Roundabout Design Guidance

Version 1.1
March 2014

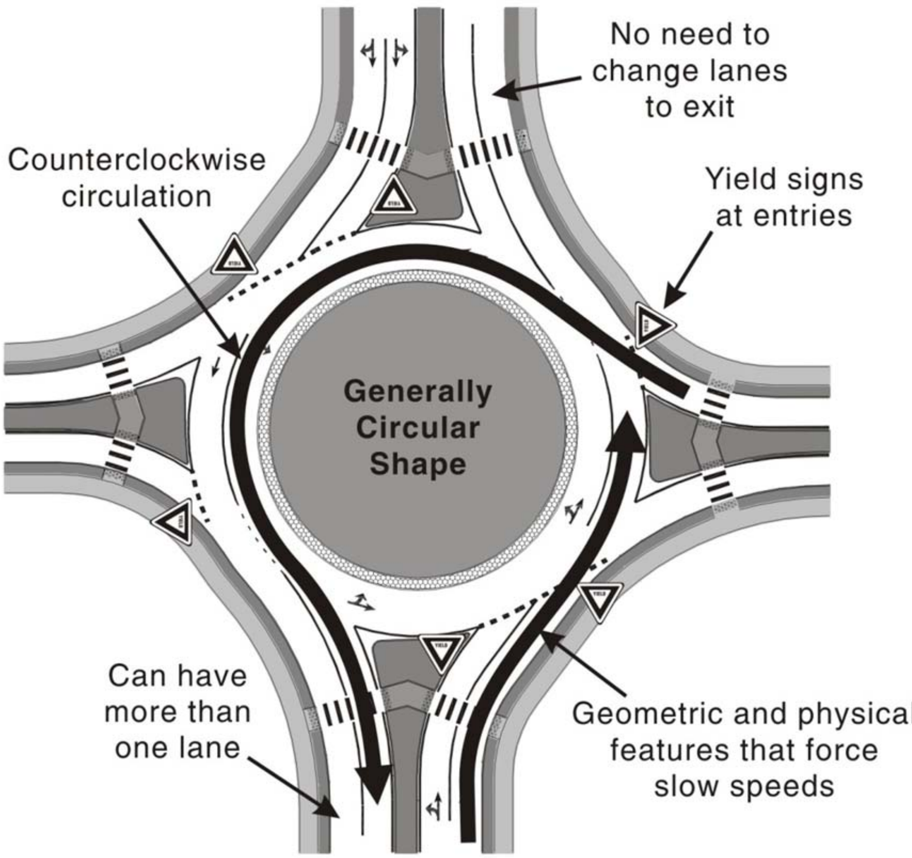
Virginia Department of Transportation

ROUNDABOUTS DESIGN GUIDANCE

A. Introduction

A roundabout is a form of circular intersection in which traffic travels counterclockwise around a central island and in which entering traffic must yield to circulating traffic. Modern roundabouts are distinctly different from other forms of circular intersections (rotaries, signalized traffic circles, etc.). Figure 1 illustrates the key characteristics of a modern roundabout.

Figure 1: Key Roundabout Characteristics



Modern roundabouts have demonstrated safety and operational benefits and should be considered as an alternative for intersection improvement projects. They can offer several advantages over signalized and stop controlled alternatives, including better overall safety performance, shorter delays, and shorter queues (particularly during off-peak periods), better management of speeds, and opportunities for community enhancement or aesthetic features.

This document is not intended to be an exhaustive review of roundabouts, but rather is meant to emphasize the key principles related to roundabouts. For detailed guidance, the user should refer to National Cooperative Highway Research Program (NCHRP) Report 672: *Roundabouts: An Informational Guide [2nd Edition]*. A principle-based approach to design is recommended, noting that each roundabout will have its own unique design based on the context and goals of a particular project. There will never be a "cookie-cutter" design for a roundabout.

When planning intersection improvements, a variety of improvement alternatives should be evaluated, including roundabouts, to determine the most appropriate alternative.

B. Planning

At the planning stage, there are a variety of possible reasons or goals for considering a roundabout at a particular intersection, including but not limited to safety, operations, access management, and aesthetics. Items to consider once a roundabout is identified as feasible include:

- Is a roundabout appropriate for this location?
- How big should it be or how many lanes are required?
- What sort of impacts are expected?
- What public education and outreach is appropriate?
- How can the construction phasing accommodate the existing traffic?

NCHRP Report 672, Chapter 1 presents a range of roundabout categories and suggested typical daily service volume thresholds below which four-leg roundabouts are expected to operate, without requiring a detailed capacity analysis. Chapter 2 introduces roundabout performance characteristics, including comparisons with other forms of intersection control. By confirming that there is a reason to believe that a roundabout is feasible and the best alternative, these planning activities avoid expending unnecessary effort required in more detailed steps.

The initial steps in planning for a roundabout are to clarify the objectives and understand the context in which the roundabout is being considered. The next step is to specify a preliminary configuration. This identifies the minimum number of lanes required on each approach and thus which type of roundabout is the most appropriate to use a basis for design: mini, single-lane, or multilane. Mini-roundabouts are not recommended on roadways with average operating speeds above 30 miles per hour.

Figure 2 summarizes and compares some fundamental design and operational elements for each of the three roundabout categories.

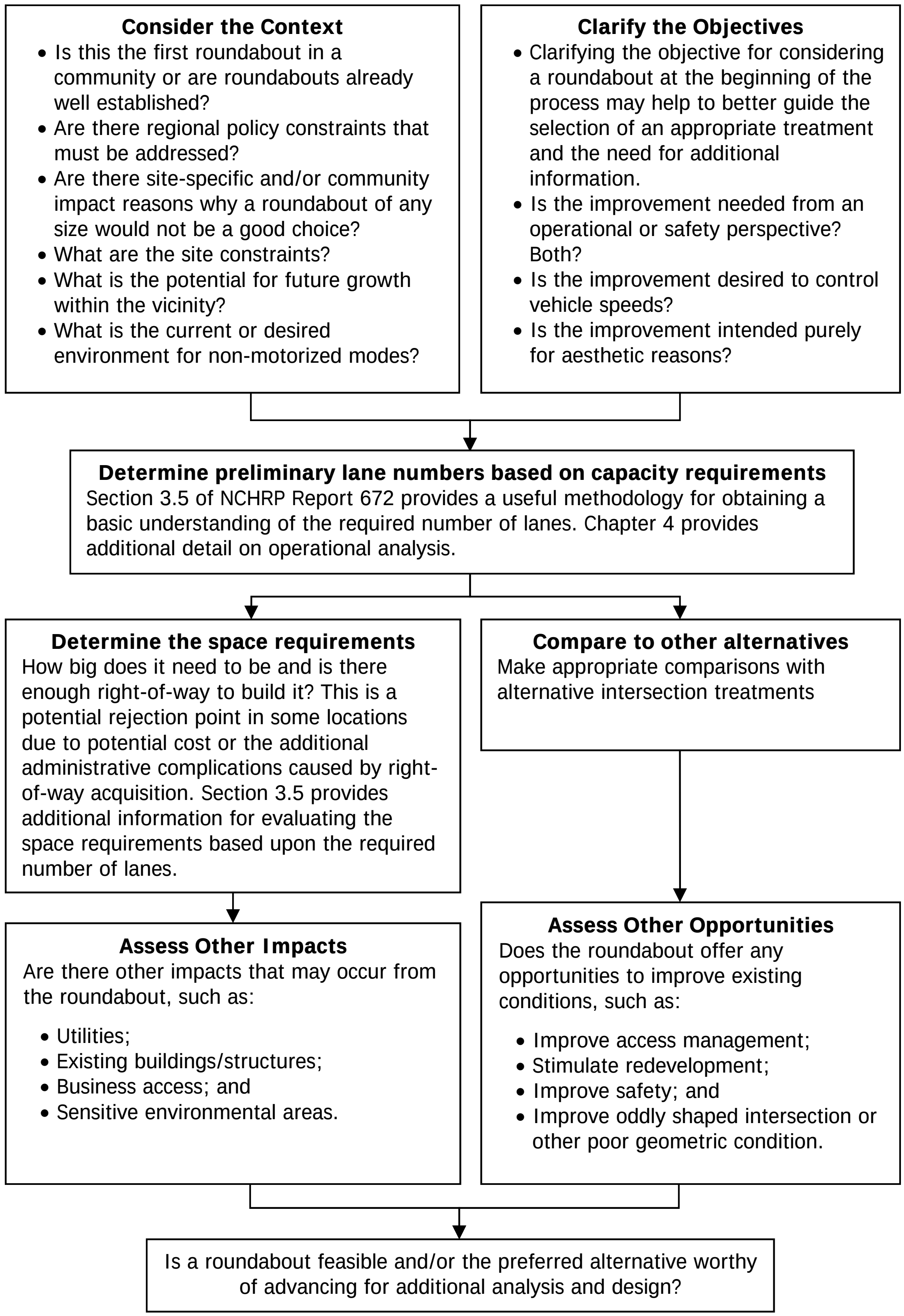
Figure 2: Roundabout Category Comparison

Design Element	Mini-Roundabout	Single-Lane Roundabout	Multilane Roundabout
Desirable maximum entry design speed	15 to 20 mph (25 to 30 km/h)	20 to 25 mph (30 to 40 km/h)	25 to 30 mph (40 to 50 km/h)
Maximum number of entering lanes per approach	1	1	2-3
Typical inscribed circle diameter	45 to 90 ft (13 to 27 m)	90 to 180 ft (27 to 55 m)	150 to 300 ft (46 to 91 m)
Central island treatment	Fully traversable	Raised (may have traversable apron)	Raised (may have traversable apron)
Typical daily service volumes on 4-leg roundabout below which may be expected to operate without requiring a detailed capacity analysis (veh/day)*	Up to approximately 15,000	Up to approximately 25,000	Up to approximately 45,000 for two-lane roundabout

*Operational analysis needed to verify upper limit for specific applications or for roundabouts with more than two lanes or four legs.

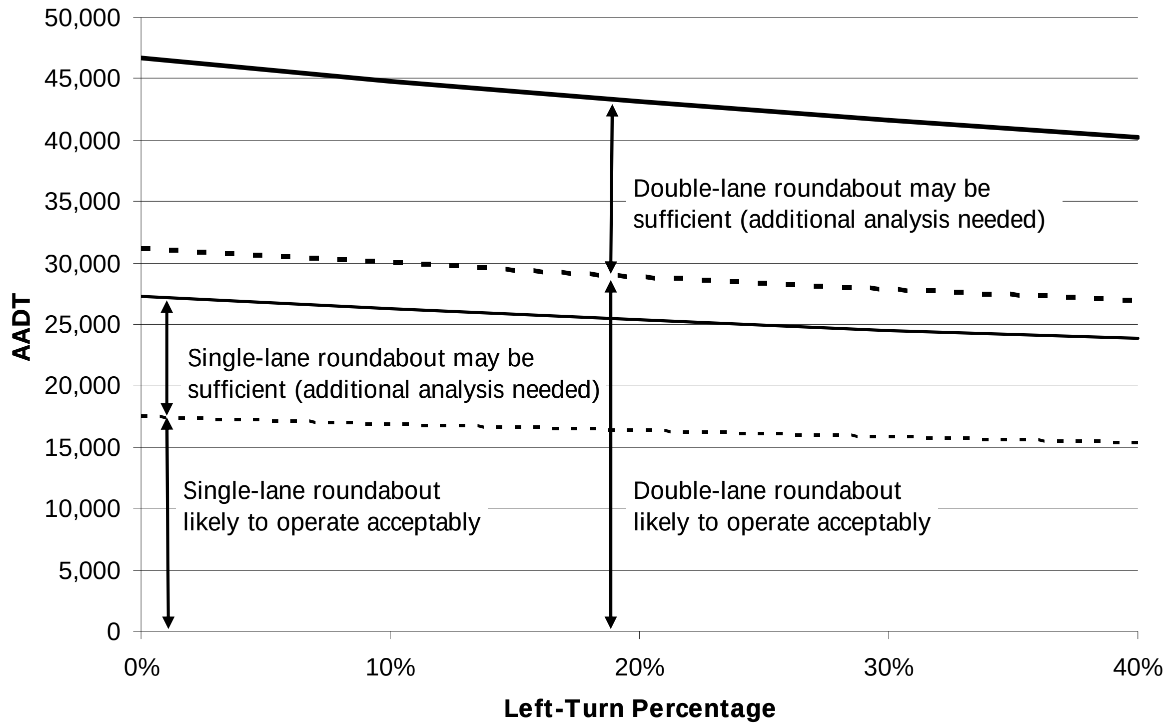
Figure 3 outlines many of the considerations that may need to be investigated prior to deciding whether to implement a roundabout at an intersection. Note that this is not meant to be all-encompassing, nor is it intended to reflect minimum requirements. Rather, it is intended to provide a general framework for the steps typically necessary to determine feasibility.

Figure 3: Planning Framework



High-level planning often requires an initial screening of alternatives where turning-movement data may not be available but Annual Average Daily Traffic (AADT) volumes are known. Figure 4 presents ranges of AADT volumes to identify scenarios under which single-lane and two-lane roundabouts may perform adequately.

Figure 4: Planning-Level Daily Intersection Volumes



If the volumes fall within the ranges identified in Figure 4 where "additional analysis is needed," a single-lane or two-lane roundabout may still function quite well, but a closer look at the actual turning-movement volumes during the design hour is required. The procedure for such analysis is presented in the 2010 *Highway Capacity Manual*, Chapter 21.

1. Economic Evaluation

An economic evaluation should be performed when considering various types of intersection control. VDOT has developed an intersection cost comparison spreadsheet to compare the life-cycle costs of roundabouts with traditional intersection forms. The spreadsheet uses safety, delay, operations and maintenance, and capital design and construction costs to compute life cycle costs. Some elements (i.e. crash frequency and severity) are determined by the spreadsheet, other elements (i.e. delay, construction cost) must be determined separately and input into the spreadsheet. To obtain a copy of the spreadsheet and user manual, visit VDOT's roundabout website at http://www.virginiadot.org/info/faq-roundabouts.asp.

2. Public Involvement

Public acceptance of roundabouts has often been found to be one of the biggest challenges facing agencies planning the first roundabout in an area. Without the benefit of explanation or first-hand experience and observation, the public is likely to incorrectly associate roundabouts with older style traffic circles or rotaries. Also, the public will often have a natural hesitation or resistance to changes in their driving behavior and driving environment.

VDOT and FHWA have produced brochures aimed at providing information to a variety of audiences. They can be downloaded from VDOT's roundabout webpage: http://www.virginiadot.org/info/faq-roundabouts.asp. For additional information regarding public education and outreach, please refer to NCHRP Report 672, Section 3.8.

C. Operations

The operational performance of roundabouts is relatively simple:

- Drivers must yield the right-of-way to circulating vehicles and accept gaps in the circulating traffic stream
- As with other types of intersections, the operational performance of roundabouts is directly influenced by geometry.

The extent to which these aspects affect operational performance varies in different roundabout analysis procedures.

Historically, deterministic software from Australia (SIDRA Intersection) and the United Kingdom (RODEL and Arcady) were used to analyze roundabouts in the US. The *2010 Highway Capacity Manual* (2010 HCM) incorporates the roundabout operational analysis model developed in NCHRP Report 572, *Roundabouts in the United States* from US data. The 2010 HCM allows for the evaluation of single-lane and multilane roundabouts (with up to two circulating lanes). In cases where the existing or planned roundabout has more than two circulating lanes, FHWA approved deterministic software (such as SIDRA Intersection, Arcady or RODEL) is needed to evaluate the roundabout operations. Whenever deterministic software is utilized to evaluate a roundabout, the user shall ensure that it is calibrated to local driver behavior and effective geometry, and adjustments should be made to account for lane configurations or system effects.

Microsimulation software such as VISSIM and Paramics can also be used for roundabout analysis. The increased time to build and calibrate a microsimulation model makes it most appropriate for analysis of network interactions (such as potential queue spillback effects) or visualizations for public involvement.

Consistent with the 2010 HCM, level of service (LOS) thresholds for roundabouts have been established using control delay, and are the same as defined for stop-controlled intersections.

D. Safety

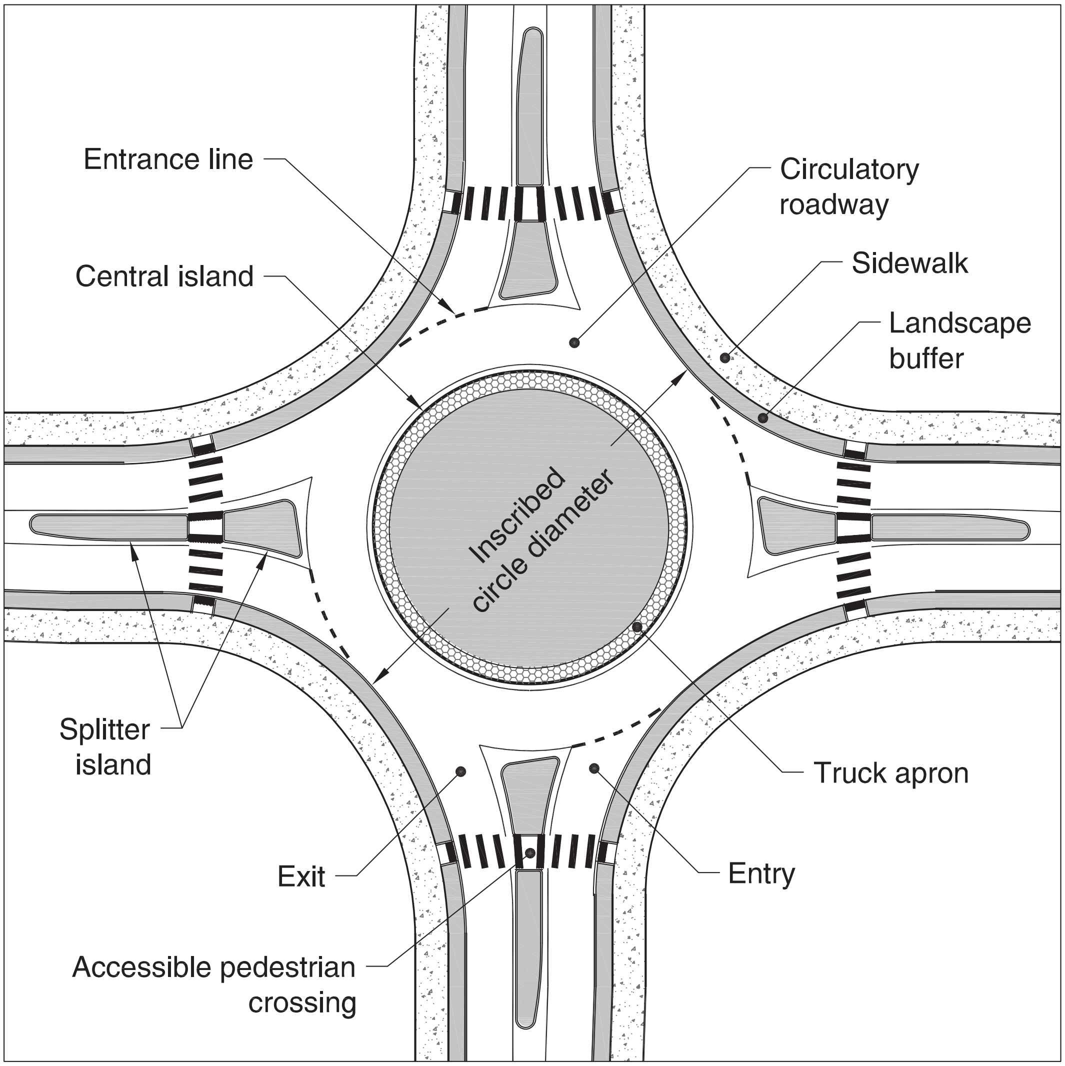
Roundabouts are a proven safety measure due to their minimal conflict points and speed control. In particular, roundabouts can provide the most safety benefits when used at intersections with historically high crash rates, roads with historical problem of excessive speeds, and at intersections with more than four legs or with difficult skew angles. In order to achieve the full safety benefits of a roundabout, a principle-based design process including the proper application of performance checks should be utilized. The subsequent section discusses the principles of roundabout design.

Further information pertaining to roundabout safety is found in NCHRP Report 672, Chapter 5.

E. Design

Roundabout design follows a principles based design process. This process is focused on achieving and balancing several key objectives. Figure 5 displays the basic geometric elements of a roundabout.

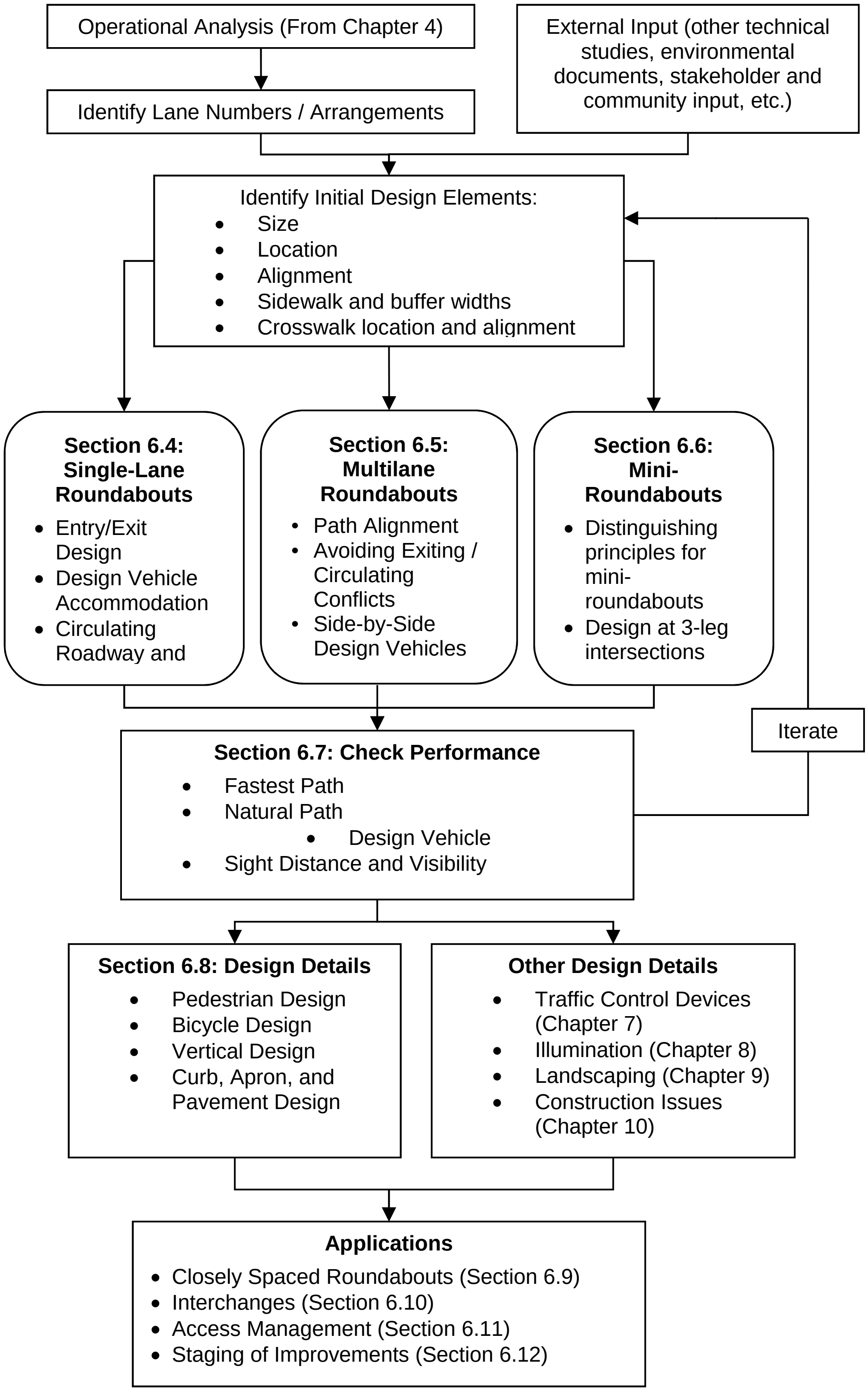
Figure 5: Basic Geometric Elements of a Roundabout



The principles and objectives of the geometric design of roundabouts are achieved using the general design process shown in Figure 6. In particular, performance checks are an important element of the design process and guidance found in the NCHRP Report 672, Section 6.7 should be followed to ensure the performance checks are completed appropriately, including sight distances.

Since modern roundabouts are somewhat new to Virginia and much of its design community, peer reviews by VDOT staff or consultants experienced in roundabout design are recommended. Peer reviews reduce the likelihood of poorly designed roundabouts being built. In addition to having operational and/or safety issues, poorly designed roundabouts can create poor public perception of roundabouts as a whole

Figure 6: General Roundabout Design Process *



* Chapter and Section references are from NCHRP Report 672.

1. Design Vehicle

The minimum recommended design vehicle for roundabouts on state highways, primary routes, and interchange ramp terminals is an AASHTO WB-67. Design vehicles for secondary routes may be smaller, but should be evaluated on a case-by-case basis. The roundabout geometry should accommodate the swept path of the design vehicle tires and body and should be evaluated using a CAD-based vehicle turning path program for each of the turning movements. The use of other design vehicles will be made on site specific considerations, usually related to truck restrictions.

2. Splitter Islands

Splitter islands should be incorporated into all roundabouts, and generally at least 50 feet in length, although specific situations or design constraints may necessitate shorter splitter islands. Splitter islands should be a minimum of 6 feet wide at crosswalk locations to adequately provide refuge for pedestrians, including those using wheelchairs, pushing a stroller, or walking a bicycle. Splitter islands also alert approaching drivers to the geometry of the roundabout. For higher speed approaches, splitter island lengths of 150 feet or more are often beneficial. A more detailed discussion of splitter island geometry for high-speed approaches can be found in NCHRP Report 672, Section 6.8.5.3. See NCHRP Report 672, Sections 6.4.1 and 6.5.5 for more information regarding general design details for splitter islands.

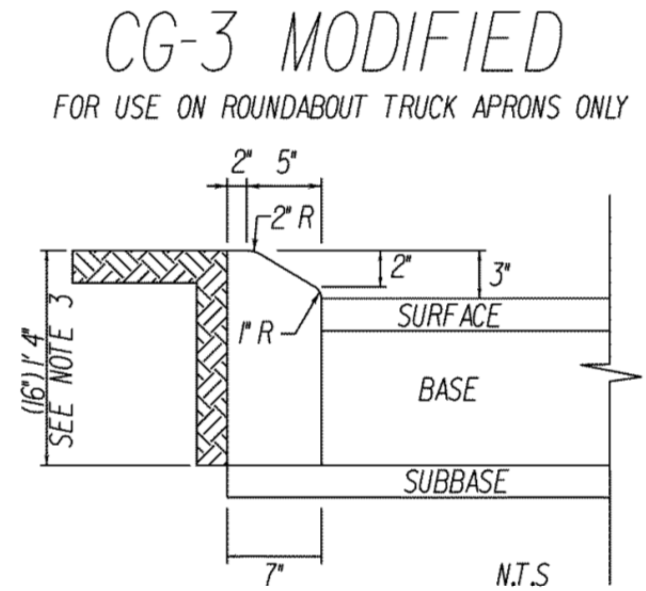
3. Truck Apron

Where truck aprons are used, the slope of the apron should generally be no more than two percent; greater slopes may increase the likelihood of loss-of-load incidents. Within the United States, truck aprons are commonly sloped toward the outside of the roundabout. However, some locations have also implemented roundabouts with truck aprons sloped inward (toward the central island) to minimize water shedding cross the roadway and to minimize load shifting in trucks. Agencies using this strategy report that additional catch basins were provided along the edge of the central island to collect water and pipe it under the circulatory roadway to connect in with the drainage system along the roundabout periphery.

The vertical design of the truck apron should be reviewed to confirm that there is sufficient clearance for low-boy type trailers, some of which may have only 6 to 8 in. between the roadway surface and bottom of the trailer. The vertical clearance can be reviewed by drawing a chord across the apron in the position where the trailer would sweep across. In some cases the warping of the profile along the circulatory roadway can create high spots that could cause trailers to drag or scrape along the truck apron.

Virginia has a specific curb detail for truck aprons (Mod. CG-3), shown below in Figure 7, also available in the cell library.

Figure 7: CG-3 Modified Truck Apron Curb Detail



NOTES:

1. THIS ITEM MAY BE PRECAST OR CAST IN PLACE.
2. CONCRETE TO BE CLASS A3 IF CAST IN PLACE, 4000 PSI IF PRECAST.
3. THE DEPTH OF CURB MAY BE REDUCED AS MUCH AS 3" (13" DEPTH) OR INCREASED AS MUCH AS 3" (19" DEPTH) IN ORDER THAT THE BOTTOM OF THE CURB WILL COINCIDE WITH THE TOP OF A COURSE OF THE PAVEMENTS SUBSTRUCTURE. OTHERWISE, THE DEPTH IS TO BE 16" AS SHOWN. NO ADJUSTMENT IN THE PRICE BID IS TO BE MADE FOR A DECREASE OR AN INCREASE IN DEPTH.
4. THE MODIFICATION TO THE STANDARD CG-3 IS TO REDUCE THE EXPOSED HEIGHT OF THE CURB AS SHOWN. MODIFIED CURB SHALL BE PAID FOR AS STANDARD CG-3.

4. Pedestrian Design Considerations

Pedestrians should generally be considered and accommodated at all roundabout intersections. Pedestrian accommodations typically include cut-throughs on splitter islands, two-stage perpendicular crossings, curb ramps and accessibility features such as detectable warning surfaces. In some situations (such as rural intersections), pedestrian accommodations may not be necessary; however, it is recommended that such splitter islands be designed to be wide enough to accommodate potential future crossings. Current Draft Public Right-of-Way Accessibility Guidelines (PROWAG) require pedestrian-activated signals at all multilane roundabout entries and exits as well as detectable edging where pedestrian crossings are not intended. Further information for the design of pedestrian accommodations for roundabouts is provided in NCHRP Report 672, Section 6.8.1. Also, refer to Chapter 6 of this manual for ADA compliance.

5. Bicycle Design Considerations

Where bicycle lanes are used on approach roadways, they should be terminated in advance of roundabouts using tapers to merge cyclists into traffic for circulation with other vehicles. For bike routes where cyclists remain within the traffic lane, it can be assumed that cyclists will continue through the roundabout in the travel lane. At multilane roundabouts consider providing bicycle ramps to allow bicyclists to exit the roadway onto the sidewalk and travel as pedestrians. Ramps should not normally be used at urban, single-lane roundabouts except where the complexity of the roundabout would make circulating like other vehicles more challenging for bicyclists. Further information for the design of bicycle accommodations for roundabouts is provided in NCHRP Report 672, Section 6.8.2.

6. High Speed Approaches

The primary safety concern in rural locations where approach speeds are high is to make drivers aware of the roundabout with sufficient advance distance to comfortably decelerate to the appropriate speed for entering the roundabout. Where possible, the geometric alignment of approach roadways should be constructed to maximize the visibility of the central island and the shape of the roundabout. Further information on treatments for high speed approaches is provided in NCHRP Report 672, Section 6.8.5 and 7.4.4.

7. Drainage

Drainage structures should normally be placed on the outer curb line of the roundabout and upstream of crosswalks, but should not be placed in the entry and exit radii of the approaches. Drainage structures located on the outer curb line of the circulatory roadway shall be designed to withstand vehicle loading. Maximum gutter spreads should match the requirements for the approach roadways. Refer to NCHRP Report 672, Section 6.8.7 and Chapter 13 of this manual for a discussion of vertical alignment considerations which includes drainage.

8. Curbing

Concrete curb should be used along the outside edge of all roundabouts which includes the entry radius, the circulatory roadway, and the exit radius, and for the splitter islands. For rural roadways it is desirable to extend outside curbing along approaches to the length of the required deceleration distance to the roundabout. A mountable truck apron curb should be used between the truck apron and the circulatory roadway. Further information on the principles of using curbs on roundabouts is provided in NCHRP Report 672, Sections 6.8.7.4 and 6.8.8.1.

9. Pavement

Asphalt or dark colored concrete is the recommended material for the circulatory roadway to differentiate it from the concrete truck apron. At locations where a single-lane roundabout is constructed with the intention of later conversion to a multilane roundabout, asphalt pavement should be considered due to the need to redo the concrete jointing during conversion. Sidewalks should be constructed with a different texture and/or color than the truck apron to differentiate the pedestrian path and to deter pedestrians from using the truck apron. Further information on the design of pavements for roundabouts is provided in NCHRP Report 672, Section 6.8.8.

10. Staging of Improvements

When projected traffic volumes indicate that a multilane roundabout is required for the design year, the duration of time that a single-lane roundabout can be expected to operate acceptably should be estimated. Consideration should be given to first constructing a single-lane where a single-lane roundabout is expected to be sufficient for ten years or more from the date the roundabout would open to traffic.

To allow for this future expansion, the right-of-way and geometric needs of both the single-lane and multilane roundabout should be acquired. For further information refer to NCHRP Report 672, Section 6.12.

11. Traffic Control Devices
Traffic control devices for roundabouts shall be in accordance with the 2009 Manual on Uniform Traffic Control Devices. NCHRP Report 672, Chapter 7 provides a helpful presentation of the application of traffic control devices to roundabouts.

12. Illumination
Lighting of roundabouts serves two main purposes:

1) It provides visibility from a distance for users approaching the roundabout; and
2) It provides visibility of the key conflict areas to improve users' perception of the layout and visibility of other users within the roundabout.

For additional guidance and details regarding lighting layouts, illuminance levels, and other considerations, please refer to NCHRP Report 672, Chapter 8.

F. Other Considerations

1. Landscaping
A realistic maintenance program should be considered in the design of landscape features, including identification of the responsible party for future maintenance, water supply, drainage, and expected growth of plantings. Maintenance Agreements with local organizations are sometimes used.

Landscaping must not reduce sight distances below minimum criteria. For a more detailed discussion of landscaping design consideration and best practices, please refer to NCHRP Report 672, Chapter 9.

2. Construction and Maintenance
Roundabouts can be constructed under three types of traffic conditions:

- With all traffic diverted away from the work area,
- With some traffic diverted, or
- Under full traffic.

The guiding principle is to minimize staging and provide large sections of the project to construct during each construction stage. This will increase quality of construction, reduce driver confusion, and reduce construction duration and cost. Generally, diverting or detouring as much traffic from the intersection as possible is the most desirable option. For a more detailed discussion of construction staging under all three types of conditions, please refer to NCHRP Report 672, Section 10.3.

3. Snow Removal

For a discussion of snow removal considerations and best practices, please refer to NCHRP Report 672, Section 10.7.2.

4. VDOT Policy, Guidelines, and Procedures

For a detailed discussion regarding Virginia-specific policies and procedures regarding the design of roundabouts, please see Appendix F Section 2 (Roundabouts) of VDOT's *Road Design Manual*, available on-line at http://www.virginiadot.org/business/locdes/rdmanual-index.asp.