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HIGHWAY DESIGN MEMORANDUM NO. 05-24

TO: Chief District Engineers
Design Engineers
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FROM: Tim Layson, P.E., Director
Division of Highway Design

DATE: June 21, 2024

SUBJECT: Intersection Control Evaluation (ICE) Implementation and Roundabout Design Guidance Updates

Intersection Control Evaluation

The use of innovative intersection and interchange designs is growing across the U.S. Experience to date with these designs suggests significant safety and operational benefits when they are implemented broadly and consistently at the system level.

As such, KYTC developed a consistent and objective Intersection Control Evaluation (ICE) process to guide the selection and evaluation of intersection control strategies that is built on performance-based criteria. Benefits of ICE include:

- Implementation of solutions that are safer, more balanced, and more cost-effective.
- Consistent documentation that improves the transparency of transportation decisions.
- Increased awareness of innovative intersection solutions and an emphasis on objective performance metrics to facilitate consistent comparisons.

The ICE process runs in parallel with other preliminary engineering activities. Adoption across KYTC will result in more thoroughly investigated intersection control options that support more confident project programming decisions earlier in the project development process.

The ICE process is divided into two phases:

- Screening (Stage 1) occurs during the scoping, planning and conceptual design phase of project development. The Project Manager (PM) and Project Development Team (PDT) develop a list of intersection alternatives that are appropriate for the project and merit further investigation.
- Intersection Alternative Selection (Stage 2) entails in-depth analysis of intersection types identified during Stage 1. A preferred alternative is chosen at the Preliminary Line and Grade (PL&G) meeting.

Consult *KYTC's ICE Guidance* for more information. The guidance is attached and is available on KYTC's Highway Design website. KYTC's ICE Forms are available on Highway Design's Forms page.

The ICE process may be used on any roadway project and should be applied on new projects. KYTC strongly encourages the application of ICE on projects that have not advanced past PL&G. If the project manager (PM) determines there is value in applying ICE on projects currently in preliminary engineering (or later phases), but the tasks for ICE were not included in the project scope, the PM should discuss the potential to include the evaluation with their Location Engineer.

Roundabout Design Guidance Update

KYTC's Roundabout Design Guidance was updated to include updated recommendations in the recently released national guidance, *Guide for Roundabouts* (NCHRP Report 1043). It omits the entry angle as a design check and includes Public Right-of-Way Accessibility Guidelines (PROWAG) for pedestrian crossings at roundabouts. Several minor updates are included. Please review the guidance for more information. It is attached and is also available on KYTC's Highway Design website.

The implementation of the ICE process also results in some minor changes to the roundabout submittal and review process. The conceptual review of the roundabout will occur along with other intersection alternatives as part of the Stage 1 ICE process and will not require the submittal of the Roundabout Design Review, Part A form. A Roundabout Design Form will be part of the DES submittal. A link to the updated Roundabout Design Form is posted on Highway Design Form's page.

KYTC's updated Roundabout Design Guidance may be used on any roadway project and shall be applied on projects that have not advanced past PL&G. For projects that have advanced past PL&G, decisions made with previous guidance are acceptable.

If you have questions about this memorandum, contact the Division of Highway Design at (502) 564-3280.

Attachments: *KYTC's ICE Guidance*

KYTC's Roundabout Design Guidance

Intersection Control Evaluation (ICE) Guidance

1. Introduction

Intersection control evaluation (ICE) is a data–driven, performance–based framework used to screen intersection alternatives and identify an optimal solution.

1.1. Benefits of ICE

Benefits of using ICE include:

- Implementation of solutions that are safer, more balanced for all users, and more cost–effective
- Consistent documentation to support transparent decision making
- Increased awareness of innovative solutions

Objective performance metrics for decision making

1.2. Types of Alternative or Innovative Intersections and Interchanges

Several types of innovative intersections and interchanges are in use across the United States. Experience with innovative designs suggests significantly greater safety and operational benefits can be realized at a system level if they are used more broadly. Table 1 lists examples of innovative intersections and interchanges.

Table 1 Innovative Intersection and Interchange Examples

Intersections	Interchanges
Reduced Conflict U-Turn (RCUT)	Single-Point Urban Interchange
Roundabout	
Mini Roundabout	Diverging Diamond Interchange (DDI)
Continuous Green-T	
Quadrant Roadway	Double Roundabout
Displaced Left Turn	
Median U-Turn (MUT)	
Bowtie	
Single Loop	

For more information and resources see KYTC's SAFERoad Solutions website. For locations of existing innovative intersection operating in Kentucky, see the Cabinet's Alternative Intersections Map.

2. Application

An ICE should be completed for all intersections — including newly created intersections — on a project if one or more of the intersecting roadways is on the state-maintained roadway system. An ICE is not needed if proposed work will not substantively change an intersection (e.g., a project limited only to mill-and-fill pavement resurfacing with no modifications to intersection geometry or control). An ICE may not be needed if actual traffic counts are available for all intersecting roadways **and** all the following conditions are met:

- EEC KAB < 0 and the EEC CO < 0
    - Intersection Excess Expected Crashes (EECs) are found on the Advanced Map of the Crash Data Analysis Tool [CDAT]. KABCO are injury level severities recorded on crash reports.
- No apparent crash patterns
- Minor road AADT < 400
- No known operational issues

When intersecting roadways lack traffic counts (e.g., county roads), the intersection may be excluded from ICE if all the following conditions are met:

- No apparent crash patterns
- Minor road does not serve many users
- No known operational issues

These criteria also apply to intersections at interchange terminals.

If an intersection is excluded from the ICE process, document the justification in the Design Executive Summary (DES). If the intersection doesn't meet the criteria, RCUTs should still be considered when a lower volume route intersects with a median-divided highway.

The Project Manager (PM) and the Project Development Team (PDT) may apply ICE to interchange projects where interchange geometry (e.g., diamond, DDI, SPUI) is being modified or a new interchange is proposed. Applying ICE on projects involving changes to interchange geometry is optional.

The ICE process runs parallel to other project development activities:

- Stage 1 of the ICE process (screening of potential intersections) occurs as early as possible in project development (e.g., planning or conceptual design phase). Stage 1 findings inform the selection of alternatives that merit further evaluation during preliminary design.
- Stage 2 (intersection selection) is completed at the end of preliminary design.

3. ICE Process

ICE is scalable. This means the level of effort put into screening and analysis should be commensurate with the magnitude and nature of the project — less effort for simple projects, more effort for complex ones.

There are two stages. Stage 1 is the screening process used to shortlist possible alternatives that merit further consideration and analysis because they meet organizational goals, project needs and are practical. Stage 2 is the intersection selection stage where alternatives are evaluated in more detail and objectively compared to other alternatives. Figure 1 displays a flowchart of the ICE Process.

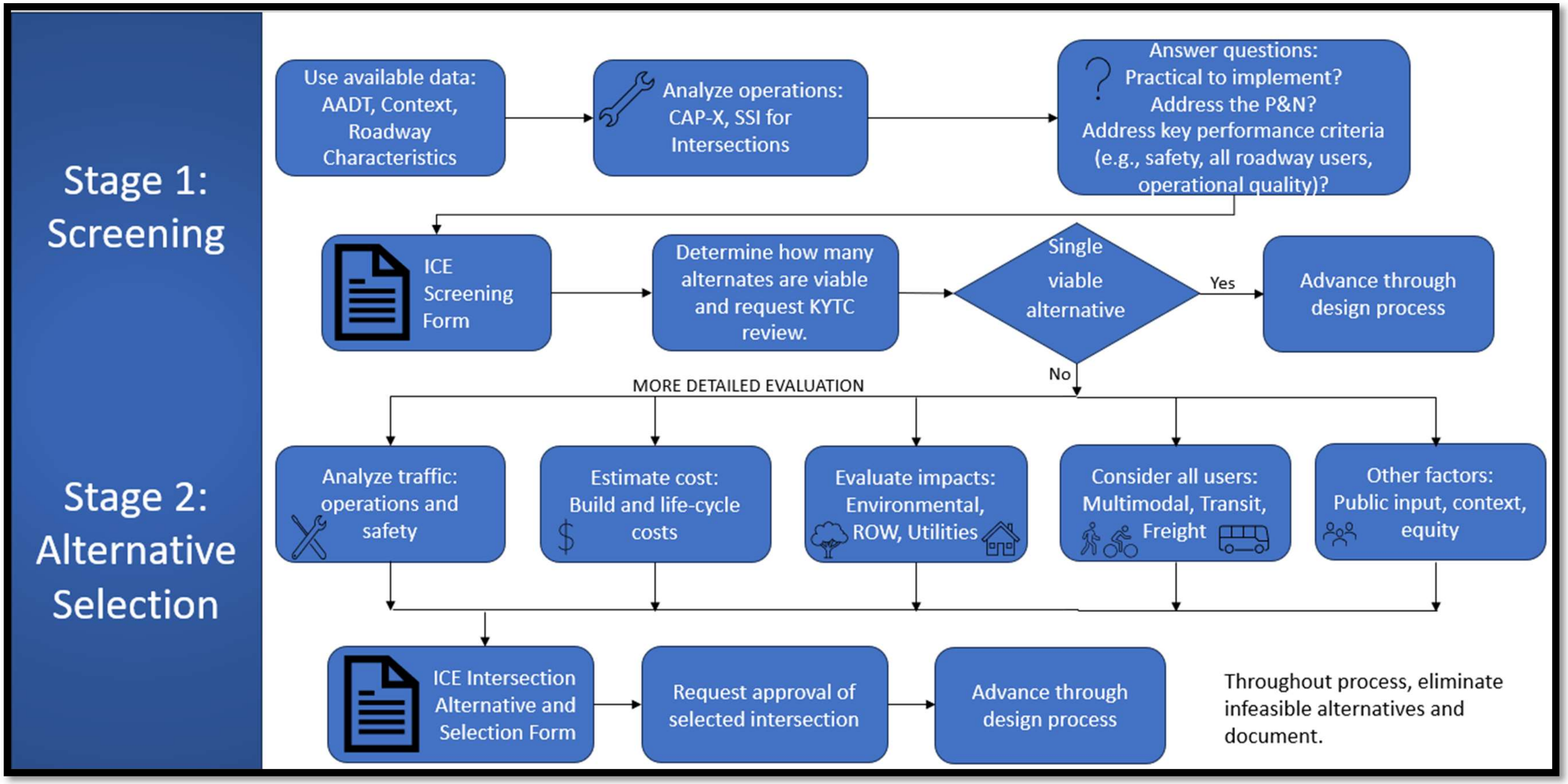


Figure 1 KYTC ICE Process Flowchart

3.1. Stage 1 — Screening

Screening eliminates non-competitive options and shortlists intersection alternatives. This screening occurs at a high level. The Project Development Team (PDT) should screen all feasible and reasonable alternatives. More in-depth analysis is needed for alternatives that progress to Stage 2.

Answer the following questions during screening:

- Is the intersection alternative impractical to implement (based on construction and operating costs, potential environmental impact, and footprint)?
- Does the alternative meet the transportation purpose and need?
- Does the alternative address key system performance criteria (e.g., safety, all roadway users, operational quality)? Consider the context classification, land use, and likely travel needs at the intersection.

In addition, the analysis used to screen feasible intersection alternatives requires the application of spreadsheet tools developed for or updated in coordination with NCHRP Report 1087 (*A Guide for Intersection Control*):

(i) *Capacity Analysis for Planning of Junctions (CAP-X)*. CAP-X is an operational analysis tool to evaluate selected types of intersection and interchange designs.

(ii) *SSI Score Calculator Tool.* The SSI tool is used for safety assessments of intersections and interchanges.

The tools include several defaults that can be overridden with project specific data if the project team agrees, and the data is available.

Table 2 Tools Used in the ICE Screening Process

Tool	Purpose
*Capacity Analysis for Planning of Junctions (CAP-X)**	An operational analysis tool based on critical lane volumes that is used to evaluate selected types of intersection and interchange designs. Provides safety assessment scores for pedestrian and bicycle accommodations.
*SSI Score Calculator Tool**	Used for the motor vehicle safety assessment of intersections based on Safe System principles – removing or reducing the number of higher-angle crashes and conflict points and reducing vehicle speeds and exposure.

*The CAP-X and SSI Score Calculator Tools may be downloaded from National Academies website.

Note: The recommended spreadsheet tools provide very high-level screenings. They were developed to require minimal inputs, and to apply to traditional and alternative intersection types. The spreadsheets may not address some details of the intersection operation. If the PDT is concerned the software is prematurely screening out feasible alternatives, the alternatives should advance to Stage 2 for a more detailed analysis.

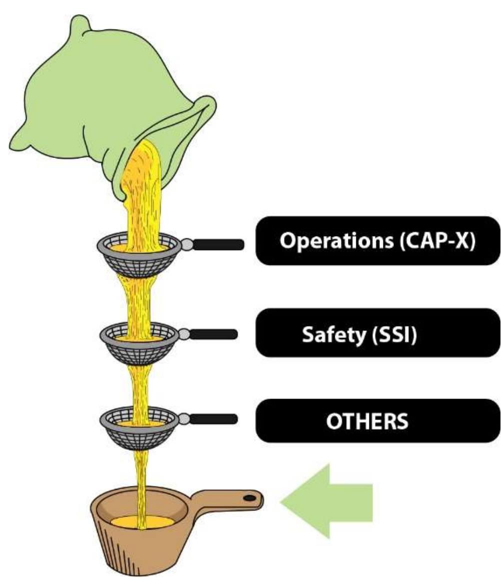
3.1.1. Data Needs

Data required to use the capacity and safety screening tools include:

- Traffic volumes (veh/hr) **including turning movements**
- % Heavy vehicles
- Growth % (optional) to project volumes for a future year if forecasted numbers are unavailable.
- Feasible alternative intersection for analysis
- Existing intersection type (if applicable)
- Facility type
- Major and minor road AADT
- Number of thru lanes at each approach
- Number of turn lanes at each approach
- Posted speeds
- Crosswalk markings

If collision data for the existing intersection is available, it should be reviewed, but is not needed for the screening tools. Collision data for intersections is available through CDAT.

3.1.2. Capacity and Safety Screening



Typically, CAP-X is used first, then the SSI Score Calculator. The spreadsheets include instructions and several default values. The PM and the PDT may consider using other values if they are available and applicable to the intersection. Below are some helpful tips for using the CAP-X and SSI tools.

CAP-X Entry Tips

- The CAP-X default for heavy vehicle percentage is 2%. Truck percentages are available for most state-maintained roads in the KYTC Traffic Count Reporting System. Enter the most recent reported truck percentages. The *Highway Capacity Manual* (HCM) includes single-unit trucks and tractor trailers as heavy vehicles.
- Volume growth percentages can be used if projecting to a design year. If the project has a completed traffic forecast, input the reported growth percentage.

Smaller-scale projects may use a growth percentage agreed upon by the PDT. **Note: Be cautious when screening alternatives based on projected traffic volumes for a design year many (e.g., 20) years into the future. Overbuilding an intersection based on traffic growth rates that may or may not occur could adversely affect intersection safety.**

- In the *Alternative Selection* section, select *yes* only for alternatives that are reasonable given the project context.

SSI Entry Tip

- Required inputs are minimal. In the Inputs tab follow instructions for optional input values. If available, enter peak hour traffic counts into the appropriate orange cells.

3.1.3. Screening Documentation

For each intersection, submit screening results on the *ICE Screening Form* with attachments (e.g., CAP-X and SSI files, crash data) for the KYTC PM to review. CAP-X results include high-level operational results for all legs of each intersection alternative. Consider this information alongside the operational results for the entire intersection reported on the form.

The PM, with input from the PDT, chooses intersection control alternatives from the screening process that will move forward to Stage 2. If a single viable intersection control strategy is identified through the screening process, include a justification on the ICE Screening Form and advance the alternative through the design process.

3.2 Stage 2 – Intersection Alternative Selection

During Stage 2, alternatives that made it through Stage 1 screening are evaluated in more detail and compared to other alternatives. Table 3 describes the recommended analysis and other factors to consider in intersection control selection.

Table 3 ICE Stage 2 Analysis and Evaluation Factors

Intersection Control Evaluation Factors	Recommended Tools & Resources
Operational Analysis • Use HCM methodologies. Analysis of less complex intersections may apply the Planning and Preliminary Engineering Applications Guide (PPEAG) tool initially developed as part of NCHRP Report 825 (*Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual*) and updated in NCHRP Report 1087 to better address alternative intersections. • Oversaturated conditions or intersections potentially impacted by a nearby intersection's operations may require microsimulation. For more information see KYTC's Microsimulation Guidelines. • Report Level of Service (LOS), volume/capacity (v/c) ratio, delay, and queue lengths at the intersection and for each leg.	Traffic Analysis Software (HCM Methodology)/ PPEAG Tool*
Motor Vehicle Safety Performance • Use the Safety Performance for Intersection Control Evaluation (SPICE) tool for Stage 2 analysis to compare the predicted safety of intersection alternatives. • Report predicted crashes.	SPICE*
Context and Equity • Summarize and consider the area's land use and context. • If an Environmental Justice Report was completed as part of the project, note findings regarding populations with disabilities, populations living in poverty, populations under 10 or over 74 years of age, households without cars, and demographics.	KYTC Stage 1 ICE Form/ Environmental Justice Study (if available).
Pedestrian and Bicyclist Safety Assessment • Consider CAP-X scores from Stage 1. • The Design Flags Calculator may be used on projects where bicycle and pedestrian activity is expected to be higher.	CAP-X Multimodal Sheets*/ Design Flags Tool*
Environmental, Utility, Right-of-Way Impacts • Summarize and consider the impacts of each intersection control alternate.	Preliminary project plans/ environmental document
Public Input • Summarize and consider public input.	Public meeting notes

Table 3 cont. ICE Stage 2 Analysis and Evaluation Factors

Intersection Control Evaluation Factors	Recommended Tools & Resources
Intersection Costs • The preliminary estimate should include the cost to build and the approximate cost of right of way and utilities. Also consider life-cycle costs (e.g., crash costs, vehicle delay, operations, maintenance). • More complex projects may benefit from life-cycle cost estimates, while a more subjective comparison may be made on less complex projects. • The Life-Cycle Cost Estimation Tool (LCCET) spreadsheet is an optional tool that lets users compare the life-cycle costs of alternative intersection designs.	KYTC preliminary cost estimate data/ LCCET*

*The spreadsheet tool may be downloaded from National Academies website.

Typically, this information should be available to the PM and the PDT during the Preliminary Line and Grade meeting for consideration resulting in the selection of an intersection control alternative.

3.2.1. Alternative Selection Documentation

The Stage 2 sheets of the *KYTC ICE Form* along with the traffic and safety analysis files are submitted and reviewed with the DES. The ICE Intersection Analysis and Selection Form indicates the intersection control type recommended by the PM and the PDT. The chosen intersection alternative is approved when the DES is approved.

4. Helpful Tools and Links

National Academies website https://nap.nationalacademies.org/catalog/27509/guide-for-intersection-control-evaluation includes the following files available for download:

- NCHRP Research Report 1087 Guide for Intersection Control Evaluation (2024)
- Capacity Analysis for Planning of Junctions (CAP-X) Tool
- Planning and Preliminary Engineering Applications Guide Tool for Intersection Control Evaluation (PPEAG ICE Tool)
- SSI Score Calculator Tool – Intersection
- SSI Score Calculator Tool – Interchange
- Safety Performance for Intersection Control Evaluation (SPICE)
- Design Flags Calculator

- Life-Cycle Cost Estimating Too (LCCET)

FHWA's Intersection Control Evaluation website – Includes a description of ICE and educational materials.

FHWA's Interchange Comparison Safety Tool

FHWA (2010). *Alternative Intersections and Interchanges Informational Report* (FHWA-RD-09-060) https://www.fhwa.dot.gov/publications/research/safety/09060/.

FHWA (2021). *A Safe System-Based Framework and Analytical Methodology for Assessing Intersections*. https://safety.fhwa.dot.gov/intersection/ssi/fhwasa21008.pdf.

Dowling, Richard et al., *Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual*, NCHRP Report 825, 2016, http://www.trb.org/NCHRP/Blurbs/174958.aspx

Kittelson & Associates, Inc.; Institute for Transportation Research and Education; Toole Design Group; Accessible Design for the Blind; and ATS Americas. 2020. NCHRP Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges*. Transportation Research Board of the National Academies, Washington, DC. https://www.trb.org/Main/Blurbs/181781.aspx.

KYTC's SAFERoad Solutions

Virginia DOT's Innovative Intersections and Interchanges website

KYTC's Alternative Intersections Map

KYTC Traffic Count Reporting System

KYTC's DDSA Website

KYTC's Microsimulation Guidelines

Life-Cycle Cost Estimation Tool (LCCET) spreadsheet

KYTC's *Highway Design Manual*

KYTC ROUNDABOUT DESIGN GUIDANCE

TEAM KENTUCKY
TRANSPORTATION CABINET

HIGHWAY Design	***Roundabout***
	Design Guidance

Contents

1.0 INTRODUCTION

The modern roundabout is an at-grade intersection with a generally circular design that uses yield control on entry (i.e., vehicles entering a roundabout must yield to vehicles already circulating the roundabout). Studies throughout the US and Kentucky demonstrate that properly designed roundabouts provide significant safety, operational, and cost benefits relative to other types of intersection control. Roundabouts have much lower fatality and injury rates than conventional intersections. Crash reductions are most pronounced when roundabout geometry forces traffic to enter and circulate at slow speeds (typically less than 30 mph).

KYTC views the roundabout as a viable intersection alternative when located appropriately and designed properly for operational conditions. This guidance reviews the planning and design of roundabouts in Kentucky and is supplemented by guidance from National Cooperative Highway Research Program (NCHRP) Report 1043 (*Guide for Roundabouts*).

Roundabouts fall into four basic categories:

- Mini-roundabouts
- Compact Roundabouts
- Single-lane roundabouts
- Multilane roundabouts

Each category is subdivided based on roundabout size (diameter or total width) and the number of lanes required for specified performance and design constraints. Single-lane and multilane roundabouts are appropriate for rural, suburban, or urban areas. Mini- and compact roundabouts are used most often in low-speed urban environments with low truck volumes.

2.0 INTERSECTION SELECTION

Roundabouts warrant consideration on projects that include a new intersection, where major reconstruction of an existing signalized intersection is proposed (e.g., adding a left-turn lane for any approach, adding an intersection leg), or on widening/reconstruction or corridor projects.

Selecting a preferred intersection type requires evaluating the potential safety and operational performance of different types in light of site constraints and other impacts. KYTC's *Highway Design Guidance Manual* (HD-203) and KYTC's Intersection Control Evaluation (ICE) Guidance provide information on evaluating intersection control.

3.0 SAFETY & OPERATIONAL ANALYSIS

Investigate factors related to the existing facility's safety and the potential to improve these conditions. Safety Performance for Intersection Control Evaluation (SPICE) can be used to conduct a planning-level analysis of safety. For a more detailed safety evaluation, refer to *KYTC's Data-Driven Safety Analysis (DDSA) Implementation Plan* for recommended levels of safety analysis. More complex intersections need a higher level of analysis. The predicted number of crashes should be used to compare roundabouts with other intersection alternatives.

A roundabout's lane configuration and approach legs are dependent on traffic volumes. Capacities vary substantially based on entering traffic volumes, turning movements, and truck percentages. Capacity Analysis for the Planning of Junctions (CAP-X) can be used to conduct a planning-level capacity analysis of roundabouts. Figure 1 displays planning-level capacities for single- and two-lane roundabouts given AADT and left-turn percentages.

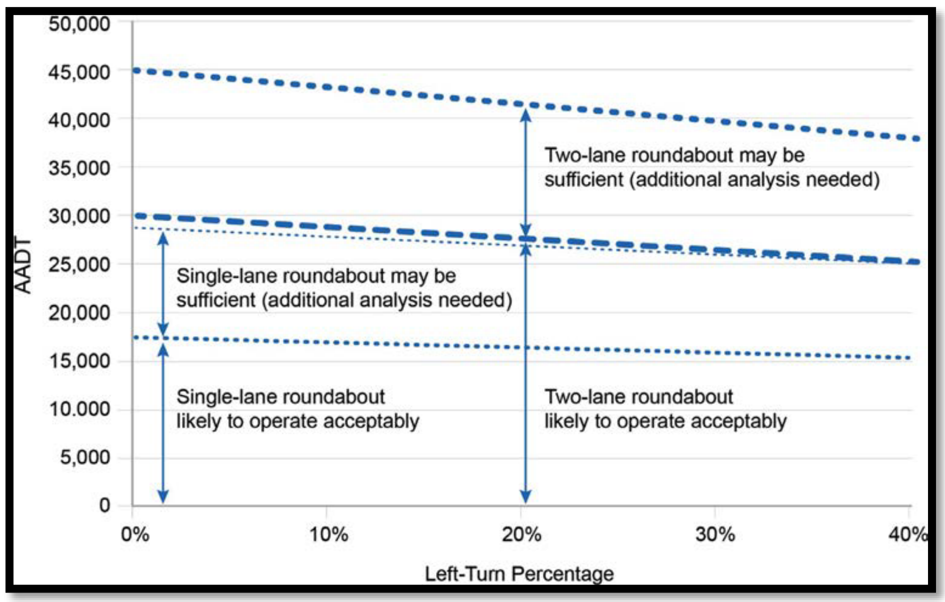


Figure 1 Planning-Level Daily Intersection Volumes for a Four-Leg Roundabout (Source: NCHRP 1043: Guide for Roundabouts Exhibit 8.2)

Table 1 is planning-level guidance that can be used to the most appropriate roundabout configuration based on entering and conflicting flows.

Table 1 Planning-Level Sizing Guide Using Peak Period Volume Thresholds

Sum of Peak Period Entering and Conflicting Flows (veh/hr)	***Type of Roundabout and Number of Lanes***
700 or less	*Single-lane roundabout with a traversable or non-traversable central island is likely sufficient.*
701 to 900	*Single-lane roundabout with a non-traversable central island is likely sufficient; single-lane roundabout with a traversable central island may be sufficient.*
901 to 1,300	*Single-lane roundabout with a non-traversable central island may be sufficient.*
1,301-1,600	*Two-lane entry into a multilane roundabout is likely sufficient; detailed turning movement analysis recommended.*
1,601 to 2,300	*Two-lane entry into a multilane roundabout may be sufficient; detailed turning movement analysis recommended.*
Greater than 2,300	*Three-lane entry into a multilane roundabout may be sufficient; detailed turning movement analysis recommended.*

Use the current *Highway Capacity Manual* (HCM) methodology for operational analysis of roundabouts during the alternative selection stage of the ICE process. Conduct a detailed capacity evaluation to verify lane numbers and arrangements. Use the current *Highway Capacity Manual* (HCM) methodology for operational analysis of roundabouts. Evaluate the following measures of effectiveness:

- Volume-to-capacity (v/c) ratio of each approach lane. Use approach lane capacity estimates and v/c ratios to determine if it is feasible for a roundabout to meet anticipated design year demand.

- Operational delay by lane, approach, and intersection. Estimates of delays for each approach lane should be used to compare roundabouts with other intersection alternatives.

- Lane group queue estimates. Determine the 95th percentile queues for each approach lane at isolated intersections. Microsimulation models may be used to generate queue estimates at roundabouts impacted by nearby traffic control devices. Use queue estimates for each approach lane to determine if a roundabout is a feasible option given the site constraints, adjacent intersections, and access points. Employ queue estimates to size necessary flared or auxiliary approach lanes.

Microsimulation is recommended where traffic patterns are impacted by intersection traffic control devices or other roundabouts located less than 1,200 ft away. Roundabouts closely spaced to other intersections may not see the random arrival patterns assumed by HCM equations. If a non-controlled intersection is within 1,200 feet of the roundabout and the property using that access may develop in the future, microsimulation may be used to analyze roundabout operation. This analysis is done at the discretion of the design team. At intersections heavily travelled by pedestrians, pedestrian movement should be modelled to determine their impact on operations. Microsimulation can be basic when used for planning-level analysis and to create models for public meetings. If microsimulation will inform design decisions, a model must be accurate and additional time should be set aside for model calibration. “Refer to KYTC’s Microsimulation Guidelines for commonly used software packages and microsimulation guidance.

Operational analysis is typically based on the design year (usually 20 years from the year of construction; however, other years may be acceptable). If the analysis indicates the forecasted traffic operations are not acceptable, supplementing operational analysis with sensitivity analysis can be beneficial to gauge how much forecasted traffic volumes must increase from existing volumes before roundabout operations become unacceptable and to determine when that condition may materialize. The immediate safety impacts of installing a roundabout may outweigh unacceptable traffic operations based on forecasted design traffic volumes.

Providing additional lanes that are not needed for capacity purposes increases crash risk by increasing the number of conflict points. If forecasts indicate a multilane roundabout is needed to accommodate the 20-year traffic horizon but a single-lane roundabout will provide acceptable operations for several years, consider building a single-lane initially. When using this option, consider designing the roundabout so future expansion to a multilane configuration can be done without difficulty. Site conditions influence whether a planned expansion should occur to the inside or outside of the single-lane roundabout construction. Either option may require significant reconstruction, which should be considered along with the safety benefits of initially constructing a single-lane roundabout. Single lane initial/two lane ultimate designs that widen to the inside may pose constructability and drop-off challenges on roundabouts with a high percentage of trucks since the truck apron would need to be removed and replaced with an inside lane. Widening to the outside may require relocation of drainage structures and modifications to splitter islands.

4.0 BASIC DESIGN ELEMENTS

Figure 2 shows a modern roundabout's basic design elements. The following sections provide in-depth discussions of each element.

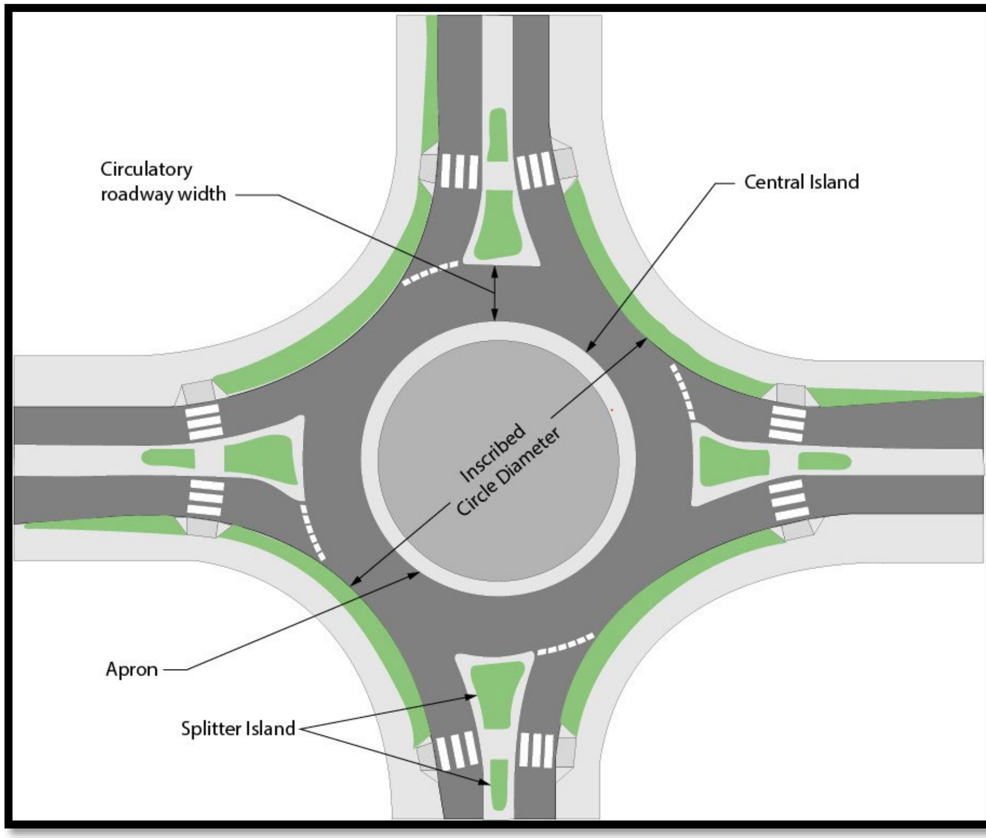


Figure 2 Basic Roundabout Design Elements

Roundabout size is typically based on its ICD and a selected planning buffer outside its perimeter to account for features such as curb, gutter, landscaping buffers, facilities for bicyclists and pedestrians, utilities, and grading needs.

Figure 3 illustrates the iterative nature of the roundabout design. The flowchart displays a process for finding the optimal balance of safety, operational performance, service for users, and accommodation of the design vehicle often while working within site-specific constraints.

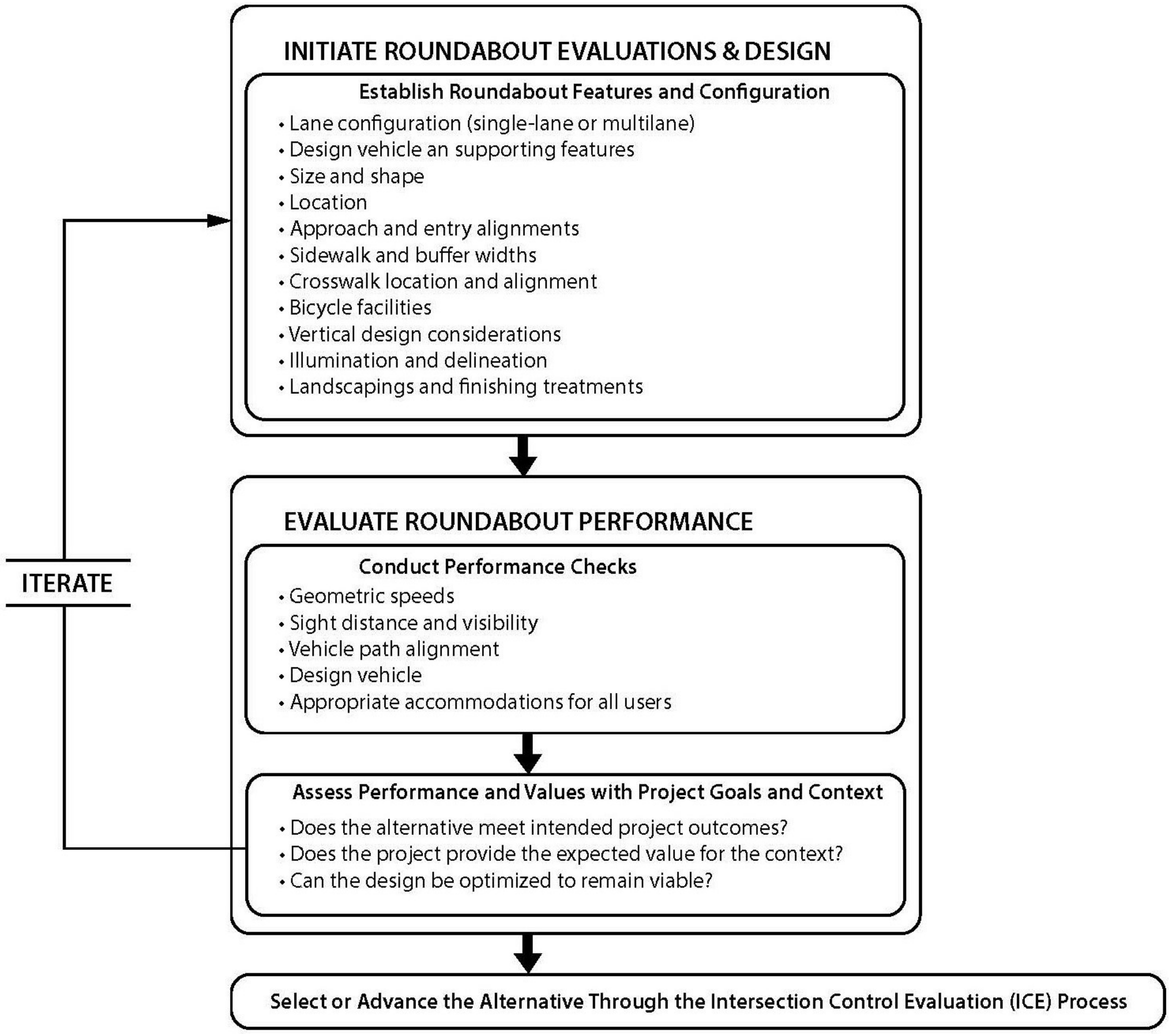


Figure 3 Roundabout Design Process

4.1 Roundabout Shapes

Circles are the preferred shape for roundabouts. However, ovals and asymmetrical designs may be used if site constrains render circular designs impractical. Striping can be used to improve the alignment of vehicle paths. Spiral markings may be used to accommodate high volumes of left-turning traffic. Figure 4 illustrates the most common roundabout shapes. Each is described below.

Circle — The most common roundabout shape is a circle with a uniform radius.

Ellipse — An ellipse is typically beneficial where a major road intersects a minor road at a skew angle, where project constraints make it difficult to use a circular shape. Ellipses are practical for separating the approaches to facilitate truck turning and to control entry speeds. However, elliptical designs tend to promote lane drifts because the driver's perception of the ellipse is limited and the elliptical shape disrupts the driver's expectation of a constant radius.

Peanut — A peanut roundabout consists of two interlinked circles where each circle does not permit a 360-degree movement. They are typically applicable when two closely spaced intersections cannot support regular circles without overlapping. They can also be used at extremely skewed intersections and/or when right of way is constrained.

Barbell/Dog Bone — A barbell or dog bone roundabout is an elongated peanut-shaped roundabout that is used when two intersections are close to one another. When used at ramp terminals, it may allow for the narrowing of lanes between ramps, resulting in a reduced bridge width.

Teardrop — A teardrop roundabout does not allow for continuous 360-degree travel within the circulatory roadway. It has one non-yielding approach. This design eliminates a portion of the circulatory roadway not used at locations like ramp terminal intersections where there is no traffic volume due to a one-way ramp configuration.

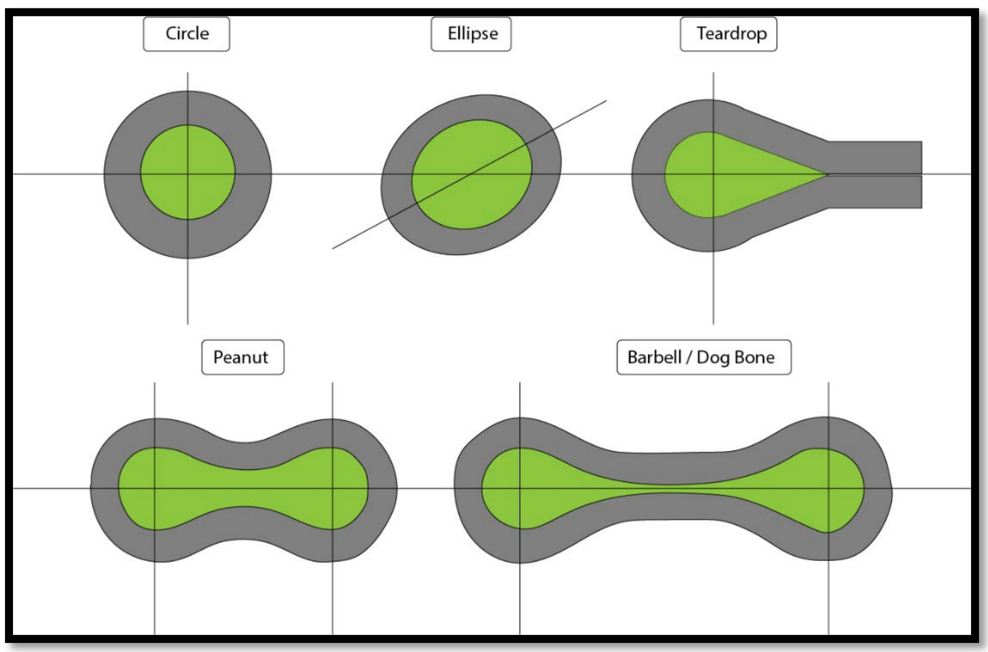


Figure 4 Roundabout Shapes

4.2 Design Vehicle

Roundabouts should be designed to accommodate the largest vehicle that can reasonably be anticipated. Because roundabouts are designed to slow traffic, narrow curb-to-curb widths and tight turning radii are used. Large trucks and buses dictate many of the roundabout's dimensions. Therefore, it is necessary to determine the design vehicle at the start of the design and investigation process.

Use the following information to aide in the selection of a design vehicle: functional classification, project context, type of intersecting roadways, adjacent and nearby land uses, and the types and volume of vehicles using the intersection. Farm equipment or other vehicles may be selected as design vehicles in some areas. Table 2 lists suggested design vehicles based on roadway designation.

Table 2 Suggested Design Vehicle

Roadway Designation	***Design Vehicle***
State Highways	*WB-67*
Ramp Terminals	*WB-67*
Major Truck Routes	*WB-67*
Other Rural Roadways	*WB-62*
Industrial	*WB-40*
Commercial	*SU, BUS*
Residential	*SU, BUS*

Account for design vehicles of special size or characteristics when establishing a roundabout's dimensions and laying out its geometric features. If smaller trucks than suggested are used as the design vehicle, but WB 67s are anticipated to use the roundabout, check the turning movements of the larger vehicle and accommodate with outside truck aprons. Emergency vehicles and school busses should be able to navigate a roundabout without mounting curbs or truck aprons.

If larger vehicles may use a roundabout (e.g., vehicles transporting mobile homes) that cannot be accommodated within the roadway or truck apron, make sure to place signing, lighting, and landscaping outside of the turning paths of such vehicles. Also consider the vertical requirements necessary to provide clearance for larger vehicles.

4.3 Circulatory Roadway

The required width of the circulatory roadway is determined based on the number of entry lanes and the turning paths of the design vehicle(s). Use turning templates to determine the swept path of vehicles through each turning movement (Figure 5). In accordance with AASHTO, provide a minimum clearance of 1 ft — and preferably 2 ft —between the outside edge of the vehicle's tire track and the curb line.

A 2% outward cross-slope is desirable. The outside of the circulatory roadway must use a Standard Curb as shown in current version of KYTC Standard Drawing No. RPM-100. Gutters assist with drainage and allow for better protection of the curbs. In locations with significant truck traffic, consider using Drop Box Inlets (DBI) Type 13 on the outside of the circulatory roadway as needed for drainage instead of curb boxes to minimize damage caused by off-tracking.

For information on joints for JPC concrete circulatory roadways, see the American Concrete Pavement Association's (ACPA) Research and Technology Update on concrete roundabouts.

Mini-Roundabouts. Make the circulatory roadway width wide enough to accommodate a passenger car without use of a truck apron. Ideally, the circulatory roadway should also be able to accommodate buses.

Single-Lane Roundabouts. On single-lane roundabouts, the circulatory roadway should accommodate a city transit bus, school bus, or single-unit truck without the use of a truck apron. Circulatory roadway width should be 16-20 ft to discourage vehicles from traveling side-by-side. Circulatory roadway width is usually 1.0 to 1.2 times the maximum entry width. When this width is insufficient to accommodate bus or single-unit truck turning paths, consider a wider inscribed diameter. Use a truck apron if the roadway is too narrow to accommodate the design vehicle.

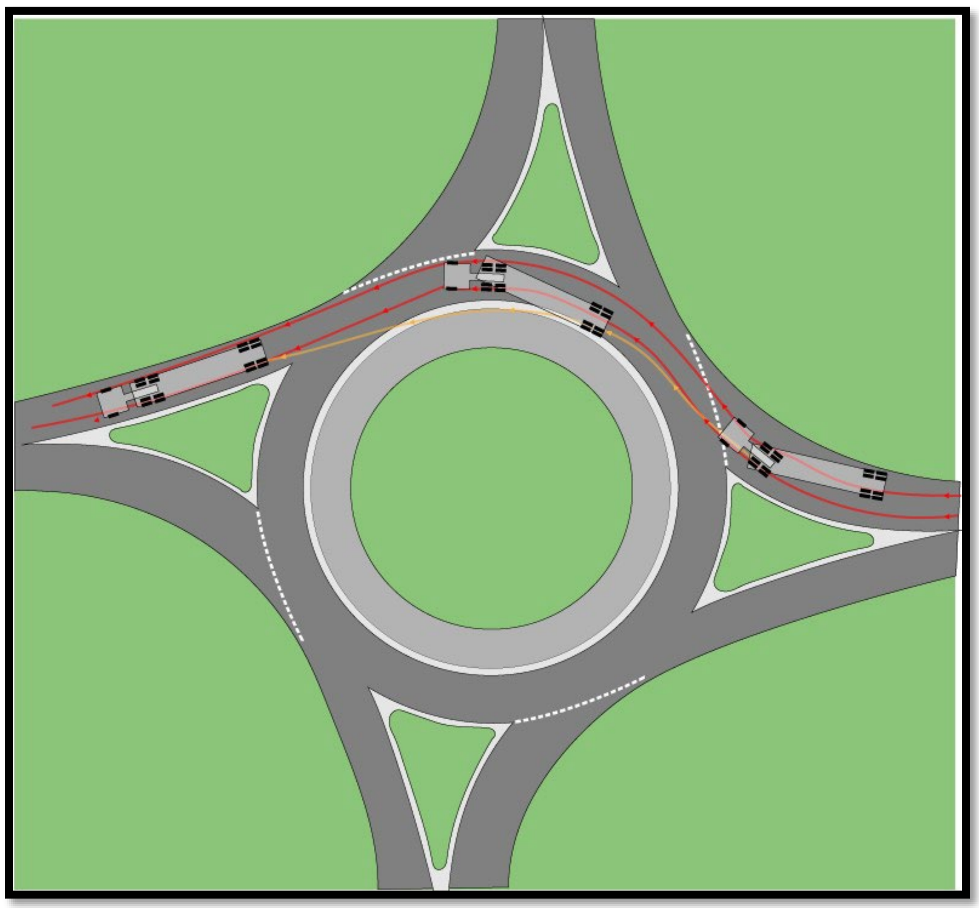


Figure 5 Design Vehicle Swept Path; Single-lane Roundabout

Multilane Roundabouts. On multilane roundabouts, the roadway should be wide enough for the design vehicle(s) to execute all permitted movements. The design vehicle may encroach upon the adjacent lane while providing adequate space (10 ft) to accommodate a passenger car traveling alongside. At intersections that see a high frequency of design vehicles, consider accommodating design vehicles without encroachment into adjacent lanes. Use turning templates to determine the swept path of these vehicles through each turning movement (Figure 6). Individual lane widths should be between 14 ft and 16 ft. If this lane width is insufficient, review the inscribed diameter.

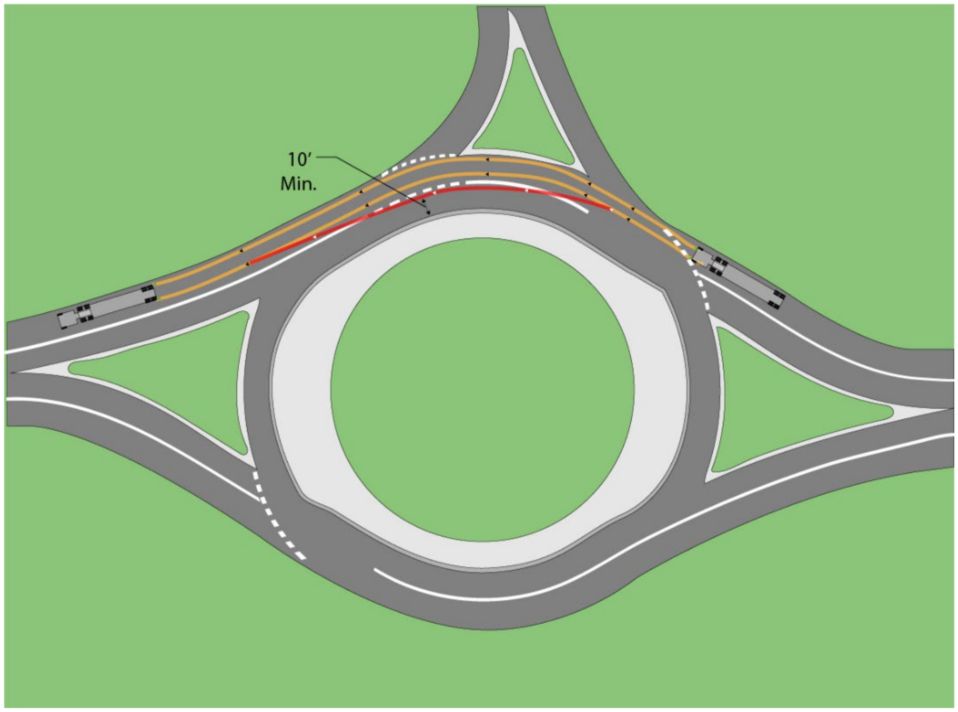


Figure 6 Design Vehicle Swept Path; Multilane Roundabout

4.4 Inscribed Circle Diameter (ICD)

Primarily controlled by the design vehicle's turning radius and the need to develop adequate entry path deflection, the ICD is the distance across the circulating roadway width, truck apron, and central island. In some instances, the design vehicle may be prohibited on local side streets. When this is the case, the design should only accommodate permitted movements. For multilane roundabouts, the design vehicle should be able to perform all permitted maneuvers with the encroachments discussed above from the outside lane. Vehicles using the interior lane may use the truck apron.

Table 3 lists typical ICD values based on design vehicle and roundabout configuration. **Note: these values are provided for preliminary layout guidance only**. Verify the final size and layout of the roundabout using turning templates.

Table 3 Typical Roundabout Inscribed Circle Diameter

Roundabout Configuration	Typical Design Vehicles*	Common ICD Range**
Mini-Roundabout	SU-30	45 to 90
Compact Roundabout	B-40, WB-67	65 to 120 ft
Single-Lane Roundabout	B-40	90 to 150 ft
	WB-40	105 to 150 ft
	WB-67	130 to 180 ft
Two-Lane Roundabout	WB-40	150 to 220 ft
	WB-67	165 to 220 ft

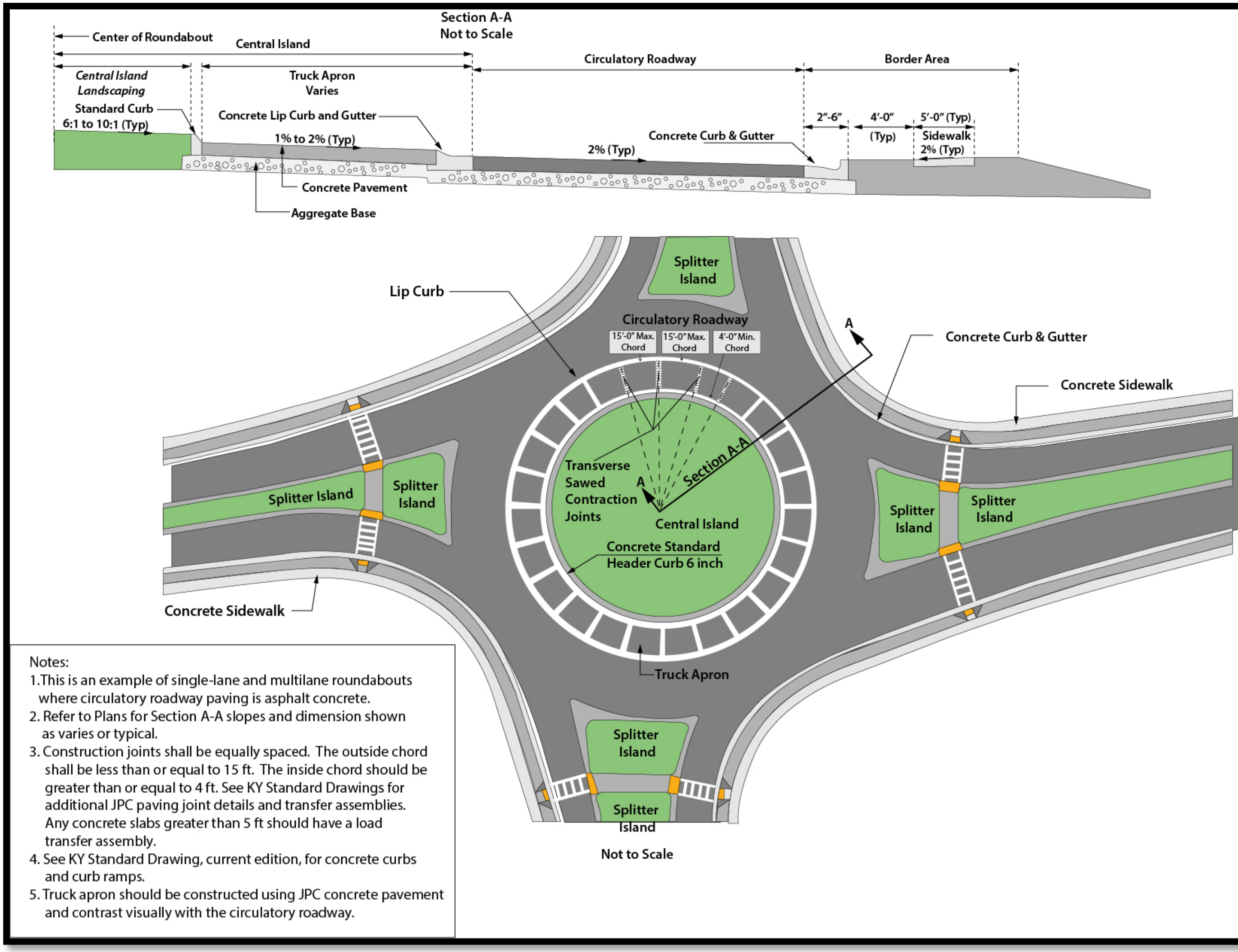
*See Table 1 for suggested design vehicles. The list of possible design vehicles is not exhaustive.
**Assumes 90° angles between entries and no more than four legs.

4.5 Truck Apron

A raised area on the central island that is traversable and used to accommodate over-tracking turning paths of the design vehicle on the inside circulatory lane while maintaining sufficient deflection and lane widths for smaller vehicles. Truck aprons must be mountable by trailers attached to the design vehicle, but their configuration should discourage mounting by cars, SUVs, and light trucks. Truck aprons should be 3-15 ft. wide. Aprons the width of a snowplow blade are easier to plow during snow and ice season. If the proposed apron exceeds these parameters, the roundabout's ICD should be reevaluated.

A truck apron should slope 1-2% away from the central island and be raised 2-3 in above the circulatory roadway. For retrofit projects, existing roadway grades and cross slopes must be considered. As such, cross slopes may differ from slopes preferred for new construction. Use a lip curb and gutter on the outside of truck aprons (see current KYTC Standard Drawing No. RPM-100).

Truck aprons should be constructed using JPC concrete pavement and contrast visually with the circulatory roadway. Establishing a strong contrast improves visibility and helps drivers navigate the roundabout. Figure 7 shows recommended joint spacing for truck aprons.



Notes:

1. This is an example of single-lane and multilane roundabouts where circulatory roadway paving is asphalt concrete.
2. Refer to Plans for Section A-A slopes and dimension shown as varies or typical.
3. Construction joints shall be equally spaced. The outside chord shall be less than or equal to 15 ft. The inside chord should be greater than or equal to 4 ft. See KY Standard Drawings for additional JPC paving joint details and transfer assemblies. Any concrete slabs greater than 5 ft should have a load transfer assembly.
4. See KY Standard Drawing, current edition, for concrete curbs and curb ramps.
5. Truck apron should be constructed using JPC concrete pavement and contrast visually with the circulatory roadway.

Figure 7 Truck Apron Joint Spacing

4.6 Central Island

The area surrounded by the circulating roadway and truck apron. On single- and multilane roundabouts, central islands should be raised, non-traversable, and surrounded by a six-inch vertical curb. Include a gutter for drainage if the truck apron slopes toward the central island. Sizing is determined by the remaining space not used by the circulatory roadway or truck apron.

The central island on single- and multilane roundabouts should slope upward from the truck apron using a slope no flatter than 10:1 and no steeper than 6:1. Installing a variety of low-maintenance plants of different heights can improve a central island's visibility which can improve safety by significantly decreasing approach speeds at roundabouts. Landscaping also breaks the headlight glare of oncoming vehicles. Plants must be at least 6 ft. from the inside edge of truck apron and clear of required sight triangles. Do not place fixed objects on central islands if the roundabout has one or more high-speed (>45 MPH) approaches.

Mini-roundabouts require a fully traversable central island that has a maximum height of 2 to 5 in. Compact roundabouts may use a traversable or non-traversable central island. Signs shall not be mounted in traversable central islands.

4.7 Splitter Island

A feature that separates entering and exiting traffic on an approach and provides a visible indication of the roundabout. Raised splitter islands must be provided on all single- and multilane roundabouts to:

- Provide refuge for pedestrians, wheelchairs, bicycles, and baby strollers
- Assist in controlling speeds
- Guide traffic into the roundabout
- Physically separate entering and exiting traffic streams
- Deter wrong-way movements.

The splitter island envelope is formed by the entry and exit curves on a leg. On low-speed approaches, the island's total length should be at least 50 ft (100 ft preferred). The island should extend beyond the exit curve to protect pedestrians and alert approaching drivers to the roundabout geometry. Low-speed (≤ 45 mph) approaches, especially those with pedestrian facilities, should incorporate 6 in curbs on both sides of the splitter island. Figure 8 shows the minimum dimensions for a splitter island of a single- or multilane roundabout with a pedestrian refuge.

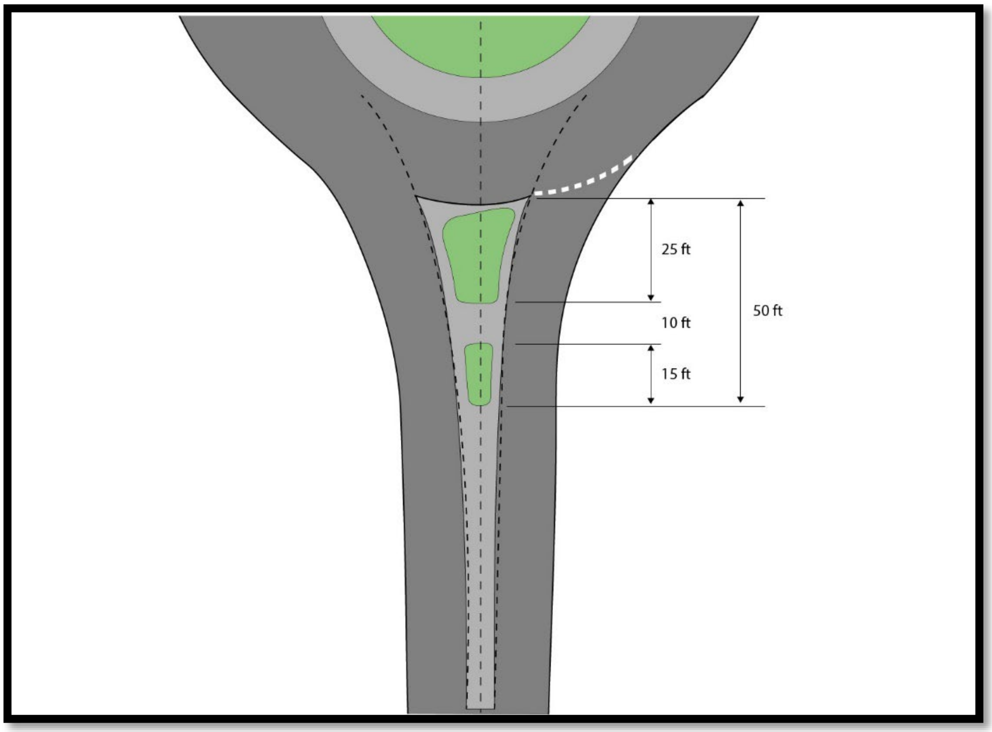


Figure 8 Minimum Splitter Island Dimensions (Low-Speed)

On high-speed (> 45 mph) approaches the splitter island must be at least 200 ft. long to provide drivers with adequate warning that they are approaching an intersection and must slow down. The splitter island and its approach pavement markings should extend back to the point where a driver can decelerate from the approach speed to yield at the roundabout entry. Vertical curbs should be placed on the right-hand side of the splitter island for at least half of the length of the splitter island (see Figure 14). The vertical curb should be a standard curb as shown in the current version of Standard Drawing No. RPM-100. The remainder of the splitter island should use mountable curb as shown in Standard Drawing No. RPM-100.

Follow standard AASHTO guidelines for island design. This includes (1) using larger nose radii at approach corners to maximize island visibility and (2) offsetting curb lines at the approach ends to create a funneling effect. Figure 9 illustrates minimum splitter island nose radii and offset dimensions for the entry and exit traveled ways.

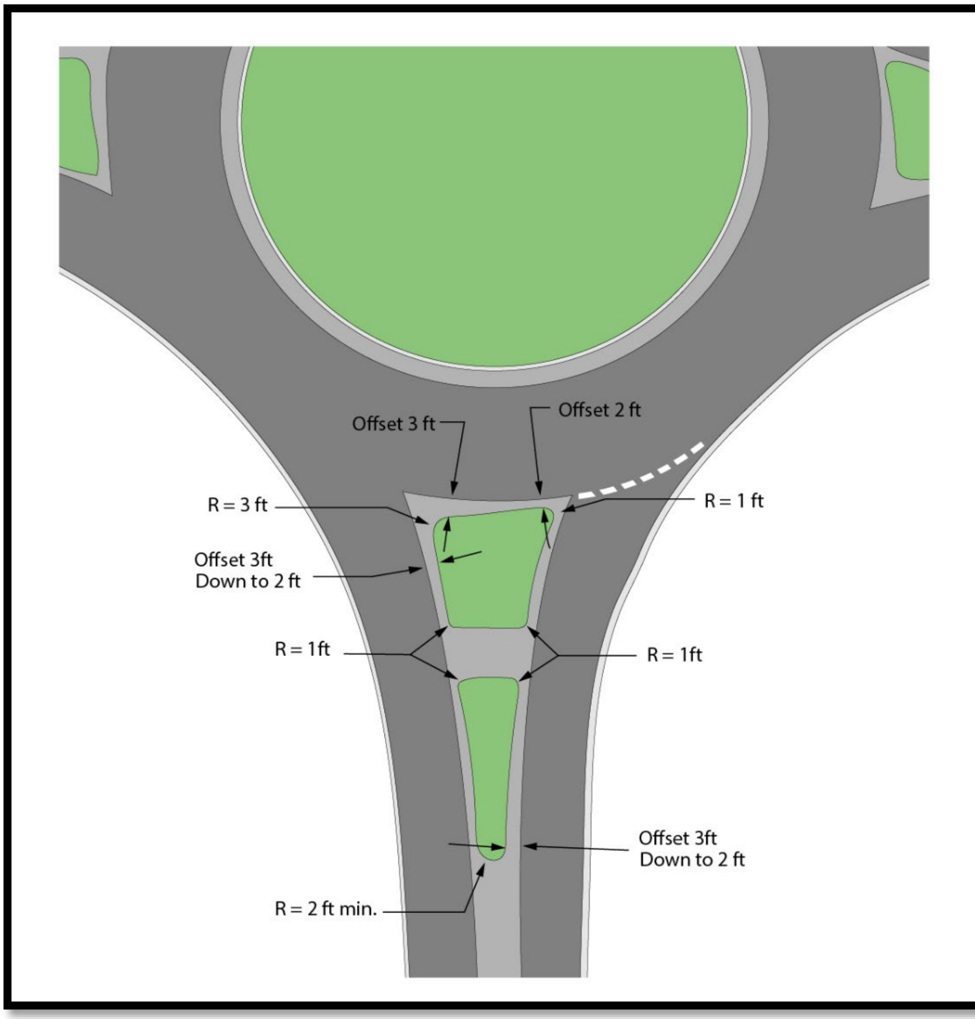


Figure 9 Splitter Island Offset Dimensions

Low-to-the-ground landscape plantings are permissible on the splitter islands and approaches, but not recommended within 50 ft of the yield point.

Where pedestrian facilities are present, the pedestrian refuge island enables safer crossings by separating and protecting pedestrians from motor vehicles as they make a two-stage crossing (i.e., pedestrians take advantage of gaps in one direction of traffic at a time). Pedestrian refuges must be at least 10 ft long, 6 ft wide, and located 25 ft behind the roundabout entrance. The pedestrian refuge is usually a cut-through of the splitter island. Use a maximum 2% cross slope to comply with ADA requirements. On single-lane roundabouts, the crosswalk can have a straight alignment through the splitter island, or the pedestrian refuge can be constructed with an angle (Figure 10). Angled pedestrian refuges let pedestrians cross the entry and exit perpendicularly. Crossings should be set back 20–25 ft on roundabout entries or single-lane exits and 50–75 ft on two-lane exits.

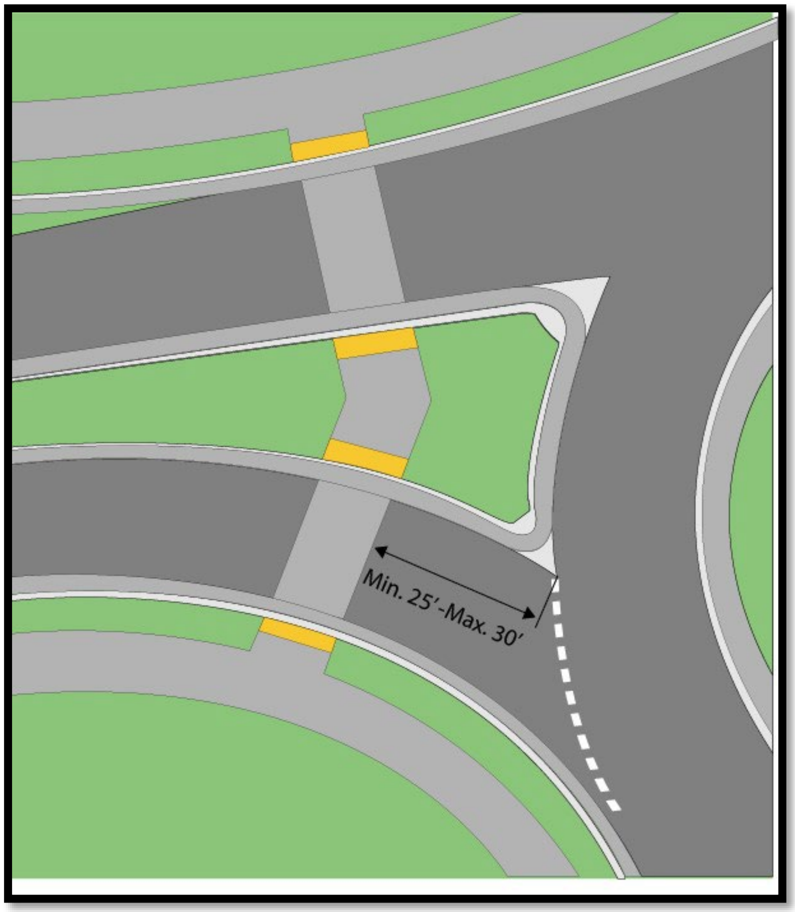


Figure 10 Angled Crosswalk in Pedestrian Refuge

Pedestrian refuges on multilane roundabouts can be angled like in Figure 9 or staggered or offset (Figure 11), where the exit crosswalk is recessed two car lengths from the roundabout and the entry crosswalk is set back one car length from the roundabout yield line. In this configuration, the crosswalk has two 90-degree turns in the splitter island. A crashworthy, pedestrian fence may be used to guide pedestrians. This configuration allows for more vehicle storage between the circulatory roadway and exit crosswalk and gives exiting drivers more time to react to pedestrians using the crosswalk. However, locating a crossing farther away from the circulatory roadway may encourage higher vehicle speeds at the crossing.

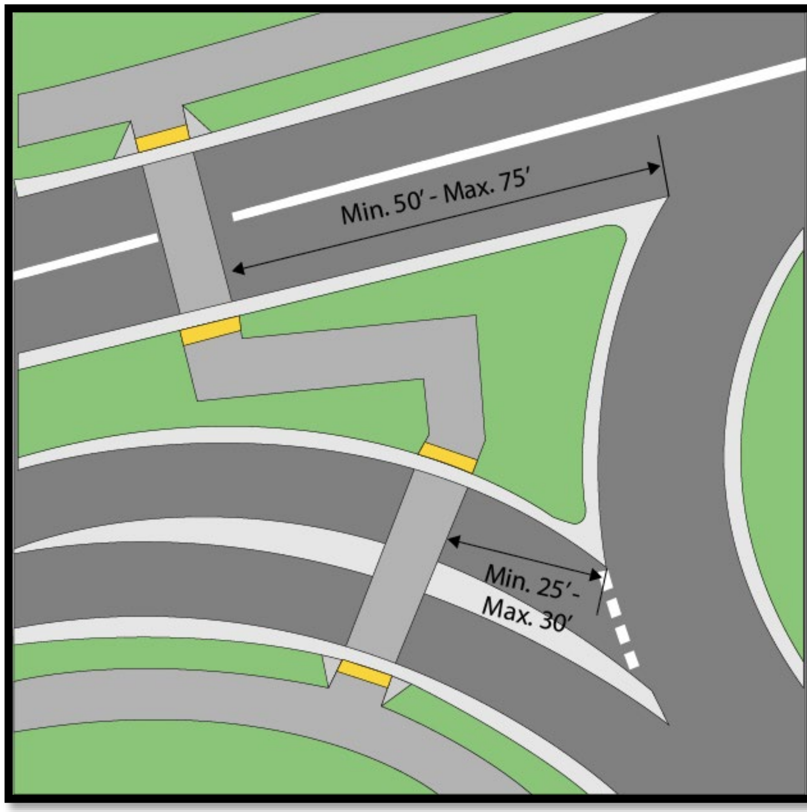


Figure 11 Offset Crosswalk in Pedestrian Refuge

Because of their size, it may be more difficult to provide splitter islands that are large enough to accommodate pedestrian facilities at mini- and compact roundabouts. Consider raised islands where there is sufficient space to provide an island with a minimum area of 50 ft^2 and where pedestrians are present. A mountable curb may be used if the design vehicle's swept path tracks over the splitter island. On minor side streets (AADT < 1,000) where the existing roadway is narrow, using paint to delineate the splitter island is acceptable but should be avoided if possible. A flush or painted island may also be considered if a minimum island area of 50 ft^2 cannot be achieved. As with other single-lane roundabouts, if there is insufficient median width (< 6 ft) to provide an adequate pedestrian refuge area, pedestrians will need to cross in one stage, and detectable warnings should not be used within the splitter island. Figure 12 provides splitter island options for constrained locations.

If raised splitter islands are not feasible, roundabouts in locations with low traffic volumes (e.g., below 15,000 ADT), low speeds (i.e., less than 45 mph), or constrained reconstruction may also include combinations of traversable and non-traversable splitter islands.

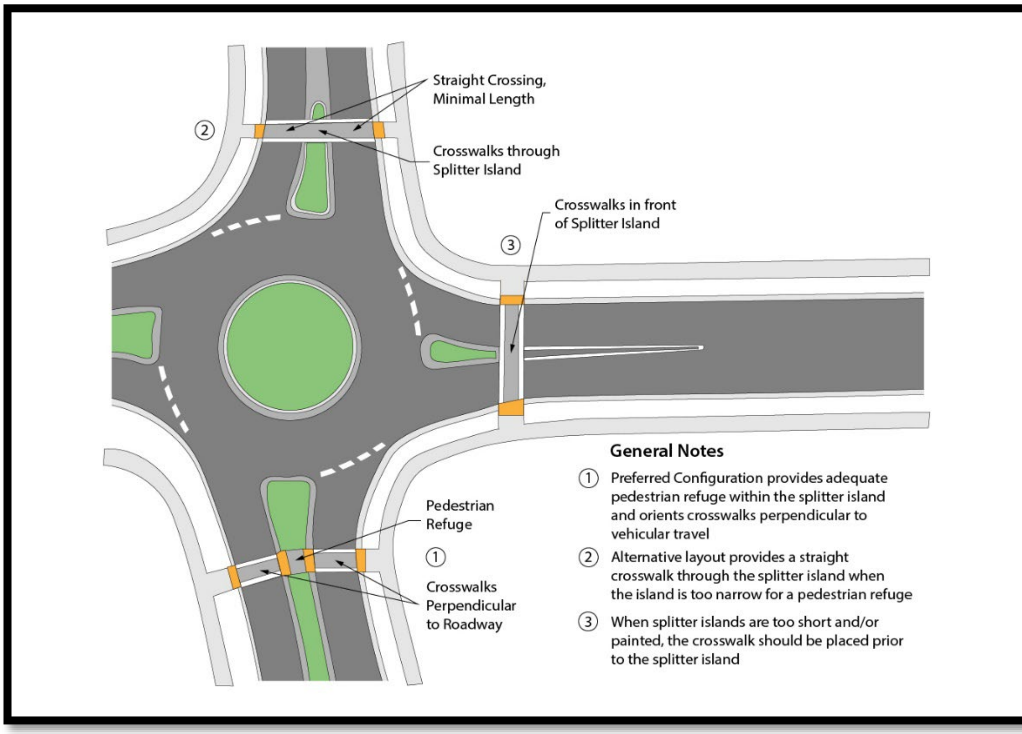


Figure 12 Splitter Island Options for Constrained Locations

For all crosswalk designs, it is important to channel visually impaired pedestrians appropriately with alignment, curbs, and detectable warnings.

5.0 GEOMETRIC DESIGN

5.1 Approach and Entry

The approach roadway's horizontal alignment should enable the design of an acceptable entry deflection without creating severe horizontal curvature or poor stopping sight distance. The alignment does not have to pass through the roundabout's center (Figure 13); however, it has a primary effect on achieving entry and exit path deflection. The optimal alignment allows for an entry design that provides adequate deflection and speed control while providing appropriate view angles to drivers and balancing property impacts/costs. Design for target vehicle speeds (e.g., 15–25 mph) throughout the roundabout, with maximum entering design speeds of 25–30 mph, depending on lane configuration.

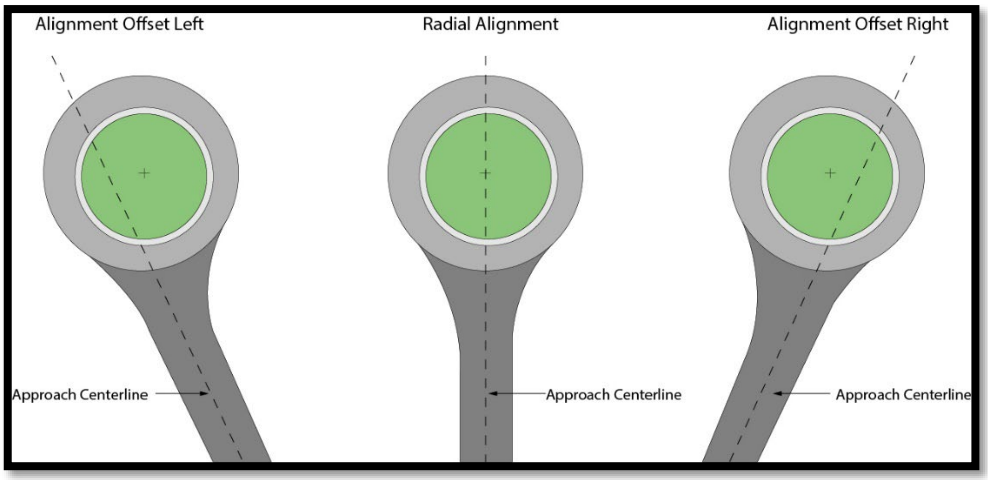


Figure 13 Approach Roadway Alignment

An offset left alignment is preferred because it allows for greater deflection and accommodates large trucks with smaller ICDs. A radial alignment through the center of the circle is acceptable. It reduces the amount of alignment changes along the approach. Only use the offset right alignment if fastest path speed objectives are met.

Preferably, there should be at least 90 degrees between approach legs, however, the angle can range between 75 degrees and 105 degrees for intersections with four legs. Larger angles may result in excess speeds. Smaller angles are difficult for trucks to navigate and degrades visibility to the left.

For T-intersections, it is preferable to deflect the outer curb line at the top of the T to provide deflection for all movements.

Design the approach profiles as flat as practical. Minimize breakovers between the approach profiles and circulatory road.

5.2 High-Speed Approaches

For high-speed approaches (> 45 mph), several methods should be considered to decrease approach speeds upstream of a roundabout. Methods may be combined or used independently. Some may be better suited for new or reconstruction and others for retrofits. They include but are not limited to:

- Longer splitter islands
- Vertical curbs on half the length of the right of the splitter island closest to the circulatory roadway
- A series of reverse curves
- Transverse pavement rumble strips
- Advisory speed signs located in advance of the roundabout
- Landscaping or signing to enhance visibility of the central island
- Lane and/or shoulder width reduction prior to the roundabout
- Optical speed bars

When implementing a series of reverse curves, the curves approaching a roundabout should be designed with successively smaller radii using a 2% normal crown — the use of superelevation encourages higher speeds. The length of the deceleration zone depends on the distance required to decelerate from the approach design speed to 0 mph at the yield line, as listed in Table 4 (from AASHTO GDHS 2018 Figure 2-34). Some roundabout approaches may only have one approach curve, in which case the curve design should be based on which zone the curve is located in. Curve radii is calculated using AASHTO GDHS 2018 Equation 3-8 with friction values from AASHTO GDHS 2018 Figure 3-4. Tables 5 and 6 list minimum curve radii for AR1 and AR2 curves, respectively. Figure 13 illustrates the curves at the approach.

Table 4 Deceleration Length for Design Speed to 0 MPH

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

Table 5 Minimum Approach Radii for Curve AR1

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

Table 6 Minimum Approach Radii for Curve AR2

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

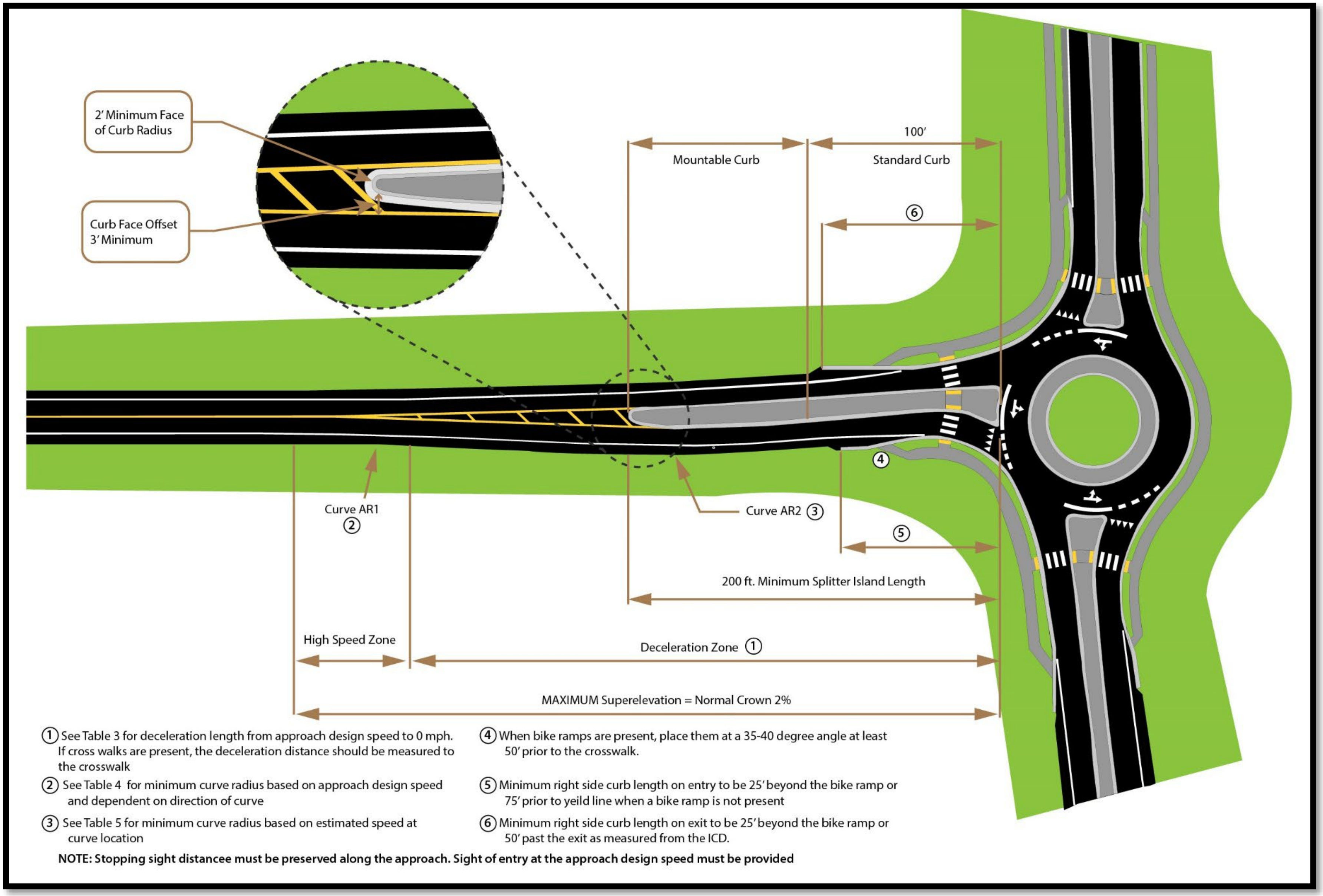


Figure 14: Curves at High-Speed Roundabout Approach

Optical speed bars are white, transverse strips that provide another option for lowering speeds at high-speed approaches. The spacing between bars gradually lessens approaching the roundabout, which increases the driver's perception of their speed and prompts them to slow down. Figure 15 is a detail of speed bar placement.

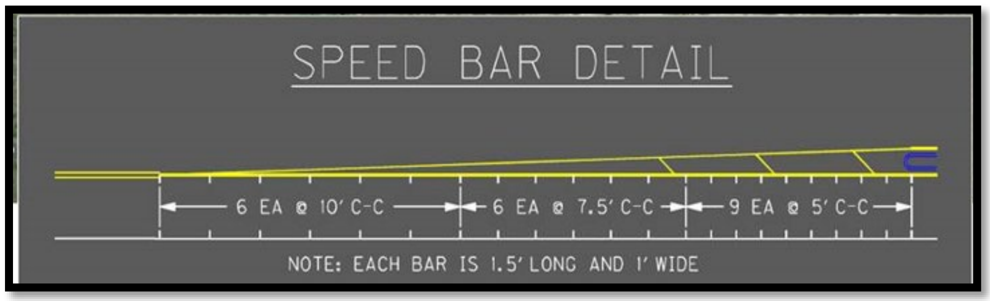


Figure 15 Optical Speed Bar Detail

5.3 Profile

The profile through the intersection can be placed on grades, but grades > 4% are not desirable. For small, retrofit projects, grades may need to match existing roadways and therefore may differ from the grades desired for new construction. For vertical design options, such as tilted circulatory roadways, see NCHRP 1043 (*Guide for Roundabouts*). Keep the profile at the roundabout approach as flat as practical keeping drainage in mind.

5.4 Entry Width

Upstream of a splitter island, maintain the typical approach lane width. Approach lanes should be widened through the approach curvature. The left edge (inside radius) of the entry path should be tangent to the central island or truck apron (Figure 16). The right edge of the entry path may require additional widening to accommodate right turn movements by the design vehicle. Single-lane entry widths should be 14-18 ft wide (15 ft recommended). Multilane entry widths should be 12-15 ft (15 ft recommended). The recommended entry radius following the outside curb line (not the same as $R_{1,}$ the entry path radius from the fastest path discussed later in this guidance) is 50-100 ft for single-lane roundabouts and > 65 ft for multilane roundabouts. This may need to be adjusted based on the fastest path check. The outside entry radius should be tangential to the outside circulatory roadway. If it is not, review the ICD.

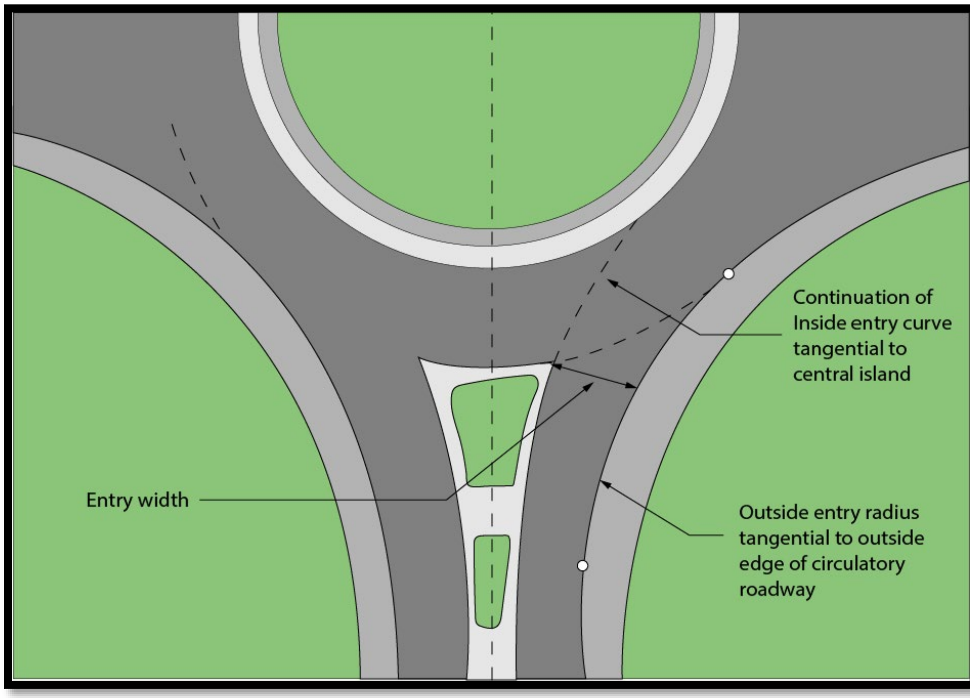


Figure 16 Entry Design

Check the entry width to verify it can accommodate all turning movements from each approach. Right turns for the design vehicle may impact this width, especially for roundabouts with acute angles between approaches.

An outside truck apron is sometimes used to accommodate the design vehicle's right-turn movement (Figure 17). However, typically this option is not preferred. Alternative options include (1) realigning approaches to be more perpendicular, (2) providing an offset-left alignment on the entry to improve the radius for truck turning, or (3) increasing the ICD.

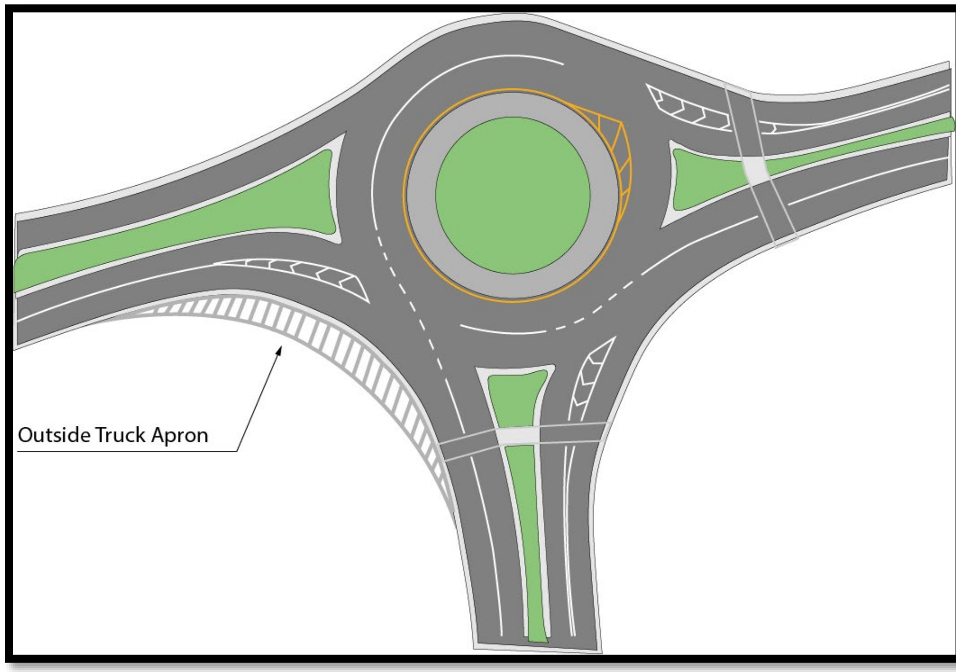


Figure 17 Outside Truck Apron

If outside truck aprons are used, passenger cars and light trucks should be able to enter and negotiate the roundabout without using the apron. A lip curb should be used on the outside of the circulatory lane and a standard curb should be used on the outside of the truck apron (Figure 18). Outside truck aprons should contrast visually with the circulatory roadway.

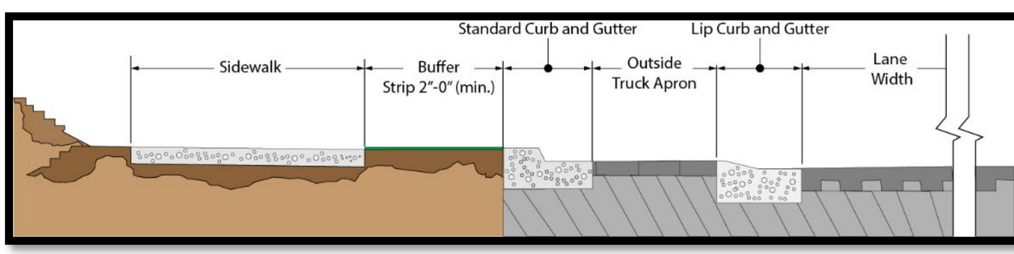


Figure 18 Curb Placement on Outside Truck Apron

5.5 Number of Approach Lanes

Determine the number of entry and exit lanes at each approach and the length of the auxiliary lanes at multilane roundabouts based on queue and capacity requirements.

Right-Turn Bypass and Partial Bypass. Only use right-turn lanes when capacity needs dictate or when other geometric layouts do not provide acceptable traffic operations or accommodations for the design vehicle.

One configuration (Figure 19) is a right-turn partial (yielding) bypass lane with curbed or painted channelization. Vehicles that take the bypass lane must yield to traffic leaving the circulatory roadway. An angle of 70 degrees or more is preferred. Align the right-turn bypass lane so the splitter island of the entry leg blocks the through path.

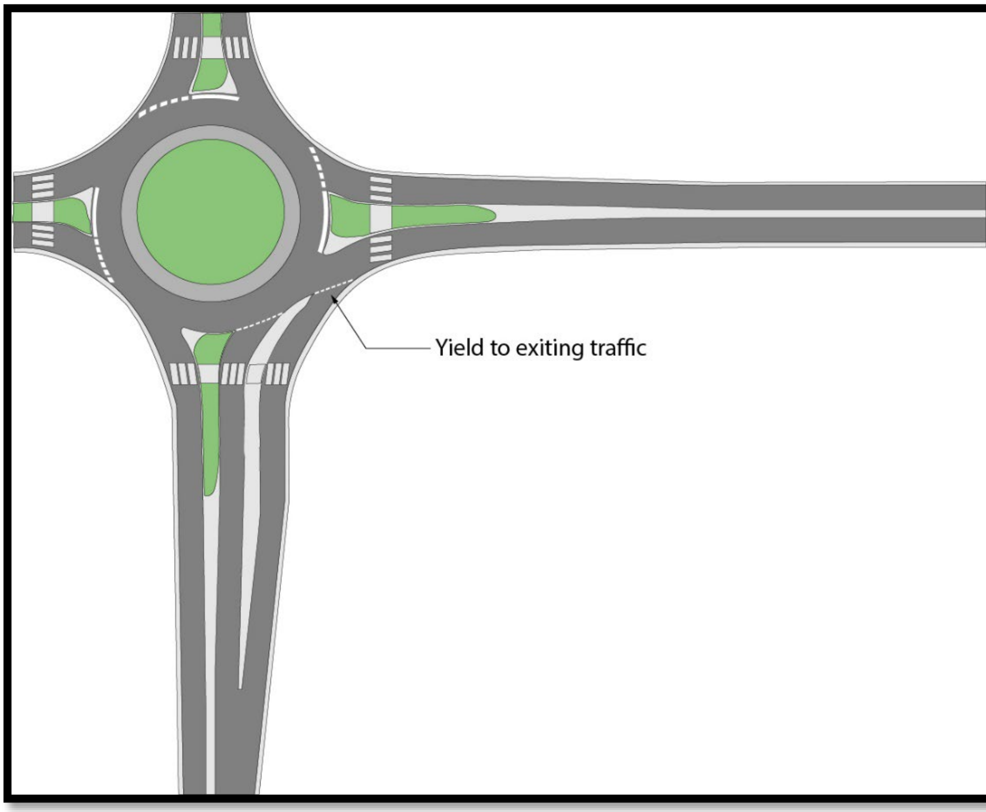


Figure 19 Right-Turn Partial Bypass Lane

Another configuration (Figure 20) is a right-turn (free-flow) bypass lane, which allows vehicles to bypass the roundabout and continue into a dedicated lane or merge into an adjacent lane. This configuration provides better operational performance than the partial bypass, but usually requires more right of way, and the free-flow traffic may be less desirable for pedestrian crossings. The right-turn bypass lane's radius should not be significantly larger than the radius of the fastest entry path provided at the roundabout. If the bypass lane merges into an adjacent lane, extend the acceleration length at least 200 ft before the lane taper begins.

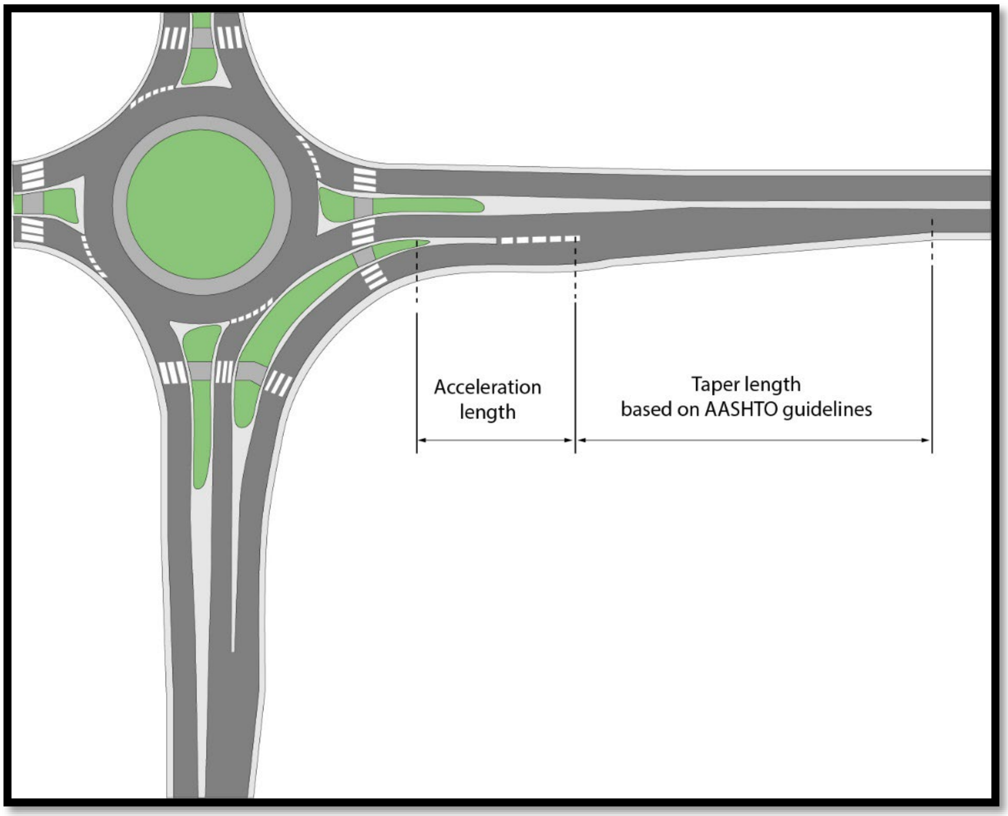


Figure 20 Right-Turn Bypass with an Acceleration Lane

6.0 DESIGN PERFORMANCE CHECKS

6.1 Entry Deflection

A primary design consideration influencing the safe operation of a roundabout is adequate deflection of the vehicle as it enters and progresses through the roundabout. Deflection is measured by identifying the fastest path of a single vehicle through the roundabout for a given movement. The fastest path is drawn assuming a vehicle starts at the left-hand edge of the approach lane, moves to the right side as it enters the roundabouts, travels to the left side of the circulatory roadway, shifts back to the right side at the exit, and completes its move at the left-hand side of the departure lane. The vehicle path centerline is drawn using the following offset distances:

- 5 ft from concrete curbs
- 5 ft from roadway centerline
- 3 ft from striped edge line or lane

Figures 21 and 22 illustrate the fastest through vehicle paths on a single-lane roundabout and a multilane roundabout, respectively. Figure 23 provides an example of an approach where the right-turn path is more critical than the through movement.

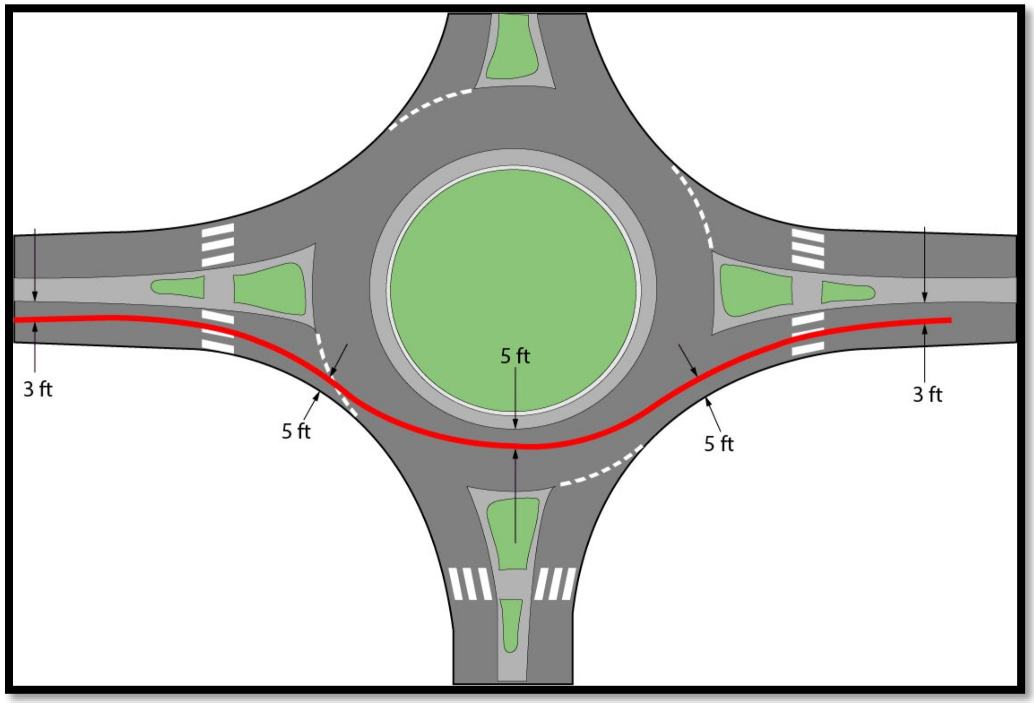


Figure 21 Fastest Path (Through) at Single-Lane Roundabout

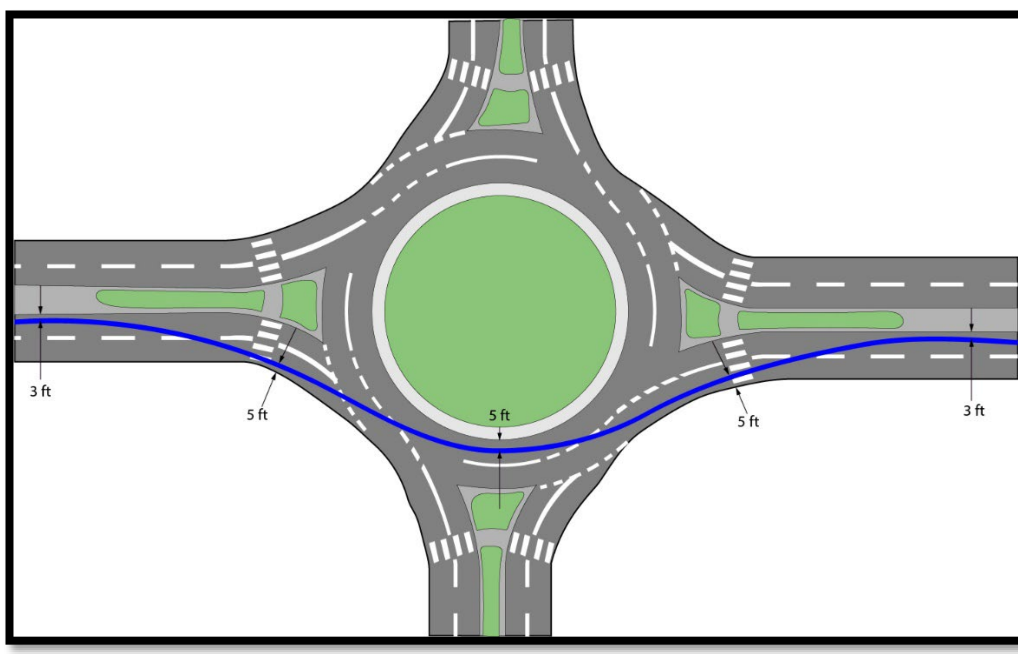


Figure 22 Fastest Path (Through) at Multilane Roundabout

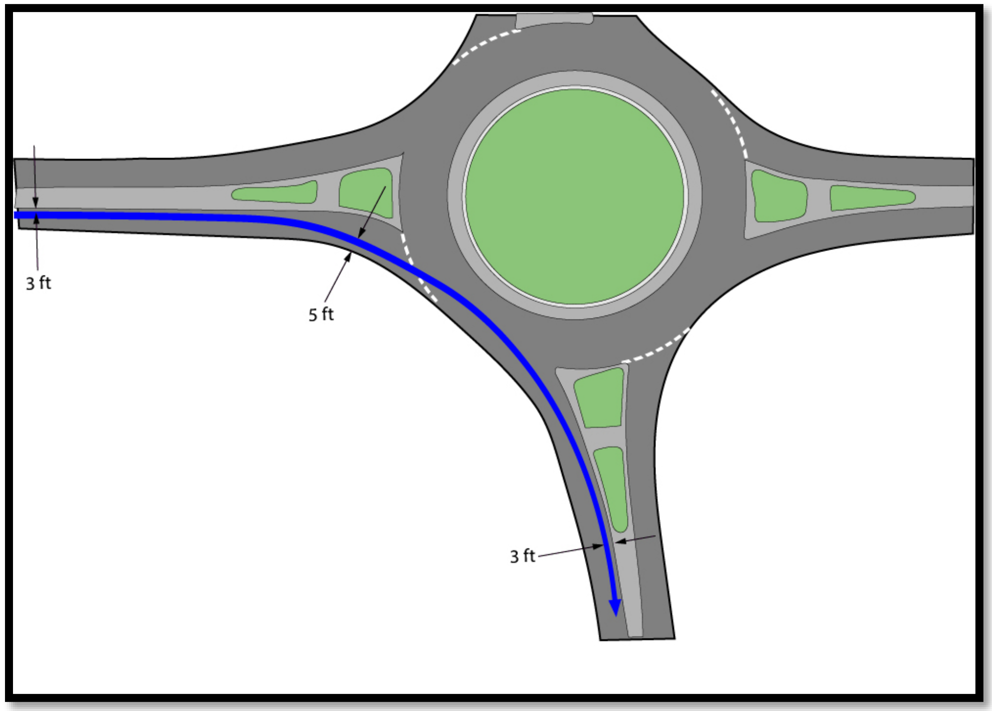


Figure 23 Fastest Path (Right Turn) at Roundabout

Deflection is determined from the entry path radius along the fastest path (i.e., as the vehicle curves to the right through entry geometry). Figure 24 shows the through entry path radius (denoted as R_1) and the right-turn path radius (denoted as R_5). Determine the through and right-turn fastest paths for all approaches. Appendix A provides instructions for creating roundabout fastest paths (spline curves) in OpenRoads.

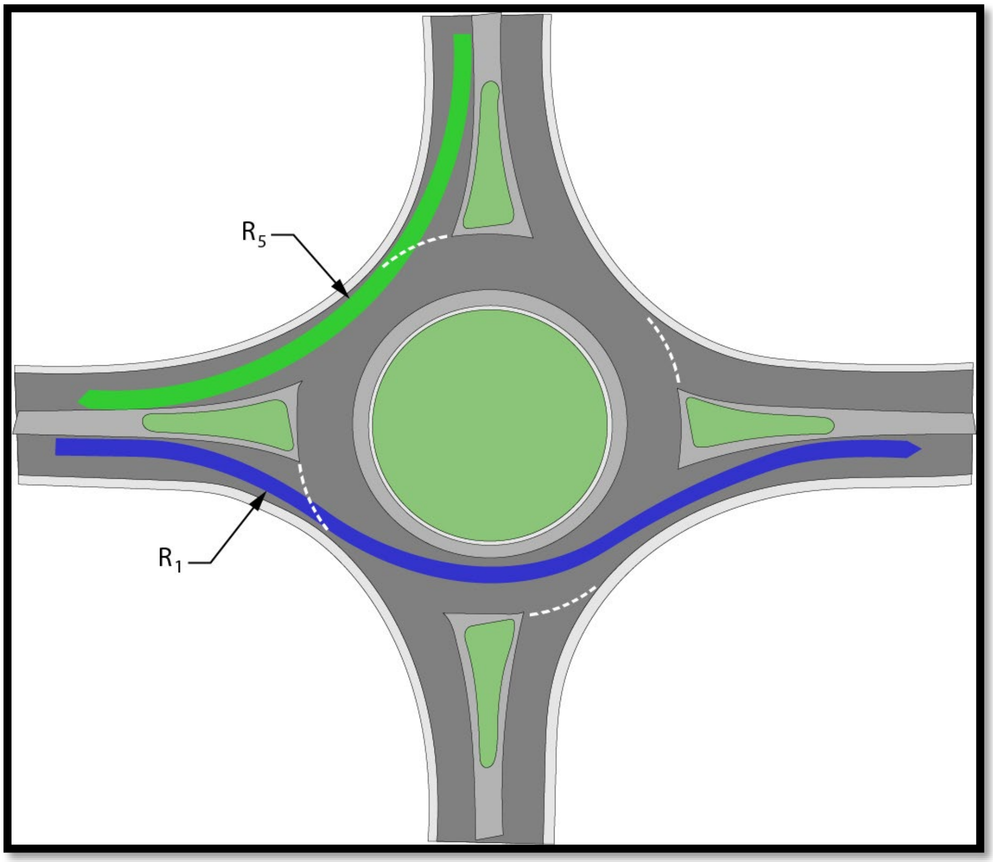


Figure 24 Entry Path Radius

The resulting entry speed is an important design factor. Equation 1 or 2 is used to calculate the speed of the fastest path radii, depending on the superelevation rate.

Equation 1: Predicted Speed Calculation for e = +0.02

$$V = 3.4415R^{0.3861}$$

Equation 2: Predicted Speed Calculation for e = -0.02

$$V = 3.4614R^{0.3673}$$

where:

V = predicted speed (mph)
R = radius of curve (ft)
e = superelevation (ft/ft)

Table 7 lists recommended entry speeds for R_1 and R_5.

Table 7 Recommended Maximum Entry Speed (R_1 and R_5)

Roundabout Configurations	Entry Speed
Mini-Roundabout	15-20 MPH
Single-Lane Roundabout	20-25 MPH
Multilane Roundabout	25-30 MPH

The designer can reduce the fastest entry path radius by offsetting the approach alignment further to the left of the roundabout center or decrease the entry radii of the approach. If an acceptable entry path radius cannot be achieved, consider adopting larger ICDs, larger central islands or angle between approach legs. These changes **will impact** the fastest path of the other legs and other design criteria (e.g., entry angle).

Designing a roundabout is an iterative process. To develop the best overall solution the fastest path entry speed, sight distance and vehicle overlap are the most critical design factors. If the recommended fastest path entry speed on multilane roundabouts — ignoring lane lines — cannot be met without unwanted impacts to roundabout geometry, note for the reviewer the speed which can be met and determine if the recommended fastest path entry speed can be met if lane lines are used to confine the path.

6.2 Exit Curves

Design exit curves to minimize the likelihood of congestion and crashes at the exits. Exit speeds should be higher than or equal to the circulating speed. The exit curve should produce an exit path radius (R_3 in Figure 25) greater than the circulating path radius (R_2). While R_3 is not a critical design factor and can produce higher speeds, keep speeds lower in areas with pedestrians.

Exit curves are also used to taper the exit lane from the circulating roadway width to the exit lane width. Extend this taper from the beginning of the exit to beyond the splitter island.

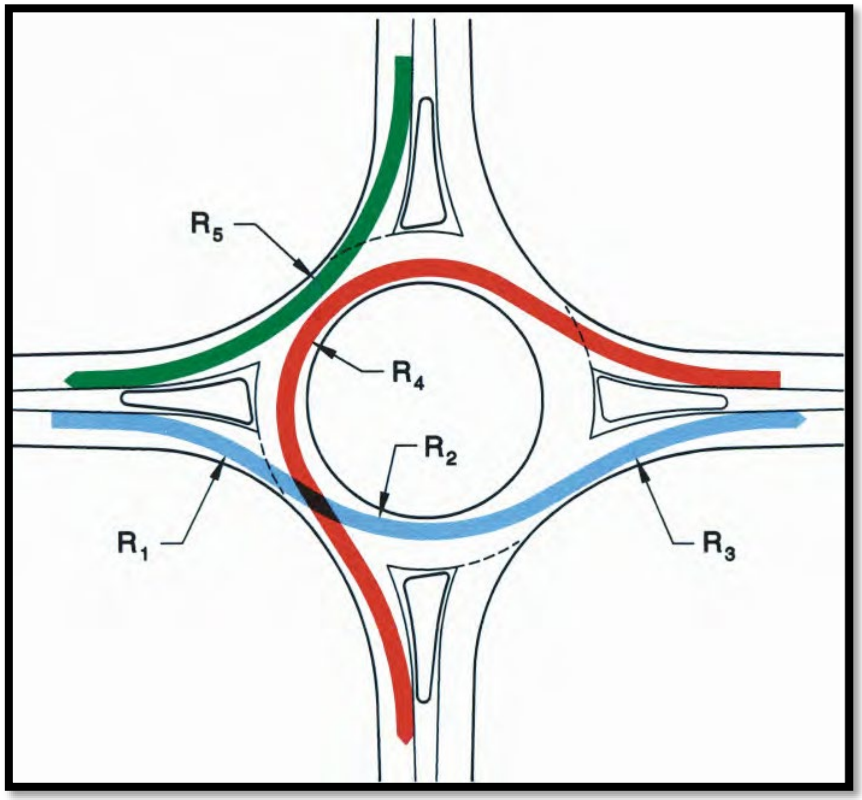


Figure 25 Fastest Path Radii

6.3 Speed Differential

The speed differential between any two consecutive fastest path radii should be no more than 10-15 mph.

6.4 Multilane Considerations

Designing multilane roundabouts is more complex than designing single-lane roundabouts due to additional conflicts introduced by multiple traffic streams. Entry curvature should balance the competing objectives of speed control, adequate alignment of the natural paths, and the need for appropriate visibility lines. A primary consideration is how the path overlap affects entry and exit because it can increase the likelihood of sideswipe crashes within the circulatory roadway (Figure 26). Using designated lane assignments for turning movements within the circulatory roadway can significantly reduce occurrences of path overlap. Consider the use of mountable raised lane dividers at the approaches or within the circulatory roadway to discourage overlap.

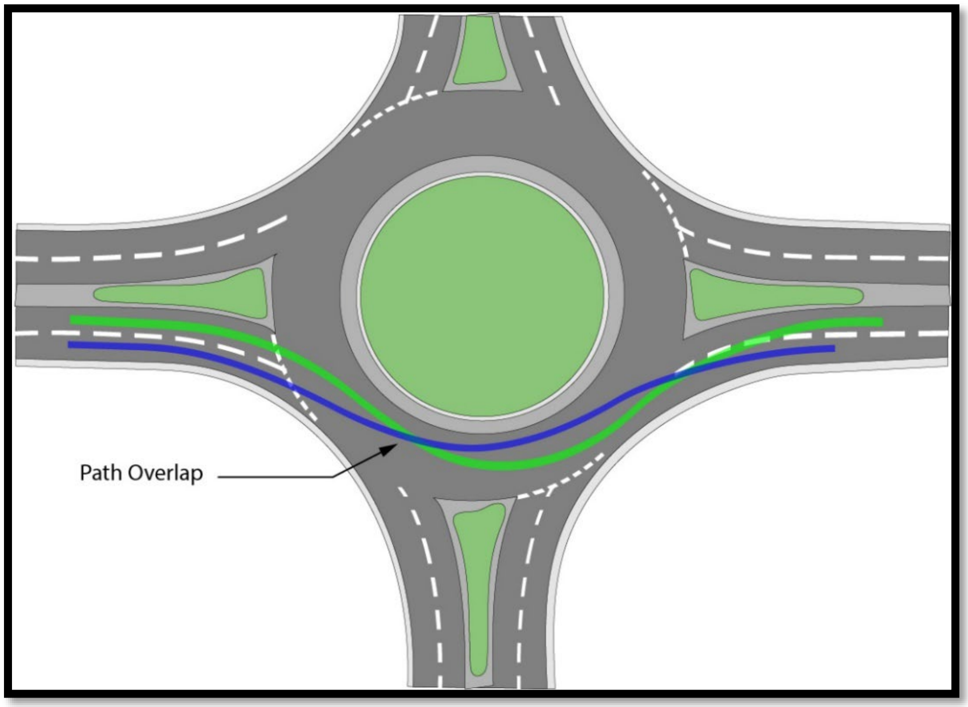


Figure 26 Entry and Exit Path Overlap

Entry Path Alignment. Address the entry path by providing a large radius (> 150 ft) or tangent downstream of the entry curve (> 65 ft) and upstream of the circulatory roadway. The length of the large radius or tangent along the travelled way should be at least one car length, or 25 ft.

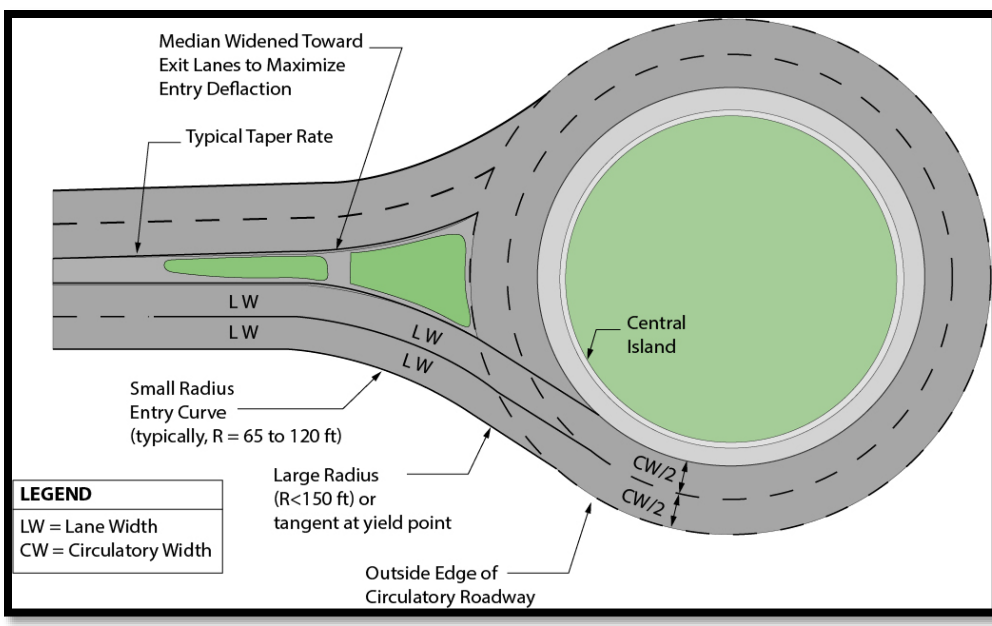


Figure 27 Entry Path Alignment

Exit Path Alignment. To address exit path overlap, provide at least 25 ft of tangent or large radius length along the exit path between the circulatory roadway and exit curve. Graphically verify the exit path overlap has been eliminated by extending the exiting vehicle path into the exit lane.

Entry Width. Multilane roundabouts may use a truck gore area to minimize lane widths (Figure 28). When used, passenger cars and light trucks should be able to enter and negotiate the roundabout without the use of the truck gore. Heavy vehicles in either the inside or outside lane should be able to enter the roundabout without encroaching on the adjacent lane.

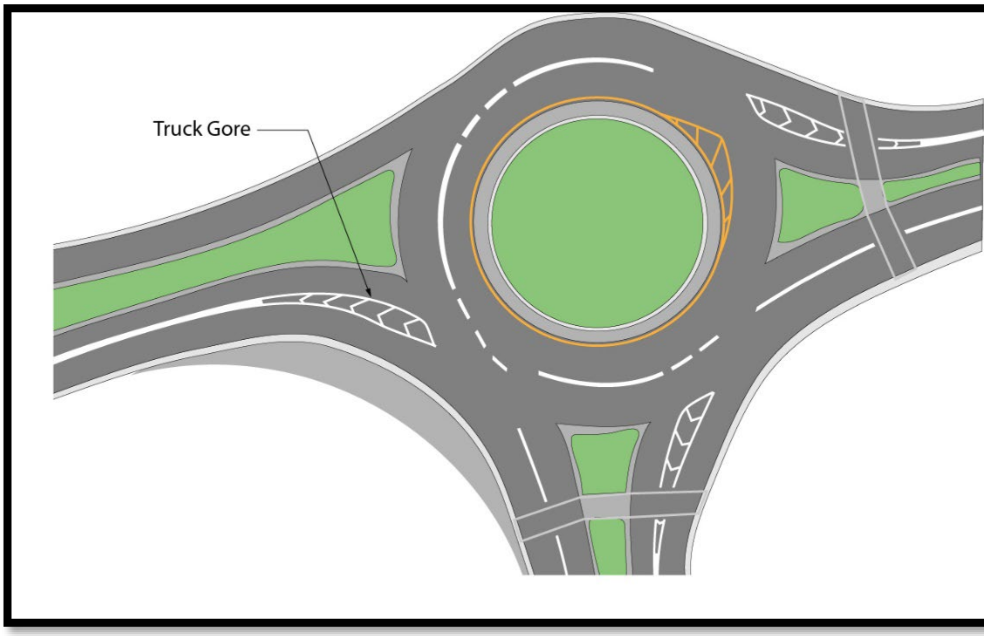


Figure 28 Truck Gore

6.5 Sight Distance

Satisfactory roundabout operation requires that a driver be able to enter the roundabout, move through circulating traffic, and separate from the circulating stream safely and efficiently. To accomplish this, a driver must be able to perceive the general layout and operation of the roundabout in time to make the appropriate maneuvers.

6.5.1 Stopping Sight Distance

Stopping sight distance is the distance required for a driver traveling at or near the design speed to perceive and react to an object in the roadway and brake to a complete stop before reaching that object. Table 8 lists recommended stopping sight distances based on design speed.

Table 8 Stopping Sight Distance by Speed (Source: Exhibit 3-1 AASHTO GDHS)

Design Speed (mph)	Stopping Sight Distance (ft)
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495

Use sight triangles to measure stopping sight distance. Stopping sight distance must be provided at every point within a roundabout **and** on each entering and exiting approach. It should be checked explicitly at a minimum of three locations (listed below). Figures 29 – 31 illustrate the following stopping sight distances for roundabouts:

- Approach sight distance (based on design speed of the approach leg, not the entry speed)
- Sight distance on the circulatory roadway (based on the left-turn fastest path (R_4) speed)
- Sight distance to crosswalk on the immediate downstream exit

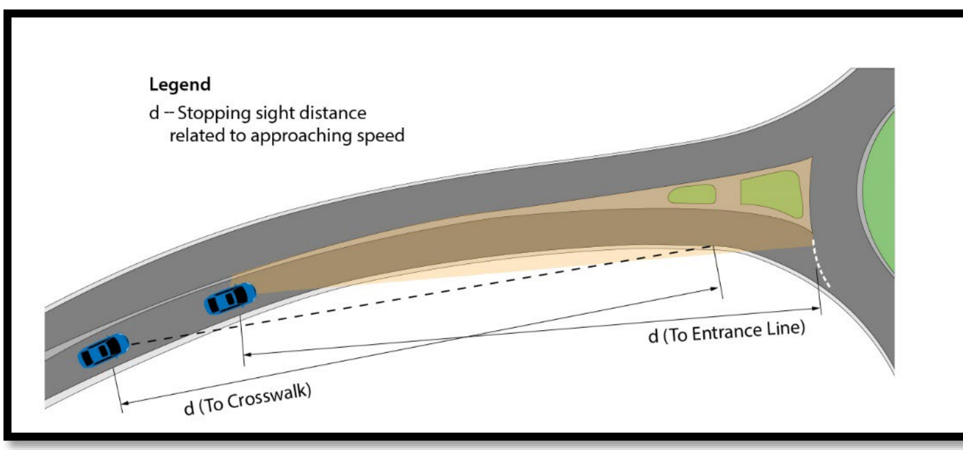


Figure 29 Approach Sight Distance

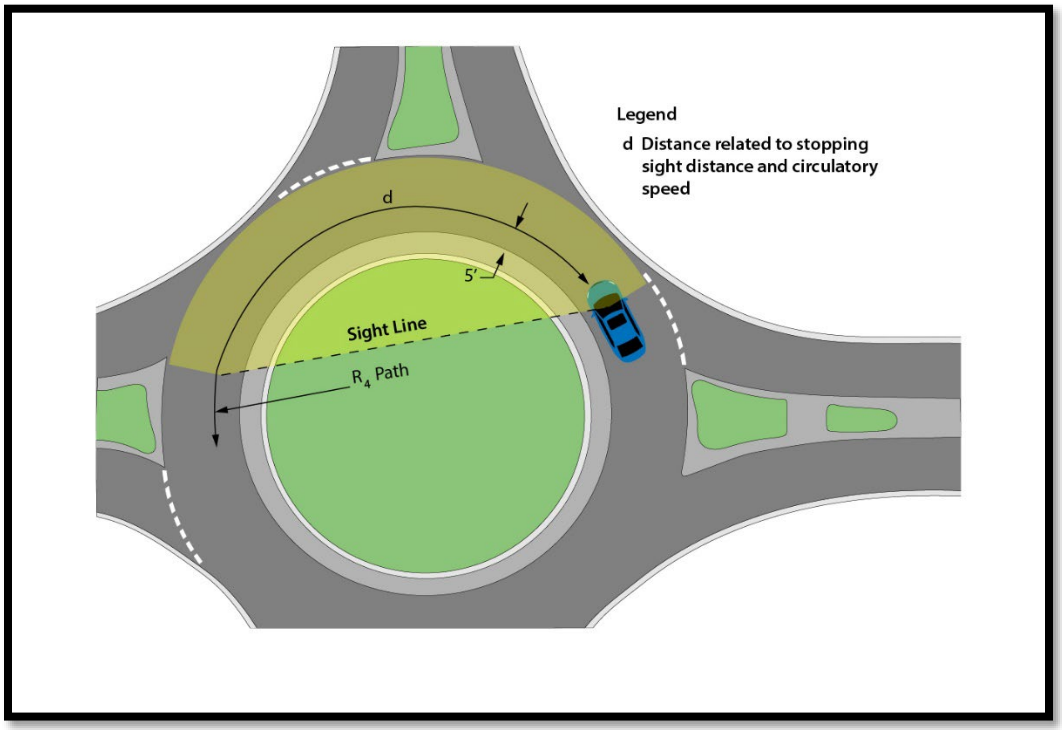


Figure 30 Sight Distance on the Circulatory Roadway

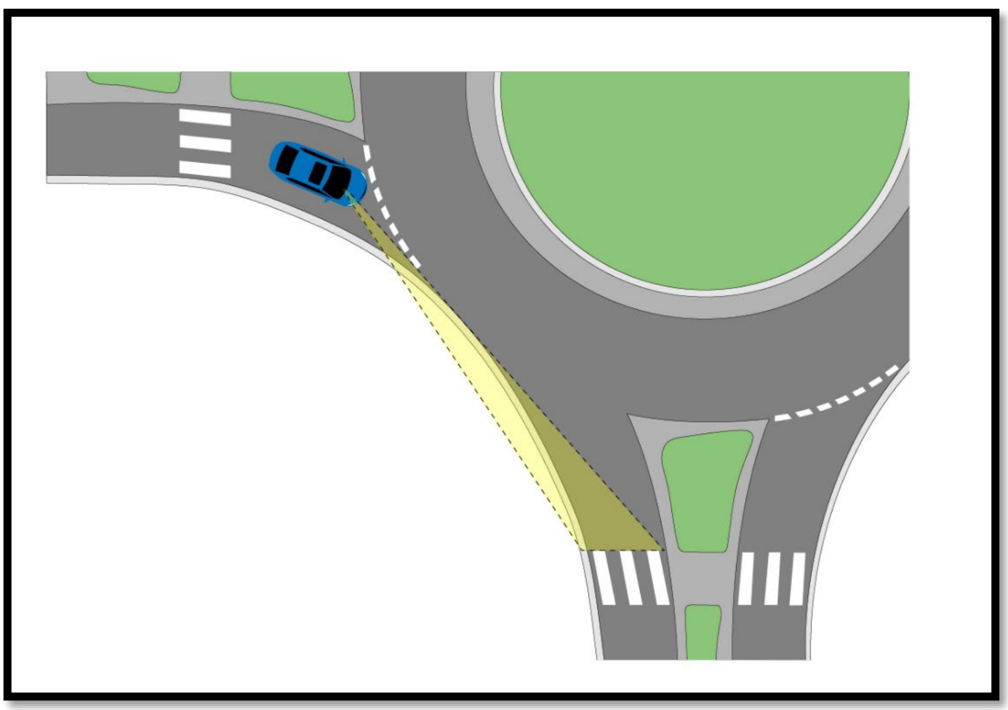


Figure 31 Sight Distance to Exit Crosswalk

Stopping sight distance assumes the driver's eye is at a height of 3.5 ft and an object height of 2.0 ft in accordance with the current edition of the AASHTO Green Book.

6.5.2 Intersection Sight Distance

Intersection sight distance (ISD) is the distance required for a driver approaching the roundabout to perceive and react to the presence of conflicting vehicles on the circulatory roadway and immediate upstream entry. Equations 3 and 4 are used to calculate ISD and are sourced from NCHRP 1043 (*Guide for Roundabouts*).

Equation 3: ISD for Entering Leg, d_1

$$d_1=(1.47)(Vmajor,entering)(t_g)$$

Equation 4: ISD for Circulating Leg, d_2

$$d_2=(1.47)(Vmajor,circulating)(t_g)$$

Where,

d_1= length of entering leg of sight triangle (ft)
d_2 = length of circulating leg of sight triangle (ft)
$Vmajor,entering$ = speed of vehicles from upstream entry for the conflicting through movement (calculated from averaging the speeds resulting from fastest-path R_1 and R_2 values) for the upstream approach
$Vmajor,circulating$ = speed of circulating vehicles (calculated from fastest path R_4 value) from opposite entry
t_g = design headway (s). Equal to 5.0 s.

Calculate ISD values for every approach from the crosswalk and the yield line. In accordance with the Green Book, ISD calculations assume the driver's eye is at a height of 3.5 ft and the target object's height is 3.5 ft. Use sight triangles to measure ISD. The limits of the sight triangle are determined by calculating 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. Figures 32 and 33 illustrates the method for determining ISD.

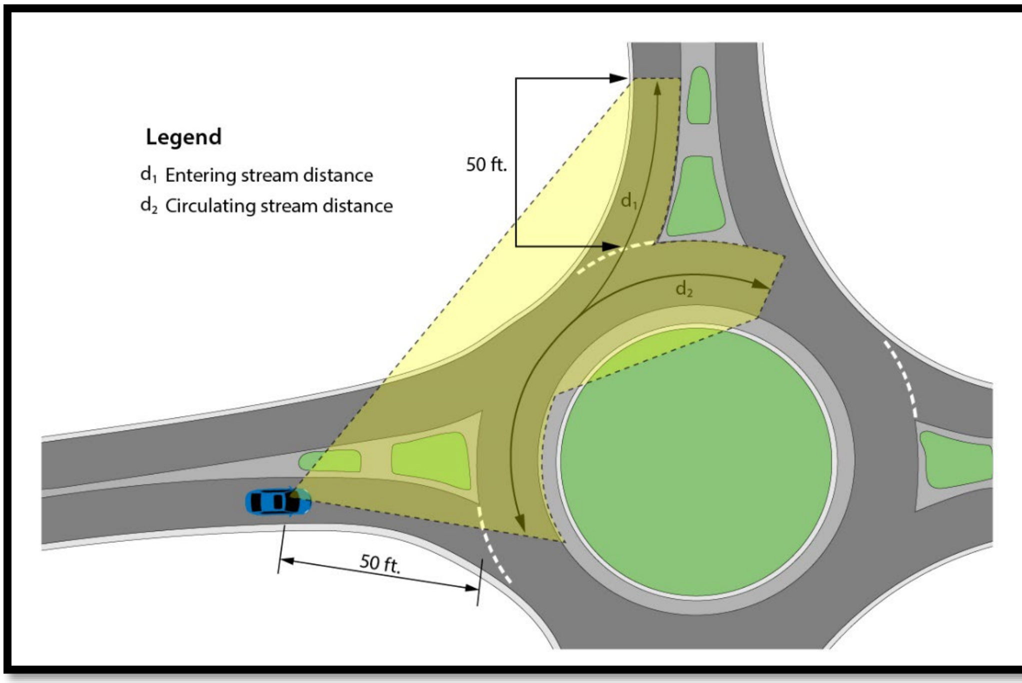


Figure 32 Intersection Sight Distance in Advance of Entry

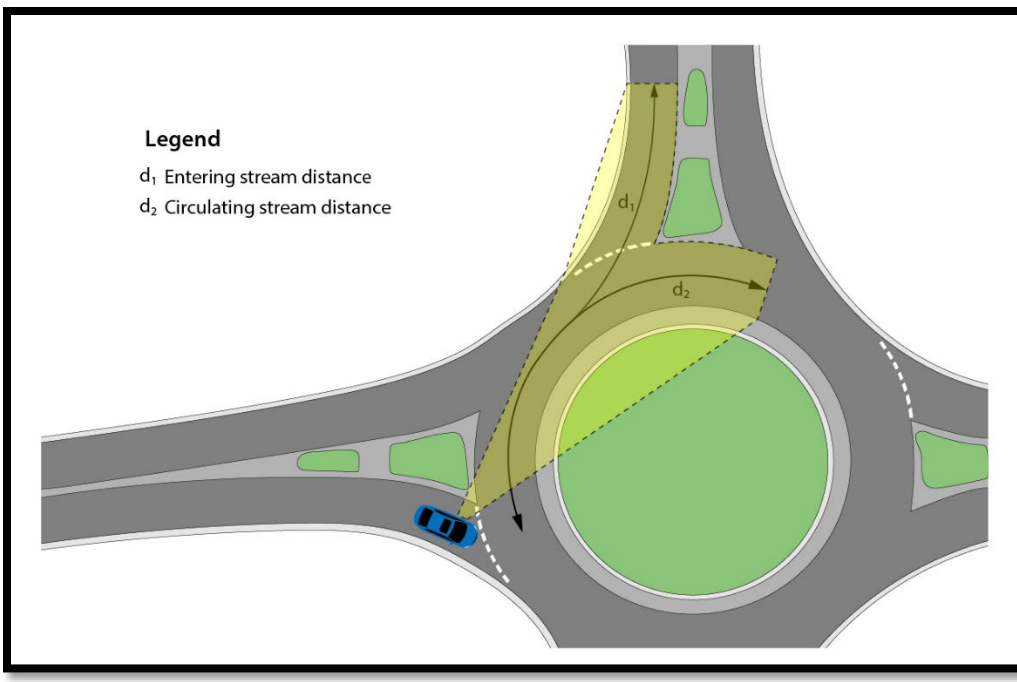


Figure 33 Intersection Sight Distance at Entry

Use sight distance triangles to determine where taller landscaping elements and other features cannot be placed within the central island. Check all sight lines in a 3D roadway model. Excessive intersection sight distance can lead to higher vehicle speeds that reduce the safety of the intersection for all road users (motorists, bicyclists, pedestrians). Landscaping can be effective in restricting sight distance to the minimum requirement.

6.6 Angle of Visibility

The intersection angle between consecutive entries must not be overly acute to allow drivers to comfortably turn their heads to the left to view oncoming traffic from the immediate upstream entry. A minimum of 75 degrees is recommended. The intersection angle may be measured as the angle between a vehicle's alignment at the entrance line and the sight line required, labeled as d_1 in Figure 33. See Figure 34 for an illustration of the angle of visibility.

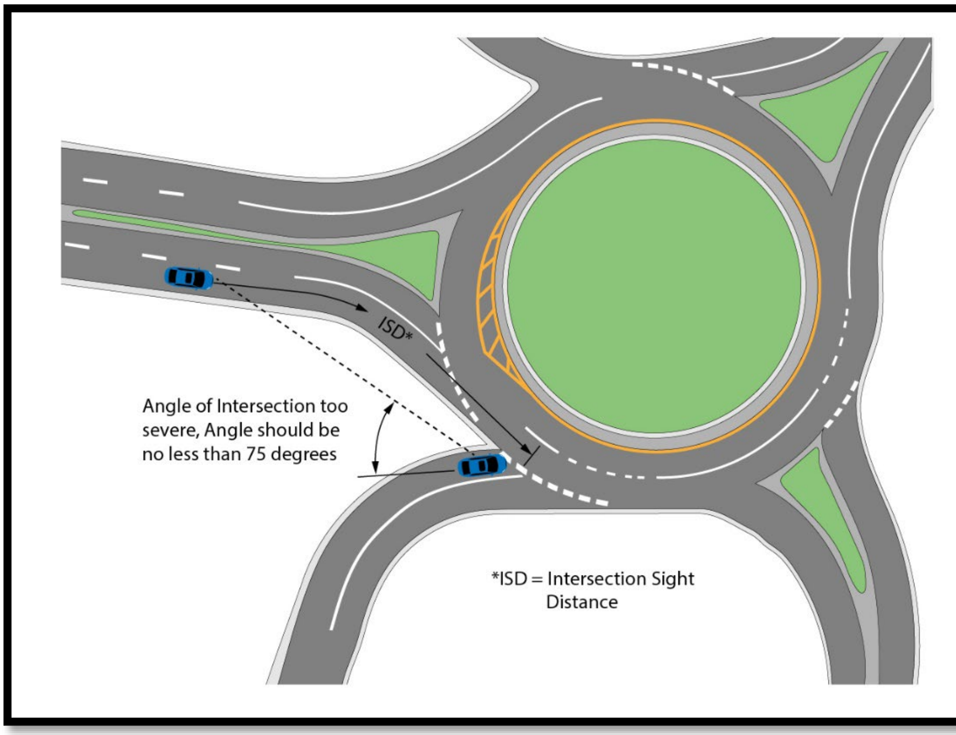


Figure 34 Angle of Visibility

7.0 ACCESS MANAGEMENT

Avoid providing direct access from driveways to roundabouts. Full access driveways and median openings are not preferred in areas where there is a splitter island. See HD-1100 for more information on access management. Minimum intersection spacing is 300 ft (600 ft is preferred). If it is necessary to provide access to a driveway within the roundabout's influence area, it should operate as right-in/right-out.

For interstate and other freeway-type interchanges, full access control must extend along the intersecting crossroad at least 100 ft in urban areas (preferred 300 ft) and 300 ft in rural areas (preferred 600 ft) as measured from the edge of the ICD. If a bypass lane is present, measure access control spacing from the end of the lane taper. Where high traffic volumes are present and the potential for development exists that would create operational or safety problems, provide longer lengths of access control. See HD-1101.5 for more information.

8.0 LIGHTING, SIGNING, & PAVEMENT MARKINGS

8.1 Lighting

Intersection lighting is required on state-maintained roundabouts. When a roundabout is the preferred intersection control alternative, contact the Division of Traffic Operations to determine whether lighting plans will be developed internally or by a consultant. It's desirable not to place lighting inside the central island. Develop the lighting design in accordance with AASHTO's *Roadway Lighting Design Guide*. See KYTC's *Traffic Operations Manual* (TO-711) for more information on illuminance levels.

KYTC is responsible for lighting installation and maintenance costs on all state-maintained roundabouts.

Use temporary lighting during construction. Staging for temporary lighting should be considered when establishing construction phasing.

8.2 Signing and Markings

Temporary and permanent pavement markings and signage is critical for successful roundabout operation. Develop comprehensive striping and signage plans — for both temporary and permanent conditions — for each project. Contractors must install markings and signage with care and pay close attention to detail. Detailed signing and marking plans must conform with the current version of the *Manual on Uniform Traffic Control Devices* (MUTCD).

Signing and marking plans submitted to KYTC shall have the following elements:

- A white edge line on the outer side of the circulatory roadway that consists of a solid line adjacent to the splitter islands and a wide dotted line across the lane(s) entering the roundabout.
- A yellow edge line on the left side of the splitter island.
- A yield line (shark's teeth) that indicates the point behind which vehicles are required to yield at the roundabout entrance. Yield lines and Yield Here to Pedestrians signs shall not be used in advance of crosswalks that cross an approach to or depart from a roundabout.
- D1-5 guidance signs on roundabout approaches with design speeds > 45 mph or D1-3d guidance signs on roundabout approaches with design speeds ≤ 35 mph. For approach design speeds between > 35 mph and 45 mph, the project team should

select either a D1-5 or the D1-3d guidance sign based on project context.

- Exit guide signs placed on the splitter islands oriented toward traffic on the circulatory roadway. The size and the placement of the sign may depend on the size of the splitter island. The project team should select either a D1-1d, D1-1e, or a route marker exit guide sign. If this signing cannot go on the splitter island, it can go on the shoulder within the circle. See Figure 2D-8 and Figure 2D-9 in the MUTCD.

9.0 PEDESTRIAN & BICYCLE ACCOMODATIONS

Consult KYTC's Complete Streets Policy and the *Complete Streets, Roads and Highways Manual* to determine if the project scope should include pedestrian or bicycle accommodations.

Provide pedestrian accommodations in the form of crosswalks and ramps on the splitter island when adjacent pedestrian facilities are present or planned as part of the proposed project. When pedestrian facilities are present, crosswalks must be marked, and the cross slope shall not exceed the street grade. Raised crossings encourage slower vehicle speeds. If raised crossings are installed, ensure drainage is addressed. When pedestrian facilities are not included in the project, splitter islands should provide adequate width to allow future retrofit of pedestrian facilities. For more information on pedestrian accommodations, see the information provided on splitter islands earlier in this guidance. Consult the Public Right-of-Way Accessibility Guidelines (PROWAG) for additional pedestrian facility accessibility at roundabouts. The following are some of the requirements:

> *Where pedestrian crossings are not intended, the pedestrian circulation path shall be either (a) separated from the roadway with landscaping or other non-prepared surface or (b) separated from the roadway by a detectable vertical edge treatment with a bottom edge 15 inches maximum above the pedestrian circulation path* (R203.6.1.2).

The pedestrian path shall be separated from the curb — crosswalk to crosswalk — by a minimum of 24 inches (R306.4.1.1).

Each multilane segment containing a crosswalk, including multilane channelized turn lanes, requires at least one of the following:

- Pedestrian signal head
- Pedestrian hybrid beacon (PHB)
- Pedestrian actuated rectangular rapid flashing beacon (RRFB)
- Raised crosswalk

If a RRFB, PHB, or pedestrian signal head is under consideration, submit a request for approval to KYTC's Director of Traffic Operations. Raised crosswalks should only be used on low-speed approaches.

Do not install bicycle lanes through the roundabout — they should be terminated upstream of the yield line. On single-lane roundabouts, cyclists should be encouraged to merge into the general travel lane. If bicycle facilities are present or planned or where sidewalks are present, bike ramps should be placed at a 35–45-degree angle; they can be sloped as high as 20% and should be placed at least 50 ft prior to the crosswalk for exiting and 50 ft after the crosswalk for rejoining the roadway or bicycle lane. Refer to NCHRP 1043 (*Guide for Roundabouts*) for bike ramp design and striping options. Consider widening sidewalks around the roundabout to the width of a shared-use path or providing a separated bicycle facility to accommodate bicyclists that choose not to ride through the roundabout.

10.0 FINAL PLANS

Include a detailed pavement development sheet and a proposed roadway model (XML file) in the final plan submittal. The pavement development sheet must contain station/offset/elevation notation and topographic features for the intersection's drainage.

On roadways continuing through the roundabout, a centerline should run through the central island and continue through the intersection without stopping (Figure 35). This centerline is used for centerline stationing on right-of-way descriptions. A baseline shall be used for each approach leg that extends to the central island and a baseline around the inscribed circle. The pavement development sheet must include stations, offsets, and elevations for the roundabout's center area.

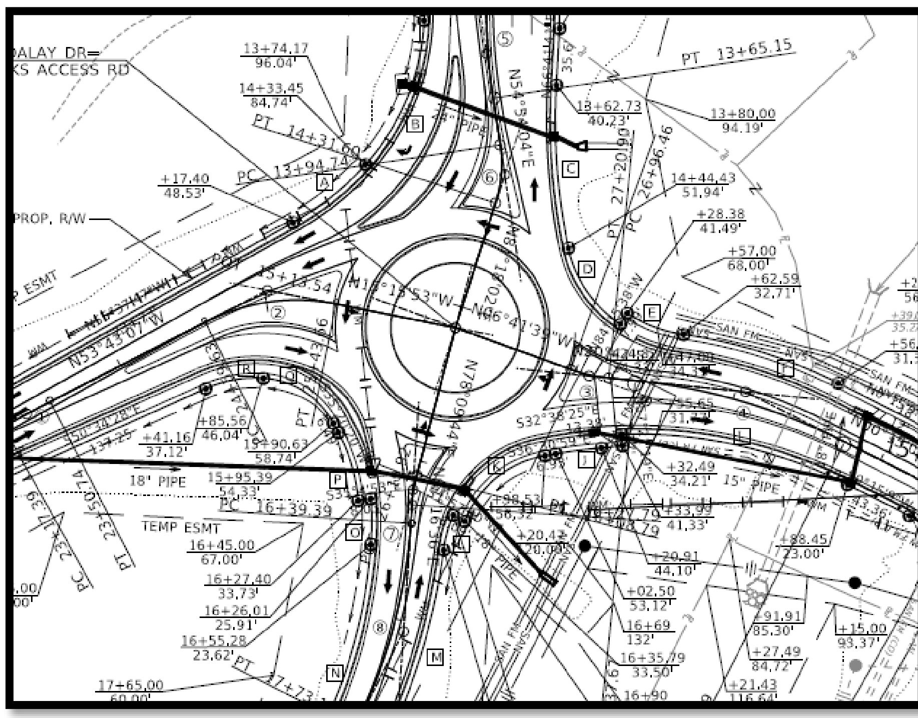


Figure 35 Example of Centerline Running Through Intersection

Include signing, pavement markings, and lighting plans with the final plan submittal.

11.0 MAINTENANCE OF TRAFFIC PHASING

Because each intersection, adjacent road network, set of user needs, and project construction method is unique, traffic control and construction phasing for roundabout construction can be addressed in a variety of ways. Roundabouts can be constructed under three types of traffic conditions:

- All traffic diverted or detoured away from the project site
- Some traffic diverted
- Under full traffic

Consider construction staging during preliminary design and review staging plans for constructability throughout project development. Examples and case studies of construction phasing are available in Chapter 15 of the NCHRP 1043 (*A Guide for Roundabouts*) and in the FHWA and American Traffic Safety Services Association (AATSA) report *Temporary Traffic Control for Building and Maintaining Single and Multi-Lane Roundabouts*.

11.1 All Traffic Diverted or Detoured

Diverting all traffic provides for the easiest construction, but it may not be feasible if detour routes are too long, or the detour or diversion cannot support the additional traffic volumes. Factor negative impacts to business access and significant delays for emergency response times when choosing a construction strategy.

11.2 Some Traffic Diverted

In certain instances, some legs of the intersection may be detoured while others are left open. Diversions could also be built for some movements while others are detoured. Examples include:

- Keeping the major street open and closing minor streets on the existing or temporary approach
- Providing access for emergency services near the roundabout

11.3 Construction Under Full Traffic

One possible sequence for staging construction under full traffic constructions is presented below:

- Install lighting or establish temporary lighting.
- Install and cover permanent roundabout signing until construction of splitter islands and the central island is complete. Traffic is expected to follow the new roundabout path once the central island is installed, which requires that proposed signing be in place and uncovered.
- Construct outside widening (as needed).
- Reconstruct or resurface approaches (if needed).
- Construct splitter islands first and delineate the central island. Permanent signing must be uncovered before an intersection can operate as a roundabout.
- Complete the central island.
- Prepare final grade and apply the paving course to the circulating roadway and entry/exit.

11.4 Other Considerations

- Any portion of the roundabout that is not complete should be marked, delineated, and signed to clearly denote the intended travel path. Remove or cover pavement markings that conflict with the intended travel path.
- If traffic is using the roundabout, the roundabout should be illuminated by temporary or permanent lighting.
- Since roundabouts have directional traffic flow, reversing traffic flow at any point during construction is discouraged because it would violate driver expectations. Although reversing traffic flow is not advisable, circumstances may dictate the need. But it should only be allowed as part of flagging operations or temporary signal during stage construction. Reverse flow should be considered for short-term closures (i.e., several hours) and discouraged for long-term closures (i.e., several days or weeks).
- If traffic cannot be diverted away from construction, night work can relieve some impacts on peak-hour traffic.
- Flagging may be used on approaches and exits so contractors can continue work.
- Work with the District Public Information Officer (PIO) to inform the public and stakeholders of traffic control changes.

Traffic control plans for each construction phase must describe methods for temporary signing and striping. Methods must comply with the current version of the MUTCD.

12. ROUNDABOUT REVIEW & APPROVAL

12.1 Design Approval

During the planning or conceptual design phase of the project, roundabout intersection alternatives are screened similarly to other intersection alternatives as part of the ICE process. If the roundabout alternative moves forward into Stage 2 of ICE, see KYTC's Intersection Control Evaluation Guidance for more information on the evaluation and submittal requirements. Since the safety and operational performance of a roundabout are dependent on its geometric design, additional information is needed for review. The design approval is subject to the Roundabout Approval Tiers described below. The project manager submits the Roundabout Design Form, (Exhibit 1 in Appendix B) with the Design Executive Summary (DES). For projects without a DES, review and approval occurs at the end of the preliminary design phase or, in the case of design-build projects, before roundabout construction. The form requires the following attachments:

- ▶ Design vehicle turning path diagrams for all through, left-turn, and right-turn movements.
- ▶ Primary roundabout layout sheet, including the ICD, lane configurations

and other basic elements (Figure 2). Label legs so they correspond to approach directions on the Roundabout Design Review form.

- Calculation of angle of visibility (diagram with ICD distance and angle labeled)
- Preliminary profiles of approach legs and the circulatory roadway.

Work with the Location Engineer to determine if substantial changes to roundabout geometry after approval will require additional reviews. If it is determined after approval of a roundabout that fastest path criteria cannot be met due to site constraints, notify the Location Engineer as early as possible to discuss how to proceed.

12.2 Final Design Review

The roundabout geometrics will be reviewed again at the time of final inspection. The Roundabout Design Form will be resubmitted with updated design parameters. A constructability review, with emphasis on MOT, should also occur at this time.

12.3 Roundabout Design Review Tiers

A tiered review process is used for roundabout design review and approval:

- **Level 1** – Review and approval by the Location Engineer if the following criteria are met:
  - Single-lane entries
  - Up to four legs
  - Intersection design year AADT ≤ 15,000
  - Sum of the entering and conflicting volumes at each leg ≤ 1,000 vehicles/hour
  - Roundabout is not on interstate ramp terminals
  - No known significant public opposition
  - Geometrics and design checks fall within ranges provided by KYTC Roundabout Design Guidance

- **Level 2** – Review and approval by the Location Engineer and the Roadway Design Branch Manager if the following criteria are met:
  - All Level 1 criteria, plus:
    - Two-lane entries
    - Bypass lanes
    - Intersection design year AADT ≤ 25,000
    - Sum of the entering and conflicting volumes at each leg ≤ 1,800 vehicles/hour
    - Project does not include a series of roundabouts
    - May include interstate ramp terminals

- **Level 3** - Review and approval by the Location Engineer, Roadway Design Branch Manager, and Director of the Division of Highway Design if the following criteria are met:
  - Projects that do not meet Level 1 and 2 parameters, including but not limited to:
    - Three-lane entries

- Five or more legs
- Closely spaced roundabouts (within 1,200 ft) where the operation of one may impact the operation of another
- Queue backup into or from an adjacent intersection is possible
- Other identified special needs

12.4 Traffic Operations Review

Submit plans for lighting, signing, and pavement markings to district engineering support staff for review at the final inspection (see HD-204.16). Lighting plans must be approved by the Division of Traffic Operations. If needed, electronically enhanced traffic control devices also require approval from the Division of Traffic Operations.

13.0 TERMS

95th percentile queue—The queue length (number of vehicles) that has a 5% probability of being exceeded during the analysis time period.

AASHTO—American Association of State Highway and Transportation Officials.

ADA—Americans with Disabilities Act.

approach—The portion of a roadway leading into a roundabout.

apron—The mountable portion of the central island adjacent to the circulatory roadway. Used in some roundabouts to accommodate the wheel tracking of large vehicles.

capacity—The maximum sustainable flow rate at which people or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a specified time period under a given roadway and geometric, traffic, environmental, and control conditions. Usually expressed as vehicles per hour (VPH), passenger cars per hour, or persons per hour (source: HCM).

central island—The raised area in the center of a roundabout around which traffic circulates.

channelization—The separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement markings to facilitate the safe and orderly movement of vehicles and pedestrians (source: AASHTO Green Book).

circulatory roadway—The curved path used by vehicles to travel in a counterclockwise fashion around the central island.

deflection—The change in a vehicle's trajectory imposed by a roadway's geometric features.

delay—Additional travel time experienced by a driver, passenger, or pedestrian beyond what would reasonably be desired for a given trip.

design vehicle—The largest vehicle that can reasonably be anticipated to use a facility.

design year—An estimation of the future traffic demand and volume expected on a facility.

detectable warning surface—A standardized surface feature built into or applied to walking surfaces or other elements to warn visually impaired people of hazards on a circulation path (source: ADAAG).

entry path radius—The minimum radius on the fastest through path upstream of the yield line.

entry radius—The minimum radius of curvature of the outside curb at the entry.

entry speed—The speed a vehicle travels at as it crosses the yield line.

entry width—The entry's width where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and inscribed circle.

exit path radius—The minimum radius on the fastest through path into the exit.

exit radius—The minimum radius of curvature of the outside curb at the exit.

exit width—The width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and inscribed circle.

fastest path—The smoothest, flattest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings.

flare—The widening of an approach to multiple lanes to provide additional capacity at the yield line and storage.

inscribed circle—The circle forming the outer edge of the circulatory roadway.

inscribed circle diameter (ICD)—The basic parameter used to define the size of a roundabout. It is the diameter of the largest circle that can be inscribed within the outline of the intersection and is measured between the outer edges of the circulatory roadway.

intersection sight distance—The distance required for a driver without the right of way to perceive and react to the presence of conflicting vehicles.

left-turn path radius—The minimum radius on the fastest path of the conflicting left-turn movement.

level of service (LOS)—A qualitative measure describing operational conditions within a traffic stream that is generally given in terms of service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience.

measures of effectiveness—A quantitative parameter whose value indicates the performance of a transportation facility or service from the perspective of the facility or service's users.

microsimulation—Modeling of individual vehicle movements on a second or subsecond basis for the purpose of assessing the traffic performance of highway and street systems, transit, and pedestrians.

mini-roundabout—Small roundabouts used in low-speed urban environments. The central island is fully mountable, and the splitter islands are either painted or mountable.

mountable—Used to describe geometric features that vehicles can drive on without inflicting damage, but which are not intended to be in the normal path of traffic.

multilane roundabout—A roundabout that has at least one entry with two or more lanes and a circulatory roadway that can accommodate more than one vehicle traveling side-by-side.

MUTCD—*Manual on Uniform Traffic Control Device*s. A compilation of national standards for all traffic control devices, including road markings, highway signs, and traffic signals. The MUTCD includes the terminology Standards, Guidance, and Options. KYTC uses the following definitions of these terms:

- ***Standard***—Requires compliance
- ***Guidance***—Should comply unless there is a reasonable justification for not doing so
- ***Option***—Not required but may be used

pedestrian refuge—An at-grade opening within a median island that lets pedestrians safely wait for an acceptable gap in traffic to cross a roadway.

queue—A line of vehicles, bicycles, or people waiting to be served by the system in which the flow rate from the front of the queue determines the average speed within the queue. Slowly moving vehicles or people joining the rear of the queue are usually considered a part of the queue. Internal queue dynamics may involve a series of starts and stops. (source: HCM)

raised—Used to describe geometric features with a sharp elevation change that are not intended to be driven on by vehicles at any time.

right-turn bypass lane—A lane provided adjacent to, but separated from, the circulatory roadway that allows right-turning movements to bypass the roundabout. Also known as a **right-turn slip lane**.

right-turn path radius—The minimum radius on the fastest path of a right-turning vehicle.

roundabout—An intersection with a generally circular shape, yield control of all entering traffic, and geometric curvature and features to induce desirable vehicular speeds.

roundabout capacity—The maximum number of entering vehicles that a roundabout can reasonably be expected to serve during a specified period of time.

sight triangle—An area required to be free of obstructions to enable visibility between conflicting movements.

single-lane roundabout—A roundabout that has single lanes on all entries and one circulatory lane.

splitter island—A raised or painted area on an approach used to separate entering traffic from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing an intersection approach in two stages. Also known as a **median island** or a **separator island**.

stopping sight distance (SSD)—The distance along a roadway required for a driver to perceive and react to an object in the roadway and to brake to a complete stop before reaching that object.

two-stage crossing—A process in which pedestrians cross a roadway by crossing one direction of traffic at a time and waiting in a pedestrian refuge between the two traffic streams — if necessary — before completing the crossing.

volume-to-capacity ratio (v/c)—The ratio of flow rate to capacity for a transportation facility.

yield—An intersection control in which controlled traffic must stop only if higher priority traffic is present.

yield line—A pavement marking used to mark the point of yielding at a roundabout entry.

Appendix A

Creating Roundabout Fastest Paths (Spline Curves) in OpenRoads

Appendix A

Creating Roundabout Fastest Paths (Spline Curves) in OpenRoads

Step 1: Copy Curb Offsets

Use single offset tools to create curb offsets (as shown in Figures 21-23 of the guidance) in the following locations:

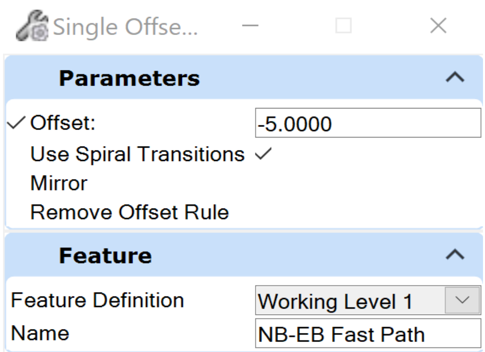


Figure A1 Single Offset Entire Element

A. 5 ft from left-side face of the curbs (or 3 ft from the painted edge line) on each approach.
B. 5 ft from the face of curbs on the driver's right side at each entry and exit.
C. 5 ft from the central island face of curb. For the lip curb, on the face of the curb 9 in from the back of the curb.
D. Not less than 165 ft from the roundabout's inscribed circle diameter (ICD). Typically, this distance may be 165 ft, but it could be more depending on how a driver would approach the yield line at high speed. "*To determine the speed of a roundabout, the fastest path allowed by the geometry is drawn. This is the most realistic, smoothest path possible for a single vehicle, in the absence of other traffic and <u>ignoring</u> <u>all lane markings</u>, traversing through the entry, around the central island and out the exit*".

Appendix A

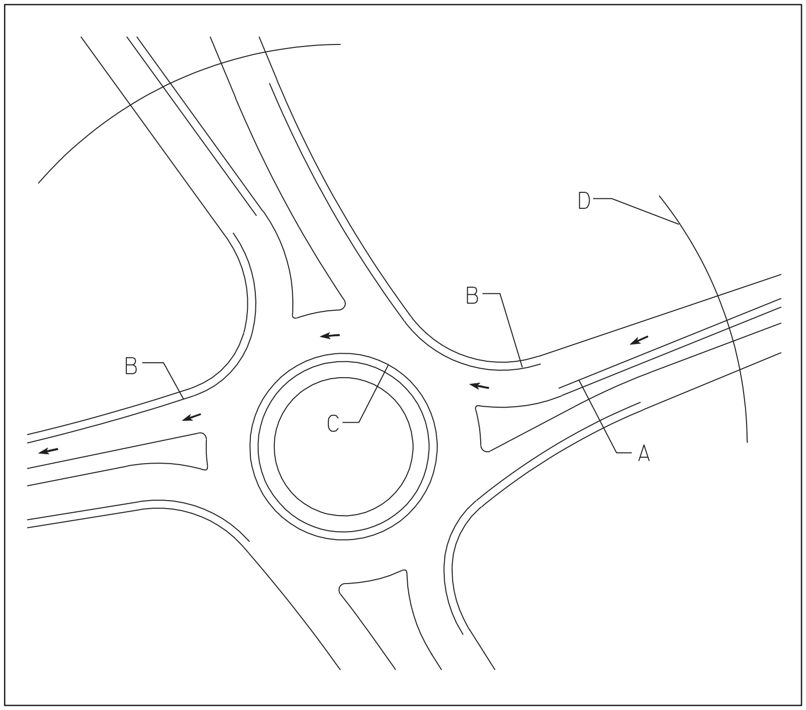


Figure A2 Offsets for Fastest Path

Step 2: Draw the Spline Curve
Choose the *Through Points* method as shown below.

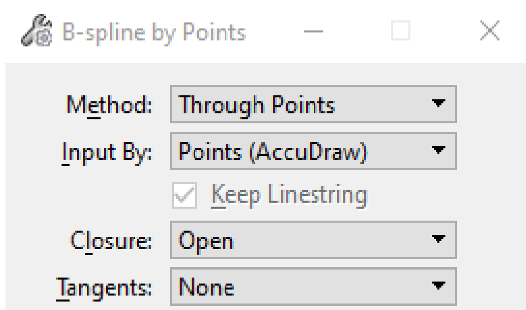


Figure A3 B-Spline by Points

Draw the spline curve for the through movement as shown below. Use *Near* snaps for all selected points.

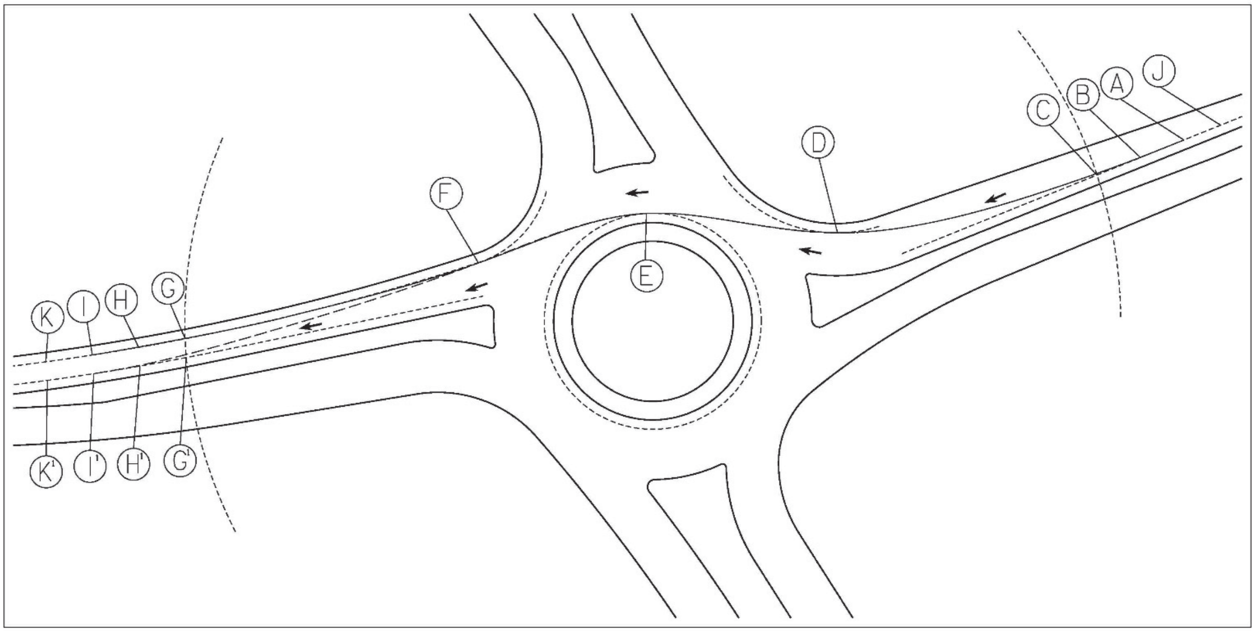


Figure A4 Spline Curve Through Movement

Clicking sequence:

1. Choose points A through C on the first 5 ft curb offset from splitter island (tentative snap, then left click to accept). Choose 3 points that are approximately 25 ft apart that approximate the path of an approaching vehicle. It is advisable to choose two points outside of the 165 ft line and one on the 165 ft line.
2. Choose point D on the 5 ft curb offset from entry curve (tentative snap, then left click to accept).
3. Choose point E on the 5 ft curb offset from central island (tentative snap, then left click to accept).
4. Choose point F on the 5 ft curb offset from exit curve (tentative snap, then left click to accept).
5. Choose points G through I, or G1 through I1, on the 5 ft offset from the right-side exit curb (tentative snap, then left click to accept). In some cases, it is appropriate to check the left side instead of the right side. Which side is checked depends on the vehicle's anticipated driving path and roadway alignment. Choose 3 points that are approximately 25 ft apart that approximate an exiting vehicle's path. Two points should be outside the 165 ft line and one point inside the 165 ft line.
6. Right click to end the spline curve.

Step 3: Evaluate If the Spline Curve Needs to Be Modified

Check the spline created in Step 2 to see whether it violates the 5 ft curb offsets. Two methods can accomplish this:

1. With the *Measure Distance* tool, use the *Minimum Between* function to measure the distance between the face of curb and the spline curve at points A through I.

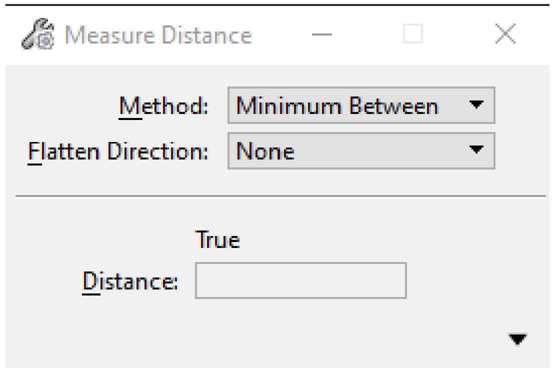


Figure A5 Measure Distance

2. Zoom into the areas of points A through I to visually inspect whether the spline curve violates the curb offsets.

In most cases, the spline may slightly violate the 5 ft curb offset. Use engineering judgment to determine if the spline needs to be modified. The situation depicted in Figure A5 requires a spline modification.

Step 4 Modify the Spline:
Modify the spline if it is located between the curb offset and the curb or outside of the curb offset.

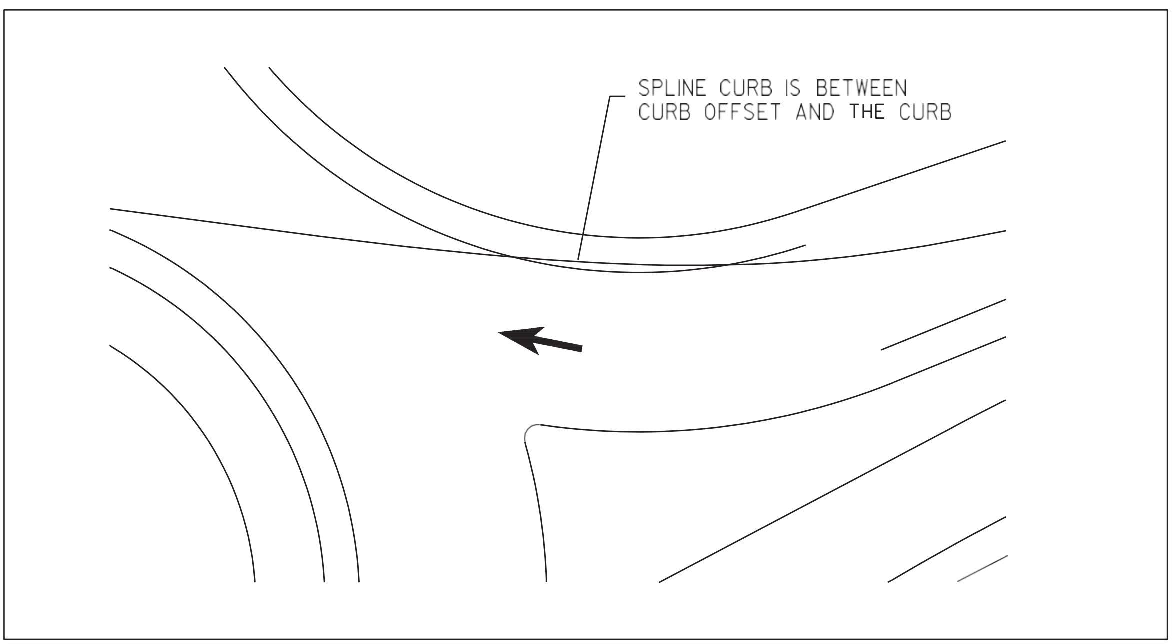


Figure A6 Spline Curve Between Curb Offset and the Curb

Using the *Modify Element* tool, select the spline curve and move it to a desired location atop the curb offset. This may need to be done a few times before the spline is on top of all the curb offsets.

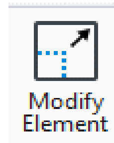


Figure A7 Modify Element

Evaluate whether the spline appears to represent the path a vehicle would use. Often, the beginning or end of the spline may need to be moved further away from the roundabout.

Step 5: Measure R Values (Critical Path Radii)

1. Once an acceptable spline is created, fit arcs to the spline to measure R values using the *Place Arc* tool.

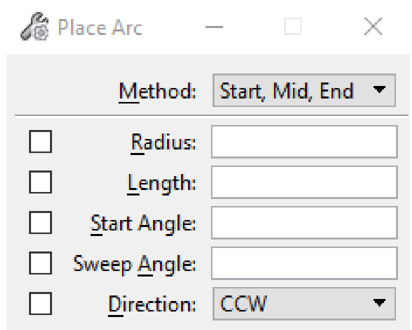


Figure A8 Place Arc

2. Using *Near* snaps, fit an arc onto the spline at a point that appears to be the tightest portion of the spline. This point should be located prior to the yield line and not more than 165 ft from the yield line.
3. Check the arc length. If the arc is not 65 to 80 ft long, recreate it to try to obtain an arc that is 65 to 80 ft long.
4. Measure the arc's radius.
5. Repeat to find the values of R_1, R_2, and R_3.
6. To find R_4, measure the radius of the 5 ft curb offset from the central island.
7. To find R_5, create a spline tangential to the three curb offsets that define the R_5 path (i.e., the 5 ft splitter island offset on the entry, the 5 ft offset on the inside of the right turn, and the 5 ft splitter island offset on the exit). Verify the arc does not cross any curb offsets, especially when the geometry of the right-turn movement is created with multiple arcs. A typical R_5 spline is shown below.

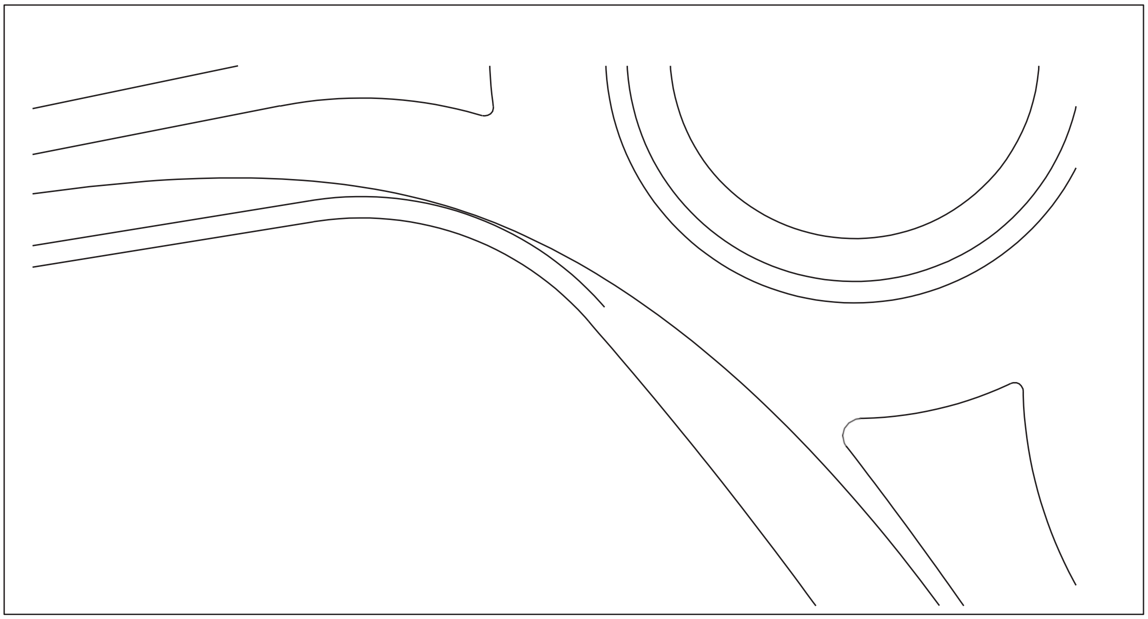


Figure A9 Example R5 Spline

Appendix B

Roundabout Review Form

Roundabout Design Form

Item #:	
County:	
Routes and Milepoints:	

ROADWAY INFORMATION	EB[7]		WB[7]		NB[7]		SB[7]		Leg 5[2]	
Approach Roadway Design Speed[1] (mph)										
	AADT	VPHPL	AADT	VPHPL	AADT	VPHPL	AADT	VPHPL	AADT	VPHPL
Design Year Volumes (AADT[3] & VPHPL[4])										

DESIGN PARAMETERS	Parameter[5]	EB[7]	WB[7]	NB[7]	SB[7]	Leg 5[2]
Entry Width (ft)	Single: 14-18 ft, Recommend 15 ft Multi: 12-15 ft per lane					
Inscribed Circle Diameter (ICD) (ft)	Mini: 45-90 ft Single: 90-180 ft Multi: 150-300 ft					
Circulatory Roadway Width (ft)	Single: 16-20 ft Multilane: 14-16 ft per lane					
Splitter Island Length (ft)	≤ 45 mph: 50 ft min., 100 ft des. >45 mph: 200 ft min.					
Entry Curb Radius (ft)	Urban Single: 50-100 ft Multi: Should be >65 ft					
Approach Profile (two car lengths from edge of circle) (%)	See KYTC Roundabout Guidance					
Angle of Visibility (deg)	75° min.					

FASTEST PATH	Parameter[5]	EB[7]		WB[7]		NB[7]		SB[7]		Leg 5[2]	
		FT	MPH	FT	MPH	FT	MPH	FT	MPH	FT	MPH
R_1, Radius (ft) & Speed (mph)	Mini: 15-20 mph Single: 20-25 mph Multi: 25-30 mph										
R_2, Radius (ft) & Speed (mph)	See KYTC Roundabout Guidance. Not usually a controlling factor.										
R_3, Radius (ft) & Speed (mph)	Should be > R2										
R_4, Radius (ft) & Speed (mph)	See KYTC Roundabout Guidance. Not usually a controlling factor.										
R_5, Radius (ft) & Speed (mph)	15-25 mph										
Bypass R_5, Radius (ft) & Speed (mph)	Should not significantly exceed R_1										

MINIMUM SIGHT DISTANCE PARAMETERS	Parameter[5]	EB[7]		WB[7]		NB[7]		SB[7]		Leg 5[2]	
		Required[6]	Met?	Required[6]	Met?	Required[6]	Met?	Required[6]	Met?	Required[6]	Met?
Approach Stopping Sight Distance (SSD) (ft)	See KYTC's Roundabout Guidance										
Circulatory Roadway SSD (ft)	See KYTC's Roundabout Guidance										
Intersection Sight Distance (ISD) (ft)	See KYTC's Roundabout Guidance										

[1] Design speed of the roadway, not the terminal.
[2] Leave blank if not applicable. Use additional form if more than five approach legs.
[3] Segment (2-way)AADT of approach roadway
[4] Approach or entering volumes per lane.
[5] Recommended values from KYTC Roundabout Design Guidance.
[6] Calculated values. If on grade ≥ 3%, see AASHTO's Greenbook Table 3-2 values for Approach SSD.
[7] Approach direction of travel.

Roundabout Design Form

Design Vehicle:	
Truck Apron Width:	
Oversize Truck Accommodations:	
Circulating Roadway Cross Slope:	
Access Control:	
Bicycle and Pedestrian Accommodations:	

Additional information to be submitted as attachments

-Vehicle turning path diagrams of the design vehicle for all through, left-turn, right-turn, and u-turn movements, if applicable.

-Primary layout sheet of the roundabout, including the inscribed circle diameter and other basic elements (See HDM Exhibit 900-02). **Label legs to correspond to this form.**

-Calculation of Angle of Visibility (diagram with ICD distance and angle labeled).

-Preliminary profiles of the approach legs and circulatory roadway.

-Additional submittals for Stage 2 of the Intersection Control Evaluation.

Designer: ____________ Tier 1 Reviewer: ____________

Tier 2 Reviewer: ____________

Review Tier: ____________ Tier 3 Reviewer: ____________