THE ROUNDABOUT: A DIFFERENT MODE OF MANAGEMENT

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SUMMARY

The Québec road system was primarily developed in the 60s and 70s. This system has now reached maturity. The constant increase in trips and the number of vehicles on Québec roads and highways has led to saturation of part of the road system, reducing traffic flow and increasing delays at certain intersections and interchanges. In the road traffic management field, the roundabout concept has resurfaced as a solution to this type of problem, in a more modern version that can be adapted to the setting.

Based on the experience of several road administrations and numerous exhaustive studies, a guide entitled *Le carrefour giratoire: un mode de gestion différent*, was published in 2002 by the Ministère des Transports du Québec. This guide brings together all the necessary information for designing a roundabout. Based on the elements of this guide, a ten-stage design method has been produced to standardize the study of projects and the preparation and development of roundabouts in Québec. These stages successively cover the selection of the main design criteria, the determination of the physical features, the location and dimensions of the roundabout, the design of the splitter islands, the estimation of vehicle transit and speed, sight distances, the capacity and saturation study, road markings, traffic control devices, and lighting as needed.

Obviously, the case studies and experience in the field should help improve the guide and eventually lead to its standardization.

Introduction

The development of the Québec road system boomed in the 60s and 70s. This system has now reached maturity. The constant increase in trips and the number of vehicles on Québec roads and highways has led to saturation of part of the road system, making traffic less fluid and increasing delays. In the road traffic management field, the roundabout concept has resurfaced as a solution to this type of problem, in a more modern version that can be adapted to the setting.

This document succinctly presents the main points discussed in a guide entitled *Le carrefour giratoire: un mode de gestion différent*, published by the Ministère des Transports du Québec in 2002. This guide seeks to provide designers with the basic information necessary for the development of roundabouts. It is the product of the combined experience of various road administrations in Europe, in North America and Oceania. Of course, the analysis of these experiences has considered the characteristics of the Québec road system and its special winter operating conditions.

Québec no longer asks whether roundabouts are effective. They have already been integrated into the intersection selection process for road redevelopment projects or creation of new intersections. The classes and characteristics of roundabouts and certain characteristics of the sites to be considered are presented here as a starting point. We then presented the various aspects to consider and a roundabout design method.

Characteristics of a roundabout

Some see no difference between a traffic circle and a roundabout. But in fact, the rules of the road and site development differ greatly. These differences concern several points: the method of control at the entrances; the deflection of the natural trajectory of the vehicles; parking in the circulatory roadway; passage for pedestrians and cyclists and the splitter islands at the entrances. For each of these points, the differences are as follows:

- drivers entering a roundabout must yield the right of way to those already driving in the circulatory roadway, while in the case of traffic circle drivers entering the circulatory roadway have priority;
- to reduce the speed differential between drivers entering a roundabout and those already driving in it, deflection is imposed on the drivers entering it, while such a deflection is not imposed in the case of a traffic circle. In fact, in a traffic circle, the design provides for high speeds to favor intersecting;
- parking of vehicles is prohibited in a roundabout, while it may be permitted in a traffic circle;

- pedestrian traffic to cross the central island of a roundabout is prohibited, while it may be permitted in a traffic circle;
- a roundabout is characterized by the compulsory presence of splitter islands at each road, while they are optional in a traffic circle;
- a roundabout is essentially a road development, to which a landscaping component is added. A traffic circle may be a public place or a park, and the road component is secondary.

These characteristics have the advantage of making the roundabout safer, while improving the flow of traffic. Figure 1 presents the physical components of a roundabout.

Classes of roundabouts

There are several types of roundabouts: mini, small, medium and large. Each type has its own geometry, but the primary characteristic differentiating them is their radius, measured from the centre of the central island to the outer limit of the roundabout. Another distinguishing characteristic is the speed entering the circulatory roadway, which is directly proportional to its dimension. The guide provides rules for development of each of these types of roundabouts.

Mini roundabouts are generally developed in residential neighbourhoods to reduce speed on streets reserved for local traffic or discourage through traffic. The roundabout's geometric components are plotted and the central island, raised and slightly convex, is textured and completely mountable. This layout is proposed in the guide but is poorly suited to the Québec climate, because the central island disappears under the snow.

Small roundabouts are developed on streets reserved for local traffic and urban municipal collector streets. They are very well suited to pedestrians and cyclists because of their raised splitter islands. A small roundabout is used on thoroughfares that mainly have car traffic and where there is only a small percentage of single unit (SU) trucks and buses. Its central island is nonmountable, thanks to a raised mountable curb.

Medium roundabouts are characterized by single-lane approach roads and single-lane circulatory roadway. They have a greater radius than small roundabouts and their entrances and exits are more tangential, assuring better flow. Developed in urban areas, they may include sidewalks, a bicycle path, pedestrian crossings and landscaping adapted to the setting. In rural areas, the radius will be increased and approaches will be developed to reduce vehicular speed.

A large roundabout is reserved for sectors with few pedestrians and cyclists, because it is less safe for them. It is primarily developed on national highways, where heavy vehicle traffic is significant. Its broader entrances and exits may have more than one lane. Its circulatory roadway, which does not have a mountable curb, is wider, allowing two vehicles to circulate. The geometry of this type of roundabout allows higher speeds, obliging the designers to pay special attention to the approaches, which generally must be lengthened to channel the traffic better.

Table 1 gives the radius and the recommended entrance speed for each class of roundabout, depending on the environment where it is developed.

For safety reasons, there must be a speed differential of less than 20 km/h between the vehicles entering and already driving in the circulatory roadway. To accomplish this, physical features must be installed to reduce vehicular speed in the approach to the intersection. The geometry of the approach and the radius and width of the entrance are geometric components that compel drivers to slow down and guide them into the circulatory roadway. Once they are in the circulatory roadway, the radius of the circulatory roadway controls their speed. The width and radius of the exit then control vehicular speed leaving the circulatory roadway.

Characteristics of the development site

A roundabout can be developed in every type of urban, periurban or rural environment, even when traffic speeds are high. This type of intersection can also be developed on all classes of roads. Table 2 presents the possibilities of development of roundabouts by road class. A roundabout can also be developed on multi-lane highways. In the specific case of four-lane highways, the roundabout is very well suited to serve as the end of an axis or as a transition between two environments (rural and urban) when the intersection is not graded.

Numerous data must be considered in designing a roundabout layout, particularly:

- the environment where the roundabout will be developed (rural, urban (residential, commercial, industrial, institutional or mixed), periurban);
- the topography of the site (a longitudinal slope over 6% makes it difficult for heavy vehicles to start and can reduce visibility);
- traffic (flows, percentage of oversized and overweight vehicles, the large number of left turns or U-turns, the presence of a reserved public transit lane);
- classes of uses (crossings for pedestrians, cyclists and people with handicaps, percentage of heavy vehicles);
- rights-of-way at the intersection (acquisition or expropriation for widening of the rights-of-way);

- safety (the high frequency of serious accidents and side impact collisions may justify development of a roundabout);
- costs (they increase with the size of the roundabout; savings on traffic lights compared to ordinary intersections).

Design aspects

Once the characteristics of the site where the roundabout will be developed are known, the design aspects must be considered. These aspects determine the conditions of the roundabout's development.

These aspects particularly include the roundabout's future users: types of vehicles, cyclists, pedestrians and people with functional limitations. The roundabout's geometry, dimensions, lighting, marking, traffic control devices, landscaping and maintenance are studied. Construction costs are another aspect weighing in the analysis. They vary depending on the characteristics of the road, the setting, the size of the roundabout, etc. Finally, the evaluation focuses on the social benefits, safety and points favorable to the environment.

The best way to integrate the characteristics of the site and the design aspects of a roundabout, while standardizing the analytical process throughout a territory, is to apply a design method.

Design method

All these aspects are integrated into an iterative design method. The iterative design method or process, to some extent, is the search for a compromise between capacity and safety. Even a minor change to the geometry of one component of the roundabout can considerably alter the safety and performance level, because the geometric components are not mutually independent. The interaction of all of the roundabout's geometric components is far more important than the effect of each of them taken individually.

The design parameter that most influences a roundabout's safety is the speed of the vehicles that drive in it. This speed is determined by the fastest route a driver can adopt depending on the roundabout's geometry. The optimal design speed achieves a balance between safety and capacity. A low uniform speed of vehicles driving in the circulatory roadway simplifies weaving maneuvers, improves user safety, reduces the gap necessary to enter traffic and optimizes the roundabout's capacity.

The proposed roundabout design method involves ten stages.

Stage 1: Selecting the principal design criteria

Selecting a design vehicle plays a crucial role in designing a roundabout. After analysis that provisionally determines the outer radius and the alignment of the roads to be connected to the roundabout, a template or specialized software must be used to simulate the passage of the design vehicle. The roundabout must allow trips by the design vehicle and the tight passage of a typical vehicle of a higher class. Table 3 shows the relationship between the design vehicle, the type of roundabout and the outer radius (Rg). The passage of oversized and overweight vehicles must also be considered when no bypass road exists.

The simulated passage of the design vehicle makes it possible to verify the radius and width of the entrance and exit lanes, the width of the circulatory roadway and the inner radius defining the central island, and, if necessary, provide for a mountable curb.

A summary analysis of the roundabout’s capacity must be used to determine the number of lanes necessary in the entrances, in the exits and in the circulatory roadway. For this purpose, one of the existing calculation methods must be applied to analyze each road of the roundabout, entrance by entrance, considering the roundabout as a series of T intersections. The capacity of an entrance depends on the traffic flow in the circulatory roadway and the presence of long enough gaps to access it. The roundabout’s capacity is influenced by the volume of priority traffic, the way that motorists judge the gaps available, the presence of pedestrians and cyclists, the distribution of movements and the distribution of traffic between axes.

During this stage, the layouts required for pedestrians and cyclists must be defined. It is recognized that roundabouts are safer for pedestrians. However, large roundabouts or those with multiple entrance and exit lanes require special layouts for pedestrians and cyclists on each road. A raised splitter island at the approaches to each road is essential to indicate the crossings for pedestrians and cyclists clearly and allow them to cross in two stages. Crossings for visually impaired persons require special layouts: reduction of the width of the entrance lanes, elevated crossing, warning markings, surface treatment of sidewalks and refuge islands, and pedestrian lights with push buttons and audible signals. Cyclists are considered to be the most vulnerable users. It may sometimes be justified to prohibit bicycle access to the roundabout and develop a bicycle path outside the circulatory roadway, or allow them to use the pedestrian crossings.

The roundabout’s landscaping, apart from its esthetic function, should help make the route more legible for motorists. The design of any landscaping must consider safety by ensuring good visibility for all users.

Stage 2: Analyzing the site

This stage is the time to analyze the site of the roundabout. Several points must be covered: it is essential to define the property lines and locate any existing public utility equipment, trees, urban furniture, parking and accesses to establish the right-of-way, whether available or to be acquired, to build the roundabout and its connecting roads.

Stage 3: Determining the physical components

It is recognized that a roundabout's safety increases as its size diminishes. The selection of the length of the outer radius must therefore consider the setting, the characteristics of the site, the road class, the entrance speed and the projected traffic (see Table 1).

The circulatory roadway width is calculated according to the length of the outer radius, the width and the number of lanes of the widest entrance, and the design vehicle. The width of the circulatory roadway must be uniform to ensure the roundabout's legibility for users and safe maneuvering. In the absence of a mountable curb, the circulatory roadway must be a minimum of 7 m wide and no smaller than the widest entrance.

The radius of the central island depends on the outer radius and the width of the circulatory roadway. The centre of the island must be located on the main axis of the roundabout, and ideally on the secondary axes as well.

Stage 4: Verifying the location and size of the roundabout

Connecting the roads of a roundabout is a crucial stage in determining its location. The best alignment for a roundabout is obtained when the centre line of the connecting roads passes through the centre of the central island. This alignment makes it possible to balance the speeds in the roundabout. If the ideal alignment is impossible, the entrance lanes must be shifted to the left of centre, to deflect the vehicles entering the roundabout. Special attention must then be paid to the exit lanes. Figure 2 shows the alignment of the approaches.

The development of the entrances and exits determines the speed at which the vehicles enter and leave the roundabout. The width of the entrances must therefore be considered as a determining factor of the roundabout's capacity and safety. The width of the entrance, established on the basis of simulated turns, will have a determining influence on its capacity. For safety purposes, the entry radius must compel drivers to slow down to maintain a speed differential of less than 20 km/h in relation to the vehicles already driving in the circulatory roadway. This radius ranges between 8 m and the length of the roundabout's outer radius. The length of the exits is generally between 5.75 m and 7.5 m. The exit radius must be greater than the entry radius to reduce the risks of congestion at the exit. In urban areas, the exit radius should be less than 15 m, so that the exit speed does not exceed 40 km/h. In rural areas, the exit radius may be greater than 15 m on condition that there are no pedestrians.

Stage 5: Designing the splitter islands

Splitter islands are compulsory physical components of roundabout design. Their geometry plays a determining role in the roundabout's functionality, capacity and safety. These triangular splitter islands fill the space between the entrance lane and the exit lane of each road of the roundabout and allow pedestrians to take refuge when crossing the intersection. There are two design methods for entrance and exit lanes and splitter islands in roundabouts.

The first method is to determine the approximate length of the entrance and exit radii, establish the entrance and exit lanes and develop the splitter island in the space available between the lanes and the circulatory roadway. The geometry can be modified by trial and error to obtain the recommended speed for vehicles in the roundabout entrance and exit lanes.

The second method proceeds in the opposite direction. The splitter island is constructed first, followed by the entrance and exit lanes and the corresponding radii. To ensure that the splitter island has the right dimensions in relation to the radius of the roundabout and that the entrance lane's deflection is adequate, a construction triangle may be used as a guide for the designer. This triangle is constructed on the axis of the approach road, which corresponds to its height, while the edge of the circulatory roadway is its base.

Stage 6: Simulation

It is now time to verify traffic maneuvers in the entrance, in the exit and in the circulatory roadway, using simulation software for the design vehicle. The test is then performed with a vehicle of a higher class, to detect whether there are any obstacles to movements and so that the necessary adjustments can be made to the roundabout's geometry. If oversized and overweight vehicles must use the roundabout, it is essential to ensure that they can pass through it by providing for special layouts.

Stage 7: Standardizing speed in the roundabout

At this stage of the design process, it is essential to verify the effectiveness of deflection at the roundabout entrance to reduce the entrance speed. The roundabout's geometry must not allow a speed greater than the one recommended for this class of roundabouts (see Table 1). It is also important to verify the uniformity of speeds in the roundabout. Standardizing the speeds in the roundabout can reduce the number and severity of accidents attributable to differences in speed.

Stage 8: Verifying sight distances

Since there is no compulsory stop at the entrance to a roundabout, the vehicles driving in the circulatory roadway must be visible to the drivers who want to enter it. The same principle applies to visibility for drivers on the outskirts of the circulatory roadway, in which the central island must not contain high components that can obstruct the view.

A constant sight triangle is thus available for drivers within the circulatory roadway. The visibility criteria to be maintained in a roundabout are stopping sight distance and intersection sight distance.

Stopping sight distance depends on the speed of the vehicles. It must totally conform to standards in the entrance and exit lanes and in the circulatory roadway. The stopping sight distance must be maintained in approaching the intersection, in relation to the "Yield" line and the pedestrian crosswalk. Figure 3 illustrates the sight distances to be maintained.

Intersection sight distance is the field of vision allowing the driver approaching the intersection to perceive and react safely in case of potential conflicts with other vehicles. Figure 4 illustrates the entrance and traffic sight distance.

Stage 9: Studying capacity and saturation

The capacity of a roundabout is determined by its geometric characteristics, the number of entrance lanes, the width of the circulatory roadway, the widening distance, the outer radius of the circulatory roadway, the entry radius and the entrance angles. Waiting time and geometric delay are two parameters that inform us of the quality of service at an intersection. Geometric delay is greater at a roundabout than at a conventional intersection. However, waiting time is often nil, because motorists do not have to make a compulsory stop. The absence of a compulsory stop and a favourable gap are two factors that contribute to traffic flow and reduce the queue storage space necessary at the approaches.

Stage 10: Finishing

The purpose of this stage is to complete the geometric design of the entrances and exits and the details of the splitter islands, such as the radii and the clearance of the approach noses. An iterative process (verification – modification – verification) is necessary to arrive at the final geometry of the roundabout.

Special layouts for the safety of pedestrians and cyclists are also completed.

The horizontal traffic control devices to be used to guide the drivers must be established according to the standards in force. The edge lines of the roads and splitter islands, the outer edge line of the circulatory roadway and the edge line of the central island, when there is no mountable curb, must be marked. The entrance and exit lanes must also be bounded by markings. "Yield" lines must also be marked at the entrances to the roundabout's roads, in continuity with the outer edge line of the circulatory roadway.

Vertical traffic control devices are also mandatory at the roundabout's approaches to signal a change in the downstream route, and within the roundabout to tell drivers which roads to take depending on their destination. Figure 5 presents all the horizontal and vertical traffic control devices that must be used in the roundabout and at its approaches.

Regarding lighting, it is recommended that all roundabouts be lit adequately, except those in rural areas where power distribution may not be available. In some cases, it is necessary to light a roundabout when: one or more of the roads are already lit; there are lit areas nearby; there is high night-time traffic; or there are pedestrians and cyclists. The location of the lighting equipment requires special care to ensure lighting of the splitter islands, the convergence and divergence zones and the crossings for pedestrians and cyclists.

Conclusion

The roundabout concept applied today is a revised, corrected and modernized version of the old roundabout concept. The roundabout appears to be a solution to traffic problems on saturated networks, where there is a lack of fluidity at intersections and interchanges. The conversion of conventional intersections into roundabouts should become widespread in the years ahead. Moreover, this type of conversion can be scalable, since the layouts can be adapted to the setting as needed according to the changing vocation of the roads, trips by road users or traffic.

Based on the experience of several road administrations and numerous exhaustive studies, the guide entitled *Le carrefour giratoire: un mode de gestion différent*, published in 2002 by the Ministère des Transports du Québec, brings together all the necessary information for designing a roundabout. Based on the elements of this guide, a ten-stage design method has been produced to standardize the study and preparation of projects and the development of roundabouts in Québec.

Some points still remain unresolved. This is particularly the case regarding the priority to be given to vehicles driving and turning on a multi-lane circulatory roadway. Another point concerns the method of developing a roundabout's physical components, the splitter islands and the central island. Some opt for a trial period, when these layouts are marked or bounded by removable curbs, so that they can be adjusted before and after debugging. Others prefer to go into more detail in the draft design study or extend the data gathering period to develop the roundabout in one stage, subject to later review.

We must now continue the experimentation and document the development of other roundabouts in Québec. It will thus be possible for us to revise the guide and flesh it out with additional new chapters on the transition period between the old intersection and the new roundabout, the communications strategy prior to development of a new roundabout, etc.

References

Ministère des Transports du Québec, *Le carrefour giratoire: un mode de gestion différent*, 145 pp., Québec, 2002.

Table 1 Classes of roundabouts

Type of roundabout	**Setting**	**Roundabout radius *(m)**	**Entrance speed (km/h)**
Mini roundabout	Urban	6 to 12	25
Small roundabout	Urban	12 to 15	25
Medium roundabout**	Urban Rural	15 to 20 17 to 25	35 40
Large roundabout**	Urban Rural	20 to 27 25 to 30	40 50

* The roundabout's outer radius is usually the dimension of reference.

**In periurban settings, the roundabout can be treated as an urban type or a rural type, as the case may be. The radius will vary according to the concept chosen, i.e. one lane or two lanes.

Table 2 Possibilities of development of roundabouts by road class

	National and regional highways, arteries	Collector roads	Municipal collectors	Local streets
National and regional highways, arteries	+*	+	-	-**
Collector roads	+	+	+	+
Municipal collectors	-	+	++	+
Local streets	-**	+	+	++

++ : very appropriate + : appropriate - : inappropriate

* The development of a graded roundabout is justified when the capacity of the road is reached, or for safety reasons.

** In principle, this type of roundabout should not be installed.

Table 3 Relationship between the design vehicle, the type of roundabout and the outer radius (Rg)

Design vehicle	**Type of roundabout and setting**	**Outer radius, Rg* (m)**
Car and SU truck	Mini urban roundabout	6 to 12
SU truck and bus	Small urban roundabout	12 to 15
WB-15 and WB-17	Medium urban roundabout	15 to 20
WB17-TST	Medium rural roundabout	17 to 25
WB17-TST	Large urban roundabout	20 to 27
TST and WB-20	Large rural roundabout	25 to 30

* For a roundabout with four symmetrical roads. These values may vary according to other characteristics of the roundabout (mountable or unmountable circulatory roadway, width of entrances, etc.).

Note: verification against the turning templates is necessary.

Figure 1 Physical and geometric components of a roundabout

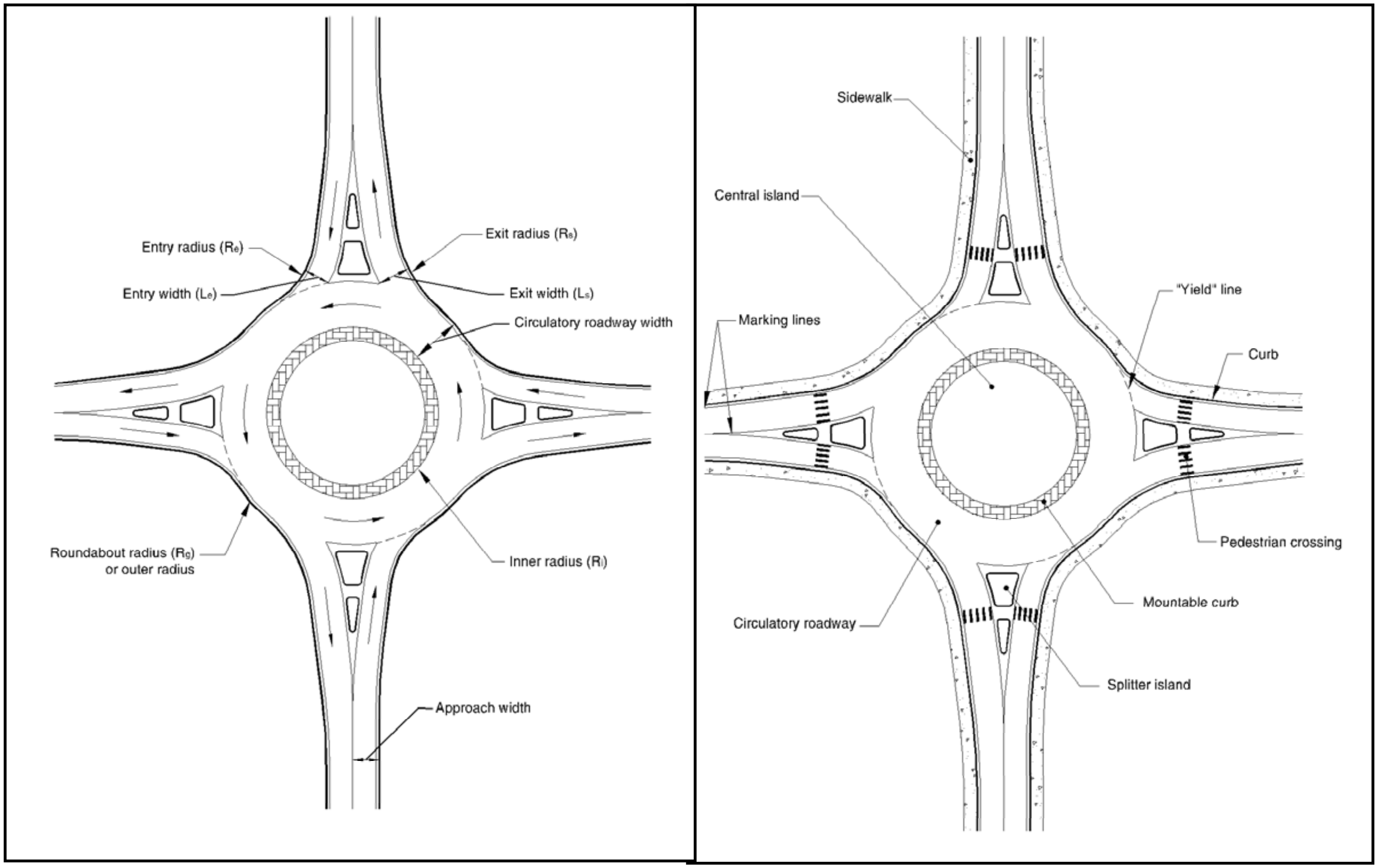

Figure 2 Alignment of the approaches

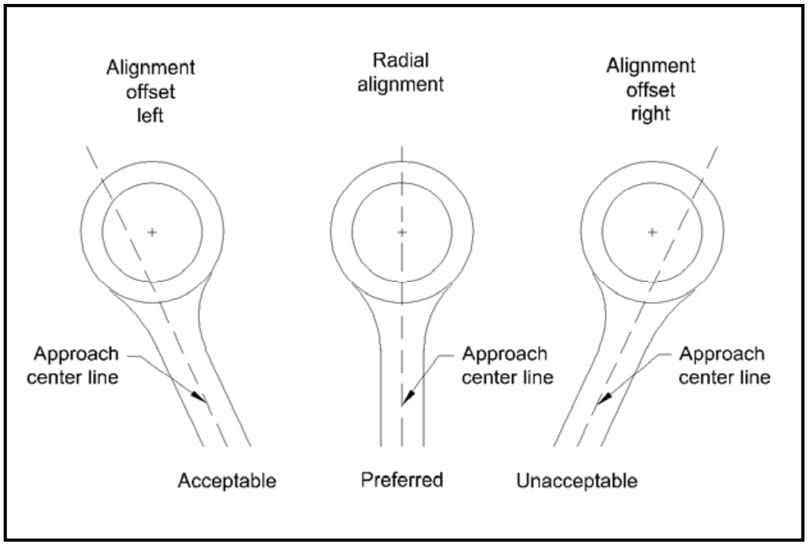

Figure 3 Stopping sight distance

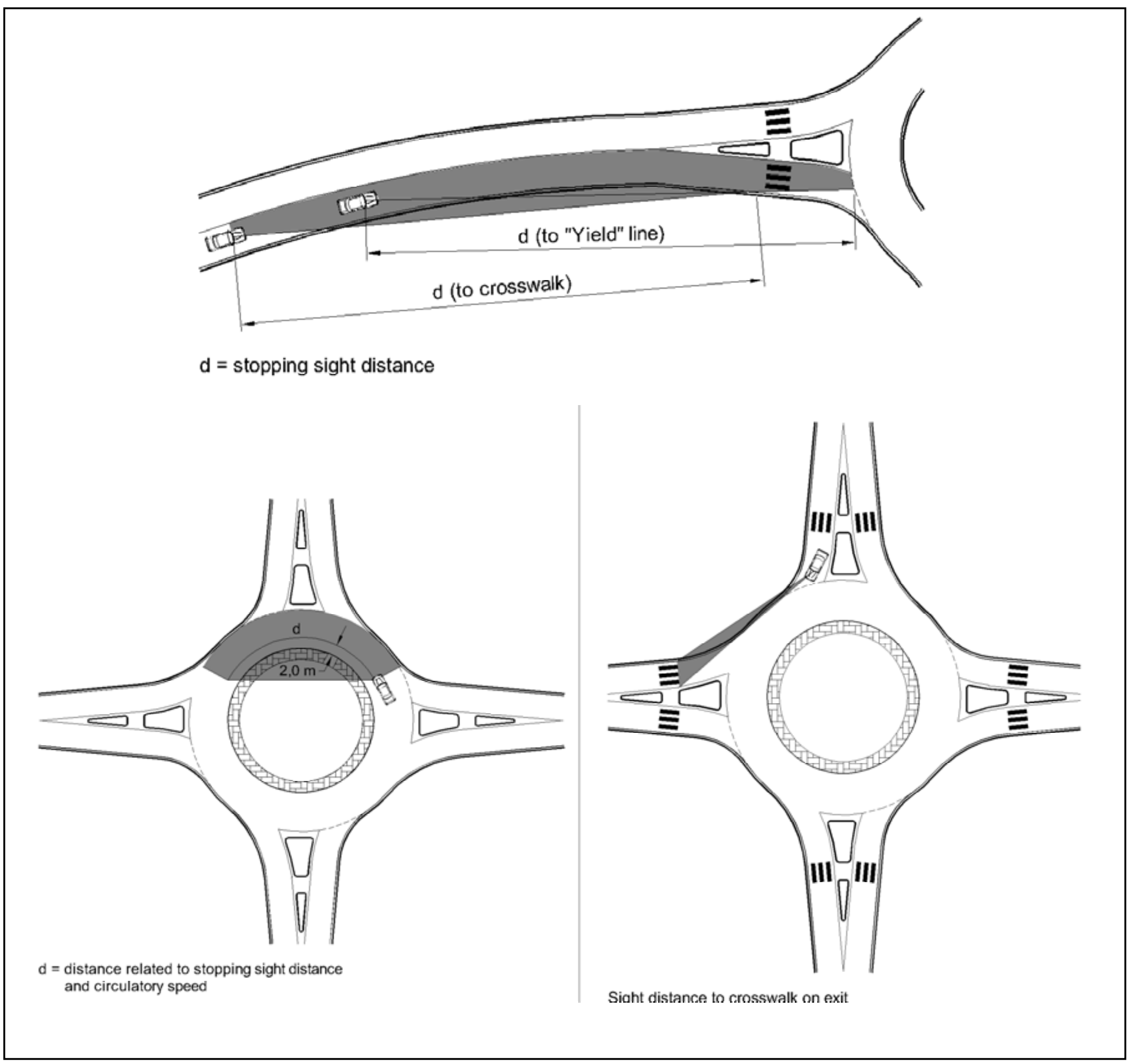

Figure 4 Intersection sight distance

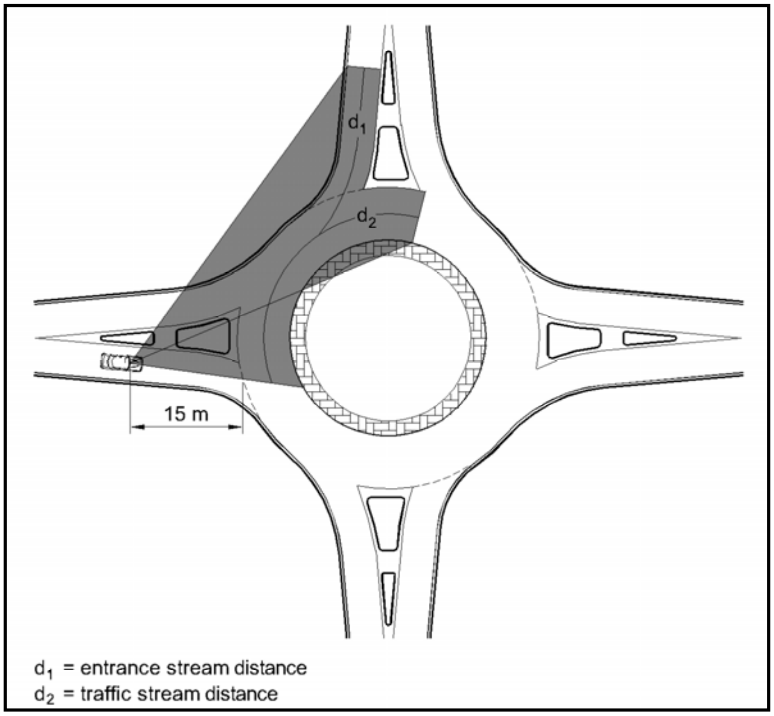

Figure 5 Traffic control devices in a roundabout