Appendix F: Roundabout Guidelines

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Appendix F: Roundabout Guidelines

Introduction

Roundabouts offer communities key safety and operational benefits. Roundabouts slow vehicle speeds and reduce conflict points while offering improved traffic operations and community aesthetics.[1] And, because they don't use traffic signals that require power and routine maintenance, roundabouts have lower operating costs and are more resilient during natural disasters when the power goes out.

To take advantage of these safety and operational benefits, the City of Rancho Cordova studied the feasibility of building roundabouts at new and existing intersections throughout the city. Produced as part of that study, these guidelines will help the City plan for future roundabout implementation.

Using this Document

This document is intended to guide the City as it plans and designs future roundabouts. The best practices in these pages are designed to:

/ Support City staff, consultants, and other practitioners involved in City projects during the roundabout planning and design process.

/ Communicate roundabout planning and design principles to guide the City and partners when siting, planning, and moving roundabouts through project development.

/ Reinforce best practices established by national guidance documents.

Guidelines in this handbook primarily draw on national guidance provided by the Highway Capacity Manual 7th Edition (*HCM*-7) from the Transportation Research Board (TRB) and NCHRP Research Report 1043: Guide for Roundabouts from the National Cooperative Highway Research Program (NCHRP).[2] Before beginning any roundabout project, be sure to check that reference material is the most recent version.

Source: Kittelson & Associates, Inc.

1 FHWA, Roundabouts, August 2023, https://highways.dot.gov/safety/intersection-safety/intersection-types/roundabouts.

2 AASHTO, *Highway Capacity Manual 7th Edition: A Guide for Multimodal Mobility Analysis* (2022), https://nap.nationalacademies.org/catalog/26432/highway-capacity-manual-7th-edition-a-guide-for-multimodal-mobility and *NCHRP Research Report 1043: Guide for Roundabouts* (2023), https://www.trb.org/Publications/Blurbs/182939.aspx.

Capacity and Number of Lanes

When planning and designing roundabouts, determining desired capacity and number of lanes is a critical first step.

Operational analysis tests whether a roundabout would adequately serve existing or projected traffic volumes and, if so, how many lanes that roundabout would need. There are several operational analysis tools to choose from, depending on how precise results need to be and available data. Typically, the level of detail required of the data increases as the project development process advances beyond a high-level assessment.

To select an assessment methodology, consider the following:

- **Output precision**—What questions does the analysis need to answer? Does it need to test whether a single or multilane roundabout could work given future volumes? Does it need to size a roundabout to develop a concept design? What outputs are necessary? Are you looking for a yes or no answer for potential viability or average travel delays?
- **Existing or projected conditions**—Are you looking for an analysis based on the intersection's current conditions? If you are interested in projected future conditions, how well developed are future volumes—are they daily link volumes or detailed turning movement counts (TMCs)? What is the level of confidence for those estimates?
- **Time period**—Is the analysis focused only on peak hours? Do you need or already have data for other analysis periods, such as 24-hour or 12-hour periods?

Use answers to those questions, **Table F1**, and **Figure F1** to select the appropriate methodology or reference. The following sections cover each methodology in more detail.

Table F1 arranges available methodologies according to input and level of detail. **Figure F1** arranges the methodologies according to the project development stage in which they'd likely be used.

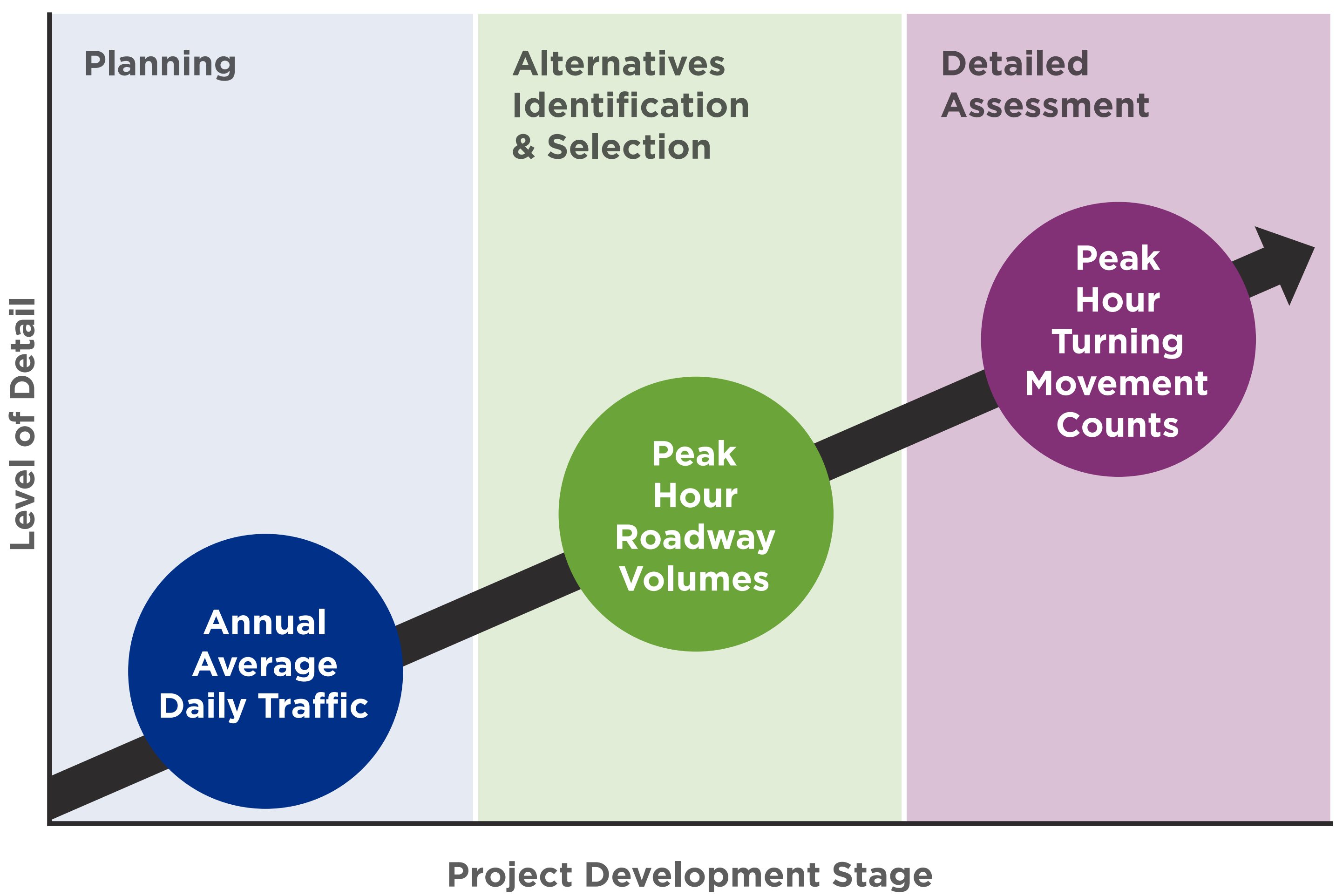
Six-Lane Roadways

The City is not pursuing roundabouts on six-lane roadways due to the high cost of retrofitting those locations. However, a planned six-lane roadway (assumed to be signalized) could be accommodated with a two-lane roundabout and become a four-lane roadway instead. A planning-level operational analysis can determine whether such a change would be feasible given current and future volumes.

Table F1. Analysis Methodologies by Input and Level of Detail

Input & Results	Project Development Stage	Application	Data Required
Less Detail	**Planning Study**	Planning-level sizing to determine feasibility and number of lanes	Annual average daily traffic
		High-level selection of suitable alternatives, such as comparing roundabout to stop control or signal	Peak hour roadway volumes
	Alternatives Identification and Selection	Lane number and assignment	Peak hour roadway volumes
		Conceptual design of roundabout, including lane numbers for each approach and exit	Peak hour turning movement counts
	Detailed Assessment	Conceptual design refinement	Peak hour turning movement counts
More Detail		Public involvement with animation or simulation of proposed alternatives	Peak hour turning movement counts

Figure F1. Data and Methodologies by Data Specificity and Project Development Stage



Annual Average Daily Traffic

Assess Demand with Daily Traffic Volumes

Planning-level volume thresholds using daily volumes can help determine whether a roundabout could serve an intersection's travel demand and, if so, then how many lanes would be required to meet mobility goals.

Guidance in this section applies to four-leg intersections with all of the following conditions:

- 9–10 percent of daily traffic occurs during the peak hour—this is the "K factor".
- During the peak hour, the peak direction carries 52–58 percent of the roadway's traffic—this is the "D factor".
- Volume-to-capacity ratio per approach of 0.9 or 90 percent—this represents this intersection's "practical capacity".

For more information about these conditions, consult NCHRP Research Report 1043, Section 8.6 or *HCM*-7.

Use the following guidelines, as well as **Figure F2**, to match daily entering vehicles to the number of lanes required:

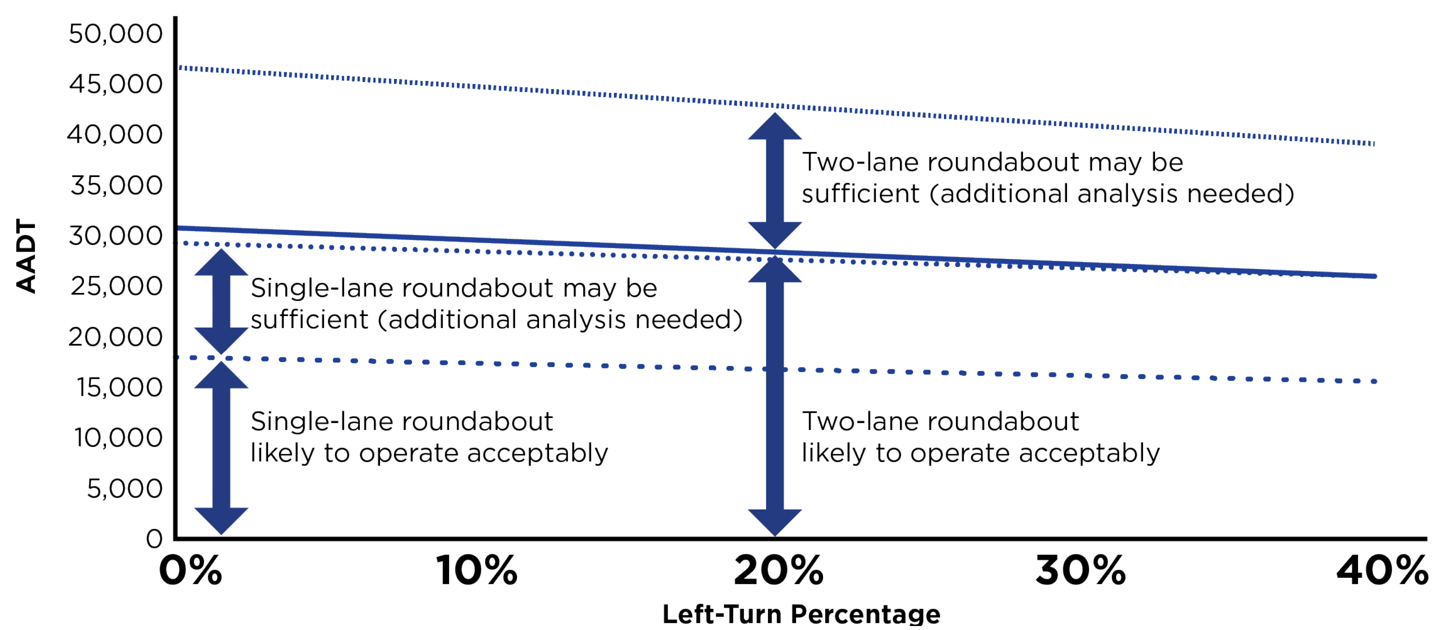
- **Intersections with less than 17,000 daily entering vehicles** would be well within a single-lane roundabout's capacity.
- **Intersections with between 17,000 and 25,000 daily entering vehicles** would be well within a two-lane roundabout's capacity. A single-lane roundabout may provide sufficient capacity but would need to be analyzed in more detail to confirm. The results would depend on the percentage of traffic occurring in the peak hour and the particular turning movements at the intersection.
- **Intersections with 27,000–42,000 daily entering vehicles** would be over capacity with a single-lane roundabout. A two-lane roundabout may provide sufficient capacity, but further analysis would be needed to confirm.

A note on left turns—These values assume a left-turn percentage of 20 percent. **Figure F2** demonstrates how changes in the left-turning percentage may impact capacity (higher left-turn percentages reduce the capacity).

Passenger-Car Equivalent Units

Throughout this guide, analysis volumes are presented in passenger-car equivalent units (PCUs). Raw traffic volumes need to be converted to PCUs by applying the conversion methodology from the *HCM*-7. In this methodology, large vehicles account for more than 1 PCU.

Figure F2. Planning-level Daily Intersection Volumes



Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.2; data derived from HCM-1

Compare Control Types with Peak Hour Roadway Volumes

Peak-hour roadway volume data can be used to compare operational performance across different intersection control types. *NCHRP Research Report 825: Planning and Preliminary Applications Guide* uses *HCM* methodologies and some base assumptions to establish comparable values among two-way stop-controlled intersections, all-way stop controlled intersections, signalized intersections, and roundabouts.

Use **Figure F3** and **Figure F4** to match peak hour roadway volumes with one or more feasible intersection control types. Replicated from NCHRP Research Report 825 and NCHRP Research Report 1043, respectively, these charts use total peak hour volume on major and minor streets to assess which type of roundabout or other intersection control type would be feasible. The charts are based on motor vehicle volumes and FHWA's Manual on Uniform Traffic Control Devices signal warrants.

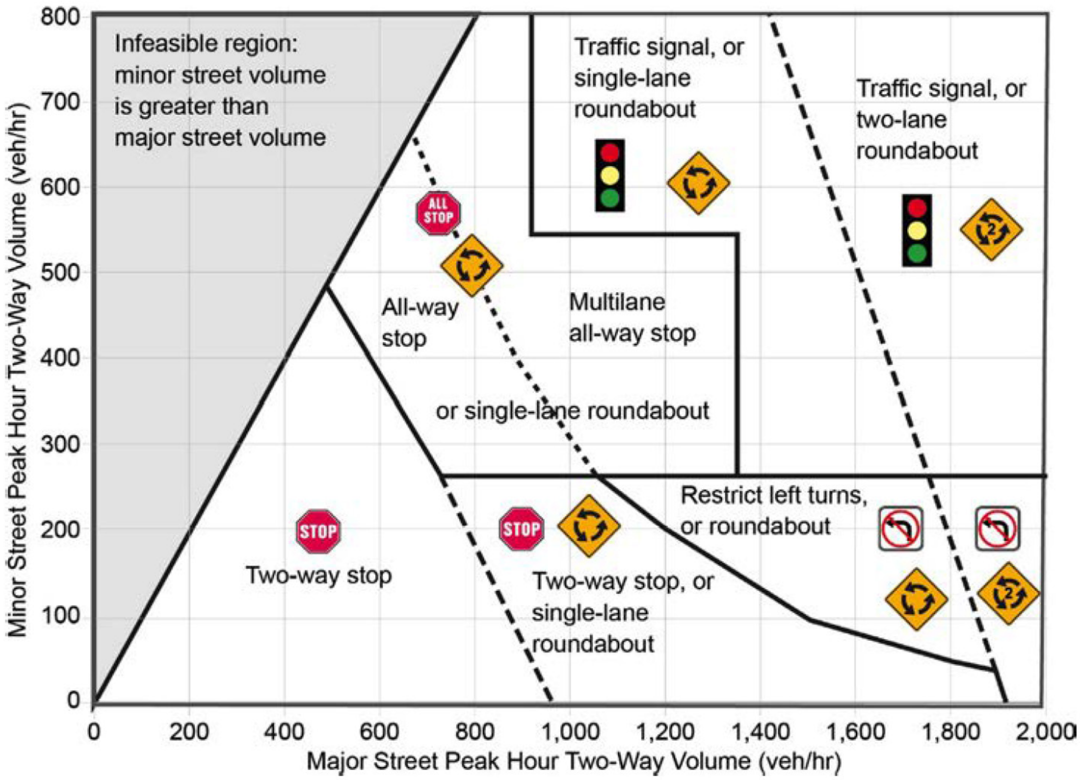
To know which chart to use, check available directional data. If streets have a roughly 50/50 split of directional traffic during the peak hour, use **Figure F3**. If this data is unavailable, consider using the more conservative 67/33 split in **Figure F4**. If data shows a particular intersection type would work for a 67/33 split, that type will work for 50/50—however, the reverse is not necessarily true.

A note on active transportation—Because these charts only show control delay for motor vehicles and do not include quality of service for bicyclists and pedestrians, they should not be used as the sole factor for choosing intersection control type.

The Peak Hour Factor

If the City desires to use a peak 15-minute analysis instead of a peak hour analysis, the analysis should adjust raw peak hour turning movement volumes with the use of a peak hour factor, as noted in the *HCM-7*.

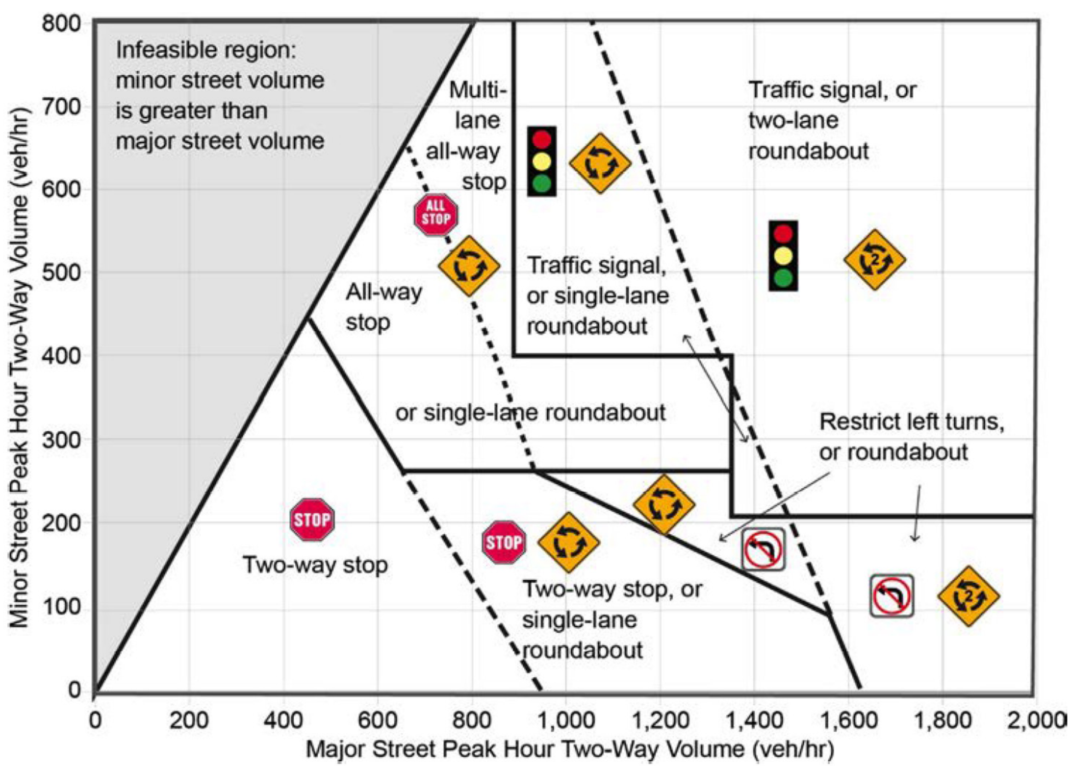
Figure F3. Intersection Control Type by Operation Performance and 50/50 Volume Distribution on Each Street



Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.7

Note: Mini-roundabouts and compact roundabouts are not included in this exhibit. Assumes eighth-highest-hour volumes equal 55 percent of peak hour volumes, peak hour factor equals 0.92, each approach has 10 percent left turns and 10 percent right turns, and each approach is a single lane in the base case. Derived from *MUTCD* 8-hour signal warrant, *MUTCD* all-way stop warrant, and *HCM* methods for two-way stop-controlled intersections and single-lane roundabouts. Source: NCHRP Report 825 (10).

Figure F4. Intersection Control Type by Operation Performance and 67/33 Volume Distribution on Each Street



Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.8

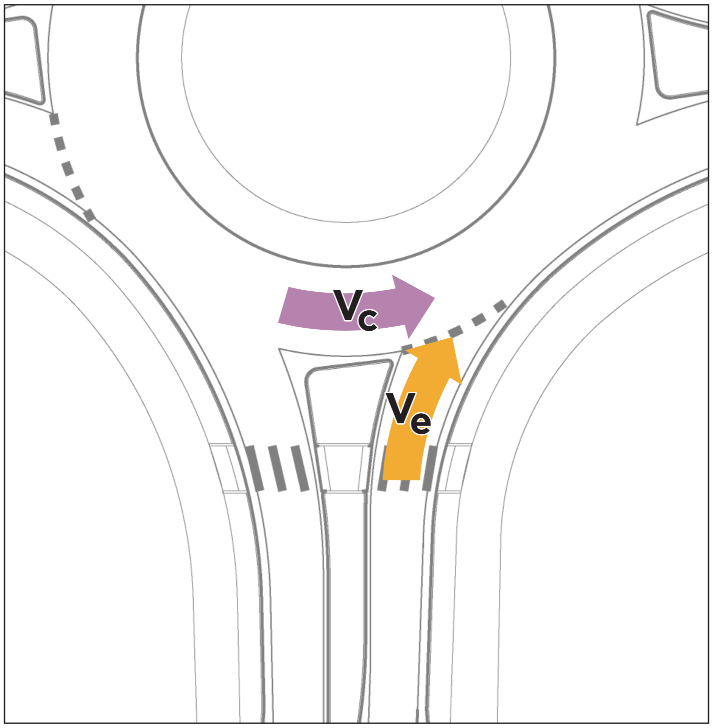
Note: Mini-roundabouts and compact roundabouts are not included in this exhibit. Assumes eighth-highest-hour volumes equal 55 percent of peak hour volumes, peak hour factor equals 0.92, each approach has 10 percent left turns and 10 percent right turns, and each approach is a single lane in the base case. Derived from *MUTCD* 8-hour signal warrant, *MUTCD* all-way stop warrant, and *HCM* methods for two-way stop-controlled intersections and single-lane roundabouts. Source: NCHRP Report 825 (10).

Estimate Capacity Using Peak Hour TMCs

If turning movement count (TMC) data is available, a more detailed analysis may be conducted. Peak hour TMCs record all through and turning movements at each intersection leg during the busiest hour of the day. These TMCs can be used to determine the two relevant traffic flows for each roundabout leg: entering vehicles and circulating vehicles (**Figure F5**). Capacity can be estimated using the volumes of these traffic flows.

In addition, an analyst or designer may use *HCM-7* methodologies or other, more current methodologies, if available.

Figure F5. Traffic Flows at a Roundabout Entry



Source: HCM-1

V_e Entering Volumes

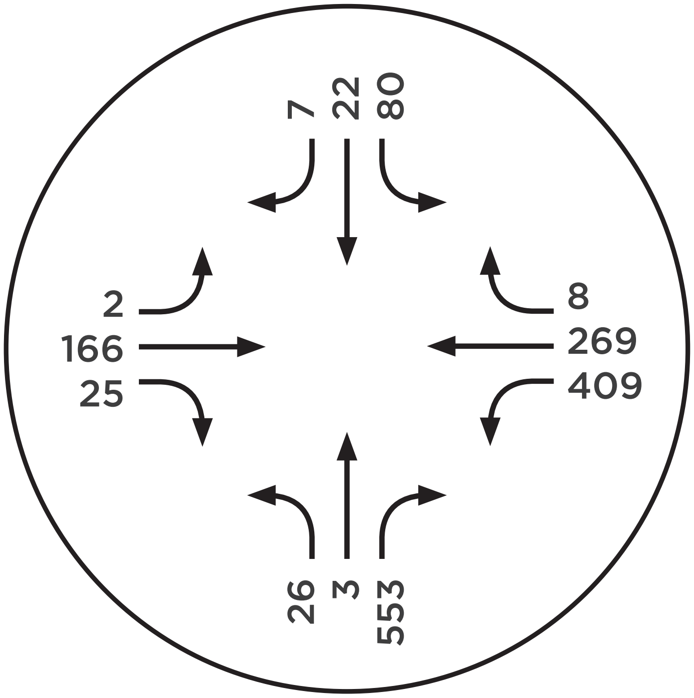
V_c Circulating Volumes

To estimate capacity using peak hour TMCs, use the following process:

1 Begin with Peak Hour TMCs

Peak hour TMC data will include all through or turning movements for each leg of an intersection during the busiest 60 minutes of a day.

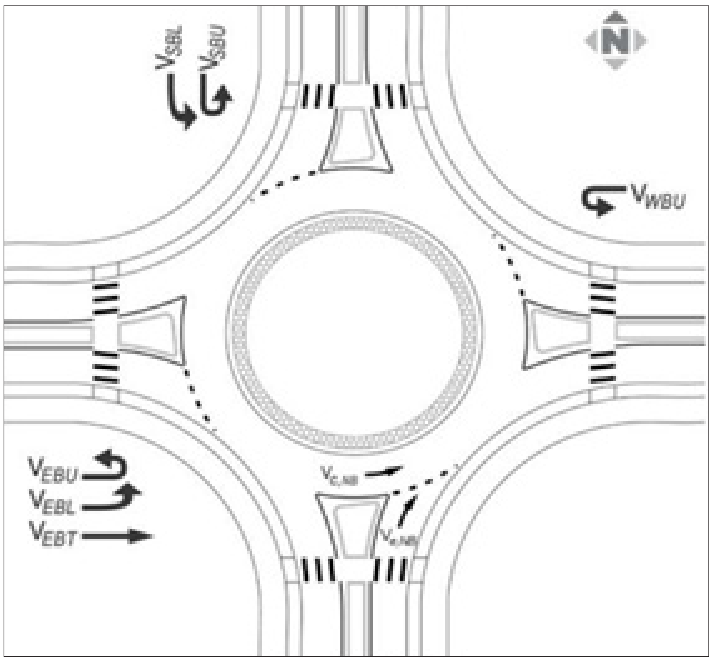
Example:



2 Calculate Relevant Volumes at Entry

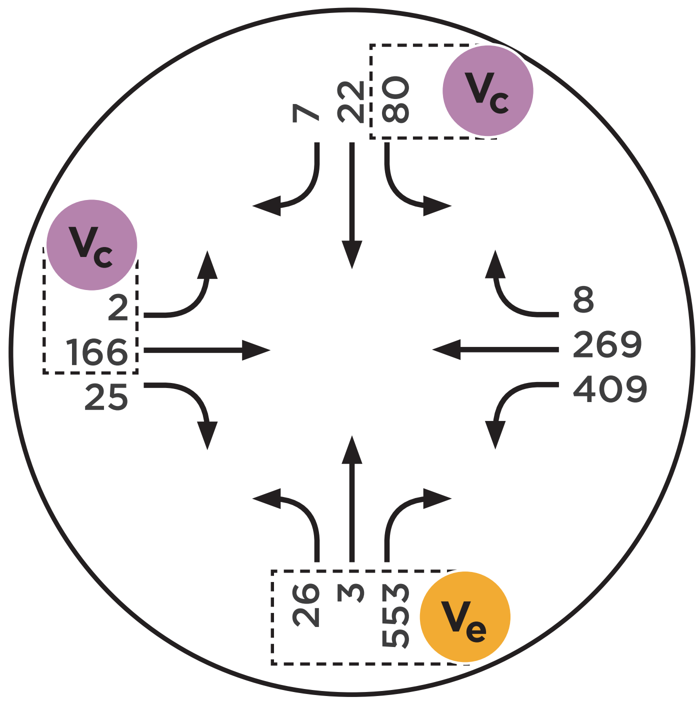
Use the TMCs to calculate the volumes entering (Ve) and circulating (Vc) for one entry leg. To calculate Vc of a selected entry leg, add each of the conflicting through, left, and U-turn movements for that entry (see **Figure F6**).

Figure F6. Calculating Circulating Volumes for South Leg



Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.4 and adapted from HCM-1

Example:



V_e **Entering = 26 + 3 + 553 = 582 veh/hr**

V_c **Circulating = 2 + 166 + 80 = 248 veh/hr**

3 Estimate Capacity

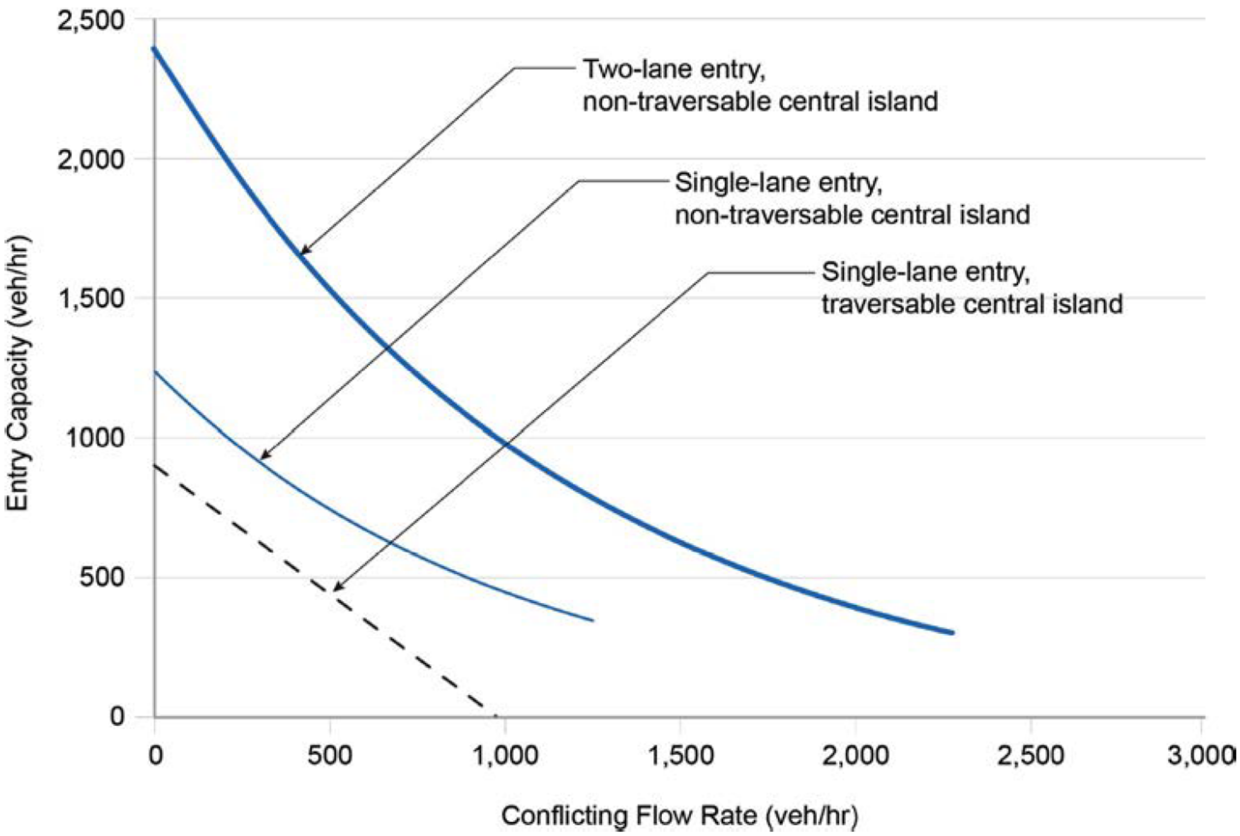
Use **Table F2** and **Figure F7** to calculate roundabout type and number of lanes. For **Table F2**, add Ve and Vc. For **Figure F7**, Vc and Ve will be the *x* and *y* axes, respectively.

Table F2. Planning-Level Sizing Guide Using Peak Period Volume Thresholds

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

Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.6

Figure F7. Planning-Level Practical Capacity Estimates Using Peak Hour Volumes for a Given Entry



NOTE: Practical capacity is assumed to be 90 percent of maximum capacity. Conclusions not valid at planning level for conflicting flow rates above 1,250 veh/hr for a single-lane circulatory roadway and 2,300 veh/hr for a two-lane circulatory roadway. Values beyond these practical limits may be possible, but further analysis is recommended. SOURCE: Derived from HCM (*1*) and Lochrane et al. (*9*).

Source: Reproduced from NCHRP Research Report 1043, Exhibit 8.5 Example:

Example:

The sum of peak period entering and conflicting flows is 830. Using **Table F2**, this flow indicates that a single-lane roundabout with a non-traversable central island is likely sufficient and that a single-lane roundabout with a traversable central island (also called a mini roundabout) may be sufficient. **Figure F7** provides a more nuanced view of the nonlinear relationship and provides the same answer: with 456 conflicting vehicles, 582 entering vehicles could be served by a single-lane with non-traversable central island and may be served with a smaller, single-lane entry at a roundabout with a traversable central island. A two-lane roundabout with a non-traversable central island would likely create unused capacity and increase implementation costs.

4 Repeat Calculations for Remaining Legs

5 Compare Estimated Capacities for Each Leg

Use the capacity estimates for each leg to sketch potential lane configurations for the roundabout. Leg capacities may all suggest the same number of lanes for all entries. Sometimes, however, different legs will require different numbers of lanes. When leg capacities are close to the thresholds for different lane numbers, use software to conduct a more detailed analysis.

Determine Desired Level of Mobility

When planning a roundabout (as with any intersection), consider the desired level of mobility, or how easily people and goods can move through an intersection.

Level of Service

One way to assess the mobility of motor vehicles is through level of service (LOS), a qualitative measure of a roadway or intersection's operations. LOS provides a letter grade from A to F to describe the average delay experienced by people in motor vehicles, with A being the best and F being the worst. Delay is measured in seconds per vehicle.

LOS thresholds for roundabouts in the *HCM* are the same as those for other unsignalized intersections. Note, however, that the *HCM* assigns LOS F if the roundabout's volume-to-capacity ratio is greater than 1.0, regardless of control delay. Simply using the LOS grade can obscure important differences in delay. (For instance, the difference between two LOS grades can be a fraction of a second of delay or many seconds.) Instead, prioritize overall average and per-user intersection delay numbers, which reflect conditions more accurately and specifically.

According to the City's existing Circulation Element, the minimum acceptable level of service in Rancho Cordova is LOS D.

Underused Capacity

It's important to balance peak hour needs against all-day needs. Achieving a low level of delay during the peak hour could result in an intersection that is "overbuilt," meaning it is underused for the vast majority of the day and that it generates unnecessary construction and maintenance cost, all while taking up valuable city space that could be used for other purposes. When setting the desired mobility, determine whether the peak hour is concentrated (occurring just 15 or 60 minutes of the day, for example) or if it represents conditions across many hours of the day.

Forecast Future Conditions

Roundabouts need to meet the city's capacity needs today and tomorrow. Currently, Rancho Cordova plans for the year 2055.

To generate 2055 volumes, the City uses a modified version of the SACSIM-19 Activity-Based Travel Model from the Sacramento Area Council of Governments (SACOG). (This modified version provides greater roadway and transit network detail and more refined traffic analysis zones in the city and adjacent areas.) This model estimates movement within Rancho Cordova and predicts how city development will interact with land use and transportation across the region.

Future volume projections provided by this model help estimate whether a roundabout will operate within desired mobility targets in the future and the extent to which new development may degrade its operations.

The 2055 land use projections in this model assume that:

/ Residential uses will be fully built out

/ About half of non-residential uses will be built out

/ Areas outside city limits will develop according to SACOG's 2020 *Metropolitan Transportation Plan/Sustainable Communities Strategy* (*MTP/SCS*) preferred land use assumptions, except in four proposed development areas in Sacramento County adjacent to the City: Cordova Hills, Easton/Glenborough, Mather South, and New Bridge. These areas will develop according to 2055 estimates.

These land use assumptions underpin the 2055 travel forecasts for daily, weekday AM peak hour, and weekday PM peak hour forecasts. These forecasts also account for future transit ridership from planned transit services in Rancho Cordova and surrounding areas, including those partially funded by the Transit Benefit District.

For more on this methodology, see the Rancho Cordova *Nexus Study*. Contact the City for relevant traffic projections.

User and Context Considerations

Trucks

The City aims to serve the community's transportation needs and balance the needs of all roadway users.

Expect Truck Use

Roundabouts that serve trucks must be large enough to accommodate wide turning movements. Due to Rancho Cordova's strategic shipping location, the City is authorized to designate certain trucking terminals as interstate truck terminals and certain City highways or parts of City highways as terminal access routes for interstate trucks (see Rancho Cordova Municipal Code 10.41). However, some very large trucks—called STAA trucks or extralegal trucks—are restricted in where they can travel in Rancho Cordova. **Figure F8** illustrates where STAA trucks may travel. Smaller trucks, including the California legal trucks, are not restricted within the city. (For more, check out Caltran's quick guide to truck lengths and routes.)

Therefore, for roundabout planning purposes, start by assuming a given intersection will be used by California Legals (in addition to smaller trucks) unless it is on a designated restricted route. The particular right- or left-turning movements needed for those trucks can be vetted with the City.

Determine and Draw ICDs

To accommodate trucks at a roundabout, begin with an inscribed circle diameter (ICD) that will meet the needs of the intended design vehicle (the largest trucks expected to use the route, although infrequently). A roundabout should be designed so that these trucks can navigate the circle while remaining in their lanes and avoiding curbs.

To determine an ICD range consult **Table F3**, which summarizes common inscribed circle diameter ranges by design vehicle and roundabout type. These values are not prescriptive but provide a good starting point for developing a design (assuming a four-leg intersection with roughly perpendicular approaches).

What is an ICD?

An inscribed circle diameter, or ICD, is the outer diameter of the roundabout. This measurement includes the center island and the width of the circulating travel lanes.

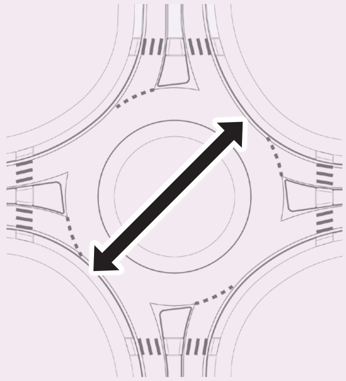


Table F3. Common Inscribed Circle Diameters

Roundabout Configuration	Typical AASHTO Design Vehicle	Common ICD Range[3]
Single-lane roundabout with a non-traversable central island	BUS-40	90–120 ft
	WB-40	100–130 ft
	WB-62 or WB-67	120–180 ft
Two-lane roundabout[4]	WB-40	135–160 ft
	WB-62 or WB-67	140–180 ft

Source: NCHRP Research Report 1043, Exhibit 10.3

3 Assumes 90-degree angles between entries and no more than four legs. This list of possible design vehicles is not comprehensive.

4 Common ICD ranges depend on whether the design vehicle will straddle or stay in-lane. These ranges do not account for special, oversized, or overweight vehicles.

Figure F8. Rancho Cordova STAA Truck Routes

Next, use this information to sketch a roundabout layout with an ICD in the appropriate range for the given design vehicles. Then use available software to test whether the design vehicle can make turning movements with the selected roundabout size. Typically, right turns will be the most constrained in entries and exits, and left turns will determine truck apron requirements around the central island. Design vehicle turning paths may be tested even at a sketch level to establish geometry before further details are developed.

For larger trucks that may occasionally but infrequently use an intersection, first consider adapting geometry to provide for required movements. If necessary, provide reinforced mountable curbs and external truck aprons in strategic locations. For more on roundabouts and trucks, see *NCHRP Research Report 1043*, Sections 9.7 and 10.5.

Walking and Bicycling

With their ability to slow vehicle speeds, roundabouts can play an important role in creating safe and comfortable space for people to walk and bicycle.

To properly incorporate pedestrians and bicyclists in roundabout plans and designs, consult facility design recommendations in the *Bicycle Master Plan* and other City design standards. Roundabouts, like any other intersection, should be planned and designed to provide adequate mobility for people walking and biking and can be designed to provide the same quality of service as the approaching roadways.

In California, bicycle facilities are defined by four types as described in the Caltrans *Highway Design Manual*:

/ **Class I: Bike Paths, Shared Use Paths, or Sidepaths** provide a completely separated facility for the exclusive use of bicyclists and pedestrians. These facilities have minimal or no conflicts with motor vehicle traffic.

/ **Class II: Bike Lanes** are on-street bikeways that provide a dedicated right-of-way for bicycles. These facilities may include painted buffers, but they are not physically separated from vehicle travel lanes.

/ **Class III: Bike Routes or Bicycle Boulevards** are shared right-of-way with motor vehicles and are designated by signs or permanent markings.

/ **Class IV: Separated Bike Lanes or Cycle Tracks** provide physical separation from motor vehicle traffic through grade separation, flexible posts, planters, on-street parking, or other strong physical barriers.

Roundabouts, like other intersections, may provide a similar level of separation, quality of service, and comfort as their approaching roadways. For example:

/ Where a Class I path is provided or planned for an approaching roadway, the roundabout should provide a ramp to a Class I path outside the roundabout to separate bicyclists from motor vehicles traveling through the circulatory roadway.

/ Where an approaching roadway has Class II bike lanes, the roundabout should provide a ramp to a multiuse path or separated bike lane to separate bicyclists from motor vehicles in the circulatory roadway.

/ Where the approaching roadway volumes and speeds are appropriate for a Class III route, the roundabout could provide a shared-lane for bicyclists.

/ Where the approaching roadway has Class IV bike lane, the roundabout should provide a multiuse path or separated bike lane to separate bicyclists from motor vehicles traveling through circulatory roadway.

Table F4 summarizes the relationship between bicycle infrastructure on an approaching roadway and the comparable facility through a roundabout. See the following subsection for more information on accommodating bicycle lanes at roundabouts.

Table F4. Roundabout Bicycle Facility Type by Approaching Class

Approaching Bike Infrastructure	Comparable Provision at Roundabout
Class I	Multiuse path or separated bike lane
Class II	Multiuse path or separated bike lane
Class III	Shared lane with motor vehicles
Class IV	Separated bike lane

Accommodate Bike Lanes

At roundabouts with pedestrian and bicycle facilities, the area outside the traveled way will need to be wider than those without them. The resulting intersection footprint will be larger.

To accommodate shared use paths at the planning level, add 28 feet to the ICD for a single lane roundabout and 32 feet for a multilane roundabout. These ranges assume 4-foot landscape buffers, 10-foot paths for a single-lane roundabout, 12-foot paths for a multilane roundabout.

To accommodate a sidewalk and a separated bike lane at the planning level, add 40 feet to the ICD. This extra width for a separated bike lane and sidewalk assumes 6-foot sidewalks, 4-foot landscape buffers, and a 10-foot separated bike lane.

To determine the total ICD for a roundabout with pedestrian and bicycle facilities according to different design vehicles, use **Table F5** and **Table F6**. These are by no means the only suitable sizes for roundabouts; they are simply a reasonable starting point for estimating spatial needs, given certain characteristics and assuming a four-leg intersection with roughly perpendicular approaches.

Table F5. Footprint Sizes for Roundabouts with Pedestrian and Bicycle Facilities—AASHTO WB-62 or WB-67 Design Vehicle

Roundabout Type	Sidewalk Only	Shared Use Path	Separated Bicycle Lanes
Single Lane	150 + 20 = 170 feet	150 + 28 = 178 feet	150 + 40 = 190 feet
Multilane	N/A	165 + 28 = 193 feet	165 + 40 = 205 feet

Table F6. ICDs for Roundabouts with Pedestrian and Bicycle Facilities—City Bus Design Vehicle

Roundabout Type	Sidewalk Only	Shared Use Path	Separated Bicycle Lanes
Single Lane	100 + 20 = 120 feet	100 + 28 = 128 feet	100 + 40 = 140 feet
Multilane	N/A	150 + 28 = 178 feet	150 + 40 = 190 feet

Locating and Designing Crossings

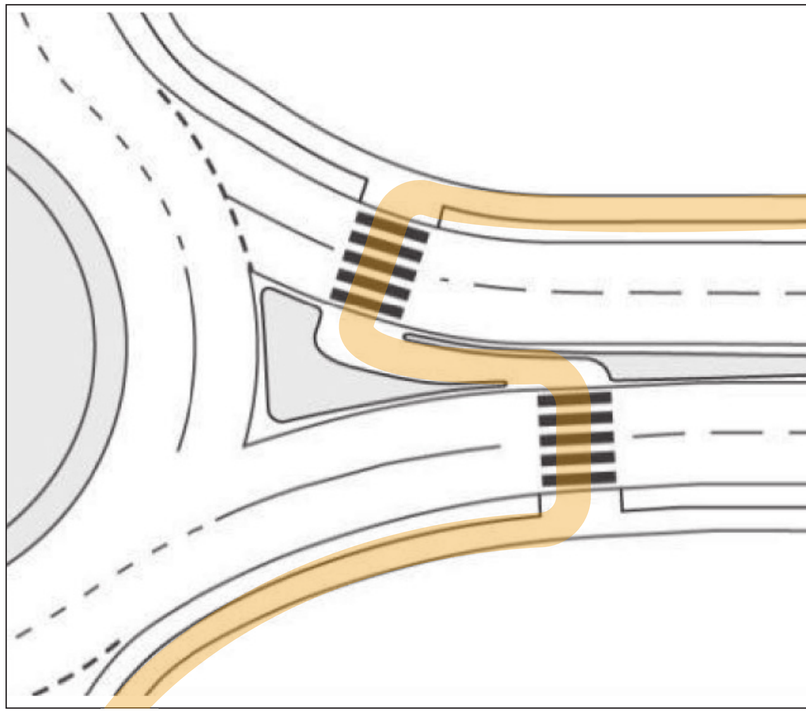
Crosswalk placement is a balancing act. Practitioners often must reconcile competing design objectives, such as:

- **Pedestrian convenience**—People walking naturally look for the shortest path between their origins and destinations. The farther a crossing is from the roundabout, the more likely pedestrians are to choose a shorter route that is not provided by the design. Often times, that shorter route increases their exposure and crash risk.
- **Pedestrian safety**—Minimizing crossing distance decreases pedestrian crash risk. Because roundabouts typically have flared entries, a location 20–25 feet back (about one car length) from the entrance provides a shorter crossing than one closer to the circulatory roadway. This setback location separates the pedestrian crossing from any vehicular conflict points and allows drivers to focus exclusively on each conflict, rather than on both simultaneously.
- **Driver stopping or yielding**—Pedestrian crossings affect roundabout operations because drivers must yield or stop for crossing pedestrians. A queuing analysis may reveal that an exit crossing should be located more than one car length away from the circulatory roadway to avoid a backup. However, that placement must be balanced against pedestrian convenience and safety needs.

Most roundabout crossings are located at least 20 feet (about one car length) back from the circulatory roadway. In some cases, crossings are located two or three car lengths on the exit. If an exit crossing is farther away from the roundabout than the typical one-car length, a two-stage crossing can be provided to accommodate staggered crossing distances with a closer entrance crossing and farther exit crossing (see **Figure F9**).

Regardless of a crossing's location, a two-stage crossing with an accessible refuge in the median splitter island simplifies crossing and improves safety for pedestrians (see **Figure F10**).

Figure F9. Roundabout with Staggered Crosswalk



Source: NCHRP Research Report 834, Figure 4-4

Figure F10. Two-Stage Crossing Example

Source: Lee Rodegerdts, NCHRP Research Report 1043, Exhibit 14.14

Source: Kittelson & Associates, Inc.

Roundabouts and Accessibility

Roundabouts can be designed to be safe and accessible for all people walking.

NCHRP Research Report 834 provides principles and checks for designing roundabouts that are accessible for people with low vision and that promote safe conditions for all people walking. The report includes an assessment that designers can use to evaluate whether a roundabout design provides accessible crossings. The assessment asks a series of questions related to the two tasks a pedestrian must complete to navigate an intersection:

- **Wayfinding**—Locating the crosswalk, aligning to cross, and maintaining correct heading while crossing the street.
- **Crossing**—Deciding when to cross the street.

The report also provides direction on how to thoughtfully design the following elements which contribute to creating accessible crossings:

- Crosswalk location and angle
- Sidewalk alignment
- Buffering the outer edge of the sidewalk
- Detectable warning and guidance surfaces
- Curb ramp location and design
- Crosswalk markings
- Median splitter island design
- Type, location, and accessibility of traffic control devices
- Signing and markings

For an example roundabout design accessibility assessment, see NCHRP Research Report 1043, Appendix A.7

Multilane Crossings

Multilane crossings are more complicated than single-lane crossings and can present greater exposure for people walking. As of September 2023, the United States Access Board has issued a final rule on the Public Right-of-Way Accessibility Guidelines (*PROWAG*), which provides minimum guidelines for implementing the Americans with Disabilities Act (ADA) of 1990 for public rights-of-way.

With the final rule, multilane roundabouts are required to implement at least one of the following four pedestrian treatments to make the crossings accessible for people who are blind or have low vision:

- **Traffic control signal with pedestrian signal head**—A signal displays red-yellow-green indications to drivers and rests in green. A pedestrian signal head displays "Walk" and flashing "Don't Walk" phases for crossing pedestrians. Signals should be sufficiently offset from the entry yield sign to prevent users from being confused by two traffic controls.
- **Raised crosswalks**—A raised crosswalk refers to an elevated crossing area relative to vehicular travel lanes, with the full crosswalk width raised (as opposed to a narrower speed bump or hump). Elevating crossing areas forces drivers to slow down and improves driver yielding (**Figure F11**). Raised crosswalks can be paired with other treatments (typically RRFBs).
- **Rectangular rapid flashing beacons** (**RRFBs**)—These push-button activated signs use flashing yellow lights to alert drivers to pedestrians or bicyclists waiting to cross the roadway (**Figure F11**). RRFBs improve driver yielding and are typically used for multilane roundabouts. Adding audible messages helps people who are blind or have low vision navigate the crossing.
- **Pedestrian hybrid beacons** (**PHBs**)—Typically mounted on mast arms, PHBs use a series of colored lights to signal drivers to stop for pedestrians. Until the device is activated, the lights are dark. When activated, the beacon flashes yellow then turns solid yellow. During the pedestrian walk interval, the lights are solid red. During the pedestrian clearance interval, the lights alternate flashing red. PHBs also signal "Walk" and "Don't Walk" to pedestrians and can be coordinated with other traffic control devices at adjacent intersections. An audible message like "Wait" or a percussive tone during the "Walk" phase may help pedestrians who are blind or have low-vision navigate the crossings.

The *PROWAG* final rule also provides for equivalent facilitation: alternative designs are allowed so long as they "result in substantially equivalent or greater accessibility and usability then the requirements."[5] Although this suggests a performance measure to compare and evaluate relative performance, no metric is provided. *NCHRP Research Report 1043*, Appendix A.6 contains more information on applying these treatments, including a potential evaluation measure.

Figure F11. A Raised Crosswalk with RRFBs

Source: Jonathan French, NCHRP Research Report 1043, Exhibit 11.15

Careful consideration should be applied when selecting crossing treatments at multilane roundabouts.

5 *PROWAG*, R102.1, https://www.federalregister.gov/documents/2023/08/08/2023-16149/accessibility-guidelines-for-pedestrian-facilities-in-the-public-right-of-way.

Transit

Transit plays an important role in Rancho Cordova's transportation network. Access to transit is critical for many residents, particularly those from groups more likely to rely on transit for their everyday needs, including people from low-income households, historically underserved communities, and marginalized backgrounds.

Two critical elements of designing roundabouts for transit are a) sizing to allow buses to travel in lane (*not* using truck aprons), and b) locating bus stops to balance access convenience with traffic and service efficiency.

Planning for SacRT

The Sacramento Regional Transit District (SacRT) is the regional transit service provider, and their buses will travel through roundabouts in Rancho Cordova. SacRT representatives played a key role in developing these guidelines and advising on key transit considerations.

When planning for transit at roundabouts, use the following guidance:

/ Design roundabouts to serve buses fully within the circulatory roadway (rather than relying on the use of a truck apron) to avoid jostling bus occupants.

/ Consult the SacRT Bus Stop Improvement Plan to determine the recommended bus stop improvements, design recommendations, and amenities recommended for the location. Corridors cited in that plan include Coloma Road, Kilgore Road, Lincoln Village Drive, Rockingham Drive, and Routier Road.

/ Consult the latest SACOG plans to determine intended future bus service and stop locations along project corridors.

/ Bus stops should not be located within the circulatory roadway. Placing stops as close to pedestrian crossings as possible minimizes out-of-direction travel. Place these stops either at nearside (on entry) or far side (on exit), using the considerations in **Table F7**.

For more on these plans, see the SacRT Bus Stop Improvement Plan and the SACOG Transit Improvement Plan.

Schools

Well-designed roundabouts can help make transportation around schools safer and more efficient for everyone. Safety near schools is a top concern for the City and for constituent schools, including Elk Grove Unified School District, Folsom Cordova Unified School District (FCUSD), Sacramento City Unified School District, and area private schools. As key stakeholders in projects near schools, FCUSD has identified the following priorities that are appropriate to consider for all projects near schools:

/ **Pedestrian Crossing Safety**—A number of design checks can be used to promote safety and comfort for pedestrians—including school-age children—crossing at roundabouts (see "Multilane Crossings" on page 79). FCUSD has expressed interest in supplemental crossing treatments like raised crosswalks and PHBs, the suitability of which can be determined on a case-by-case basis. In some cases, schools may request post-implementation evaluation to determine if additional interventions (such as additional signage or RRFBs) are desirable.

/ **Landscape and Plant Height**—To provide adequate sight distance, landscape and plants should be maintained to meet the sight distance checks conducted as part of typical roundabout design. (For more detail on roundabout sight distance and landscaping, see NCHRP Research Report 1043, Chapters 9 and 14.) A maintenance agreement can provide a framework to keep landscape features compliant with sight distance needs.

Table F7. Bus Stop Location Considerations

Nearside	Far Side
In-lane stops on a single-lane approach just upstream of the pedestrian crossing are well located but stop traffic temporarily to board and alight passengers. On multilane approaches: • An in-lane bus stop may allows for the “multiple-threat” condition in which the bus stops for pedestrians crossing but an adjacent driver does not see the pedestrian. • A bus pullout avoids the “multiple threat,” but buses existing the pullout may further obstruct visibility between pedestrians and entering traffic.	Bus stops located just beyond the pedestrian crossing improve the visibility of crossing pedestrians, who cross behind the bus. Bus pullouts reduce the potential for vehicles to queue into the roundabout when the bus stops to board and alight passengers.

Application

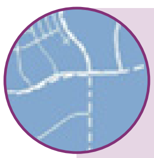
The process outlined in this section provides a blueprint that City staff can use to identify, plan, and implement roundabouts for future developments.

Identify Development Area

Identify potential areas early on in the parcel acquisition, subdivision, and development process. This increases the number of available opportunities for implementation before site and off-site improvement plans lock in constraints.

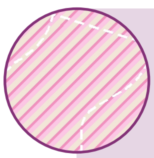
To identify roundabout opportunities in upcoming areas, use **Figure F12**. Consider all future intersections of roadways with functional classifications of collectors and above and with fewer than six lanes.

This map categories Rancho Cordova areas into two area types:



No tentative maps approved. These areas have the fewest constraints and the most potential for roundabouts. Intersections in these areas that meet the functional classification and lane criteria can proceed through the screening process explained in the following section.

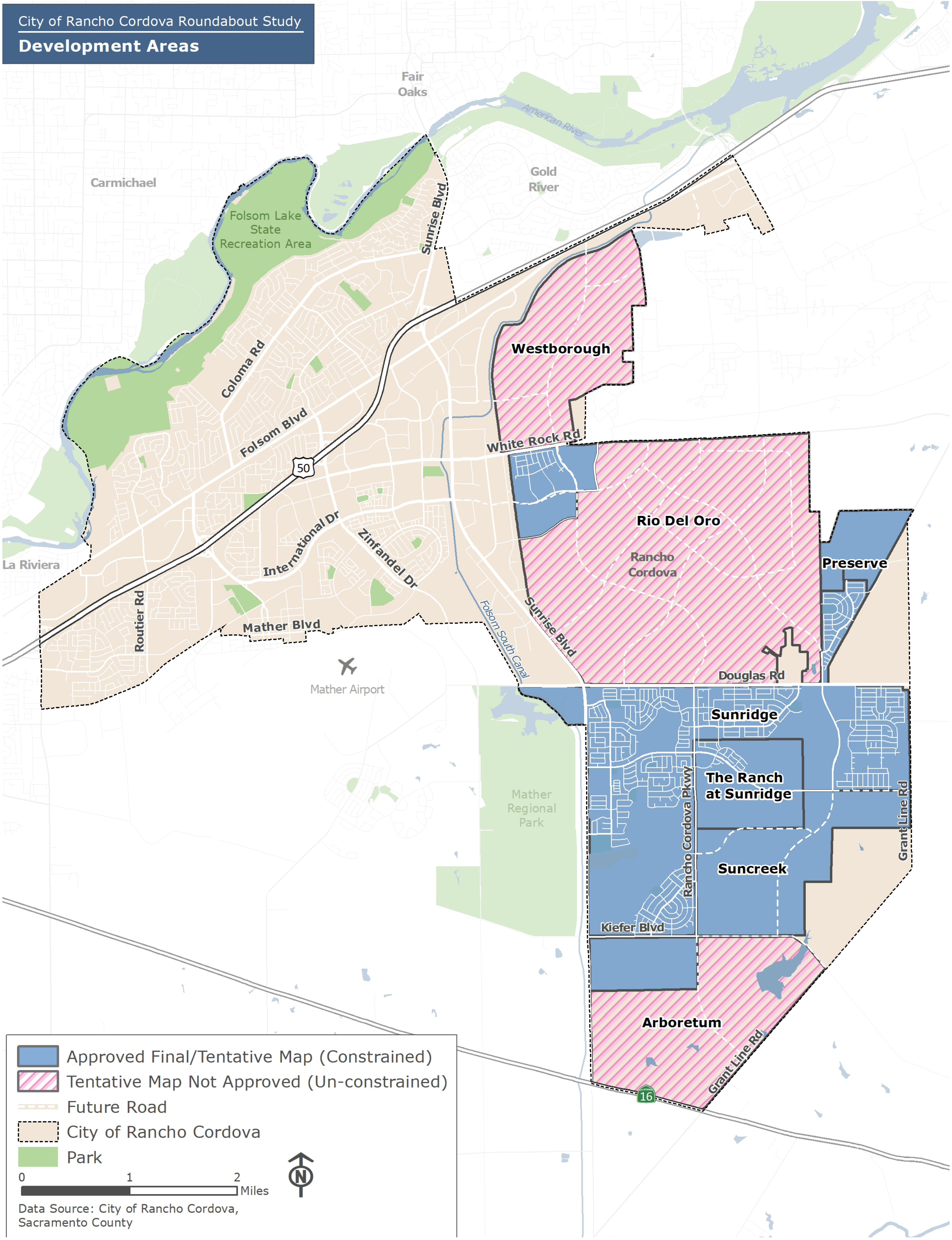
Local examples: Arboretum and Westborough



Approved final or tentative maps. These areas are well on their way to development and have the most constraints. Given those constraints, these areas are unlikely to have as much roundabout potential. Nevertheless, City staff should engage in discussions with developers as early as possible. Intersections in these areas can be evaluated using the screening process in the following section.

Local example: The Ranch at Sunridge

Figure F12. Roundabout Opportunity Areas by Land Constraints



Screen Potential Locations

To identify future locations for roundabouts, use the following three-step screening process:

Step 1: Assess Capacity and Number of Lanes

A/ Determine the anticipated lane arrangement (single lane or multilane) according to existing and anticipated traffic volumes and the planned number of lanes on the intersecting roadways.

To determine appropriate analysis volumes, either modify existing count data or refer to the model. Existing count data will likely be unavailable for greenfield development locations. In those cases, refer to the City's travel demand model to determine traffic volumes for the appropriate analysis year. The model will provide daily or peak-hour bidirectional volumes. If necessary, methods are available to estimate turning movement volumes from model link volumes.

More information on converting model link volumes to turning movement counts is beyond the scope of this document but is available in *NCHRP Research Report 765: Analytical Travel Forecasting Approaches for Project-Level Planning and Design* (2014).

Step 2: Test Roundabout Size

A/ Select the appropriate design vehicle based on functional classification, roadway ownership, and existing or planned transit service.

B/ Identify the appropriate inscribed circle diameter (ICD) range to test based on the number of lanes and the design vehicle.

C/ Identify additional width needed for existing and planned pedestrian and bicycle facilities according to the Active Transportation Plan or other relevant planning documents and data. For City planning documents and data, visit https://data-ranchocordova.opendata.arcgis.com/.

Step 3: Develop Footprint Sketch

A/ Overlay circles with the widths from steps 2B and 2C on aerial imagery. Include right-of-way and building lines.

B/ Assess this sketch for the feasibility of implementing a roundabout based on the following factors: potential right-of-way impacts, building impacts, topographical challenges, and impacts to roadway configuration. Note that this feasibility sketch is based on the expected width of the circular portion of the roundabout and does not include potential right-of-way impacts of the approaches.

Sample Application: Rio Del Oro

To see the roundabout prioritization process in action, review the following test case in Rio del Oro. The Rio Del Oro Plan Area includes 3,828 acres in Rancho Cordova south of White Rock Road, east of Sunrise Boulevard, and north of Douglas Road (just east of Mather Airport). At the time of the 2016 plan, the land was predominantly used for mining and grazing. The *Rio Del Oro Specific Plan* was intended to present a balanced, mixed-use community consistent with the City's General Plan. This Rio del Oro test case shows the process to screen potential locations early in the entitlement process; it does not reflect final roundabout locations.

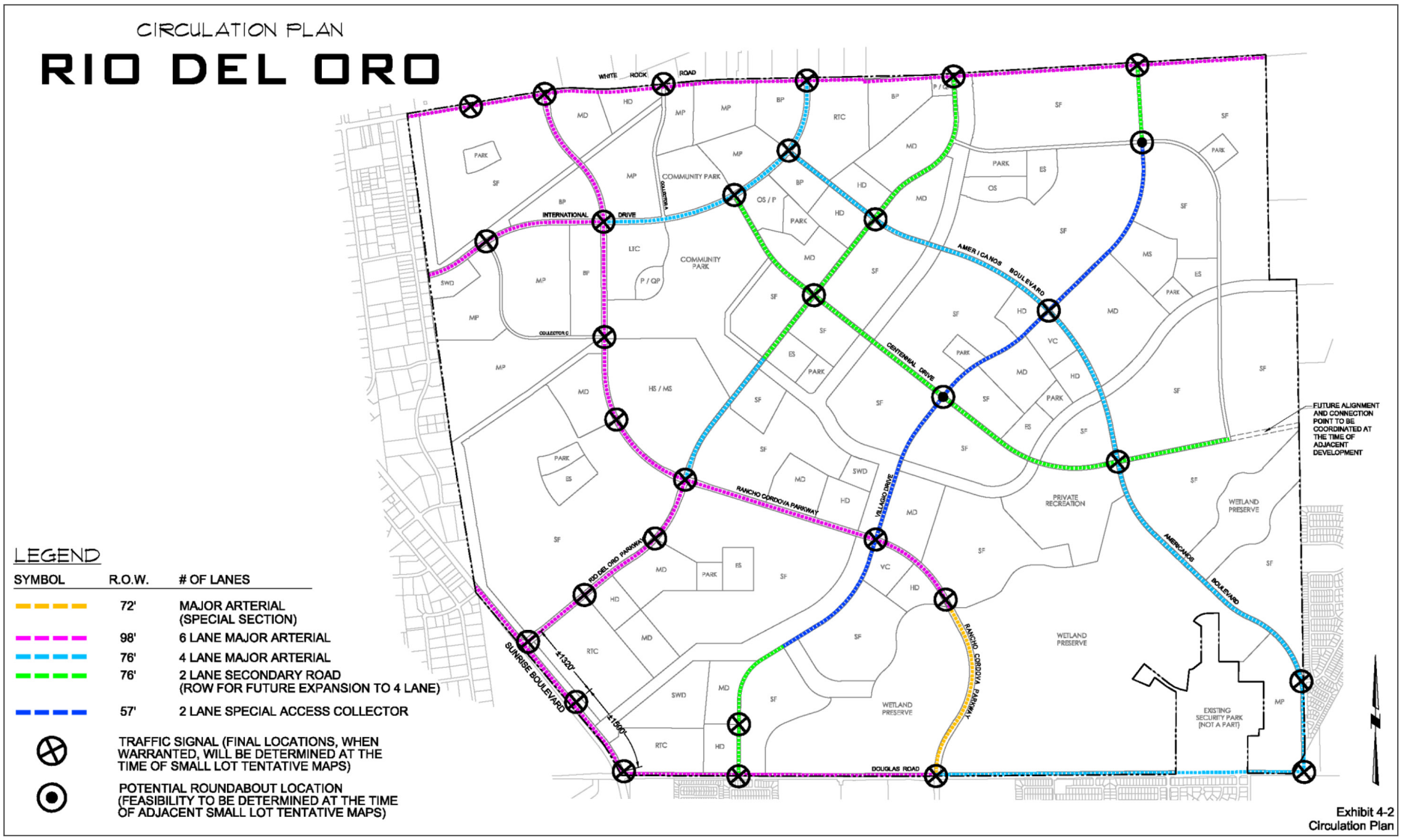
Step 1: Assess Capacity and Number of Lanes

To determine the number of lanes, we tested intersections identified in the published Rio Del Oro Circulation Plan (**Figure F13**). All of the intersections were on collectors and above. Some of the roadways are six lanes today, and some are planned to be six lanes. We used preliminary testing to understand whether those lanes could be reduced and better served with a roundabout.

A/ Determine whether a single or multilane roundabout is appropriate according to traffic volumes and the number of lanes on the intersecting roadways.

We used SACSIM future model volumes, which provide annual average daily traffic (daily, two-way volumes). From those numbers, we estimated daily total entering vehicles and compared the future volume estimates to the planning-level daily Intersection volumes in **Figure F2**.

Figure F13. Rio Del Oro Intersections Tested



Source: Rio Del Oro Specific Plan

Step 2: Test Roundabout Size

A/ Select the appropriate design vehicle based on functional classification, roadway ownership, and existing or planned transit service.

Because all intersections in Rio Del Oro are expected to serve trucks, we selected an AASHTO WB-67 as the design vehicle.

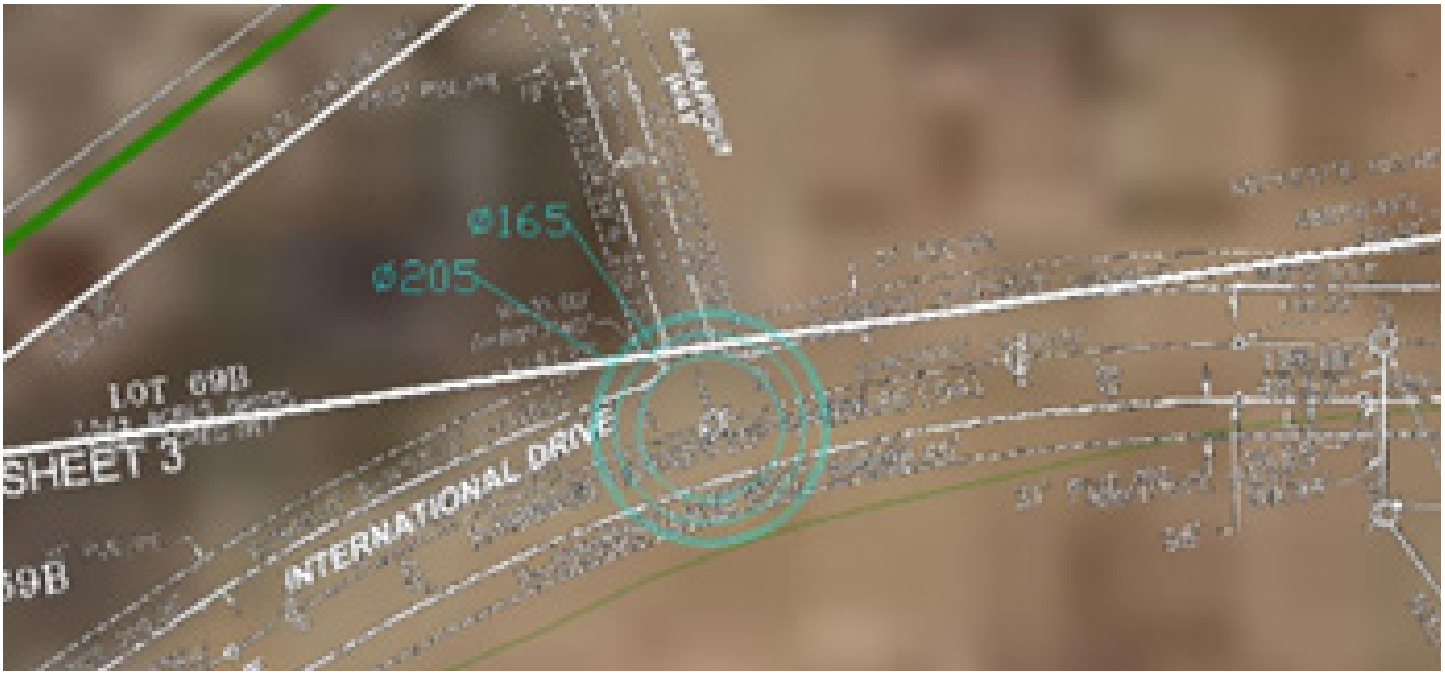
B/ Identify the appropriate inscribed circle diameter (ICD) range to test based on the type of roundabout and the design vehicle.

We selected single-lane and multilane roundabouts with ICDs of 150 feet and 165 feet, respectively, to provide for WB-67 design vehicles.

C/ Example Footprint Selection

We used the Bicycle Master Plan to identify where bike lanes and paths were proposed. We added appropriate buffer distances to the ICDs and determined the appropriate total footprint for each intersection. The resulting footprint estimates ranged from 170 to 205 feet. **Figure F14** shows single-lane and multilane footprints at two different roundabout locations in Rio del Oro.

Figure F14. Rio Del Oro Sample Footprints



This location was tested as a multilane roundabout with a 165-foot ICD and a 205-foot total footprint. The roundabout was overlaid over an existing development plan where—as this aerial shows—there are potential constraints.

Step 3: Develop Footprint Sketch

A/ Overlay circles with the widths from steps 3 and 4 on aerial imagery. Include right-of-way and building lines.

To determine feasibility, we overlayed the ICD footprint on a GIS map of planned roadways in Rio Del Oro and a plan-set development along the Rancho Cordova Parkway corridor (**Figure F15**).

B/ Assess this sketch for the feasibility of implementing a roundabout based on the following factors: potential right-of-way impacts, building impacts, topographical challenges, and impacts to roadway configuration. For example, assess whether the roadway would need to be reconfigured to match the number of lanes through the roundabout. Note that this feasibility sketch is based on the expected width of the circular portion of the roundabout and does not include potential right-of-way impacts of the approaches.

This high-level exercise revealed that this particular intersection would be a challenge to implement due to committed right-of-way within the footprint.

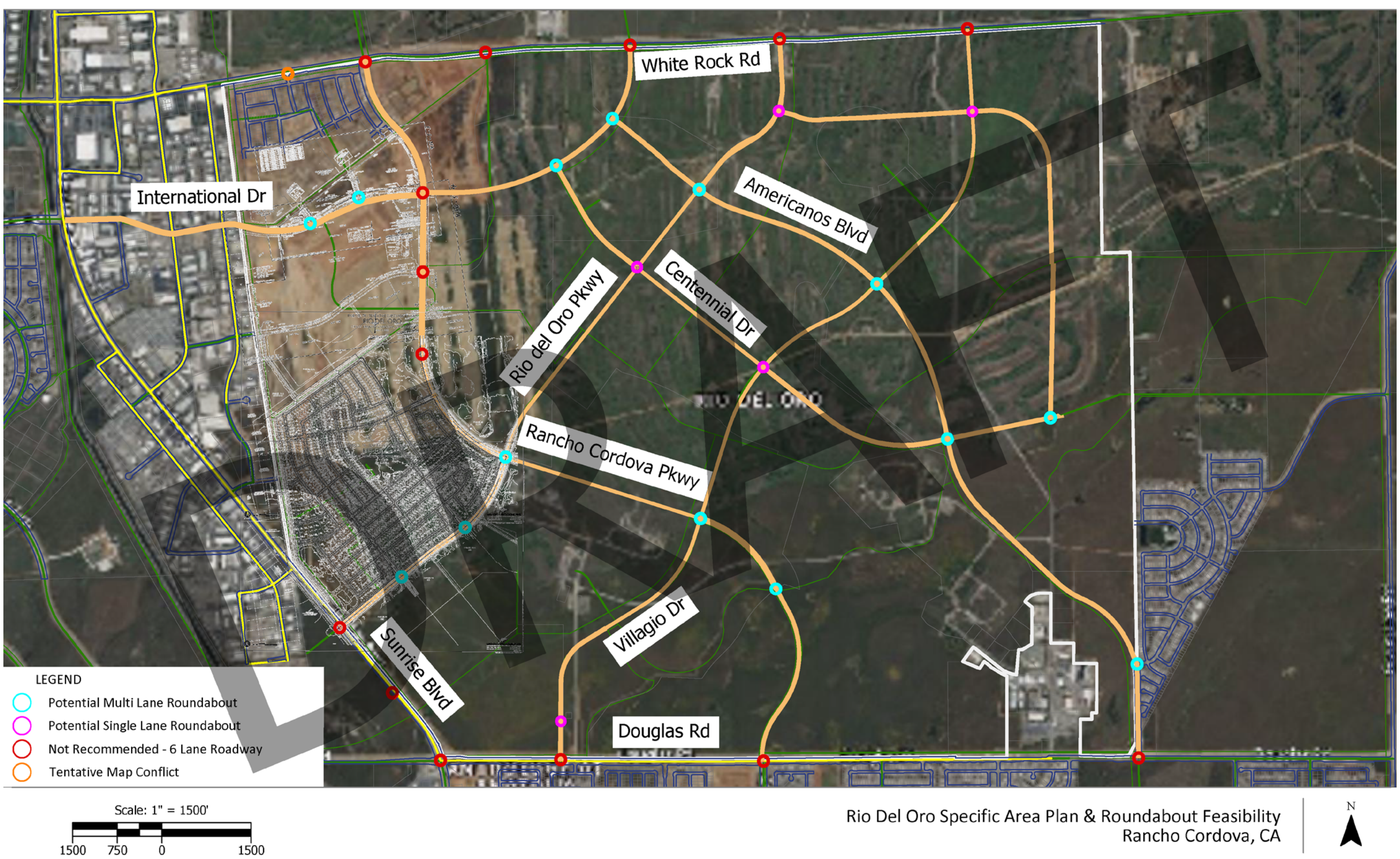
We repeated this exercise for all test intersections in Rio del Oro, and the result was a map of prospective roundabout locations, organized by number of lanes and feasibility (**Figure F16**).

Out of 34 locations we identified 5 potential single-lane roundabouts and 14 potential multilane roundabouts.

We ruled out 15 locations, one for having a tentative map conflict (according to constraints of development currently underway) and 14 for being on existing six-lane roadways.

Figure F15. Roundabout Footprint and Potential Parcel Conflict

Figure F16. Resulting Assessment of Possible Roundabout Locations



Note: This Rio del Oro test case shows the process to screen potential locations early in the entitlement process; it does not reflect final roundabout locations.