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INVESTIGATION OF THE CLEAR SIGHT AREAS ON SUBURBAN ROUNDABOUTS

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Abstract

To achieve safe and unobstructed traffic flow at roundabouts and their approaches, the important condition that needs to be met is adequate visibility. Namely, a clear line of sight must be ensured to enable a driver without the right of way to engage in the roundabout traffic flow safely and to note on time the position of the vehicle in front of him. The issue of sight distance evaluation on suburban single-lane roundabouts will be analysed in this paper. A critical review of several roundabout design standards and guidelines (Australian, Croatian, and Italian) that describe procedures for determining the necessary sight distance at these intersections will be given. Influential parameters for defining clear sight areas will be presented in detail, with an emphasis on the diversity of roundabout sight distance evaluation approaches. Key issues of the existing Croatian guidelines will be identified, and recommendations for the improvement will be given. Test results obtained on a theoretical example of a suburban roundabout will also be commented on.

Keywords: intersection sight distance, circulating carriageway sight distance, guidelines, standards, theoretical example, analysis

1 Introduction

The development of modern roundabouts began in the 1960s in the United Kingdom with the adoption of the yield-at-entry rule, which gave the circulating traffic priority over entering traffic [1]. Modern roundabouts spread to other parts of the world in the 1980s [2], and their intensive construction of roundabouts has begun in the last 30 years. European countries that stand out in the total number of roundabouts are France, Spain, and Italy [3], while Australia is also pursuing policies of mass roundabout construction [4].
Due to the yield-at-entry rule, an appropriate sight distance must be ensured on roundabouts to enable a driver without the right of way to engage in the roundabout traffic flow safely and to note on time the position of the vehicle in front of him. At the same time, the driver entering the intersection must have an obstructed view of the opposing exit. This is ensured by the proper design of roundabout geometric elements [5]. In this paper, the focus is set on displaying key elements of the roundabout sight distance evaluation procedures described in the roundabout design regulations applied in Italy and Australia, and their comparison with the approach applied in Croatia. This investigation is a continuation of research on international approaches on sight distance performance checks that was conducted at the University of Zagreb Faculty of Civil Engineering in 2016, where the focus was set on the analysis of roundabout sight distance evaluation procedures applied in Austria, Croatia, France, USA, Serbia, and Switzerland. Italy and Australia were selected for this research due to the significant number of roundabouts

constructed in these countries. Namely, there are over 31,000 roundabouts today in Italy [3], while in Australia, there is one roundabout per every 65 intersections [4].
The aim of the research presented in this paper is to gain further insight into the diversity of the evaluation of sight distances approaches used in the countries with rising numbers of roundabouts. Influential parameters for the sight distance and the clear sight areas determination will be presented in detail in the second section of this paper. The sight distance and the clear sight area analysis results for a theoretical example of a suburban roundabout will be commented on in the third section. Conclusion and the directions for further research will be given in the fourth section.

2 Sight distance evaluation methodology

For traditional four-legged intersections, the sight distance analysis is based exclusively on defining a sight triangle, which is defined as an area in which there should not be any obstacles that could prevent the driver from seeing and safely reacting to potentially conflicting vehicles [6]. Due to the specific design features of roundabouts, the sight distance analysis on these intersections consists of determining the intersection sight distance (achieved by providing for the sight triangle at every entry) and determining the sight distance for the vehicle on the circulating carriageway [5].
The required sight distance at the roundabout entry is achieved by providing for the sight triangle at every entry. According to the previous research [5], the following approaches concerning the method for the investigation of the intersection sight distance are in use. In the first approach (used in Austria, Serbia, and the USA), the sight distance is defined based on a calculated or set path length of a vehicle with the right of way entering the roundabout and a vehicle on the trajectory around the central island, position of the driver's eye, and point of conflict of the considered traffic flow. In the second approach (used in Croatia and Switzerland), the sight distance is defined based on a set path length of the vehicle with the right of way on the trajectory around the central island, position of the driver's eye, and point of conflict of the considered traffic flow. In the third approach (used in France), the sight distance is defined based on the position of the driver's eye for two locations on the approach leg, the outer radius of the roundabout, and the circulating carriageway width.
Two approaches are utilized for the determination of sight distance for the driver on the circulating carriageway. In the first approach (used in Croatia, Serbia, and the USA), the sight distance is defined based on the calculated or set trajectory-length values for a vehicle moving along a circulating carriageway, position of the driver's eye, and obstacle position. In the second approach (used in Austria, France, and Switzerland), only guidelines for the central island design, i.e., for installation of visibility obstacles within the central island are given. Namely, a clear sight area extending over the entire central island can instigate drivers entering the roundabout to neglect the right of way of vehicles that are already driving through the roundabout. For this reason, and to ensure the clarity of the roundabout in the traffic network as well, it is necessary to limit the sight distance over the central island by planting vegetation or installing traffic equipment [5].

2.1 Australia

According to [7], roundabouts must be designed to provide the same approach sight distance as other intersections. However, drivers at the entry lines at roundabouts are provided with minimum gap sight distance rather than the safe intersection sight distance. Three sight distance criteria must be applied to the combination of vertical and horizontal geometry at roundabouts: Criterion 1 (which refers to the approach sight distance) and 2 (which relates to a car driver entering a roundabout having adequate sight distance to a vehicle entering from

the approach immediately to the right and a vehicle travelling on the circulating carriageway) are both mandatory requirements, while Criterion 3 (which relates to a car driver approaching a roundabout having adequate sight distance to see other entering vehicles well before that driver reaches the entry line) is not mandatory. In this paper, only Criterion 2 will be analysed.

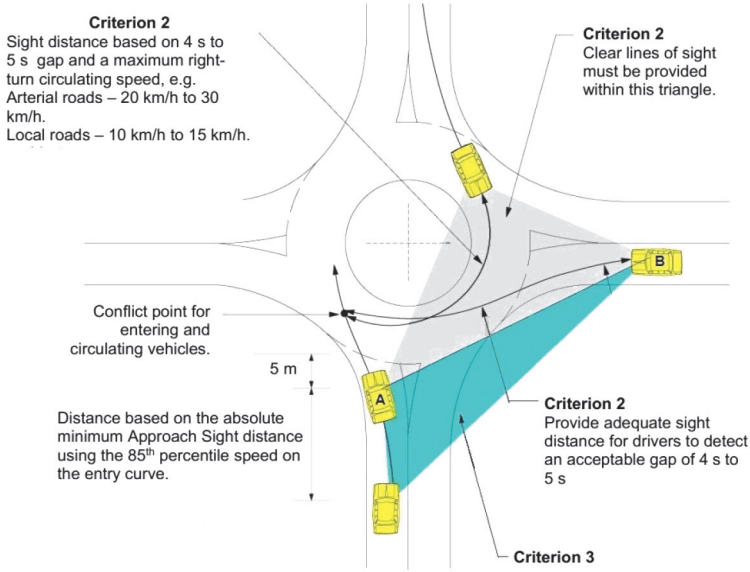

Figure 1 Construction of clear sight areas (Criterion 2 and 3) according to [7]

According to Criterion 2, a driver in car A, stationary at the roundabout entry line, should have a clear line of sight to an entering vehicle (car B) on the approach immediately to the right, for at least a distance representing the travel time equal to the critical acceptance gap for the driver of car A (Figure 1). It is measured from a driver's eye height of 1.1 m to an object height of 0.65 m. For a driver waiting at the entry line, the distance should be based on the 85th percentile speed of vehicles entering the roundabout from the approach immediately to the right of the driver. The distance is measured from the conflict point along each vehicle's travel path as shown in Figure 1. A critical gap of five seconds, resulting in a 70 m distance based on an entry speed of 50 km/h for car B is considered the minimum for arterial road roundabouts.

The Criterion 2 sight distance should also be checked in respect to vehicles on the circulating carriageway having entered from the approaches other than the approach immediately to the right. The speed of these vehicles should be based on the 85th percentile speed on the circulating carriageway. These speeds may range from 15 km/h for small urban roundabouts to 60 km/h for large rural roundabouts. Criterion 2 sight distances for vehicles using roundabouts on arterial roads are in the range from 28 to 84 m.

2.2 Croatia

According to the Croatian guidelines, all approaching drivers must be able to see the entire width of the roundabout [8]. This is achieved by enabling the sight distance to the left and forward sight distance at entry. While analysing sight distance to the left, the path length must be greater than or equal to 40 m, the visibility obstacle is positioned in the middle of the circulating carriageway, and the driver's eye in the middle of the entry line. The Guidelines recommend that on the approaches with high approach speeds analysis of the sight

distance to the left is conducted by positioning the driver's eye in the middle of the unexpanded lane, 15 m from the stopping line (Figure 2). The sight distance to the left is analysed for the height of the driver's eye from 1.1 to 2.0 m, and the obstacle height of 2.0 m.
The forward sight distance at entry is defined by using the path length of the vehicle with the right of way, which should be greater than or equal to the length of the stopping sight distance. The latter depends on the design speed of the vehicle with the right of way, which amounts to 40 km/h for medium suburban roundabouts (with the outer radius ranging from 15 to 22.5 m). The recommended stopping sight distance, which is to be used while checking visibility at roundabouts, amounts to 50 m. The minimum stopping sight distance given in the Guidelines is 35 m for the design speed of 40 km/h (this stopping distance corresponds to the value defined in the [9]). The trajectory of the vehicle with the right of way is positioned in the middle of the circulating carriageway (Figure 2). The driver's eye is positioned in the middle of the lane at 15 m from the entry line. The height of the driver's eye, in the forward sight distance at entry analysis, is 1.1 to 2.0 m. It can additionally be noted that the height of the object that should be seen by all drivers approaching the entry line, at full width of the roundabout, from the distance equal to the stopping sight distance of no less than 40 meters, ranges from 0.25 to 2.0 m.
The sight distance on the circulating carriageway depends on the stopping distance of the vehicle moving along the circulating carriageway, the position of the driver's eye, and the obstacle. The length of the path is measured along the trajectory of the vehicle offset 2 meters from the curb of the central island, i.e., the driver's eye and the obstacle are offset for 2 meters from the curb of the central island. The stopping distance of the vehicle moving along the circulating carriageway should be greater than or equal to 40 m (Figure 2). When analysing visibility in the roundabout, the driver's eye height ranges from 1.1 to 2.0 m, and the obstacle must be visible from the height ranging from 0.1 m to 2.0 m.

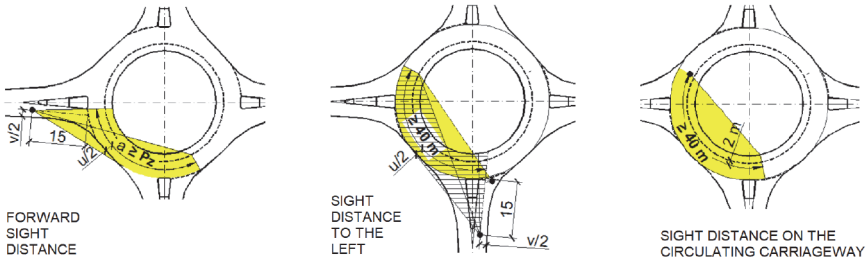

Figure 2 Construction of clear sight areas at entry and on at circulatory lane according to [8]

2.3 Italy

With up to 1 roundabout per 1000 inhabitants in northern parts of the country, and around 31,000 roundabouts in total [3], Italy is among EU member states that stand out in the total number of roundabouts today. In Italy, there is a national standard covering all intersection types which contains only three pages concerning roundabout design [10].
According to this standard [11], drivers approaching the roundabout must see the vehicles driving on the circulating carriageway due to the yield-at-entry rule. This is ensured by clear sight areas which are located over the left quarter of the circulatory roadway and constructed by positioning the observer 15 and 5 m from the entry line. The sight line for the observer at 15 m from the entry line is tangential to the outer edge of the roundabout, while the sight line for the observer at 5 m from the entry line is tangential to the circle that is offset for 2.5 m from the edge of the central island (marked as "bordo dell'isola centrale", Figure 3).

Italian standard does not give instructions for the determination of sight distance for the driver on the circulating carriageway, nor the driver's eye and the obstacle height.

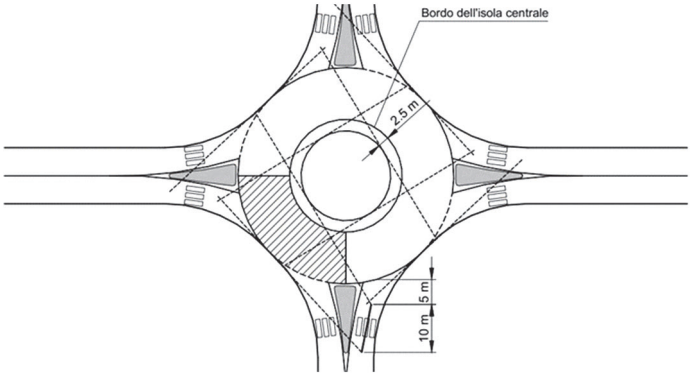

Figure 3 Construction of clear sight areas according to [11]

3 Clear sight areas analysis and results

The sight distance analysis was conducted on a theoretical example: a four-legged single-lane roundabout with the outer radius of 20 m with basic design elements (outer radius, entry and exit widths, circulating carriageway width, the shape and the dimensions of the splitter island and the right curb at the approaches) in line with recommendations given in Croatian guidelines for roundabout design [8] (Figure 4). For this investigation, the speed of the vehicle approaching the roundabout was set to 50 km/h. The speed of the vehicle circling on the circulatory roadway was set to 25 km/h, due to the curvature of the vehicle trajectory around the central island. To enable the comparison between clear sight areas, Australian guidelines were adapted for the right-hand traffic.

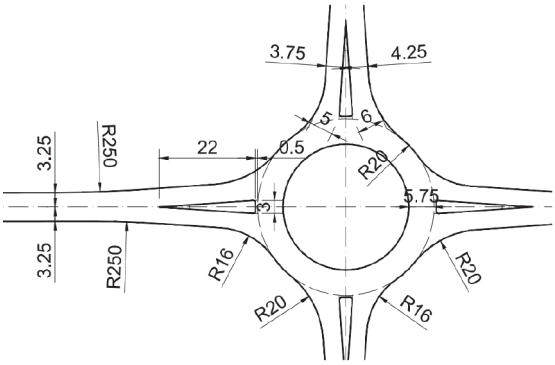

Figure 4 Basic design elements

According to Australian guidelines [7], a distance representing the travel time equal to the critical acceptance gap for the driver of car A is 70 m for the speed of 50 km/h. At the same time, sight distance in respect to vehicles on the circulating carriageway having entered from the approaches other than the approach immediately to the left is between 28 and 42 m. For this analysis, this distance is set to 42 m. According to Croatian guidelines [8], the smallest recommended sight distance to the left and on the circulatory roadway is 40 meters, while the length applied for forward sight distance at entry analysis amounts to 50 m [12].

The resulting total clear sight areas for the analysed roundabout are given in Figure 5. The following can be concluded based on these results [12]:

- The greatest total clear sight area for the required sight distances is the one constructed according to the Australian guidelines due to the longest sight distance to the left.
- The smallest total clear sight area is the one constructed according to the Italian standard.
- The requirement for obstructing the line of sight towards the opposing intersection exit is not fulfilled with the clear vision area defined in the Croatian guidelines. According to these guidelines, the central island may contain visibility obstacles only at a distance greater than 9.5 m from the curb, to ensure the required sight distance on the circulating carriageway. At that, the correct design of the central island is disabled, as the line of sight towards the opposing exit (marked with an arrow) should be disrupted by visibility obstacles within the central island.

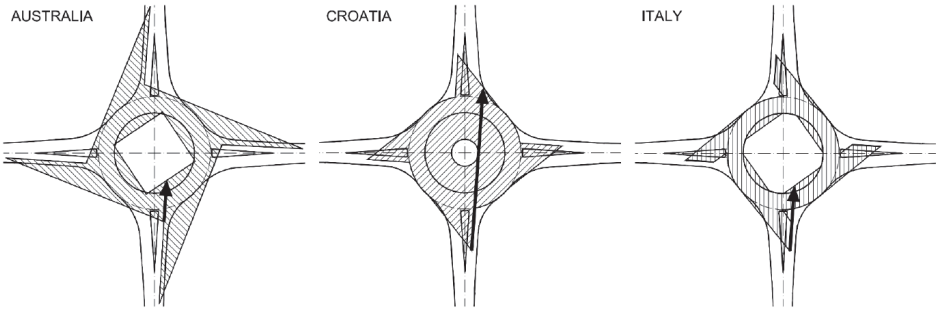

Figure 5 Resulting clear sight areas [12]

4 Conclusions

In this paper, an overview of roundabout visibility checks given in Australian, Croatian, and Italian standards and guidelines was presented and test results obtained on a theoretical example of a suburban roundabout were commented on. It can be concluded that the sight distance evaluation approaches given in the aforementioned documents differ in the extensiveness of their instructions and influential parameters for the construction of clear sight areas. Namely, the Italian standard is providing just basic instructions for the investigation of intersection sight distance. Also, according to this standard, the size of clear sight areas depends solely on the size of the roundabout outer radius and the size of its central island. This approach groups Italy with France concerning the investigation of the intersection sight distance. On the other hand, Australian and Croatian guidelines are providing very detailed instructions for the investigation of intersection sight distance. According to these documents, the size of the clear sight areas depends on the stopping sight distances, i.e., the vehicle speed, as well as roundabout size.

The determination of sight distance for the driver on the circulating carriageway is not described in Italian standard and Australian guidelines, which places them with Austria, France, and Switzerland. The investigation of sight distance for the driver on the circulating carriageway is given in Croatian guidelines, which places them in the group with American guidelines and Serbian regulations. The issue with the approach given in Croatian guidelines is that with the resulting clear sight area the line of sight towards the opposing intersection exit is not obstructed, which may result in the lack of clarity of the roundabout in the traffic network. Furthermore, a clear sight area extending over the entire central island can instigate drivers entering the roundabout to neglect the right of way of vehicles that are already driving

through the roundabout. Therefore, it is necessary to limit the sight distance over the central island by planting vegetation or installing traffic equipment. The issue with the unobstructed line of sight towards the opposing intersection exit could become insignificant for roundabouts with the outer radius larger than 20 m.

To gain further insight into the diversity of the evaluation of sight distance approaches used in the countries with rising numbers of roundabouts, further investigation will include Spanish regulations (since Spain, with around 37,000 roundabouts, stands out in the total number of these intersections today), as well as regulations and roundabout design guidelines used in Portugal, Slovenia, and Poland (as countries that are pursuing policies of roundabout mass construction in recent years). This insight could provide recommendations for the improvement of the existing Croatian guidelines concerning the construction of clear sight areas.

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