Facilities Development Manual

ORIGINATOR Director, Bureau of Highway Development		PROCEDURE 11-26-1
CHAPTER 11	Design	
SECTION 26	Roundabouts	
SUBJECT 1	General	

The modern roundabout is a subset of many types of circular intersections. The term modern roundabout and roundabout are used interchangeably throughout this document. The roundabout is a one-way circular intersection with specific design control features. The term “modern roundabout” is used in the United States to differentiate roundabouts from the older and often large diameter non-conforming traffic circles, rotaries or very small traffic calming circles used on residential streets.

Traffic circles fell out of favor in this country by the mid 1950’s because they encountered safety and operational problems as traffic volumes increased beyond their operational thresholds. However, substantial progress has been achieved in the subsequent design of circular intersections, and the modern roundabout should not be confused with the traffic circles of the past.

Modern Roundabout vs. Other Circular Intersections

The modern roundabout is defined by three basic principles that distinguish it from a traffic circle.

1. Yield-at-Entry: Vehicles approaching the circular intersection must wait for a gap in the circulating flow, or yield, before entering the circle.
2. Traffic Deflection: Traffic entering the roundabout is directed or channeled to the right with an appropriate curved path into the circulating roadway that avoids the central island.
3. Geometric Curvature: The radius of the circular road and the angles of entry can be designed to slow the speed of vehicles. Key geometric design parameters and the fastest speed path are critical to achieve proper design and are addressed later in this section of Chapter 11.

On the surface, modern roundabouts and old traffic circles and rotaries look similar; however, there are subtle differences that distinguish the two intersection concepts. The fundamental difference is their differing design philosophies. Modern roundabouts are to control and maintain low speeds for entering and circulating traffic. This is achieved by small diameters and low-speed entry geometry. By contrast, traffic circle geometry encourages high-speed merging and weaving, made possible by larger diameters and large, high-speed entry radii. Modern roundabouts control vehicle speed by geometric design elements that allow only slow speeds. This creates safer driving conditions. The common characteristics distinguishing a modern roundabout from a traffic circle or a rotary type intersection are summarized in Table 1.

Table 1 Distinguishing Characteristics of Modern Roundabouts

Feature	Modern Roundabout	Traffic Circle or Rotary
Control at Entry	Yield at entry	Stop, signal, or give priority to entering vehicle.
Operational Characteristics	Vehicles are sorted by destination at the approach. Weaving within the circulatory roadway is minimized.	Weaving is unavoidable and weaving sections are provided to accommodate conflicting movements.
Deflection	Large entry angle helps to create entry deflection to control speed through the roundabout.	Entry angle likely to be reduced to allow higher speed at entry.
Speed	Maintain relatively low speeds (< 25 mph).	Higher speeds allowed (> 25 mph).
Circle Diameter	Smaller diameters improve safety.	Larger diameters allowed. Small diameter circle sometimes used for traffic calming.
Pedestrian Crossing	No pedestrian activity on central island.	Some large traffic circles allow pedestrian crossing to and from the central island.
Splitter Island	Required	Optional
Parking	No parking on the circulatory roadway or in close proximity of the yield line.	On large traffic circles, occasional parking permitted within circulating roadway.

Advantages and Disadvantages

Table 2 lists the advantages and disadvantages of roundabouts versus other intersection alternatives.

Table 2. Advantages and Disadvantages of Roundabouts vs. Other Alternatives

Category	Advantages	Disadvantages
Safety	• Reduced number of conflict points compared to other non circular intersections. • Elimination of high angles of conflict and lower operational speeds; fewer and less severe accidents. • Reduction in conflicting speeds passing through the intersection. • Reduced decision making at point of entry. • Long splitter islands and other geometric features provide good advanced warning of the intersection. • Raised level of consciousness for drivers.	• Accidents may temporarily increase due to improper driver education. • During emergencies, signalized intersections can preempt control.
Capacity	• Traffic yields, nonstop, continuous traffic flow. • Generally higher capacities experienced.	• Coordinated signal systems can increase capacity of the network.
Delay	• Generally reduced delay as compared with an equivalent volume for signalized intersection. • During off-peak hours, signal timing can create undue delay at signalized intersections.	• As queues develop, drivers accept smaller gaps which may increase crashes.
Cost	• Maintenance of signals (heads, loop detectors, controllers) and power is eliminated. • Lower accident rate and severity; reduced accident costs.	• Central island landscaping maintenance. • Possible illumination cost. • Possible higher construction cost. • Possible higher ROW costs.
Pedestrians & Bicyclists	• Splitter islands provide pedestrian refuge and shorter one-directional traffic crossing. • Low speed conditions improve bicycle and pedestrian safety.	• Pedestrians, especially handicapped may experience increased delay in securing acceptable gaps to cross. • Longer travel path.
Environmental	• Reduced starts and stops; reduced air pollution.	

Design References and Methods

The Federal Highway Administration **(FHWA)** has published a design guide for roundabouts [1]. The guide, "Roundabouts: An Informational Guide," is available at FHWA Roundabout Guide. This document is an informational guide. It is not intended to be an inflexible "rule book" but rather it attempts to explain some principles of good design and indicate potential tradeoffs.

There have been multiple studies on the use and effectiveness of roundabouts. One of the most recent studies was conducted by researchers at Ryerson Polytechnic University and the University of Maine [2]. It is available on line at www.highwaysafety.org/srpdfs/sr3505.pdf.

Roundabout intersection analysis models generally fall into two categories. Empirical models rely on field data to develop relationships between geometric design features and performance measures such as capacity and delay. Analytical models are based on the concept of gap acceptance theory. Extensive research [3], [4], [5] conducted in England supports the empirical formula method of roundabout analysis over the gap acceptance method of analysis. RODEL and ARCADY are software programs that are based on this research and the empirical formula method. RODEL permits the designer to quickly and easily test "what-if" scenarios, thus allowing designers to optimize their design rather than just settle on the one that meets minimum criteria. This is important as small changes in roundabout geometry such as entry width or flare length may increase the probability that the roundabout will perform well at high v/c ratios. Therefore, the Department requires the final analysis of the roundabout design and operation to be conducted using RODEL. RODEL is available from:

RODEL Software
Marcus House, Park Hall Business Village
Stoke on Trent ST3 5XA
United Kingdom
Telephone: 011-44-1782-599313
rslcrown@aol.com

Other resources containing roundabout information include 2001 GDHS, pages 578-583 and the 2000 Highway Capacity Manual, Chapter 17, pages 45-48.

Introduction

Proper roundabout design requires a range of expertise, depending upon the intersection complexity and anticipated design hourly volume **(DHV)** entering the intersection. The low end of design expertise involves the design of single lane roundabouts with fewer than 1,500 vehicles per hour entering the intersection. At this volume design imperfections may have a limited adverse impact on the overall level of service (LOS) and intersection safety. At high v/c ratios the design of a single lane roundabout requires a higher level of expertise to design correctly. Roundabout design difficulty increases as the number of intersection legs increases, the number of lanes and volume increases, as the skew angles increase, and as space for the roundabout is constrained by high cost real estate. The challenge in the design of the roundabout is to balance the various design aims to provide safe, efficient traffic flow for all users including cars, pedestrians, bicycles, and large trucks. To achieve this, a range of design considerations such as curvilinear approach, fastest speed path and other design parameters along with drainage, sight distance, grades, cross slopes, signing, pavement marking, lighting, and landscaping must be addressed.

It is not usually productive to take an individual standard for each part and then to combine the various parts to produce a design because the relationships between the parts may be poor, even though each part is fine by itself. Therefore, the following section provides a design review hierarchy based on the level of roundabout complexity, design difficulty and designer experience.

Roundabout Selection

In general terms, any intersection, urban or rural, that meets the criteria for a four-way stop condition or traffic signal, also qualifies for evaluation as a modern roundabout. Therefore, if an intersection warrants a signal or a 4-way stop within the design life of the proposed project, then include the roundabout alternative in the overall analysis. Where there is an existing 4-way stop or signal and there are operational problems with the current control, then the roundabout should be considered as a viable alternative. In either case, roundabouts should remain a potential intersection control strategy until such time that the analysis or corridor considerations indicate that the roundabout alternative is not appropriate.

There are no warrants for when to construct roundabouts; however, there are two situations that must be improved if a roundabout is to be considered.

- Where there is insufficient stopping sight distance prior to the entrance or
- On grades in excess of 5%.

Typical intersection analysis will include criteria such as crash data, crash diagrams, user delay or level of service for all traffic movements, appropriate design vehicle and other safety improvements for pedestrians and bicyclists.

FHWA and AASHTO have made intersection safety a high priority. The objective is to improve the design and operation of highway intersections. When compared to signalized intersections, studies show that roundabouts typically reduce overall delay and congestion, they increase capacity and they improve safety. For example, right-angle collisions are a prominent cause of death at signalized intersections. Studies have shown [2] that signalized intersections converted to roundabouts experienced significantly fewer crashes, injuries and fatalities.

Design review process

The Department has established a roundabout design review process to ensure that roundabouts are properly selected and designed to meet the balance of needs stated above.

All roundabout designs shall be reviewed at the 30%, 60% and 90% level of roundabout plan completion. These reviews shall be coordinated through the Bureau of Highway Development **(BHD)**. Contact the appropriate project development engineer to arrange for these reviews. The BHD will also coordinate roundabout design reviews with the Bureau of Highway Operations and the FHWA as needed.

There are three levels of roundabout design review based on the complexity of the proposed design.

- Level 1 roundabout design/review – The design complexity at this level is limited to roundabouts where all legs (not to exceed 4 legs) are single lane entries and the entering DHV is 1,500 or less with no bypass lane(s). A level 1 reviewer must have a minimum understanding of roundabout design with high confidence in designing truck aprons, developing appropriate values for the six geometric parameters, fastest speed path and be comfortable with running and evaluating output from the RODEL software program.

- Level 2 roundabout design/review –The design complexity at this level involves roundabouts where:
  - All legs are single lane entries and the entering DHV is greater than 1,500 or
  - The roundabout has one or more legs that have a 2-lane entry or
  - A bypass lane is included in the design.

A level 2 reviewer must have a good understanding of the empirical method of roundabout design and provide examples, when requested by BHD, of locations where they have conducted a level 1(or higher) type review or design and that roundabout is in operation.

- Level 3 roundabout design/review –The design complexity at this level involves roundabouts where all legs may be multi-lane entries. This complexity level also involves roundabouts where one or more legs have a 3-lane or 4 lane entry and or bypass lane(s). A level 3 reviewer must have demonstrated skills in the empirical method of roundabout design and provide examples, when requested by BHD, of locations where they have conducted a level 2 (or higher) type review or design and that roundabout is in operation.

Statutory Authority for Through Highway Declarations (ss 340.01(67) & 349.07)

By statutory authority signal, roundabout or stop sign installations on a state trunk highway require an approval process. Guidance on "Through Highway Declarations" is provided in the Traffic Guidelines Manual **(TGM)**, Section 13-1 (dotnet link) (extranet link) This requirement applies to new or modified traffic control installations on the STH. Regardless of the type of traffic control proposed, associated "through highway declarations" need to be developed and are maintained by the District Traffic staff.

Statutory Authority of Speed Zone Declarations (ss 346.57 & 349.11)

Also by statutory authority speed zone declarations are required when the traffic on a STH is required to reduce speed as a result of a regulatory speed sign installation. Guidance on "Speed Limits" is provided in the TGM, Section 13-5. This generally will occur in rural areas where the posted or regulatory speed is 55 mph and it is desirable to step down the speed to 45 mph in advance of a signal, roundabout or stop condition on a STH.

Defining Physical Features

Roundabout features are shown and described in Figure 1.

Key roundabout design parameters are shown and defined in Figure 2. Figure 2 includes two methods for determining the appropriate entry.

This figure provides a description of key roundabout design parameters with dimensions shown in metric. Metric dimensions are used because the RODEL software, at this time, will accept only metric units. Plan sheet values shall show US Customary units. In preliminary design there may be rounding of the metric values to achieve even foot dimensions for inscribed diameter, lane width, circulatory roadway width or effective flair length or other dimensions if desired.

Figure 3 shows typical relationships between the six geometric design parameters and roundabout capacity. Figure 3 shows that entry width, flare length and entry radius have a much greater impact on the roundabout capacity than the inscribed circle diameter.

References

[1] "Roundabouts: An Informational Guide," Publication No. FHWA-RD-00-067, June 2000
[2] Status Report: Roundabouts, Vol. 35, No. 5, Insurance Institute for Highway Safety, May 13, 2000
[3] Traffic Queues and Delays at Road Junctions, TRRL Report LR 909, 1979. Kimber, RM and Hollis EM
[4] The Traffic Capacity of Roundabouts TRRL Report LR 942 1980 Kimber RM
[5] Gap-Acceptance and Empiricism in Capacity Prediction, TRRL Kimber RM

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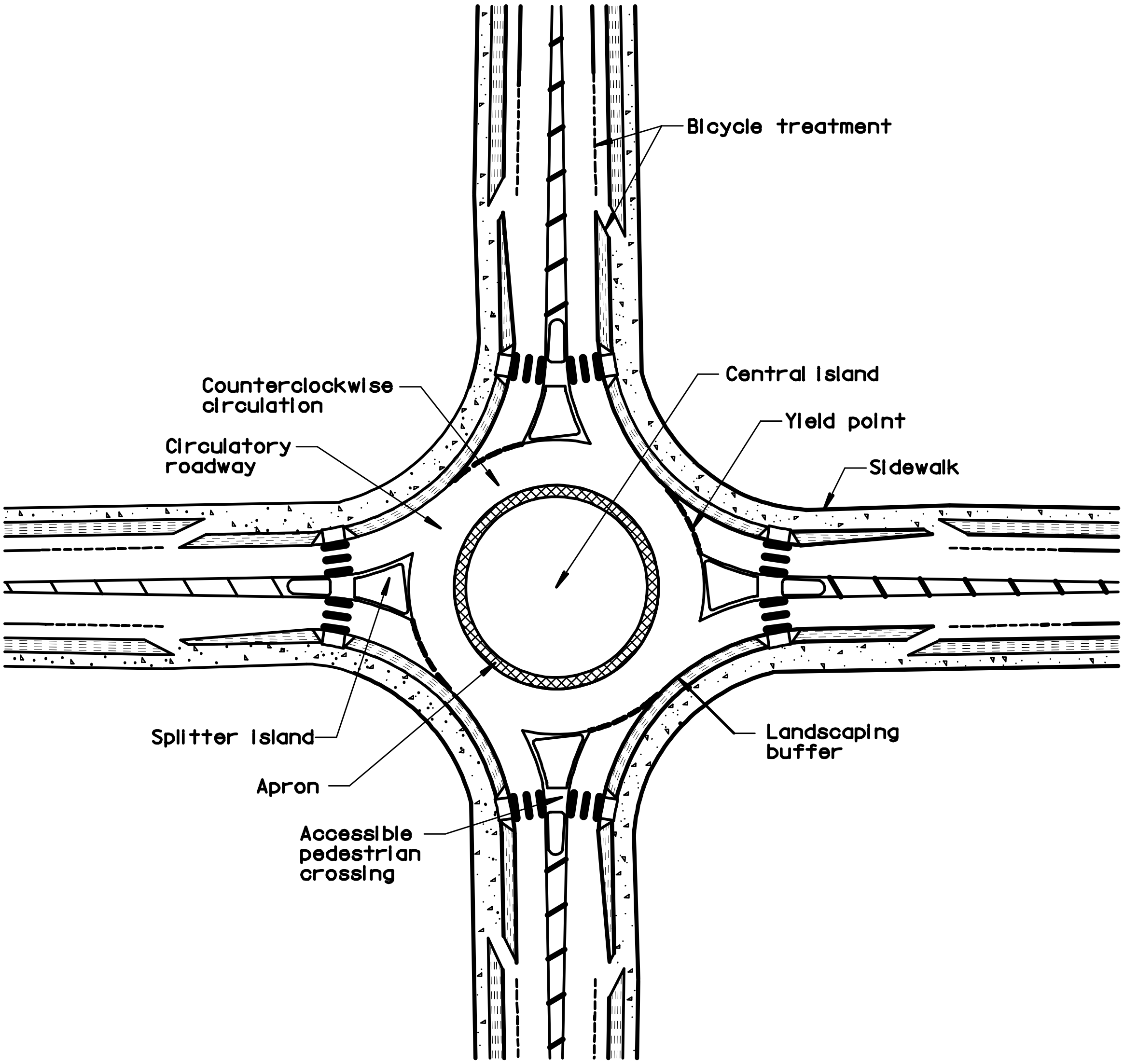
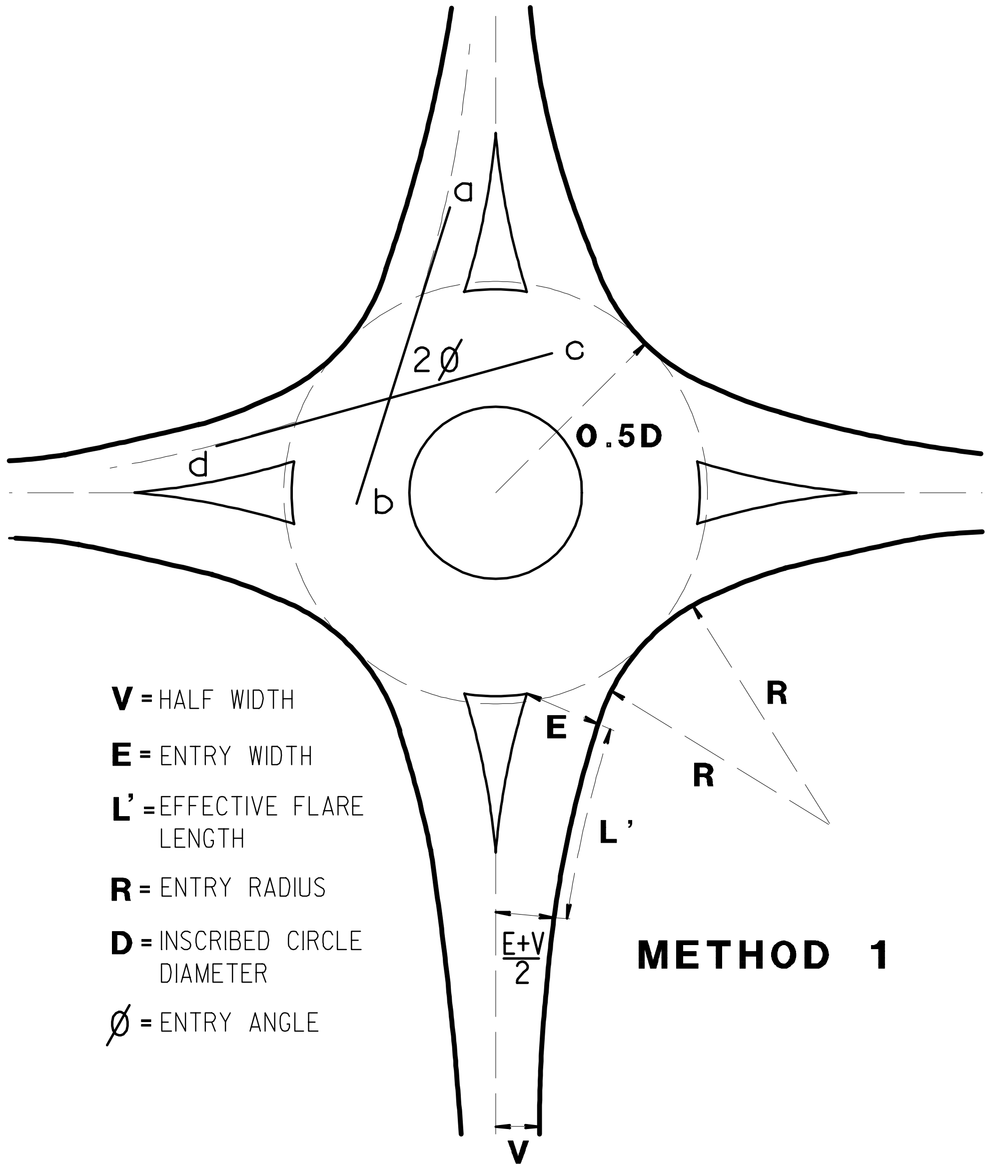


Roundabout Features

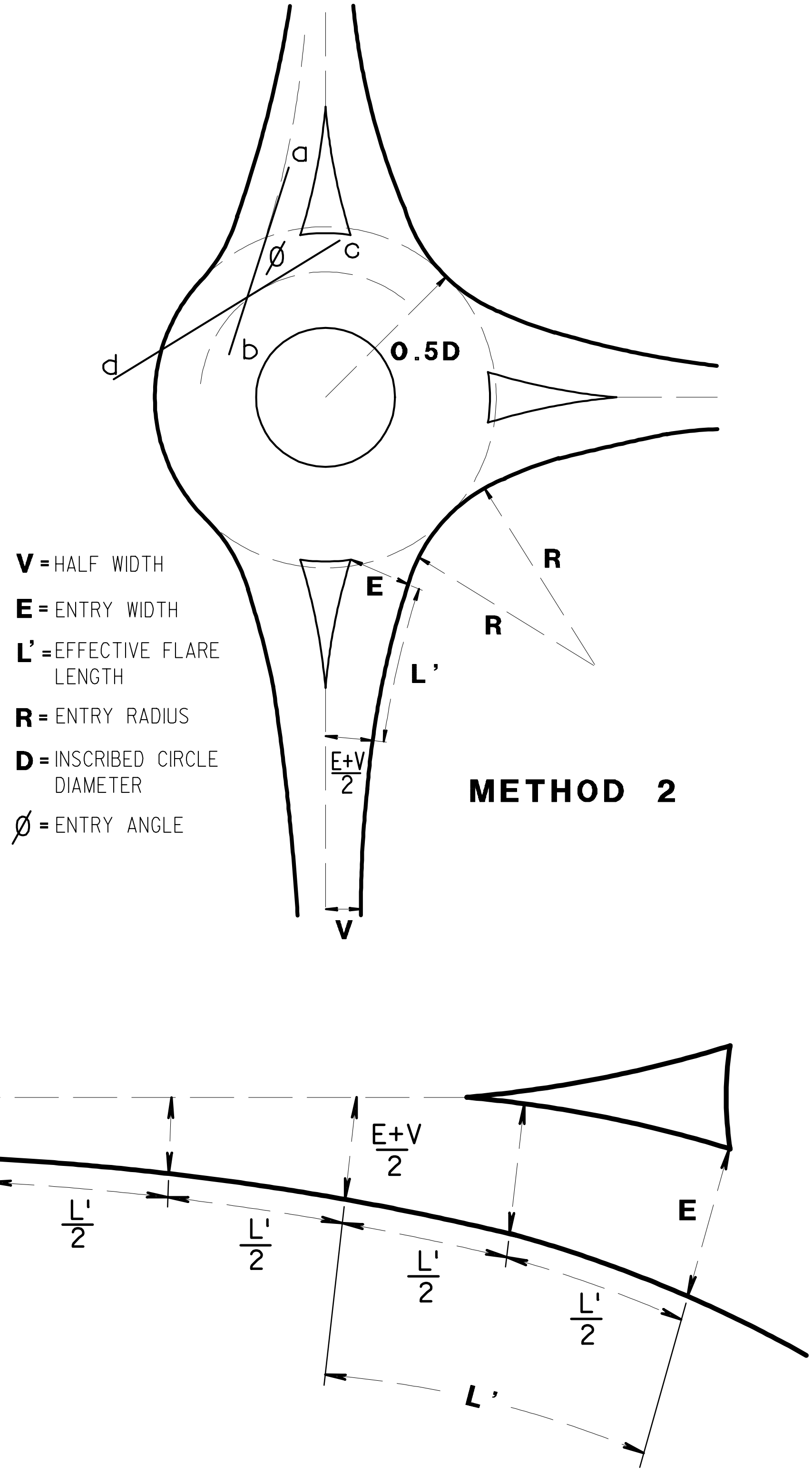
Key Roundabout Features

Feature	Description
Central island	The raised area in the center of a roundabout around which traffic circulates.
Splitter island	A raised curb (special situations may be painted) area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and to provide refuge for pedestrians crossing the road in two stages.
Circulatory roadway (counter clockwise circulation)	The curved path used by vehicles to travel in a counterclockwise fashion around the central island. The width of the circulatory roadway is typically 1.0 to 1.2 times the width of the widest entry width.
Apron	The mountable portion of the central island adjacent to the circulatory roadway. It may be required on smaller roundabouts to accommodate the wheel tracking of long or oversized vehicles.
Yield Point	A point of demarcation separating traffic approaching the roundabout from the traffic already in the circulating roadway. The yield point is usually defined by dotted edge line pavement marking. Entering vehicles must yield to circulating traffic. Technically, yield line pavement marking consists of a row of solid white isosceles triangles pointing toward approaching vehicles and is defined further in the 2003 MUTCD, Section 3B.16.
Accessible pedestrian crossings	Provide accessible pedestrian crossings at all roundabouts. The crossing location is set back from the yield line, typically one car length. The splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.
Bicycle treatments	Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either by riding in the travel lane as a vehicle, or by exiting the roadway and using the crosswalk as a pedestrian, or as a cyclist using the shared-use path, depending on the bicyclist's level of comfort.
Landscaping buffer	Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection.
Sidewalk	Pathway for pedestrians to walk. In the urban environment it is common to provide a multi-use path at the perimeter of the roundabout to accommodate pedestrians and bicyclists.



Source: RODEL software manual

Key Roundabout Design Parameters, Method 1 and 2



Source: RODEL software manual

Key Roundabout Design Parameters

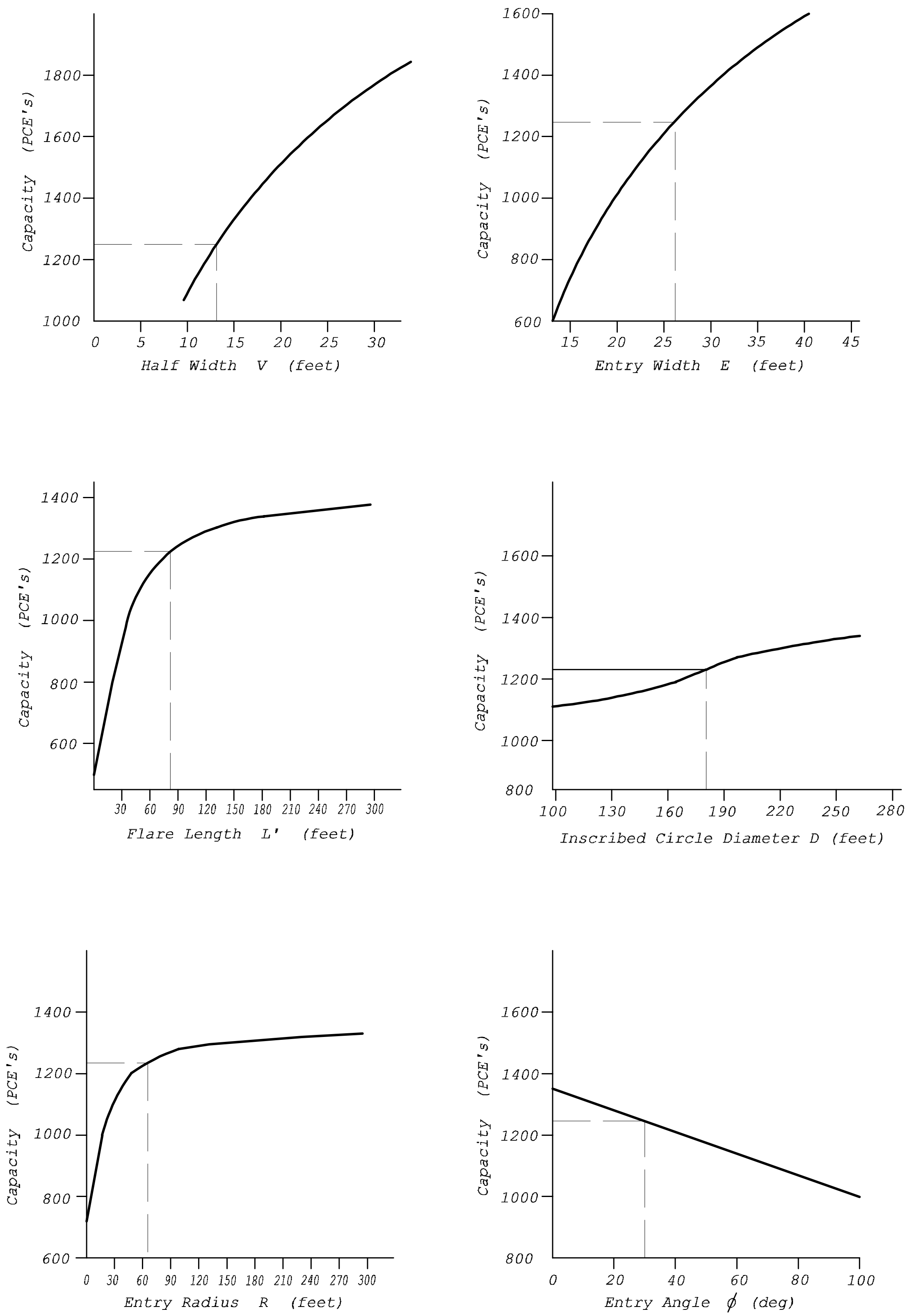
Parameter	Description
Half Width = V, meters	The half width is the width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The half width is typically no more than half of the total width of the roadway. If the facility has a marked bike lane the half width is to the white line. If there is no marked bike lane then the width is measured from the curb face on the right side to the curb face of the splitter island, or marked centerline, on the left side.
Entry width = E, meters	The entry width defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the outside curb face to the inside curb face at the splitter island nearest point to the inscribed circle.
Effective Flare Length = L', meters	Half the total distance between V and E. At this distance the approach roadway width equals the average of V and E. The flare must be developed uniformly and avoid a sharp break where the flare starts. Full flare length is twice the effective flare length.
Entry radius = R, meters	The entry radius is the minimum radius of curvature of the outside curb at the entry.
Entry Angle = ∅, degrees	**Method 1**. Half the angle formed by the junction of the tangent line (a-b) projected from the entry lane and the tangent line (c-d) projected from the adjacent exit lane(s). ∅ is used in the empirical formula. **Method 2**. The angle formed by the intersection of the tangent line (a-b) projected from the entry lane(s) with a tangent line (c-d) drawn along the middle of the circulatory roadway. Used at "T" intersections or where the adjacent entrance and exit lane(s) are far apart.
Inscribed Circle Diameter = D, meters	The inscribed circle diameter is the basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.

Following is a list of other important factors that are incorporated into the roundabout design.

Fastest speed path	The fastest speed path is a basic principle of roundabout design to restrict operating speed by deflecting the paths of entering and circulating vehicles. Refer to the FHWA Roundabout Guide, Chapter 6 and Exhibit 6-12, for additional information on vehicle path curvature.
Circulatory roadway width	The width between the outer edge of the inscribed diameter at the curb face of this roadway and the central island curb face. It is typically 1.0 to 1.2 times the width of the widest entry width. It does not include the width of any mountable apron, which is defined to be part of the central island. The circulatory roadway width defines the roadway width, curb face to curb face, for vehicle circulation around the central island.
Exit radius	The radius of curvature of the outside curb at the exit.
Exit width	The exit width defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right curb face edge of the exit to the intersection point of the left curb face edge and the inscribed circle.

The following radii are used to define the fastest path through a roundabout. They are illustrated in Exhibit 6-12 of the FHWA Roundabout Guide.

Entry Path Radius, R1	The minimum radius on the fastest through path prior to the yield line. This is not the same as Entry Radius.
Circulating Path Radius, R2	The minimum radius on the fastest through path around the central island.
Exit Path Radius, R3	The minimum radius on the fastest through path into the exit.
Left Turn Path Radius, R4	The minimum radius on the path of the conflicting left-turn movement.
Right Turn Path Radius, R5	The minimum radius on the fastest path of a right-turning vehicle.



Source: RODEL software manual

Geometric Design Parameters