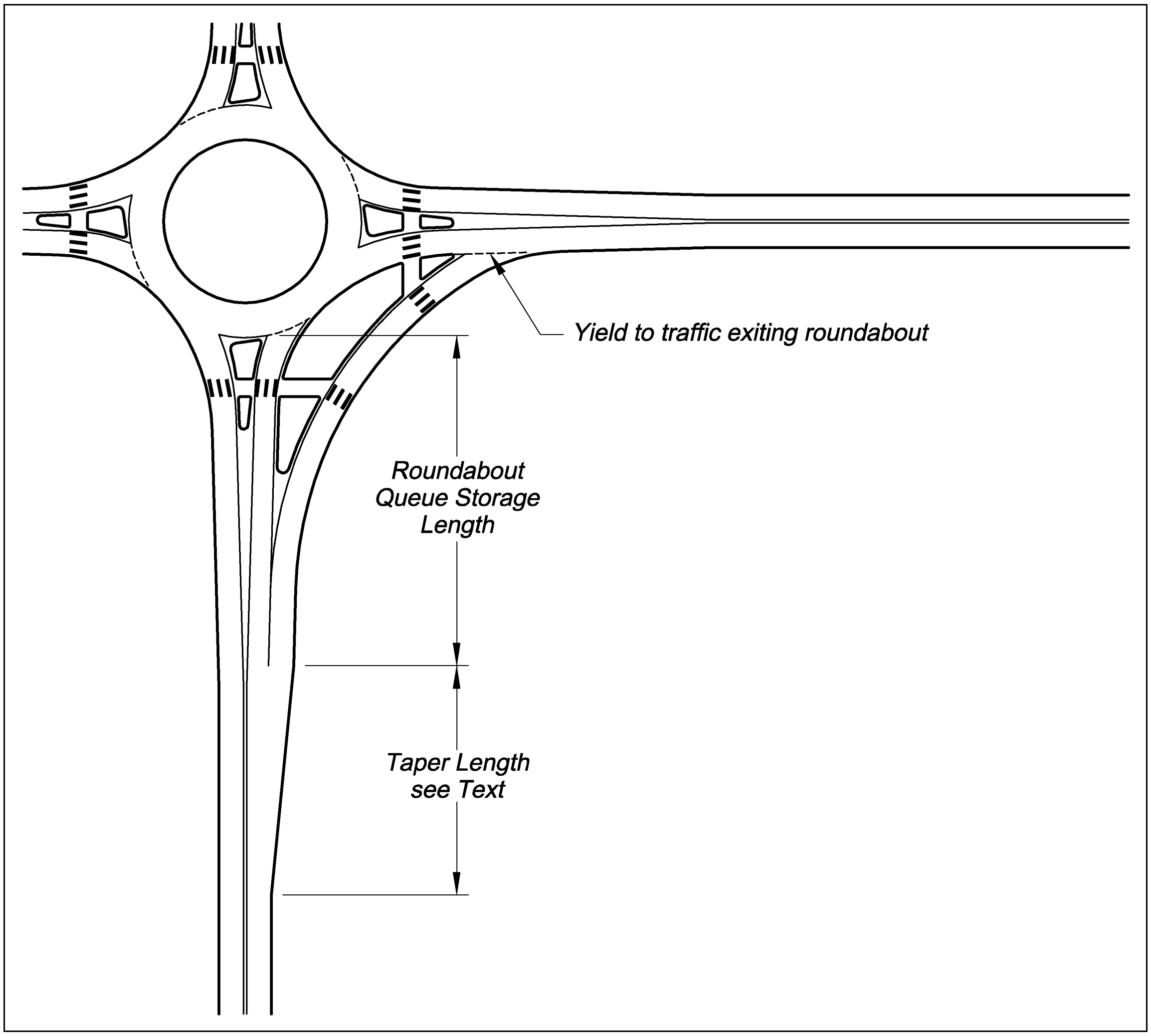
There are two design options for right-turn bypass lanes. The first option, shown in Exhibit 6-17, is to carry the bypass lane parallel to the adjacent exit roadway, and then merge it into the main exit lane from the roundabout. Under this option, the bypass lane should be carried alongside the main 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.