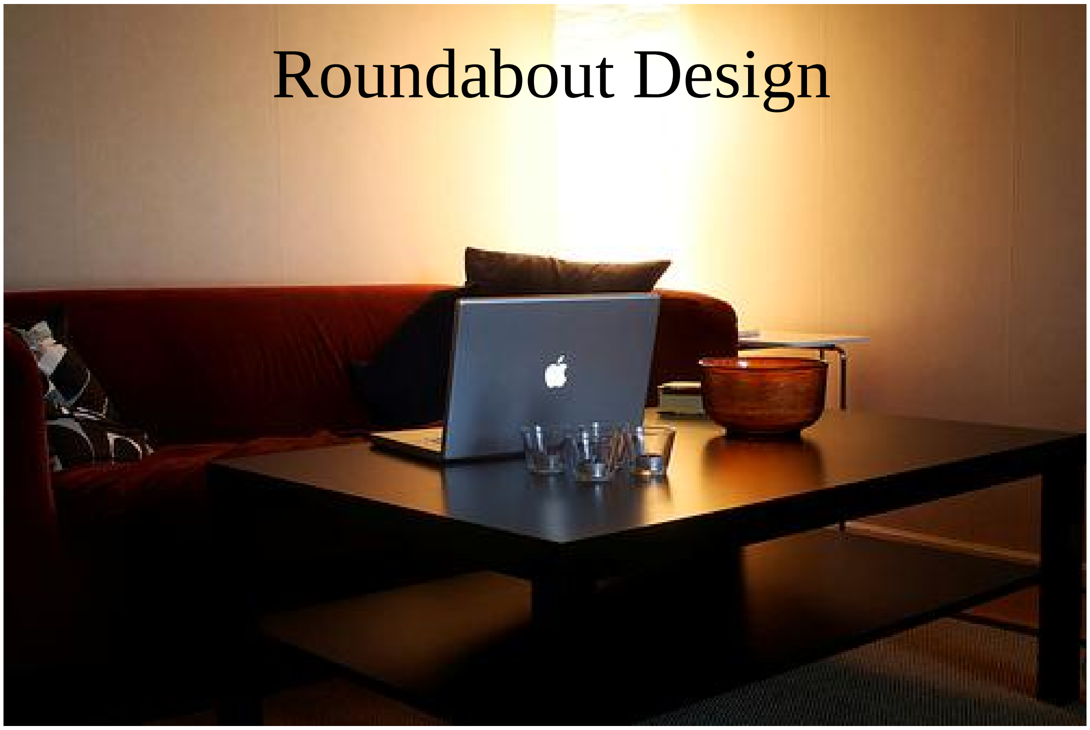

Roundabout Design

By

Debra Kennaugh, P.E.

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Debra A. Kennaugh, P.E.

I. Introduction

Traffic circles have been part of the transportation system in the United States since 1905. This device was designed by William Eno on Columbus Circle in New York City. Subsequently, many large circle or rotaries were built in the United States. The prevailing designs enabled high-speed merging and weaving of vehicles. Priority was given to entering vehicles, facilitating high-speed entries. High crash experience and congestion in the circle led to rotaries falling out of favor in the mid-1950's.

The modern roundabout was developed in the United Kingdom to rectify problems associated with these traffic circles. In 1966, the United Kingdom adopted a mandatory "give-way" rule at all circular intersections, which required entering traffic to give way, or yield, to circulating traffic. This rule prevented circular intersections from locking up, by not allowing vehicles to enter the intersection until there were enough gaps in circulating traffic.

These changes improved the safety characteristics of the circular intersection by reducing the number and particularly the severity of collisions. Thus, the resultant modern roundabout is significantly different from the older style traffic circle both in how it operates and in how it is designed.

A. Types of Circular Intersections

A roundabout is a type of circular intersection, but not all circular intersections can be classified as roundabouts. In fact, there are at least three distinct types of circular intersections:

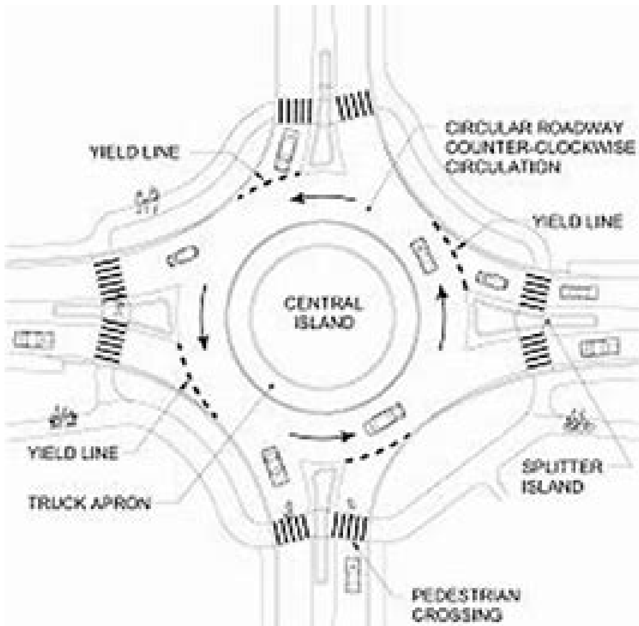
- *Rotaries* are old-style circular intersections common to the United States prior to the 1960's. rotaries are characterized by a large diameter, often in excess of 300 feet. This large diameter typically results in travel speeds within the circulatory roadway that exceed 30 mph. They typically provide little or no horizontal deflection of the paths of through traffic and may even operate according to the traditional "yield-to-the-right" rule, i.e., circulation traffic yields to entering traffic.

- *Neighborhood traffic circles* are typically built at the intersections of local streets for reasons of traffic calming and/or aesthetics. The intersection approaches may be uncontrolled or stop-controlled. They do not typically include raised channelization to guide the approaching driver onto the circulatory roadway. At some traffic circles, left-turning movements are allowed to occur to the left of (clockwise around) the central island, potentially conflicting with other circulating traffic.

- *Roundabouts* are circular intersections with specific design and traffic control features. These features include yield control of all entering traffic, channelized approaches and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less that 30 mph.

B. Roundabout Features

The following illustration details the features of a roundabout. It is followed by the definitions of these features.



Definitions

Central Island. The raised area in the center of a roundabout around which traffic circulates.

Splitter Island. A raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic and provide storage space for pedestrians crossing the road in two stages.

Circular Roadway. The curved path used by vehicles to travel in a counterclockwise fashion around the central island.

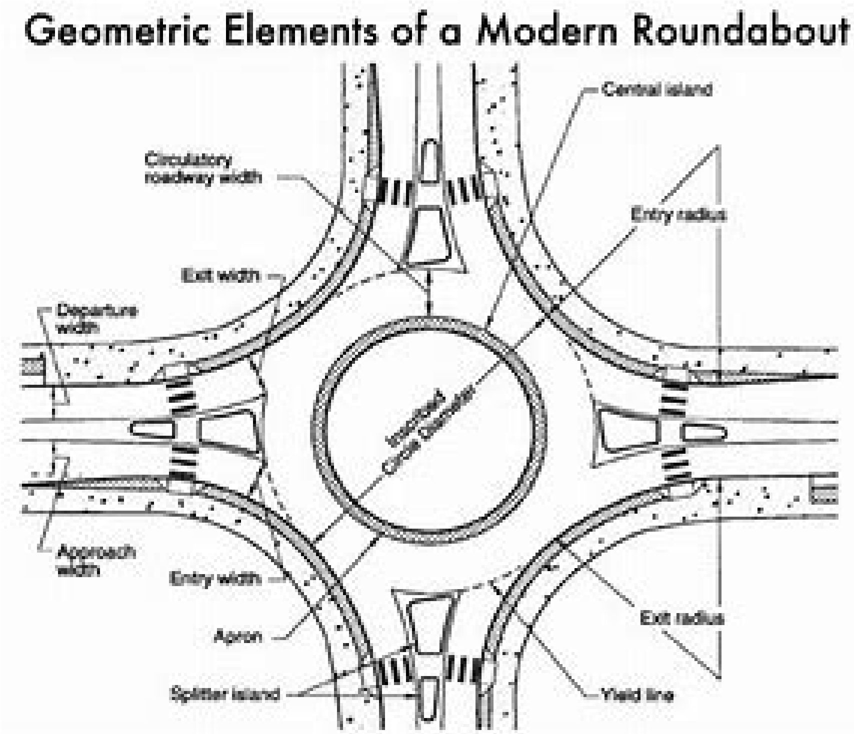
Truck Apron. The mountable potion of the central island adjacent to the circulatory roadway.

Yield Line. A pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.

Pedestrian Crossings. Should be provided at all roundabouts. The crossing location is set back from the yield line, and the splitter island is cut to allow pedestrians, wheelchairs, strollers and bicycles to pass through.

C. Roundabout Dimensions

The following illustration details the key dimensions of a roundabout. It is followed by the definitions of these dimensions.



Definitions

Inscribed Circle Diameter. The basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.

Circulatory Roadway Width. Defines the roadway width for vehicle circulation around the central island. It is measured as the width between the outer edge of this roadway and the central island. It does not include the width of any mountable apron, which is defined to be part of the central island.

Approach Width. The width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The approach width is typically no more than half of the total width of the roadway.

Departure Width. The width of the roadway used by departing traffic downstream of any changes in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the roadway.

Entry Width. Defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribe circle.

Exit Width. Defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.

Entry Radius. The minimum radius of curvature of the outside curb at the entry.

Exit Radius. The minimum radius of curvature of the outside curb at the exit.

D. Roundabout Characteristics

Roundabouts have been demonstrated to be generally safer for motor vehicles and pedestrians than other forms of at-grade intersections.

Good roundabout designs encourage speed reduction and speed consistency. Potential safety benefits of low vehicle speeds include:

- Reduce crash severity for pedestrians and bicyclists, children and impaired persons;
- Provide more time for entering drivers to judge, adjust speed for and enter a gap in circulating traffic;
- Allow safer merges into circulating traffic;
- Provide more time for all users to detect and correct for their mistakes or mistakes of others;
- Make collisions les frequent and less severe; and
- Make the intersection safer for novice users.

Low circulating speeds can provide greater capacity because:

- The faster the circulating traffic, the larger the gaps that entering traffic will comfortably accept. This translates to fewer acceptable gaps and therefore more instances of entering vehicles stopping at the yield line.

- Entering traffic, which is first stopped at the yield line, requires even larger gaps in the circulating traffic in order to accelerate and merge with the circulating traffic. The faster the circulating traffic, the larger the gap must be. This translates into even fewer acceptable gaps and therefore longer delay for entering traffic.

II. Types of Roundabouts

There are six basic categories of roundabouts based on environment, number of lanes and size:

- Mini-roundabouts
- Urban compact roundabouts
- Urban single-lane roundabouts
- Urban double-lane roundabouts
- Rural single-lane roundabouts
- Rural double-lane roundabouts

Design Element	**Mini-Roundabout**	**Urban Compact**	**Urban Single-Lane**	**Urban Double-Lane**	**Rural Single-Lane**	**Rural Double-Lane**
Recommended maximum entry design speed	15 mph	15 mph	20 mph	25 mph	25 mph	30 mph
Maximum # of entering lanes per approach	1	1	1	2	1	2
Typical inscribed circle diameter	45 to 80 ft	80 to 100 ft	100 to 130 ft	150 to 180 feet	115 to 130 feet	180 to 200 ft

Mini-roundabouts are small roundabouts used in low-speed urban environments with average operating speeds of 35 mph or less. The mini-roundabout is designed to accommodate passenger cars. The central island is mountable so large vehicles may cross over it but not to the left of it. They can be useful in cases where conventional roundabout design is precluded by right-of-way constraints. In retrofit applications, mini-roundabout are relative inexpensive because they typically require minimal additional pavement at the intersecting roads. The following illustration provides an example of a typical mini-roundabout.

Urban compact roundabouts are intended to be pedestrian and bicyclist friendly because their perpendicular approach legs require very low vehicle speeds to make a distinct right turn into and out of the circulatory roadway. All legs have sign-lane entries. Capacity should not be a critical issue for this type of roundabout. The geometric design includes raised splitter islands that incorporate at-grade pedestrian storage areas and a non-mountable central island. There is usually an apron surrounding the non-mountable part of the compact central island to accommodate large vehicles. The following illustration provides an example of a typical urban compact roundabout.

Urban single-lane roundabouts have a single lane entry at all legs and one circulatory lane. They have a larger inscribed circle diameter and more tangential entries and exits than the urban compact roundabout. This results in higher capacities. The geometric design includes raised splitter islands and a non-mountable central island without and apron. The following illustration provides an example of a typical urban single-lane roundabout.

Urban double-lane roundabouts have at least one entry with two lanes. They require wider circulatory roadways to accommodate more than one vehicle traveling side by side. The geometric design includes raised splitter islands, no truck apron and a non-mountable central island. Alternate routes may be provided for bicyclists who choose to bypass the roundabout. The following illustration provides an example of a typical urban double-lane roundabout.

Rural single-lane roundabouts generally have high average approach speed in the range of 50 to 60 mph. They require supplementary geometric and traffic control devices on approaches to encourage drivers to slow to an appropriate speed before entering the roundabout. Rural roundabouts may be larger diameters than urban roundabouts to allow slightly higher speeds at the entries, on the circulatory roadway and at the exits. There is no apron because their large diameter central island should accommodate larger vehicles. The following illustration provides an example of a typical rural single-lane roundabout.

Rural double-lane roundabouts generally have high average approach speed in the range of 50 to 60 mph. They have two entry lanes on one or more approaches. Consequently, many of the characteristics and design features of rural double-lane roundabouts mirror those of their urban counterparts. The main design differences are the higher entry speeds, larger diameters and recommended supplementary approach treatments. The following illustration provides an example of a typical rural double-lane roundabout.

A. Spatial Requirements

Roundabouts usually require more space for the circular roadway and central island than the rectangular space inside traditional intersections. Therefore, roundabouts often have a significant right-of-way impact on the corner properties at the intersection. The dimensions of a traditional intersection are typically comparable to the envelope formed by the approaching roadways. However, to the extent that a comparable roundabout would outperform a signal in terms of reduced delay and thus shorter queues, it will require less queue storage space on the approach legs. If a signalized intersection requires long or multiple turn lanes to provide sufficient capacity or storage, a roundabout with similar capacity may require less space on the approaches. As a result, roundabouts may reduce the need for additional right-of-way on the links between intersections, at the expense of additional right-of-way at the intersections themselves.

Careful attention should be paid to driveway connections where a traditional intersection is being converted to a roundabout. The driveway connections should not interfere with the pedestrian crossings or the yield zone.

B. Operation and Maintenance Costs

Compared to signalized intersections, a roundabout does not have signal equipment that requires constant power, periodic light bulb and detection maintenance and regular signal timing updates. Roundabouts, however, can have higher landscaping maintenance costs, depending on the degree of landscaping provided on the central island and splitter islands. Illumination costs for roundabouts and signalized intersections are similar. The service life of a roundabout is significantly longer, approximately 25 years, compared with 10 years for a typical signal.

C. Pedestrians

Pedestrians are accommodated by crossings around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrian can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The roundabout should be designed to discourage pedestrians from crossing the central island, e.g., with landscape buffers on the corners. Pedestrian crossings are set back from the yield line by on or more vehicle lengths to:

- Shorten the crossing distance compared to locations adjacent to the inscribed circle;
- Separate vehicle-vehicle and vehicle-pedestrian conflict points; and
- Allow the second entering driver to devote full attention to crossing pedestrians while waiting for the driver ahead to enter the circulatory roadway.

D. Large Vehicles

Roundabouts should always be designed for the largest vehicle that can be reasonably anticipated (the "design vehicle"). For single-lane roundabouts, this may require the use of a mountable apron around the perimeter of the central island to provide the additional width needed for tracking the trailer wheels. At double-lane roundabouts, large vehicles may track across the whole width of the circulatory roadway to negotiate the roundabout.

The following illustrations show the difference between a curbed central island and a central island with an apron. The central island with the apron can accommodate larger vehicles.

The illustration above shows a semi-trailer negotiating a central island without an apron and the illustration below shows a central island with an apron.

III. Operation

A roundabout brings together conflicting traffic streams, allows the streams to safely merge and traverse the roundabout, and exit the streams to their desire directions. The geometric elements of the roundabout 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 of the roundabout and to 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 line, they must check for conflicting vehicles already on the circulating roadway and determine when it is safe to enter the circulating stream. The widths of the approach roadway and entry determine the number of vehicle streams that may form side by side at the yield line 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 on the roundabout. The width of the circulatory roadway determines the number of vehicles that may travel side by side on the roundabout.

A. Capacity

The maximum flow rate that can be accommodated at a roundabout entry depends on two factors: the circulating flow on 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 divers and more than one vehicle may enter each gap. As the circulating flow increases, the size of the gaps in the circulating flow decrease, and 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 element is the width of the entry and circulatory roadways, or the number of lanes at the entry and on the roundabout. Two entry lanes permit nearly twice the rate of entry flow as does one lane. Wider circulatory roadways allow vehicles to travel alongside, or flow, each other in tighter bunches and so provide longer gaps between bunches of vehicles. The inscribed circle diameter and the entry angle have minor effects on capacity.

Roundabouts should be designed to operate at no more that 85 percent of their estimated capacity. Beyond this threshold, delays and queues vary significantly from their mean values.

B. Exit Capacity

An exit flow on a single lane of more than 1,400 veh/h, even under good operating conditions for vehicles (i.e., tangential alignment, and no pedestrians and bicyclists) is difficult to achieve. Under normal urban conditions, the exit lane capacity is in the range of 1,200 to 1,300 veh/h. Therefore, exit flows exceeding 1,200 veh/h may indicate the need for a double-lane exit.

C. Performance Analysis

Three performance measures are typically used to estimate the performance of a given roundabout design: degree of saturation, delay and queue length. Each measure provides a unique perspective on the quality of service at which a roundabout will perform under a given set of traffic and geometric conditions. Whenever possible, the analyst should estimate as many of these parameters as possible to obtain the broadest possible evaluation of the performance of a given roundabout design. In all cases, capacity estimate must be obtained for an entry to the roundabout before a specific performance measure can be computed.

Approach speed is governed by approach roadway width, roadway curvature and approach volume.

IV. Safety

Roundabouts may improve the safety of intersections by eliminating or altering conflict types, by reducing speed differentials at intersections and by forcing drivers to decrease speeds as they proceed into and through the intersection. Though roundabout crash records in the United States are limited, the experiences of other countries can be used to help design roundabouts in this country. Understanding the sensitivity of geometric element parameters, along with the crash experience will assist the designer in optimizing the safety of all vehicle occupants, pedestrians and bicyclists.

The reasons for the increase safety level at roundabouts are:

- Roundabouts have fewer conflicts points in comparison to conventional intersections. The potential for hazardous conflicts, such as right angle and left turn head-on crashes is eliminated with roundabout use. Single-lane approach roundabouts produce greater safety benefits than multilane approaches because of fewer potential conflicts between road users, and because pedestrian crossing distances are short.
- Low absolute speeds associated with roundabouts allow drivers more time to react to potential conflicts, also helping to improve the safety performance of roundabouts.
- Since most road users travel at similar speeds thorough roundabouts, i.e., have low relative speeds, crash severity can be reduced compared to some traditionally controlled intersections.
- Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabouts, as compared with unsignalized intersections. The conflict locations between vehicles and pedestrians are generally not affected by the presence of a roundabout, although conflicting vehicles come from a more defined path at roundabouts (and thus pedestrians have fewer places to check for conflicting vehicles). In addition, the speeds of motorists entering and exiting a roundabout are reduced with good design.

A. Conflicts

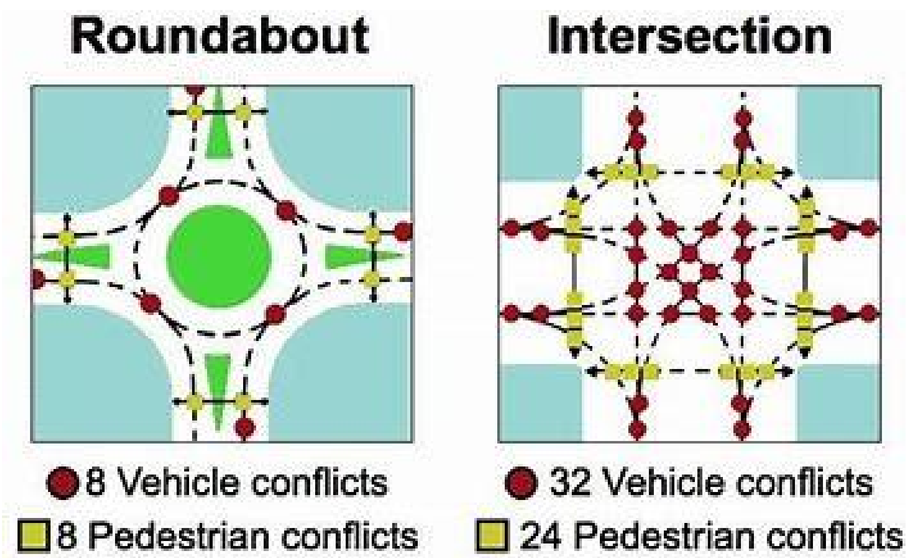
The frequency of crashes at an intersection is related to the number of conflict points at an intersection, as well as the magnitude of conflicting flows at each conflict point. A conflict point is a location where the paths of two motor vehicles, or a vehicle and a bicycle or pedestrian queue, diverge, merge or cross each other.

Besides conflicts with other road users, the central island of a roundabout presents a particular hazard that may result in over-representation of single-vehicle crashes that tend to occur during periods of low traffic volumes. At cross intersections, many such violations may go unrecorded unless a collision with another vehicle occurs.

Conflicts can arise from both legal and illegal maneuvers; many of the most serious crashes are caused by failure to observe traffic control devices. Both legal conflicts (queuing at an intersection, merging into a traffic stream) and conflicts prohibited by law or by traffic control devices (failure to yield to pedestrians, running a stop sign) have been included for completeness. Even though traffic control devices can significantly reduce many conflicts, they cannot eliminate them entirely due to violations of those devices. Many of the most serious crashes are caused by such violations.

B. Vehicle Conflicts

The following illustration for a traditional four-leg intersection and a four-leg roundabout details the conflict points associated with the movements. The number of vehicle-vehicle conflict points for roundabouts decreases from 32 to 8 for four-leg intersections. A four-leg single-lane roundabout has 75% fewer vehicle conflict points compared to a conventional intersection.



Conflicts can be divided into three basic categories, in which the degree of severity varies, as follows:

- *Queuing Conflicts.* These conflicts are caused by a vehicle running into the back of a vehicle queue on an approach. These types of conflicts can occur at the back of a through-movement queue or where left-turning vehicles are queued waiting for gaps. These conflicts are typically the least sever of all conflicts because the collisions involve the post protected parts of the vehicle and the relative speed difference between vehicles is less that in other conflicts.

- *Merge and Diverge Conflicts.* These conflicts are caused by the joining or separating of two traffic streams.

- *Crossing Conflicts.* These conflicts are caused by the intersection of two traffic streams. These are the most sever of all conflicts and the most likely to involve injuries or fatalities. Typical crash types are right-angle crashes and head-on crashes.

A roundabout reduces vehicular crossing conflicts by converting all movements to right turns. Again, separate turn lanes and traffic control (stop signs or signalization) can often reduce but not eliminate the number of crossing conflicts at a traditional intersection by separating conflicts in space and/or time. However, the most sever crashes at signalized intersections occur when there is a violation of the traffic control device designed to separate conflicts by time (e.g., a right-angle collision due to running a red light). Therefore, the ability of single-lane roundabouts to reduce conflicts through physical, geometric features has been demonstrated to be more effective than the reliance on driver obedience of traffic control devices. In a roundabout, all movements are given equal priority.

C. Collision Types

It is important for designers to examine details of collision types and location at roundabouts.

The following table presents a summary of the percentage of crashes by collision type. The data was collected from France, Australia, and the United Kingdom.

Collision Type	France	Australia	United Kingdom[1]
1. Failure to yield at entry	36.6%	50.8%	71.1%
2. Single vehicle run off the circulatory roadway	16.3%	10.4%	8.2%[2]
3. Single vehicle loss of control at entry	11.4%	5.2%	[2]
4. Rear-end at entry	7.4%	16.9%	7.0%[3]
5. Circulating-exiting	5.9%	6.5%	
6. Pedestrian on crosswalk	5.9%		3.5%
7. Single vehicle loss of control at exit	2.5%	2.6%	[2]
8. Exiting-entering	2.5%		
9. Rear-end in circulatory roadway	0.5%	1.2%	
10. Rear-end at exit	1.0%.	0.2%	
11. Passing a bicycle at entry	1.0%		
12. Passing a bicycle at exit	1.0%		
13. Weaving in circulatory roadway	2.5%	2.0%	
14. Wrong direction in circulatory roadway	1.0%		
15. Pedestrian on circulatory roadway	3.5%		[4]
16. Pedestrian at approach outside crosswalk	1.0%		[4]
Other collision types		2.4%	10.2%
Other sideswipe crashes		1.6%	

Notes:

1. Data are for “small” roundabouts (curbed central islands > 13 ft diameter).
2. Reported findings do not distinguish among single-vehicle crashes.
3. Reported findings do not distinguish among approaching crashes.
4. Reported findings do not distinguish among pedestrian crashes.

Three of the predominant types of collision are: (1) failures to yield at entry to circulating vehicles, (2) single vehicle run-off the circulatory roadway, and (3) single vehicle run-into the central island.

V. Geometric Design

Designing the geometry of a roundabout involves choosing between trade-offs of safety and capacity. Roundabouts operate most safely when their geometry forces traffic to enter and circulate at slow speeds. Horizontal curvature and narrow pavement widths are used to produce this reduced-speed environment. Conversely, the capacity of roundabouts is negatively affected by thee low-speed design elements. As the widths and radii of entry and circulatory roadway are reduced, so also the capacity of the roundabout is reduced. Furthermore, many of the geometric parameters are governed by the maneuvering requirements of the large vehicles expected to travel through the intersection. Thus, designing a roundabout is a process of determining the optimal balance between safety provisions, operational performance and large vehicle accommodation.

A. Design Process

The process of design roundabouts requires a considerable amount of iteration among geometric layout, operational analysis and safety evaluation. Small changes in geometry can result in substantial changes to operational and safety performance. Although it is easy to get caught in the desire to design each of the individual components of the geometry to comply with specifications, it is much more important that the individual components are compatible with each other so that the roundabout will meet its overall performance objectives.

The most critical design objective is achieving appropriate vehicular speeds through the roundabout. Increasing vehicle path curvature decreases relative speed between entering and circulating vehicles, but also increases side friction between adjacent traffic streams in multilane roundabouts.

The design speed of the roundabout is determined from the smallest radius along the fastest allowable path. The smallest radius usually occurs on the circulatory roadway as the vehicle curves to the left around the central island. However, it is important when designing the roundabout geometry that the radius of the entry path is not significantly larger than the circulatory path radius.

B. Speed-Curve Relationship

The relationship between travel speed and horizontal curvature is documented in the American Association of State Highway and Transportation Official's document, 'A policy on Geometric Design of Highways and Streets,' commonly known as the Green Book. The following equation can be used to calculate the design speed for a given travel path radius.

$$V^2 = 15R(e+f)$$

Where V = design speed, mph

R = radius, ft

E = superelevtion, ft/ft

F = side friction factor

Superelevation values are usually assumed to be +0.02 for entry and exit curves and –0.02 for curves around the central island.

Side friction factors can vary with vehicle speed but can be assumed 0.20 for most cases.

C. Design Vehicle

Another important factor determining a roundabout's layout is the need to accommodate the largest motorized vehicle likely to use the intersection. The turning path requirements of this vehicle, known as the "design vehicle," will dictate many of the roundabout's dimensions.

The choice of the design vehicle will vary depending upon the approaching roadway types and the surrounding land use characteristics. Commonly, WB-50 vehicles are the largest vehicles along collectors and arterials. Larger trucks, such as WB-67 vehicles, may need to be addressed at intersections on interstate freeways or state highway systems. Smaller design vehicles may often be chosen for local street intersections.

A truck apron may be used to provide additional traversable area around the central island for lard semi-trailers. Truck aprons, though, provide a lower level of operation than standard non-mountable islands and should be used only when there is no other means of providing adequate deflection while accommodating the design vehicle.

D. Non-Motorized Design Users

The design criteria of non-motorized potential roundabout users (pedestrians, bicyclists, wheelchair users, strollers, etc.) should be considered when developing many of the geometric elements of a roundabout design. These users span a wide range of ages and abilities that can have a significant effect on the design of a facility.

Key Dimensions of Non-Motorized Design Users		
User	**Dimension**	**Affected Roundabout Feature**
Pedestrians (walking)		
Width	1.6 ft	Sidewalk width, crosswalk width
Bicycles		
Length	5.9 ft	Splitter island width at crosswalk
Minimum operating width	4.9 ft	Bike lane width
Lateral clearance on each side	2.0 ft 3.3 ft to obstructions	Shared bicycle-pedestrian path width
Wheelchair		
Minimum width	2.5 ft	Sidewalk width, crosswalk width
Operation width	3.0 ft	Sidewalk width, crosswalk width
Person pushing stroller		
Length	5.6 ft	Splitter island width at crosswalk

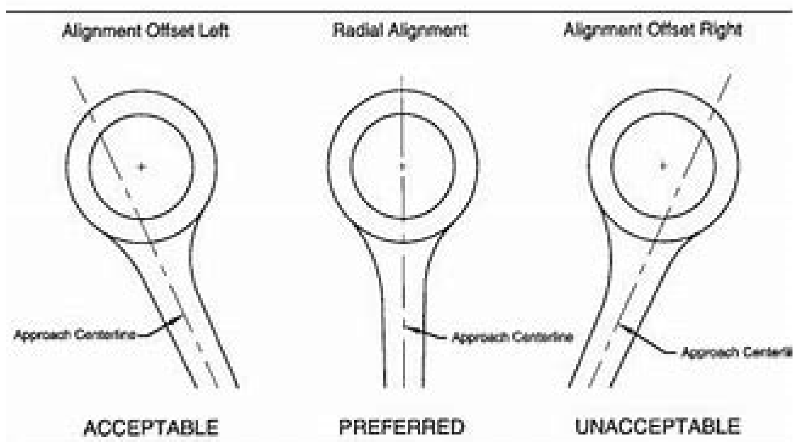
E. Alignment of Approaches and Entries

In general, the roundabout is optimally located when the centerlines of all approach legs pass through the center of the inscribe cir le. This location usually allows the geometry to be adequately designed so that vehicles will maintain slow speeds thorough both the entries and exits. The radial alignment also makes the central island more conspicuous to approaching drivers.

If it is not possible to align the left through the center point, a slight offset to the left (i.e., the centerline passes to the left of the roundabout's center point) is acceptable. This alignment will still allow sufficient curvature to be achieved at the entry, which is of supreme importance.

It is almost never acceptable for an approach alignment to be offset to the right of the roundabout's center point. This alignment brings the approach in at a more tangential angle and reduces the opportunity to provide sufficient entry curvature. Vehicles will be able to enter the roundabout too fast, resulting in more loss-of-control crashes and higher crash rates between entering and circulating vehicles.

The following is an illustration of the radial alignment of entries.



F. Geometric Elements

The specific parameters and guidelines for the design of each geometric element of a roundabout are not independent of each other. The interaction between the components of the geometry is far more important than the individual pieces. Care must be taken to ensure that the geometric elements are all compatible with each other so that the overall safety and capacity objectives are met.

1. Inscribed Circle Diameter

The inscribed circle diameter is the distance across the circle inscribed by the outer curb of the circulatory roadway. It is the sum of the central island diameter (which includes the apron, if present) and twice the circulatory roadway.

Recommended Inscribed Circle Diameter Ranges		
Site Category	**Typical Design Vehicle**	**Inscribed Circle Diameter Range**
Mini-Roundabout	Single-Unit Truck	45-80 ft
Urban compact	Single-Unit Truck/Bus	80-100 ft
Urban Single lane	WB-50	100-130 ft
Urban Double Lane	WB-50	150-180 ft
Rural Single Lane	WB-67	115-130 ft
Rural Double Lane	WB-67	180-200 ft

2. Entry Width

Entry width is the largest determinant of a roundabout's capacity. The capacity of the approach is not dependent merely on the number of entering lane, but on the total width of the entry. The entry capacity increases steadily with incremental increases to the entry width. Therefore, the basis sizes of entries and circulatory roadways are generally described in terms of width, not number of lanes. Entries that are of sufficient width to accommodate multiple traffic streams (at least 20 feet) are striped to designate separate lanes.

Entry width is measured from the point where the yield line intersects the left edge of the traveled-way to the right edge of the traveled-way, along a line perpendicular to the right curb line. The width of each entry is dictated by the needs of the entering traffic stream. The circulatory roadway must be at least as wide as the widest entry and must maintain constant width throughout.

To maximize the roundabout's safety, entry widths should be kept to a minimum. The capacity requirements and performance objectives will dictate that each entry be a certain width, with a number of entry lanes. In addition, the turning requirements of the design vehicle may require that the entry be wider still. However, larger entry and circulatory widths increase crash frequency. Therefore, determining the entry width and circulatory roadway width involves a trade-off between capacity and safety. The design should provide the minimum width necessary for capacity and accommodation of the design vehicle in order to maintain the highest level of safety. Typical entry width for single-lane entrances range from 14 to 16 feet.

3. Circulatory Roadway Width

The required width of the circulatory roadway is determined from the width of the entries and the turning requirements of the design vehicle. In general, it should also be at least as wide as the maximum entry width (up to 120 percent of the maximum entry width) and should remain constant throughout the roundabout.

4. Central Island

The central island of a roundabout is the raised, non-traversable area encompassed by the circulatory roadway; this area may also include a traversable apron. The island is typically landscaped for aesthetic reasons and to enhance driver recognition of the roundabout upon approach. Central islands should always be raised, not depressed, as depressed islands are difficult for approaching drivers to recognize.

In general, the central island should be circular in shape. A circular-shaped central island with a constant-radius circulatory roadway helps promote constant speeds around the central island. Oval or irregular shapes, on the other hand, are more difficult to drive and can promote higher speeds on the straight section and reduced speeds on the arcs of the oval. This speed differential may make it harder for entering vehicles to judge the speed and acceptability of gaps in the circulatory traffic stream. It can also be deceptive to circulating drivers, leading to more loss-of-control crashes.

In cases where right-of-way, topography, or other constraints preclude the ability to expand the inscribed circle diameter, a mountable apron may be added to the outer edge of the central island. This provides additional paved area to allow the overtracking of large semi-trailer vehicles on the central island without compromising the deflection for smaller vehicles.

5. Entry Curves

Entry curves are the et of one or more curves along the right burb (or edge of pavement) of the entry roadway leading into the circulatory roadway.

The entry radius is an important factor in determining the operation of a roundabout as it has significant impact on both capacity and safety. The entry radius, in conjunction with the entry width, the circulatory roadway width and the central island geometry, controls the amount of deflection imposed on a vehicle’s entry path. Larger entry radii produce faster entry speeds and generally result in higher crash rate between entering and circulating vehicles. In contrast, the operational performance of roundabouts benefits from larger entry radii.

The entry curve is designed curvilinearly tangential to the outside edge of the circulatory roadway. Likewise, the projection of the inside (left) edge of the entry roadway should be curvilinearly tangential to the central island. The primary objective in selecting a radius for the entry curve is to achieve the speed objectives.

6. Exit Curves

Exit curves usually have larger radii than entry curves to minimize the likelihood of congestion at the exits. This, however, is balanced by the need to maintain low speeds at the pedestrian crossing on exit. The exit curve should produce an exit path radius no smaller than the circulating path radius. If the exit path radius is smaller that the circulating path radius, vehicles will be traveling too fast to negotiate the exit geometry and may crash into the splitter island or into oncoming traffic in the adjacent approach lane. Likewise, the exit path radius should not be significantly greater than the circulating path radius to ensure low speeds at the downstream pedestrian crossing.

The exit curve is designed to be curvilinearly tangential to the outside edge of the circulatory roadway. Likewise, the projection of the inside (left) edge of the exit roadway should be curvilinearly tangential to the central island.

7. Pedestrian Crossing Location and Treatments

Pedestrian crossing locations must balance pedestrian convenience, pedestrian safety and roundabout operations.

- *Pedestrian Convenience*. Pedestrian want crossing locations as close to the intersection as possible to minimize out-of-direction travel. The further the crossing is from the roundabout, the more likely that pedestrian will choose a shorter route that may put them in greater danger.

- *Pedestrian Safety*. Both crossing location and crossing distance are important. Crossing distance should be minimized to reduce exposure of pedestrian-vehicle conflicts. Pedestrian safety may also be compromised at a yield-line crosswalk because driver attention is directed to the left to look for gaps in the circulating traffic stream. Crosswalks should be located to take advantage of the splitter island; crosswalks located too far from the yield line require longer splitter islands. Crossings should also be located at distances away from the yield line measure in increments of approximate vehicle length to reduce the chance that vehicles will be queued across the crosswalk.

- *Roundabout Operations*. Roundabout operations can also be affected by crosswalk locations, particularly on the exit. A queuing analysis at the exit crosswalk may determine that a crosswalk location of more than one vehicle length away may be required to reduce to an acceptable level the risk of queuing into the circulating roadway.

Pedestrian crossing should be design as follows:

- The pedestrian refuge should be a minimum width of 6 feet to adequately provide shelter for persons pushing a stroller or walking a bicycle.

- At single-lane roundabouts, the pedestrian crossing should be located one vehicle-length (25 feet) away from the yield line. At double –lane roundabouts, the pedestrian crossing should be located one, two, or three car lengths away from the yield line.

- The pedestrian refuge should be designed at street level, rather than elevation to the height of the splitter island. This eliminates the need for ramps within the refuge area which can be cumbersome for wheelchairs.

- Ramps should be provided on each end of the crosswalk to connect the crosswalk to other crosswalks round the roundabout and the sidewalk network.

- It is recommended that a detectable warning surface, as recommended in the Americans with Disabilities Act Accessibility Guidelines (ADAAG), be applied to the surface of the refuge within the splitter island.

Special care should be taken in the design of roundabouts located at existing school crossing locations. Adequate space should be provided to accommodate the crossing guard and groups of children.

8. Splitter Islands

Splitter islands should be provided on all roundabouts, except those with very small diameters at which the splitter island would obstruct the visibility of the central island. Their purpose is to provide shelter for pedestrians, assist in controlling speeds, guide traffic into the roundabout, physically separate entering and exiting traffic streams and deter wrong-way movements. Additionally, a splitter islands can be used as a place for mounting signs.

The total length of the island should generally be at least 50 feet to provide sufficient protection for pedestrians and to alert drivers to the roundabout geometry. Additionally, the splitter island should extend beyond the end of the exit curve to prevent exiting traffic from accidentally crossing into the path of approaching traffic. Larger splitter islands enhance safety but require that the inscribed circle diameter be increased.

9. Stopping Sight Distance

Stopping sight distance is the distance along a roadway required for a driver to perceive and react to an object in the roadway and to brake to a complete stop before reaching that object. Stopping sight distance should be provided at every point within a roundabout and on each entering and exiting approach.

$$d = (1.468)(t)(V) + 1.087(V^2/a)$$

Where: d = stopping sight distance, ft

t = perception-brake reaction time, assumed to be 2.5 s

V = initial speed, mph

a = driver deceleration, assumed to be 11.2 ft/s^2

Stopping sight distance should be measured using an assume height of driver's eye of 3.5 ft and an assume height of object of 2 ft.

At roundabouts, three critical types of locations should be checked at a minimum:

- Approach sight distance
- Sight distance on circulatory roadway
- Sight distance to crosswalk on exit

10. Bicycle Provisions

With regard to bicycle treatments, the designer should strive to provide bicyclists the choice of proceeding through the roundabout as either a vehicle or a pedestrian. In general, bicyclists are better served by treating them as vehicles. However, the best design provided both options to allow cyclists of varying degrees of skill to choose their more comfortable method of navigating the roundabout.

To accommodate bicyclists traveling as vehicles, bike lanes should be terminated in advance of the roundabout to encourage cyclists to mix with vehicle traffic. Under this treatment, it is recommended that the bike lanes end 100 feet upstream of the yield line to allow for merging with vehicles. This method is most successful at smaller roundabouts with speeds below 20 mph where bicycle speeds more closely match vehicle speeds.

To accommodate bicyclists who prefer not to use the circulatory roadway, a widened sidewalk or a shared bicycle/pedestrian path may be provided physically separated from the circulatory roadway. Ramps leading to a shared pathway can be used to accommodate bicyclists traveling as pedestrians. The designer should exercise care in locating and designing the bicycle ramps so that they are not misconstrued by pedestrians as an unmarked pedestrian crossing.

11. Sidewalk Treatments

Where possible, sidewalks should be set back from the edge of the circulatory roadway in order to discourage pedestrians from crossing to the central island. A recommended setback distance of 5 feet should be used and the area between the sidewalk and curb can be planted with low shrubs or grass.

VI. Traffic Design

A. Signing

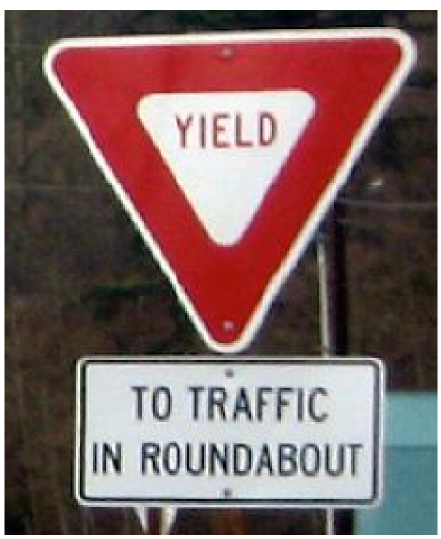
The overall concept for roundabout signing is similar to general intersection signing. Proper regulatory control, advance warning and directional guidance are required to avoid driver expectancy related problems. Signs should be located where they have maximum visibility for roads users but a minimal likelihood of obscuring pedestrians who are the most vulnerable of all roundabout users. Signing needs are different for urban and rural applications and for different categories of roundabouts. Refer to the 'Manual on Traffic Control Devices' (MUTCD) for signing specifics.

Regulatory Signs

A number of regulatory signs are appropriate for roundabouts and are described below.

Yield Sign

A yield sign is required at the entrance to the roundabout. For single-lane approaches, one yield sign placed on the right side is sufficient. For approaches with more than one lane, the designer should place yield signs on both the left and right side of the approach. This practice is consistent with the recommendations of the MUTCD on the location of stop and yield signs on single-lane and multilane approaches. To prevent circulating vehicles for yielding unnecessarily, the face of the yield sign should not be visible from the circulatory roadway.



One Way Sign

One way signs may be used in the central island opposite the entrances. The one way sign may be supplemented with chevron signs to emphasize the direction of travel within the circulatory roadway.

Warning Signs

A number of warning signs are appropriate for roundabouts. The amount of warning a motorist needs is related to the intersection setting and the vehicular speed on approach roadways. The specific placement of warning signs is governed by the MUTCD.

Circular Intersection Sign

A circular intersection sign may be installed on each approach in advance of the roundabout. When used, it is recommended that the sign be modified to reflect the number and alignment of approaches.

It is also recommended that an advisory speed place be used with this sign. The speed given on the advisory sped plate should be no higher that the design speed of the circulatory roadway.

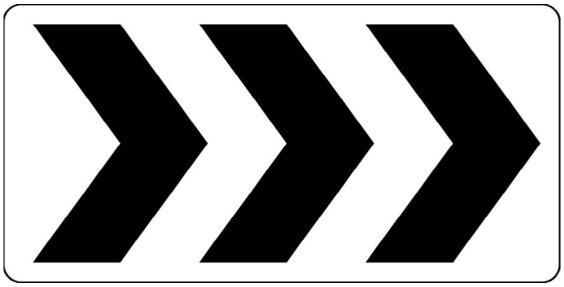
The roundabout ahead sign is an alternative to the circular intersection sign. At a minimum it is recommended that the roundabout ahead sign be used in place of the circular intersection sign at mini-roundabouts.

Yield Ahead Sign

A yield ahead sign should be used on all approaches to a roundabout in advance of the yield sign. These signs provide drivers with advance warning that a yield sign is approaching. They should be placed 100' to 150' in advance of the yield sign.

Chevron Plate

The large arrow may be supplemented or replaced by a long chevron board to emphasize the direction of travel within the circulatory roadway.



Pedestrian Crossing

Pedestrian crossing signs may be used at pedestrian crossing within a roundabout at both entries and exits. Pedestrian crossing signs should be used at all pedestrian crossings at double-lane entries and double-lane exits.

Lane Control Signs

Lane control signs can be customized for any roundabout configuration providing positive guidance to the driver as to the designation of each lane.

Guide Signs

Guide signs are important in providing drivers with proper navigations information. This is especially true at roundabouts where out-of-direction travel may disorient unfamiliar drivers. A number of guide signs are appropriate for roundabouts.

Advance Destination Guide Signs

Advance destination guide signs should be used in all rural locations and in urban/suburban areas where appropriate. The sign should be either a destination sign using text or use diagrams. Diagrammatic signs are preferred because they reinforce the form and shape of the approaching intersection and make it clear to the driver how they are expected to navigate the intersection.

Exit Guide Signs

Exist guide signs are recommended to designate the destination of each exit from the roundabout. These signs are conventional intersection direction signs or directional route marker assemblies that can be place either on the right-hand side of the roundabout exit or in the splitter island.

1. Rural and Suburban Signing Considerations

Rural and suburban conditions are characterized by higher approach speeds. Route guidance tends to be focused more on destinations and numbered routes rather than street names.

In cases where high speeds are expected (in excess of 50 mph) and the normal signage and geometric features are not expected to produce the desired reduction in vehicle speeds, the following measure may also be considered:

- Large advance warning signs
- Addition of hazard identification beacons to approach signing
- Use of rumble strips in advance of the roundabout
- Use of speed warning signs triggered by speeds exceeding an acceptable threshold

B. Pavement Markings

Typical pavement markings for roundabouts consist of delineating the entries and the circulatory roadway.

1. Approach and Entry Pavement Markings

Approach and entry pavement markings consist of yield lines, pavement word and symbol markings, and channelization markings. In addition, multilane approaches require special attention to pavement markings.

2. Yield Lines

Yield lines should be used to demarcate the entry approach from the circulatory roadway. Yield lines should be located along the inscribed circle at all roundabouts except mini-roundabouts. No yield lines should be placed to demarcate the exit from the circulatory roadway.

The recommended yield line pavement marking is a broken line treatment consisting of 16 inch wide stripes with 3 ft segments and 3 ft gaps.

More recently, yield line marking consisting of a series of white triangles (known as "shark's teeth). These markings tend to be more visible to approaching drivers.

3. Pavement Word and Symbol Markings

In some cases, the designer may want to consider pavement word or symbol markings to supplement the signing and yield line marking. This typically consists of the word YIELD painted on the entrance to the roundabout immediately prior to the yield line.

4. Circulatory Roadway Pavement Markings

In general, lane lines should not be striped within a single lane circulatory roadway. Circulatory lane lines should be striped in a multi-lane circulatory roadway.

VII. Illumination

For a roundabout to operation satisfactorily, a driver must be able to enter the roundabout, move through the circulating traffic and separate from the circulating stream in a safe and efficient manner. To accomplish this, a driver must be able to perceive the general layout and operation of the intersection in time to make the appropriate maneuvers. Adequate lighting should therefore be provided at all roundabouts.

Need for Illumination

The need for illumination varies somewhat based on the location in which the roundabout is located.

Urban conditions

In urban settings, illumination should be provided for the following reasons:

- Most if not all approaches are typically illuminated.
- Illumination is necessary to improve the visibility of pedestrians and bicyclists.

The following shows the use of high mast lighting in an urban setting.

Suburban conditions

For roundabouts in suburban settings, illumination is recommended. For safety reasons, illumination is necessary when:

- One or more approaches are illuminated.
- An illuminated area in the vicinity can distract the driver's view.
- Heavy nighttime traffic is anticipated.

The following shows the use of traditional street lighting in a suburban setting.

Rural conditions

For rural roundabouts, illumination is recommended but not mandatory.

Recommended Street Illumination Levels			
Street Classification	**Area Classification**	**Average Maintained Illuminance Values (footcandles – fc)**	**Illuminance Uniformity Ratio (Average to Minimum)**
Arterial	Commercial	1.7 fc	3 to 1
	Intermediate	1.3 fc	
	Residential	0.9 fc	
Collector	Commercial	1.2 fc	4 to 1
	Intermediate	0.9 fc	
	Residential	0.6 fc	
Local	Commercial	0.9 fc	6 to 1
	Intermediate	0.7 fc	
	Residential	0.4 fc	

VIII. Landscaping

Landscaping in the central island, in splitter islands and along the approaches can benefit both public safety and community enhancement.

Advantages

The landscaping of the roundabout and approaches should:

- Make the central island more conspicuous
- Improve the aesthetics of the area
- Minimize introducing hazards to the intersection, such as trees, poles, walls, guide rail, statues or large rocks
- Avoid obscuring the form of the roundabout or the signing to the driver
- Maintain adequate sign distances
- Clearly indicate to the driver that they cannot pass straight through the intersection
- Discourage pedestrian traffic through the central island

Central Island Landscaping

The central island landscaping can enhance the safety of the intersection by making the intersection a focal point and by lowering speeds. Plant material should be selected so that sight distance is maintained, including consideration of future maintenance. Large, fixed landscaping (trees, rocks, etc.) should be avoided in areas vulnerable to vehicle runoff.

The following illustrates the use of low height ground cover to add to the aesthetics of the roundabout without sacrificing sight distance.

Splitter Island and Approach Landscaping

In general, unless the splitter islands are very large or long, they should not contain trees, planters or light poles. Care must be taken with the landscaping to avoid obstructing sight distance, as the splitter islands are located within the critical sight triangle.

Roundabout Design - Quiz

Updated: 9/21/2020

1. _________ are circular intersections with specific traffic control features including yield control of all entering traffic, channelized approaches and appropriate geometric curvature to ensure low travel speeds.

a. rotaries

b. neighborhood traffic circles

c. roundabouts

d. all of the above

2. Potential safety benefits of low vehicle speeds in roundabouts include all the following, except:

a. provide more time for entering drivers to judge gaps in circulatory traffic

b. reduce crash severity

c. difficulty in merging

d. make collisions less frequent

3. Which type of roundabout is a small roundabout used in low-speed urban environments designed to accommodate passenger cars.

a. mini

b. urban compact

c. urban single lane

d. rural single lane

4. Roundabouts usually require less space for the circular roadway and central island than the rectangular space inside traditional intersections.

a.True

b.False

5. Roundabouts allow pedestrians access to the central island.

a.True

b.False

6. Pedestrian crossings should be set back from the yield line by one or more vehicle lengths for all the following reasons, except:

a. separate vehicle-vehicle and vehicle-pedestrian conflict points

b. make pedestrians cross between vehicles

c. shorten the crossing distance compared to locations adjacent to the inscribed circle

d. allow the second entering driver to devote full attention to crossing pedestrians

7. Approach speed is governed by all the following, except:

a. approach grade

b. approach roadway width

c. roadway curvature

d. approach volume

8. Roundabouts should be designed to operate at no more than ___% of their estimated capacity.

a. 75

b. 80

c. 85

d. 90

9. An exit flow exceeding _______ veh/h may indicate the need for a double-lane exit.

a. 1100

b. 1200

c. 1300

d. 1400

10. Key performance measures for roundabouts include all the following, except:
a. speed
b. queue length
c. delay
d. degree of saturation

11. A four-leg single-lane roundabout has ___% fewer vehicle conflict points compared to a conventional intersection.
a. 65
b. 70
c. 75
d. 80

12. Which of the following types of conflicts are reduced or eliminated with the addition of a roundabout?
a. right-turn
b. merging
c. diverging
d. crossing

13. In a roundabout, all movements are given equal priority.
a. True
b. False

14. The collision type with the greatest percentage at roundabouts is:
a. rear-end at exits
b. failure to yield at entry
c. circulating-exiting
d. weaving in circulatory roadway

15. The three predominant types of collisions at roundabouts consist of all the following, except:

a. single vehicle run-off the circular roadway

b. failure to yield at entry to circulating vehicles

c. single vehicle run info the central island

d. single vehicle loss of control at exit

16. Calculate the appropriate radius (to the nearest 10) for a roundabout with a design speed of 30 mph, superelevation of +0.02 and coefficient of friction of 0.20.

a. 130

b. 150

c. 270

d. 300

17. A superelevation of ___ should generally be used for entry and exit curves around the central island.

a. 0.02

b. 0.00

c. 0.01

d. 0.02

18. _________ is the largest determinant of a roundabout's capacity.

a. entry width

b. inscribed circle diameter

c. central island diameter

d. circulatory roadway width

19. Central islands are all the following, except:

a. landscaped

b. depressed into the ground

c. a non-traversable area

d. circular in shape

20. The pedestrian refuge should be a minimum width of ___ feet to adequately provide shelter for persons pushing stroller or walking a bicycle.

a. 4

b. 6

c. 8

d. 10

21. Splitter islands should be provided at all roundabouts to do the following:

a. provide shelter for pedestrians

b. deter wrong way movements

c. physically separate entering and exiting traffic streams

d. all of the above

22. Calculate the stopping sight distance, rounded to the nearest ten, using an initial speed of 40 mph, perception-brake reaction time of 2.5 sec, and driver deceleration of 11.2 ft/sec^2.

a. 200

b. 250

c. 300

d. 360

23. In urban settings, the Yield Ahead warning sign should be placed ________ in advance of the Yield sign depending on approach speed.

a. 25’-50’

b. 50’-100’

c. 100’-150’

d. 150’-200’

24. Lane lines should be striped within a single lane circulatory roadway.

a. True
b. False

25. Landscaping in the central island can provide all the following advantages, except:

a. improve the aesthetics of the area

b. make the central island more conspicuous

c. clearly indicated to the driver that they cannot pass straight through the intersection

d. encourage pedestrian traffic through the central islan