1 - 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 http://www.tfhrc.gov/safety/00068.htm. This document is an informational guide and 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, effectiveness and safety of roundabouts. One such study was conducted by researchers at Ryerson Polytechnic University and the University of Maine.

2 - Roundabout Operation

A roundabout brings together conflicting traffic streams, allows the streams to safely cross paths and traverse the roundabout and exit to their desired directions at reduced speeds. Modern roundabouts do not have merging or weaving between conflicting traffic streams. Compactness of circle size and geometric speed control make it possible to establish priority to circulating traffic. The geometric elements of the roundabout reinforce the rule of circulating traffic priority and provide guidance to drivers approaching, entering, and traveling through a roundabout.

Drivers approaching a roundabout must slow to a speed that will allow them to safely interact with other users and negotiate the roundabout. The width of the approach roadway, the curvature of the roadway, and the volume of traffic present on the approach govern this speed. As drivers approach the yield point, they must first yield to pedestrians and then to conflicting vehicles already in the circulatory roadway. The widths of the approach roadway and entry determine the number of vehicle streams that may form side-by-side at the yield point and govern the rate at which vehicles may enter the circulating roadway. The size of the inscribed circle affects the radius of the driver's path, which in turn determines the speed at which drivers travel in the roundabout. The width of the circulatory roadway determines the number of vehicles that may travel side-by-side in the roundabout.

2.1 - Space Requirements and Capacity Limitations

The inscribed circle diameter needed for a roundabout is one of the most critical space requirements when considering impacts. The following table gives general inscribed circle diameters and daily service volumes for the different WisDOT categories of roundabouts. Use Table 1 for inscribed circle diameter values to help in the roundabout analysis. Diameters will vary and may fall outside these prescribed ranges in some situations. Table 1 also provides a rough estimate of capacity for the WisDOT roundabout categories.

Table 1. Typical Inscribed Circle Diameters and Daily Service Volumes

Roundabout Type	**Typical Inscribed Circle Diameter**[1]	**Typical Daily Service Volume**[2] **(vpd) 4-leg roundabouts**
Urban Single-Lane	120 -150 ft **(35 – 45 m)**	less than 25,000
Urban Multilane (2-lane entry)	160 - 215 ft **(50 – 65 m)**	25,000 to 55,000
Urban Multilane (3 or 4-lane entry)	215 - 275 ft **(65 – 85 m)**	55,000 to 80,000
Rural Single-Lane	130 -150 ft **(40 – 45 m)**	less than 25,000
Rural Multilane (2-lane entry)	165- 215 ft **(50 – 65 m)**	25,000 to 55,000
Rural Multilane (3-lane entry)	215 - 300 ft **(65 – 90 m)**	55,000 to 70,000

[1] The diameters provided are for general guidance.

[2] Capacities vary substantially depending on entering traffic volumes and turning movements.

3 - Roundabout Capacity

The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout during a given time period under prevailing traffic and roadway (geometric) conditions. An operational analysis considers a precise set of geometric conditions and traffic flow rates defined for the design hour volume (DHV) for each roundabout entry. Analysis of the peak hour period is critical to assess the level of performance of the roundabout and its individual components. The capacity of the entire roundabout depends on many factors. In each case, the capacity of an entry or approach is computed as a function of traffic on the other (conflicting) approaches, the interaction of these traffic streams, and the intersection geometry.

For a properly designed roundabout, the yield point is the relevant point for capacity analysis. The approach capacity is the capacity provided at the yield point. This is determined by a number of geometric parameters in addition to the entry width. On multilane roundabouts, it is important to balance the traffic use of each lane otherwise some lanes may be overloaded while others are under utilized. Also, poorly designed exits may influence driver behavior and cause lane imbalance and congestion at the opposite leg.

The maximum flow rate that can be accommodated at a roundabout entry depends on two factors: the circulating flow in the roundabout that conflicts with the entry flow, and the geometric elements of the roundabout. When the circulating flow is low, drivers at the entry are able to enter the roundabout without significant delay. The larger gaps in the circulating flow are more useful to the entering drivers and more than one vehicle may enter each gap. As the circulating flow increases, the size of the gaps in the circulating flow decreases, thus the rate at which vehicles can enter also decreases.

The geometric elements of the roundabout also affect the rate of entry flow. The most important geometric elements are the width and number of lanes at entry, and the circulatory roadway width within the roundabout. Two entry lanes permit nearly twice the rate of entry flow compared to one lane. A wider circulatory roadway allows vehicles to travel side-by-side or staggered, which creates a tighter group of vehicles, thereby providing longer gaps. The effective flare length can substantially increase capacity while the inscribed circle diameter and entry angle (phi) generally have minor effects on capacity.

3.1 - Single-lane Roundabout Entry Capacity

Roundabout capacity is site specific since it is related to the geometric features of each site. For planning purposes, single-lane roundabouts can be expected to handle an AADT of approximately 25,000 veh/day(vpd) and peak-hour flows between 2,000 vph and 2,500 vph. This rate exceeds 1,900 vph, which is the typical single-lane capacity of a signalized intersection (reported in passenger car equivalents per hour of green time per lane; 2000 Highway Capacity Manual, Chapter 16). This higher rate is achieved for several reasons. First, this is the total of all the approaches, where this is typically two approaches for signalized intersections. Second, because of multiple approaches and right turns, much of the traffic does not conflict and may enter the intersection simultaneously.

3.2 - Single Lane Exit Capacity

It is difficult to achieve an exit flow on a single lane of more than 1,400 vph, even under good operating conditions for vehicles (i.e., tangential alignment, and no pedestrians and bicyclists). Under normal urban conditions, the exit lane capacity will be in the range of 1,200 vph to 1,300 vph. Therefore, exit flows exceeding 1,200 vph may indicate a lower LOS or the need for a multilane exit.

3.3 - Multilane Roundabout Capacity

For planning purposes, multilane roundabouts (two- and three- lane entries) can be expected to handle AADTs between 25,000 and 55,000 vpd and peak-hour flows between 2,500 vph and 5,500 vph. The expected capacity can be even higher with the use of by-pass lanes.

3.4 - Pedestrian Effects on Entry and Exit Capacity

Pedestrians crossing at a marked crosswalk that has priority over entering motor vehicles can have a significant effect on the entry capacity. In such cases, if the pedestrian crossing volume and circulating volume are known, multiply the vehicular capacity by a factor M according to the relationship shown in Exhibit 4-7 or 4-8 of the FHWA Roundabout Guide for single-lane and double-lane roundabouts, respectively. Note that the effects of conflicting pedestrians on the approach capacity decrease as conflicting vehicular volumes increase, as entering vehicles become more likely to have to stop regardless of whether pedestrians are present. Consult the Highway Capacity Manual for additional guidance on the capacity of pedestrian crossings if the capacity of the crosswalk itself is an issue. A similar concern may occur at the roundabout exit where pedestrians cross.

4 - Operational Analysis Tools

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], [6] 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

The current RODEL manual is available at (RODEL link) for WisDOT staff.

5 - Key Roundabout Parameters Affecting Operating Capacity

The key roundabout design parameters are shown in Figure 1 and defined in Table 2.

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 2 shows typical relationships between the six geometric design parameters and roundabout capacity. Figure 3 shows that the inscribed circle diameter typically has less impact on roundabout capacity than entry width, flare length and entry radius.

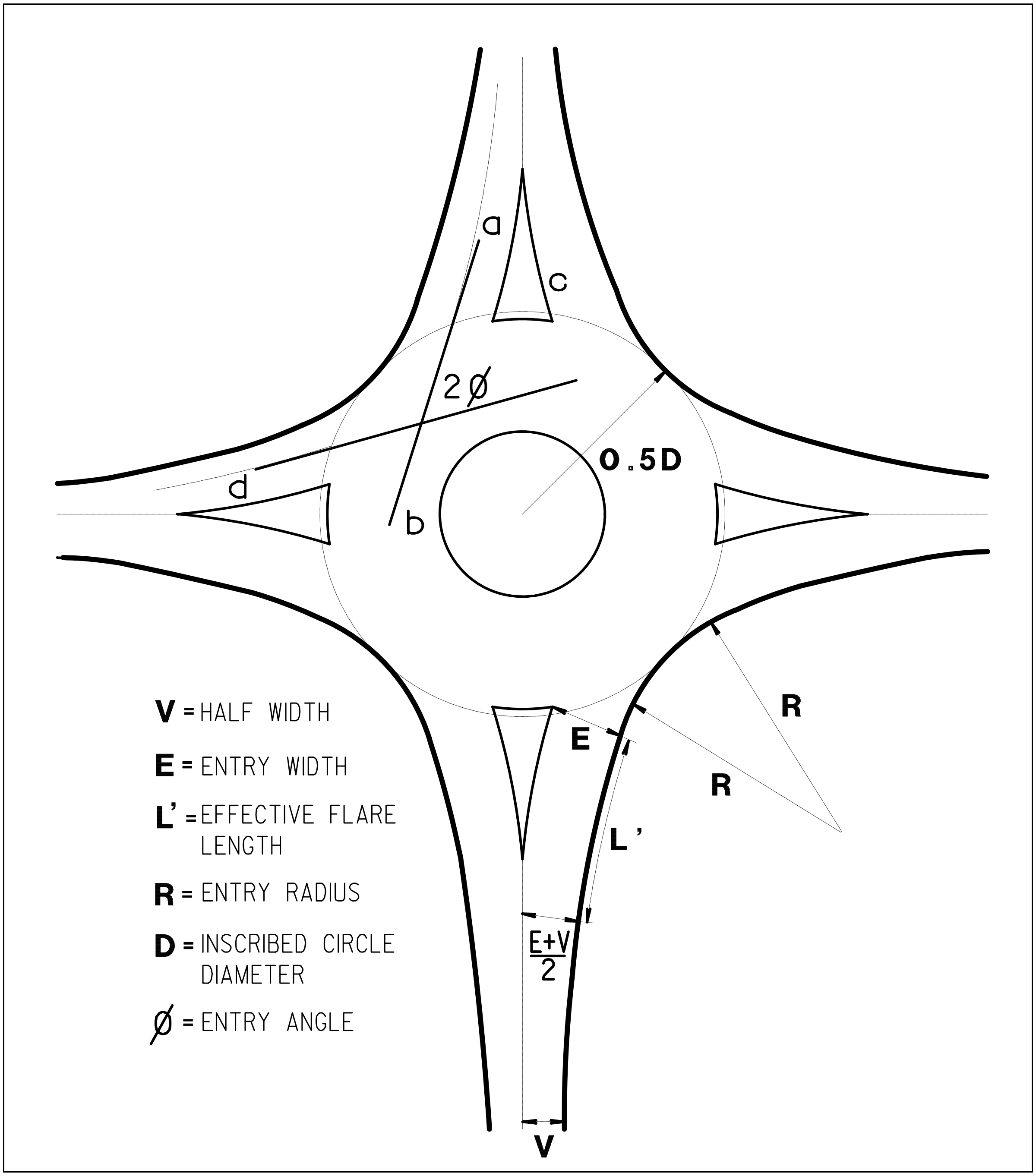
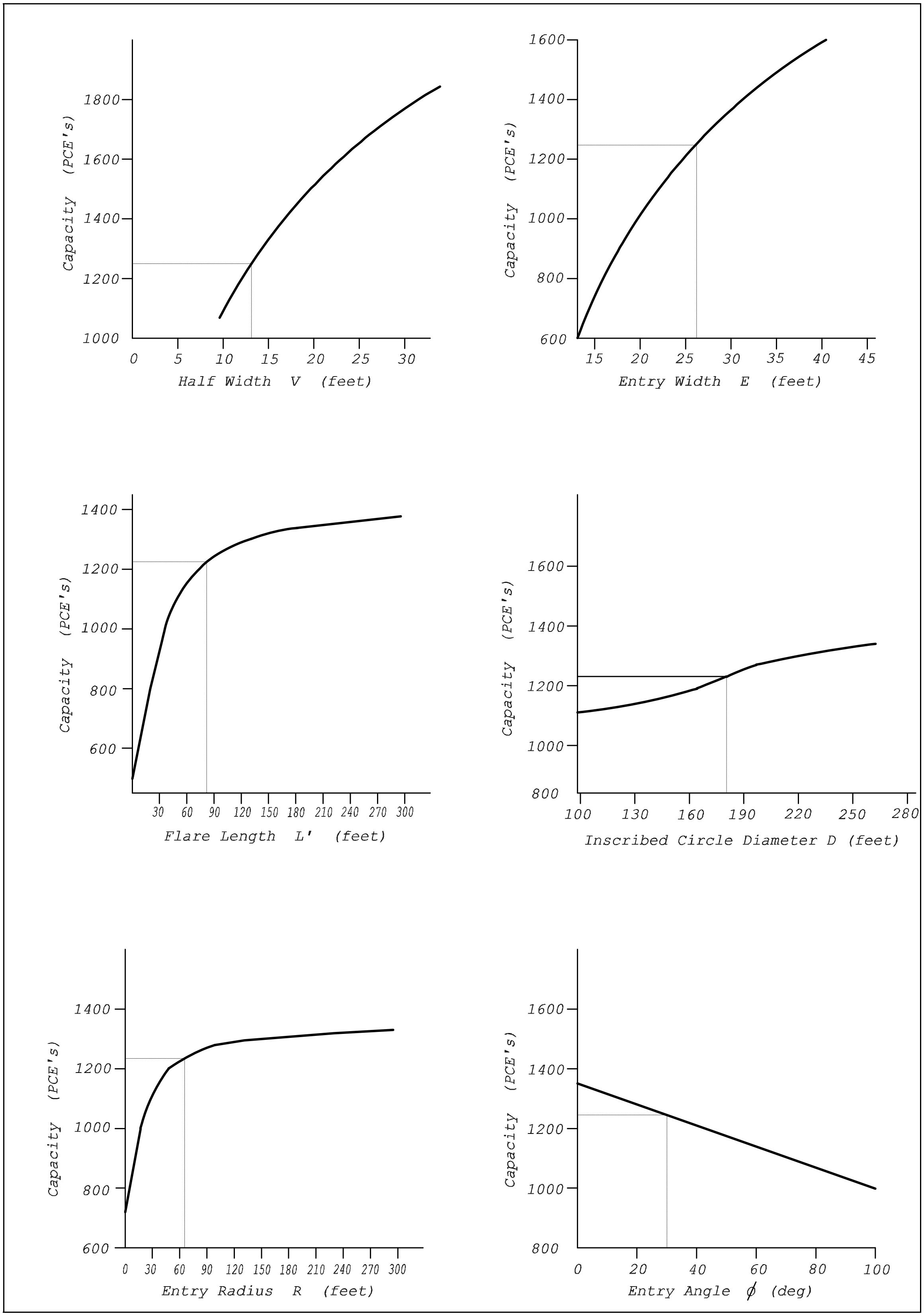


Figure 1. Key Roundabout Design Parameters

Table 2. Description of 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 yield line.
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	∅ is used in the empirical formula.
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.



Source: RODEL software manual converted to US Customary units

Figure 2. Geometric Design Parameters

British research indicates that approach width, entry width, effective flare length, and entry angle have the most significant effect on entry capacity. When circulating flows are high, increasing the inscribed circle diameter (ICD) will substantially increase capacity. Figure 3 shows that the capacity on one leg of the roundabout is increased by 401 vehicles per hour when the ICD is increased from 130 ft to 195 ft. This increased capacity can happen on more than one leg.

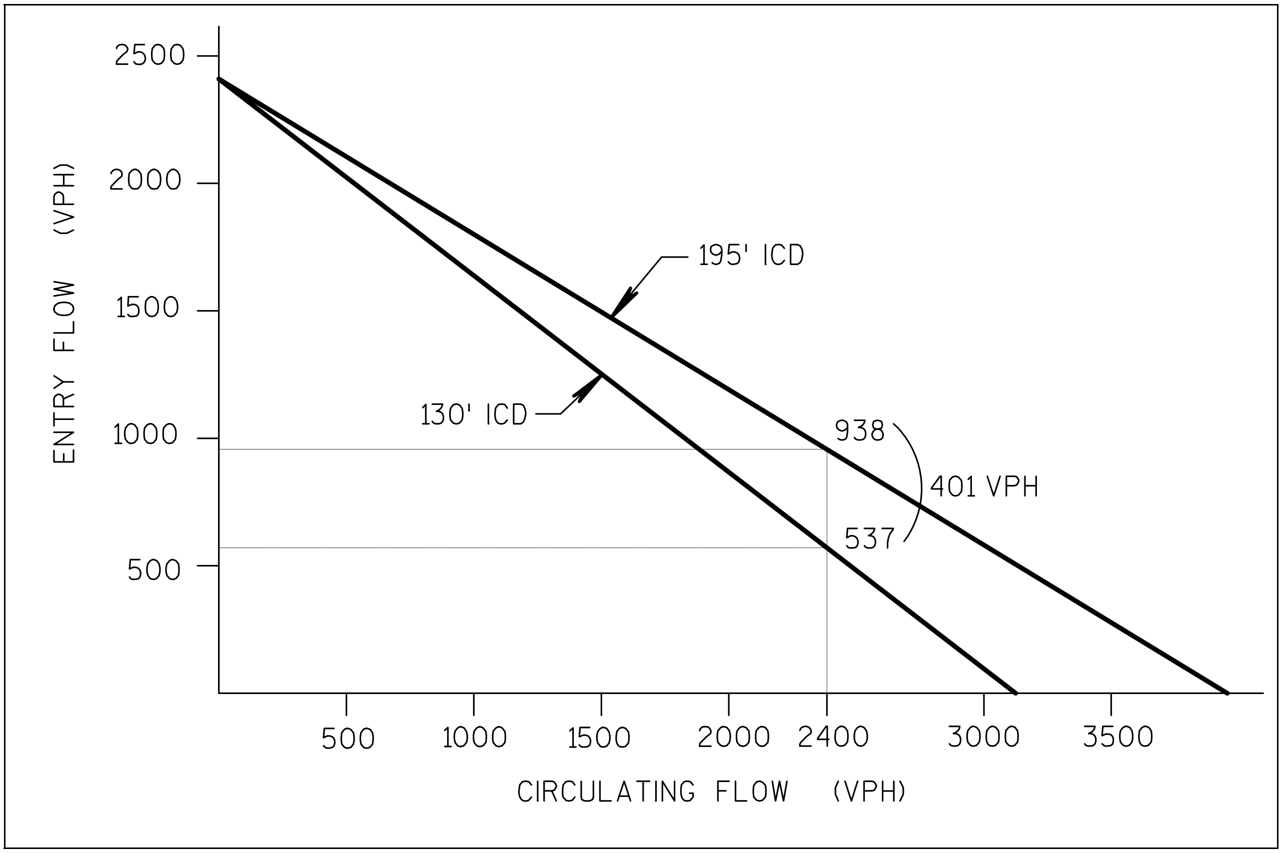


Figure 3. Capacity vs. Inscribed Circle Diameter

The entry radius has little effect on capacity provided that it is 65 feet or more. Using an entry radius significantly lower than 45 ft reduces capacity with increasing severity. A small entry radius tends to produce large entry angles and the converse is also true. Perpendicular entries (70 degrees or more) and small entry radii (less than 50 feet) will reduce capacity, therefore do not use these values. The RODEL model described in the following section allows designers to perform sensitivity analysis by manipulating geometric design elements to determine the operational effects of these elements on their designs. Thus, the geometric elements of a roundabout, together with the volume of traffic desiring to use a roundabout at a given time, determine the efficiency of roundabout operation.

6 - Rodel Software

RODEL is based on the above described empirical relationships that directly relate capacity to both traffic characteristics and roundabout geometry. The empirical relationships reveal that small changes in the geometric parameters produce significant changes in capacity. For instance, if the approach is flared, additional capacity will be provided. Flaring the approach from one lane to two lanes can nearly double the approach capacity, without requiring a two-lane roadway prior to the roundabout. A flared entrance is designed to have equal width and taper and there is equal lane length. Wider entries require wider circulatory roadway widths. This provides more opportunities for the circulatory traffic to bunch together, thus increasing the number of acceptable gaps for vehicles to enter the roundabout. Only a small number of vehicles may be able to enter into an acceptable gap in the circulating traffic. Because drivers frequently use short lanes to reduce the queue length, short lanes can be very effective at increasing vehicle group sizes and the resultant increase in roundabout capacity.

RODEL is a fully interactive program for aiding roundabout design. The purpose of RODEL is to:

1. Improve design quality and operational efficiency
2. Reduce design time
3. Reduce land costs

4. Allow rapid exploration of many options
5. Derive the optimum layout within the conflicting constraints of cost, delay and safety.

Rather than simply checking designs after they have been drawn, RODEL generates geometry prior to preliminary design. This avoids the time consuming practice of repeated designing and checking. The program operates in two modes:

1. Mode 1 can be used to help generate a set of minimum and maximum entry and effective flare combinations for each leg that are equivalent to target parameter inputs entered by the user. There are four different target parameters that can be chosen in mode 1; average delay, maximum delay, maximum queue and maximum v/c ratio. The user can use one of these target parameters to help fit the roundabout to the site constraints in the AM and PM peak traffic periods. Sets of entry geometry are generated for each approach. Mode 1 is rarely used because most designers use default geometry to initially size roundabouts.
2. Mode 2 is used to refine the Mode 1 results or the default geometry provided in Table 3. Mode 2 uses a flow and capacity factor on each leg for a check of sensitivity and design robustness. The simultaneous display of input and output allows the selected geometry to be repeatedly modified and refined. The resulting queues and delays are displayed every 1 or 2 seconds enabling the designer to develop a "feel" for the design and to converge on a preferred layout within the constraints. It is recommended that designers use Mode 2 with the default values provided in Table 3. Further information on the RODEL modes is available in RODEL Interactive Roundabout Design Manual.

RODEL achieves balanced designs by means of the Flow Factor. When an acceptable set of geometry has been found in conjunction with cost and delay characteristics, the Flow Factor can be used to increase the flows on all legs incrementally. Usually one leg fails well before the rest. Minor changes in the geometry can improve the worst leg at the expense of the better legs to derive a balanced design that should preform equally well on all legs.

It is essential that the geometry used in RODEL is the 'EFFECTIVE GEOMETRY' otherwise the actual queues and delays will be considerably greater than the RODEL results. This is particularly true for the Entry Width E, the Entry Lane Markings and signs, the Flare Length L', and the Exit Geometry.

6.1 - Entry Width

The empirical capacity equations reveal that capacity is very sensitive to the entry width. The effective entry (default values used for RODEL,Table 3) width is often less than the physical entry width (typical design values, Table 4), particularly for single lane roundabouts that provide for large trucks needing wide entries but still operate as single lane roundabouts. Because capacity is so sensitive to the entry width, this can lead to a severe under estimation of queues and delays.

Entry width and circulating width are measured between curb faces. A single lane entry width is sometimes widened to provide space for truck turning movements. When widening a single lane entry the capacity increases due to three mechanisms. First the side friction is reduced. Second a staggered or “zippered” queuing on either side of the lane takes place which reduces the follow time of vehicles. Third doubling of vehicles at the yield line starts and occurs increasingly as the lane widens.

The third, and in some ways the second will not occur if the circulating width of the roundabout is a single lane. These effects would require a circulating width of at least two lanes. Unfortunately, RODEL cannot differentiate between these options because a circulating width is not entered into the program. Thus, RODEL assumes the entry width corresponds to the correct circulating width. At 6.0m RODEL treats the entry as two 3.0m lanes. Consequently, effective entry widths greater than 4.3m or 14 ft should not be entered into RODEL for a single lane entry unless it feeds a two lane circulating roadway even if the design width is wider to accommodate trucks. Do not use entry width greater than 8.0 m for dual lane entries or more than 12.0 m for triple lane entries. The default values input into RODEL may differ from the actual design geometrics values.

Table 3 provides default RODEL parameters for single lane, dual lane and triple lane roundabouts. Note, these parameters will not always match design values shown in Table 4.

Table 3. Rodel – Default Geometric Parameters

Geometric Parameters [A]	Single-Lane Entry	Dual-Lane Entry	Triple-Lane Entry
Entry Width (E) [B]	**4.0-4.3 m** (13-14 ft)	**6.7-8.0 m** (22-26 ft)	**9.75-12.0 m** (32-39 ft)
Effective Flare Length (L') [B]	**40 m** (130 ft)	**40 m** (130 ft)	**40 m** (130 ft)
Half Width (V) [B]	**3.65 m** (12 ft)	**7.30 m** (24 ft)	**10.95 m** (36 ft)
Entry Radius (RAD)	**20 m** (65 ft)	**20 m** (65 ft)	**20 m** (65 ft)
Entry Angle (phi)	25	25	25
Inscribed Diameter (DIA)	**45 m** (150 ft)	**50 m** (165 ft)	**65 m** (215 ft)
Grade Separation (GRAD SEP)	0 or 1	0 or 1	0 or 1

[A] At this time RODEL works only with metric values

[B] High influence on capacity

Table 4. Typical Range of Design Values

Geometric Parameters	Single-Lane Entry	Dual-Lane Entry	Triple-Lane Entry
Entry Width (E)	18-22 ft (5.5-6.7 m)	24-28 ft (7.3-8.5 m)	34-40 ft (10.4-12.2 m)
Effective Flare Length (L')	15-300 ft (5-100m) if needed for capacity		
Half Width (V)	Traveled lane width approaching the roundabout prior to any flared section (paint to paint distance)		
Entry Radius (RAD)	55-90 ft (17-27 m)	55-100 ft (17-30 m)	65-100 ft (20-30 m)
Entry Angle (phi)	16-30	16-30	16-30
Inscribed Diameter (DIA)	120-150 ft (35-45 m)	160-215 ft (50-65 m)	200-300 (60-90 m)
Circulatory Roadway Width	Typically 1.0 to 1.2 times the width of the widest entry into the roundabout		
Exit Radius	Exit curves should be larger than entry curves and typically have R3 speeds higher than the R2 speed (Range 200-1000 ft)		

6.2 - Roundabout Performance Measures

Two measures are typically used to estimate the performance of a given roundabout design: delay, and queue length. Each measure provides a unique perspective on the quality of service of a roundabout under a given set of traffic and geometric conditions. Delay is a standard parameter used to measure the performance of an intersection or approach. The Highway Capacity Manual identifies delay as the primary measure of effectiveness for both signalized and un-signalized intersections, with level of service determined from the delay estimate. RODEL determines the average and maximum delay in seconds for each approach at a roundabout, as well as the roundabout's overall average delay. This overall average delay is used in determining the roundabout's level of service (LOS).

The delay and LOS values provided by RODEL are based on total delay, which is similar to other highway capacity software. However, the delay thresholds used by RODEL to define LOS do not always correspond to the Highway Capacity Manual thresholds. The LOS values in RODEL may be modified to match the Highway Capacity Manual in the RODEL folder file called LOSDATA using MS Word or Notepad. For similar delay values, RODEL typically assigns a worse LOS. The 50 percent confidence level (CL) is the industry standard for software evaluating capacity, delay and queuing. The default CL for RODEL is also 50 percent, but the 85th percentile CL is always tested to review the sensitivity of the design. See FDM 11-26-50, Section 5 for additional information on stop delay verses total delay and comparing signal delay to roundabout delay.

Queue length is important when assessing the adequacy of the geometric design of the roundabout approaches. RODEL calculates an average and maximum queue for each approach in number of vehicles. The approach roadway should have adequate storage capacity so the queue does not obstruct driveway access or another intersection. Depending on location, a queue of 10 vehicles may be unacceptable at one site while a queue of 50 vehicles at another site may not present a problem. The RODEL queue length is the mean of the random queue length distribution. The random 95% queue is about two times the RODEL queues. If the roundabout is operating well with RODEL set at the 85% capacity confidence level, then the 50% queue lengths will be small. See FDM 11-26-50, Section 7 “Maximum Queue” for additional information.

6.3 - Testing for Weaknesses in Geometry and Capacity

The two performance measures, delay and queue length, need to be checked at two confidence levels with RODEL. Perform a RODEL analysis at both the 50% and 85% confidence levels (CL). The 50% CL analysis represents real expectations of the modern roundabout’s performance and provides for an equal comparison to other intersection types because a 50% CL is built into other software programs used to evaluate other types of intersections. The 85% CL analysis is a sensitivity check for excessive delay on any of the approaches when there are minor changes in traffic flow and capacity. A sharp rise in delay at the 85% CL on any approach leg indicates that design of that entry is approaching a high v/c ratio. A high v/c ratio indicates to the designer to re-evaluate if a modest geometric layout refinement will provide a lower v/c ratio and consequently prolong the life of the roundabout by avoiding failure of that leg.

Use engineering judgment to determine if a design resulting in an unacceptable level of service at the 85% confidence level is the best alternative at the specific location. Regardless of the level of service reported when reviewing the 85% CL, use the results from RODEL at the 50% CL when doing a comparison with other intersection alternatives.

The designer should review the residual capacity of the roundabout by using the 50% CL and increasing the flow factor (FLOF). The designer should continue to increase the flow factor until one leg or legs reach an average delay for LOS D (~ 35 seconds unsignalized control, ~ 55 seconds signalized controlled). For example, if traffic projections increase at 2 percent a year and the flow factor is increased to 1.10 before a leg or more legs reach LOS D (~ 35 seconds unsignalized control, ~ 55 seconds signalized controlled) of average delay then the roundabout would have approximately 5 years (0.10 ÷ 0.02) of residual capacity beyond its 20 year design life. This residual capacity review is a way to project/anticipate how long a roundabout will operate at acceptable LOS. The review will also indicate an overly designed roundabout by showing excessive design life which in turn could produce undesirable initial conditions such as faster entries, higher crash severity, longer pedestrian crossings, higher maintenance, etc.

6.4 - Testing for Exclusive Lane performance and Lane by Lane Performance

At this time, we understand the new version of RODEL (RODEL 2.0) will further address lane by lane performance assessments and the analysis will no longer be conducted in the following way.

A multilane roundabout should be assessed for capacity performance of each leg. To accomplish this in RODEL the user must utilize the capacity factor (CAPF) function.

When performing a lane by lane performance assessment on a two-lane entry roundabout set the CAPF to 0.5 for each leg. Limit approximately half the traffic volume to one lane making sure to assign adequate lane volumes for the proposed lane configurations. For example, if your traffic volumes indicate 100 right turns, 500 through movements, and 400 left turns; you may consider 100 right turns and 400 through movements in one lane and 400 left turns and 100 through movements in the other lane. See Figure 4 option 1 for example. When assessing the right turn and through movement lane insert 000 as the volume for the left turning movement and reduce the volume for the through movement by 100 to eliminate that volume from the through/right assessment and vice versa for the other lane check. Check both lanes at the 50% CL for performance. If one assessment indicates an unacceptable LOS a redistribution of traffic on each lane may be needed. Another lane configuration to try may be option 2 of Figure 4. This may be a very iterative process in order to achieve a desired lane balance and configuration.

When performing a review of lane by lane performance assessments on a three-lane entry roundabout set the CAPF to 0.67 for two lanes or 0.33 for individual lane analysis. Check and balance the lanes similar to the dual lane example explained above. See FDM 11-26-50, Section 6 for additional information on lane balance.

Exclusive right turn lanes can be configured as full bypass lanes or partial bypass lanes. See FDM 11-26-30 Section 5.15 for additional information on right turn bypass lanes. Operating RODEL for exclusive right turns requires deleting the right turn volume if a full bypass lane is utilized, use 000 in the RODEL input to show this elimination of traffic. For exclusive right turn lanes that are not bypassing the roundabout entry, the volume remains in the RODEL input as part of the total approach flow only if there is no vane island or separation median. The right turns still yield but with a vane island or separation median, the right turns must be treated as a single lane entry, apart from the other approach traffic.

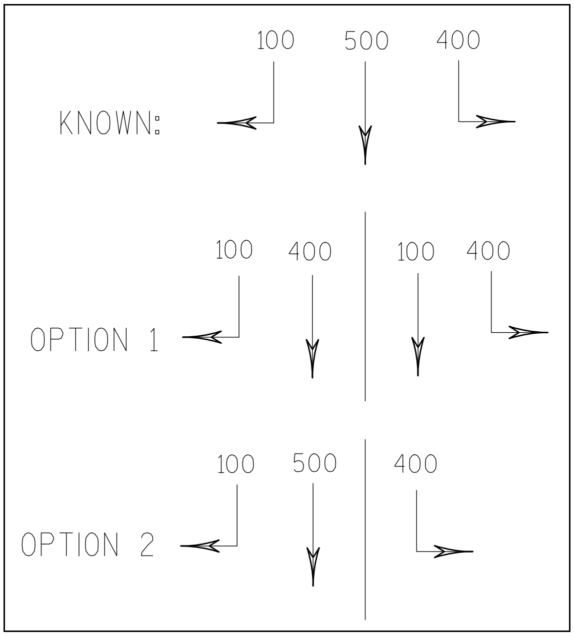


Figure 4. Lane by Lane Performance Example

6.5 - Volume Diagram and Lane Configuration Sketch

Use Figure 5 to provide traffic volumes, existing peak hour turning volumes (AM, PM, Weekend) and design year peak hour turning volumes. Compare design year flows with existing flows and check any anomalies. It is critical that the design year flows do not exceed the capacity of the surrounding network. Figure 5 provides a format for a 3 or 4-leg intersection, or interchange ramp with a roundabout. Type the existing or projected peak-hour traffic volumes, by movement, in the 4 boxes at each approach and the interactive Excel spreadsheet will calculate the circulating traffic volume in the circulatory roadway adjacent to each splitter island, the exit volume and entrance volume. Circulating flow will be shown in the boxes in the center of the diagram and are used in the initial analysis of the roundabout.

The spreadsheet will also provide the correct input placement and values for RODEL. The southbound or north leg of the roundabout shall be entered as Leg 1 into RODEL. The legs shall continue to be entered into RODEL in a counter-clockwise order around the intersection. Turning flows for each leg should be entered with the first turning movement corresponding to the first exit and so on. For example, on a four legged roundabout the right turn would be the first exit, the through movement would be the second exit, the left turn the third exit and the u-turn the fourth exit.

Generally U-Turn traffic will be 1 percent of the entering traffic volume and may be much greater where there is no median opening between roundabouts. The U-turn volume shall be included in the traffic analysis.

See FDM 11-26-020, xls1 (Traffic Flow Worksheet) for a working version of Figure 5 and store it on your computer. The numbers that are in the figure are example numbers. In the interactive mode the yellow cells are read-only. Enter turning volumes in the white cells.

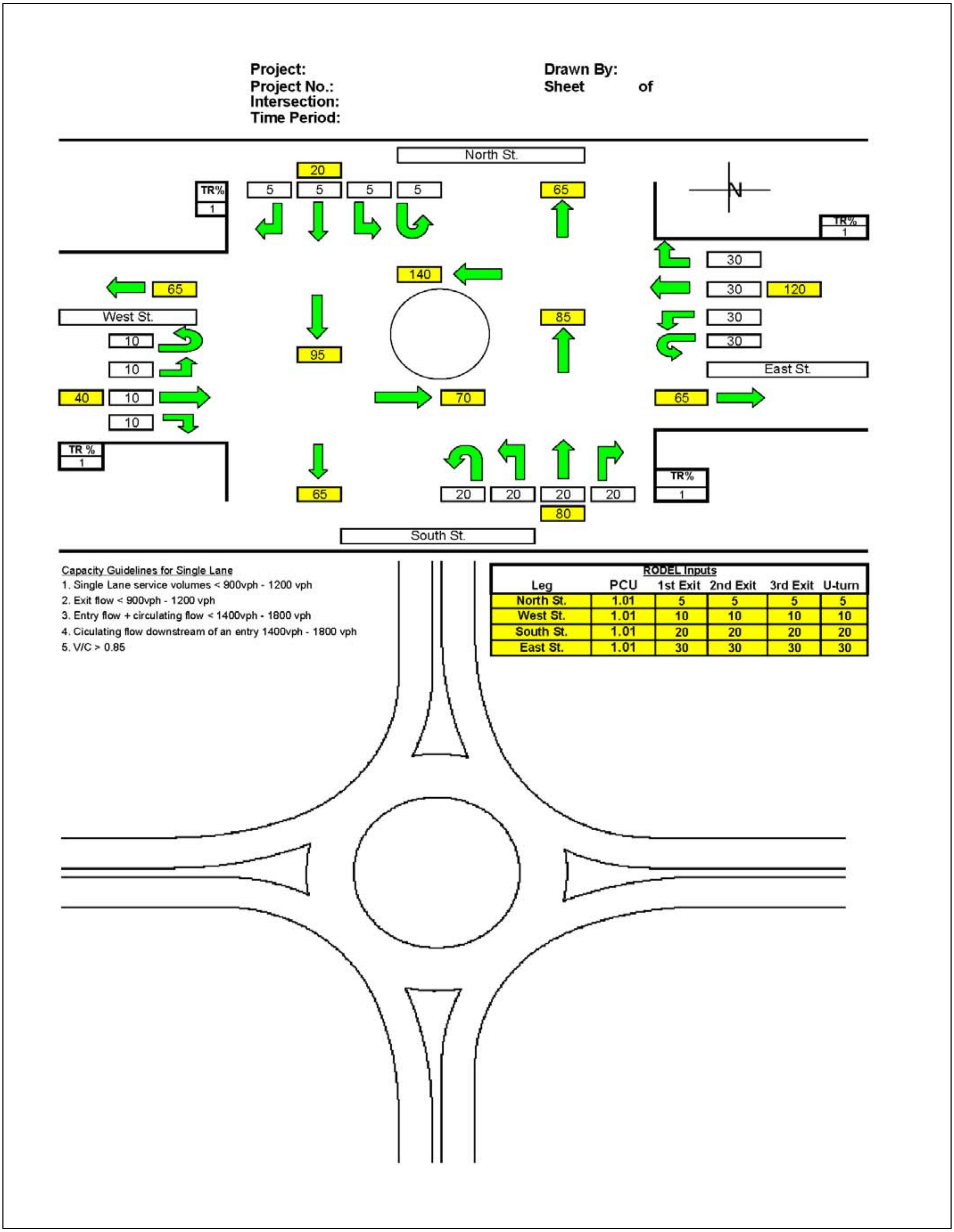


Figure 5. Traffic Flow Worksheet

A lane configuration for each entry must accompany the volume diagram to facilitate the selection of the number of lanes and the lane assignments. This is a critical step that precedes the roundabout capacity analysis and the layout process because it affects the geometry. In Figure 6, the assessment of lane assignments for the north leg (leg 1) could include three different options.

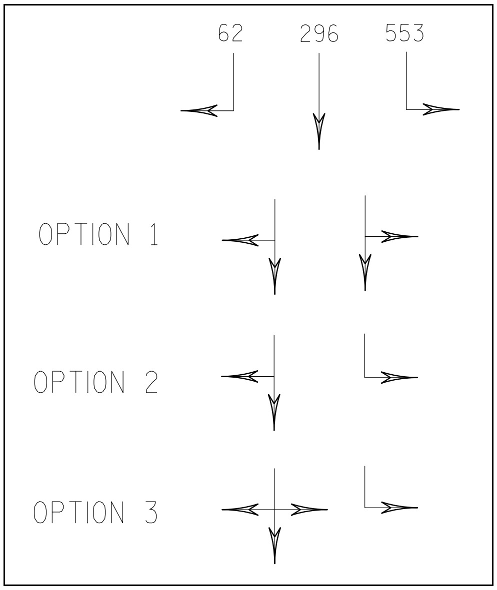


Figure 6. Lane Configuration Options for North Leg

Depending on the option, a spiral marking treatment to spiral out the westbound left turn may be needed. Also, the southbound exit may become one lane. Option 1 is the preferred and simplified lane configuration that works for both peak and off-peak periods. Figure 7 is an example of the final roundabout layout.

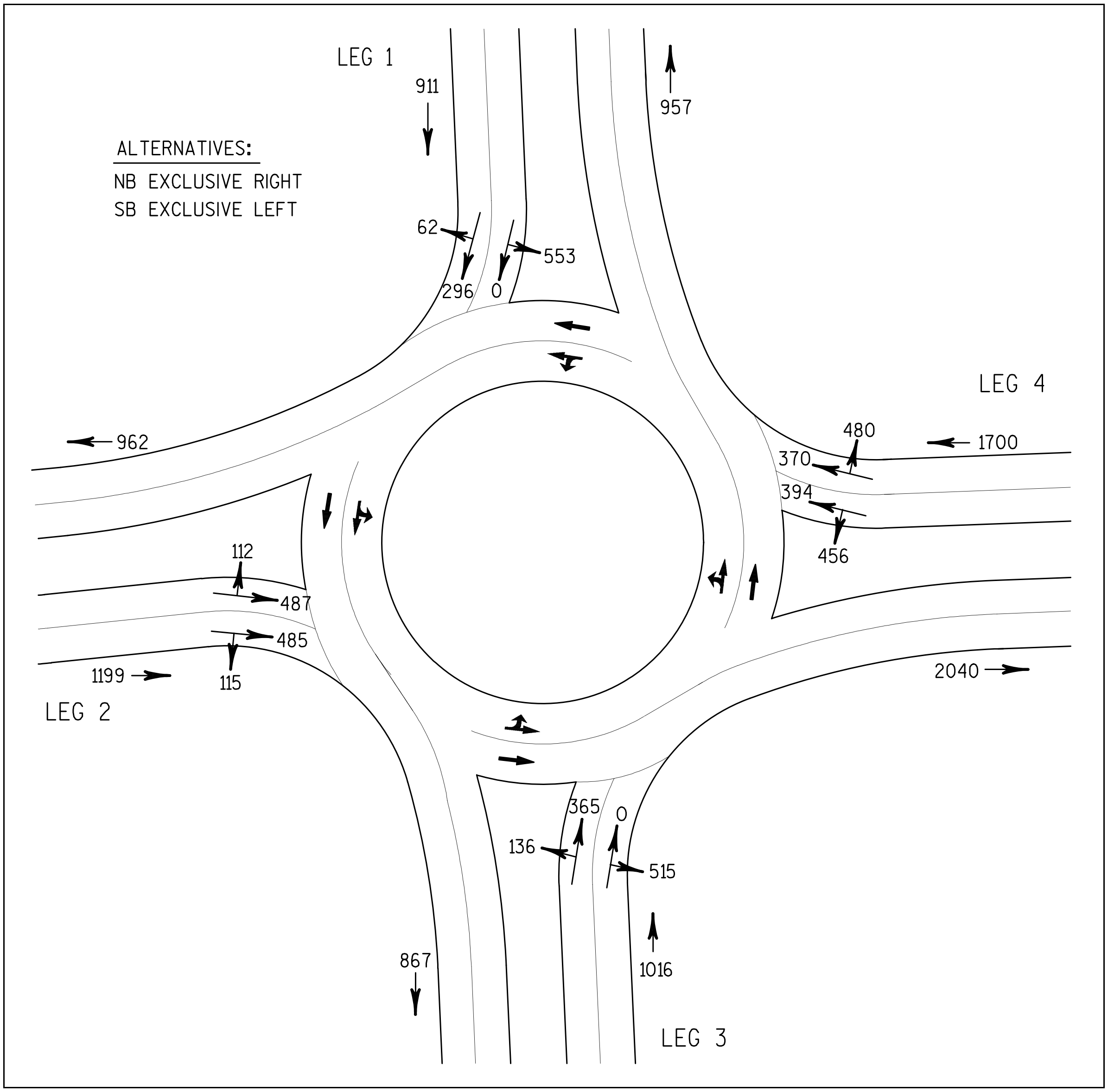


Figure 7. Lane Configuration Sketch

7 - Operations and Entry Lane Pavement Markings

RODEL's capacity equations assume that there are no lane arrows on the approach lanes of roundabouts with equal traffic flow distribution between lanes. The correct use of lane arrows can be very beneficial to help approaching traffic achieve a desirable distribution of traffic between lanes. Inappropriate use of lane arrows can also reduce capacity if used incorrectly, and RODEL may therefore under estimate queues and delays in such cases.

The reduction in capacity arising from the incorrect use of lane arrows can be quite severe when a high proportion of the approach volumes use one exit. For example, assume an approach on a 4-leg roundabout has three lanes, with arrows left, straight and right. If 60% of the approach flow is straight ahead, it is constrained to the middle lane, which only has 1/3 of the approach capacity. The resulting queues can quickly expand beyond the beginning of the flare preventing access to the left and right turn lanes, further reducing capacity.

In some situations the use of appropriate lane arrows can encourage balanced lane use, thus improving capacity. Traffic often has a bias towards the right most lane. Lane arrows can either encourage this bias, or can encourage lane balance. Figure 8 shows the alternative pavement marking. The best marking for an approach will depend on the turning volumes. The markings that produce the most balanced lane utilization are preferred. Figure 8 (a) would be utilized with a heavy right turn and through movement. Figure 8 (b) would be utilized with a heavy left turn and through movement.

Lane arrows can be very complex with subtle problems that can reduce capacity and cause accidents, so great care and understanding is needed before the geometric layout is commenced.

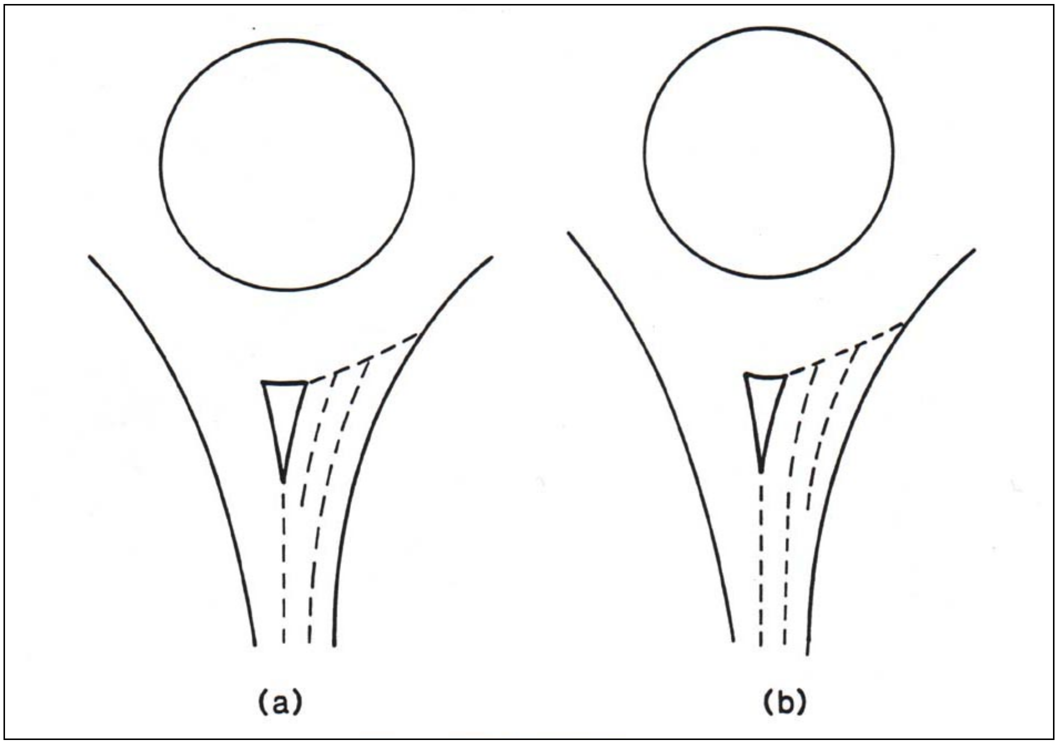


Figure 8. Lane Markings

8 - Through Highway Declaration (ss 340.01(67) & 349.07)

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

9 - 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. If speed reductions are required in advance of an intersection traffic control device, develop a declaration based on an engineering study coordinated with Region Traffic staff.

10 - References

[1] Roundabouts: An Informational Guide, Publication No. FHWA-RD-00-067, June 2000
http://www.tfhrc.gov/safety/00068.htm

[2] Status Report: Roundabouts, Vol. 35, No. 5, Insurance Institute for Highway Safety, May 13, 2000
http://www.iihs.org/sr/pdfs/sr3505.pdf

[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

[6] Accidents At 4-Arm Roundabouts, TRRL Report LR 1120, 1984. Maycock, G and Hall, RD