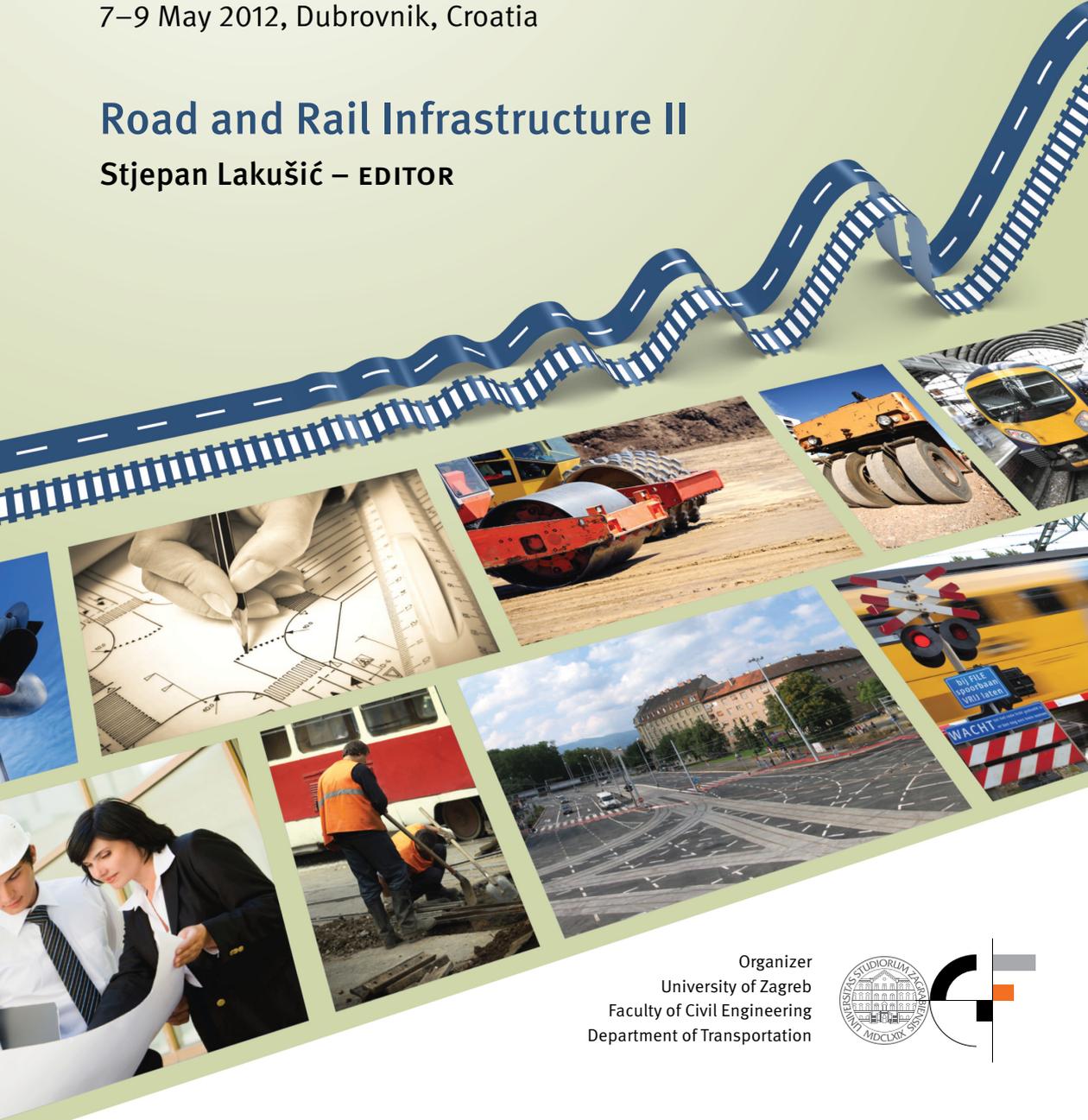


CETRA²⁰¹²

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
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DESIGN ELEMENTS OF MODERN ROUNDABOUTS

Mario Njegovec, Željko Stepan, Ana Rigo

University of Zagreb, Faculty of Civil Engineering, Croatia

Abstract

Roundabouts are used in the transportation system all around the world. Design elements of German, Swiss and Austrian guidelines are analyzed in the paper. Different approaches in determining design elements and their differences and similarities are discussed. The advantages of roundabouts when compared to conventional intersections are based on the appropriate geometric design. Based on implemented and designed roundabouts in the county of Varaždin a comparison to the guidelines is shown. Options in geometry optimization for increasing the efficiency of the analyzed roundabouts are also presented.

Keywords: roundabouts, geometric design, intersection planning

1 Introduction

Today modern roundabouts are the most attractive kind of intersections in many countries. They are characterized by the improved safety, time saving and road capacity.

The modern roundabout was developed in the United Kingdom in the 1960s by introducing a rule of that required entering traffic to give way to circulating traffic. This changed the design and the analysis of intersection capacity. Traditional roundabouts where circulating traffic yields the right of way to any entering vehicles are designed with a large diameter which provides more longer circular segments for path overlap, and stopping in the circulating lane causes a total congestion in the intersection. The new rule provides the reduced size of a roundabout with equal road capacity, increased traffic safety and the prevention of the congestion at the very intersection.

Positive experiences with modern single-lane roundabouts contributed to further research and development of other types of roundabouts. Substantial practical experiences initiated the formation of guides for designing such roundabouts. The recent achievements in this field for Germany [1], Austria [2], Switzerland [3] and the United States of America [4] are shown in the Table 1. Geometric design is crucial for appropriate operation of roundabouts in terms of the safety and the road capacity.

Table 1 Overview of the guides

Country	Guides	Year
Germany	Merkblatt für die Anlage von Kreisverkehren	2006
Austria	Plangleiche Knoten-Kreisverkehr – RVS 03.05.14	2010
Switzerland	Schweizer Norm SN 640 263	1999
USA	NCHRP: REPORT 672, Roundabouts: An Informational Guide, 2nd Ed.	2011

2 Achievements in different countries

2.1 General

The basic principle of the geometric design is to induce the desirable vehicular speeds resulting in improved intersection safety. Types of roundabouts are defined by spatial limitation, location and traffic capacity (Table 2).

Mini-roundabouts are a type of roundabout characterized by a small external diameter and traversable central island for large vehicles. They are commonly used in urban environments with average operating speeds of 50 km/h or less.

Single-lane roundabouts represent a standard solution and they are characterized by single entry lane, exist lane and circulatory lane. There is a non-traversable central island and they are used both in urban and rural environments. Their geometric design typically includes raised splitter islands.

Multi-lane roundabouts have two or more entry and exit lanes which means that more vehicles can travel side by side in circulatory lane. Due to a possibility of path overlap at the entry and the exit as well as higher speeds these multi-lane roundabouts are less safe in comparison with single-lane roundabouts.

Table 2 Types of roundabouts

	Germany (D)	Austria (A)	Switzerland (CH)	United States of America (USA)
Types of roundabouts	Mini	Mini	Mini	Mini
	Small single lane	Single lane	Single lane	Single lane
	Small with two lane curculatory lane	Multi lane		Multi lane
	Big with traffic lights			

2.2 German guides

Mini-roundabouts have a diameter of 13 m to 22 m and the road capacity of 18000 veh/day. A central island is traversable and has truck apron raised by 4 cm–5 cm, and 12 cm maximum in the center. The width of circulatory lane is between 4 m and 6 m with transversal inclination of 2.5% outwards. The entry and exit radius is from 8 m to 10 m.

Small single-lane roundabouts have the road capacity of 25000 veh/day. The external diameter is from 26 m to 45 m, the entry radius is from 10 m to 16 m and the exit radius is from 12 m to 18 m. These dimensions provide great traffic safety. Smaller radii are used in urban environments. Distance of transit traffic around the central island should not be less than double widths of approach lane. Circulatory lane being 6.5 m–9 m wide consists of driving and traversable part used by large vehicles.

Small double-lane roundabouts have one or two lane entry with the entry radii of 12 m–16 m, depending on the traffic load and one lane exit with the exit radii of 12 m–18 m. In the circulating area there are two traffic lanes with the total width of 8 m–10 m, but they are not marked with the horizontal signalization. Diameter varies from 40 m to 60 m with the maximum road capacity of 32000 vehicles a day.

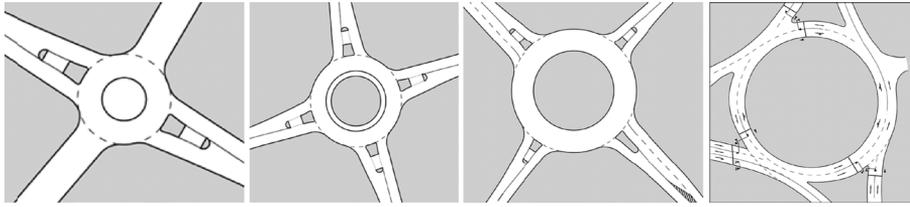


Figure 1 Types of roundabouts in German guides

Light signalization is used at big roundabouts. Their diameter is more than 60 m and they have two or more lanes in entry, exit and circulatory lanes.

According to the German guides the designing of small double-lane roundabouts is not allowed due to the reduced safety. The solution of the problem of increased through traffic is found in the use of roundabouts with the spiral traffic course, the so called 'turbo roundabouts'. This type of a roundabout was developed in the Netherlands and it provides the safety characteristics of a single-lane rotary with the capacity increased up to 30% in comparison with a double-lane roundabout. The idea of the turbo roundabouts is based on lane change maneuver prior to entering the intersection and on the spiral traffic course to the desired exit. The entry is perpendicular to the circulatory lane. Lanes are separated by spiral horizontal signalization and physically splitted by small cambers. A number of conflict points is reduced from 16 to 10 when compared to classical double-lane roundabouts [5] and [6]. Several such roundabouts, with certain modifications, are built all over Germany. Lanes are separated only by road surface marking. The guides for such roundabouts are expected to be issued. The concept of turbo roundabout is shown in the Figure 2.

2.3 Austrian guides

Table 3 shows the main characteristics of roundabouts with the basic geometric design elements. The geometric elements in mini-roundabouts are determined on the basis of curve of the course of design vehicles. It is recommended that single-lane roundabouts have the external diameter of 35 m to 40 m and that multi-lane roundabouts have the external diameter of 50 m to 60 m.



Figure 2 Basic concept of turbo roundabout and its design in the Netherlands and Germany

Table 3 Design elements of roundabouts in Austria

	Mini roundabouts	Single-lane roundabouts	Multi-lane roundabouts
Environment	urban	urban or rural	urban or rural
External diameter	< 26 m	≥ 26 m	≥ 40 m
Circulatory lane	single lane	single lane	multi lane
Entry lane	single lane	single lane	single or multi lane
Exit lane	single lane	single lane	single or multi lane
Central island	traversable	non-traversable	non-traversable
Entry radius	–	10–14 m (12–16 m)	10–14 m (12–16 m)
Exit radius	–	12–16 m (15–25 m)	12–16 m (15–25 m)
Circulatory lane width	–	6.5–9.0 m	8–10 m
Maximum capacity	10000 veh/day	25000 veh/day	30000 veh/day

2.4 Swiss guides

Mini roundabouts and single-lane roundabouts are designed with the entry radii of 10 m to 12 m, while the approach radius is five times larger. In a properly designed entry the entry angle α has to be as large as possible. The exit radius is from 12 m to 14 m. Small roundabouts with circulatory lane width of 7–8 m are characterized by external diameter of 14–16 m. Single-lane roundabouts have external diameter of 26–40 m. The deflection angle of $\beta > 45$ gon has to be reached for achieving the necessary deflection.

The Figure 3 left shows the design elements of Swiss roundabouts. Appropriate operation at low entry and circulatory lane speeds by defining the entry/exit radius is regulated by the entry angle (Figure 3 right) and the deflection angle.

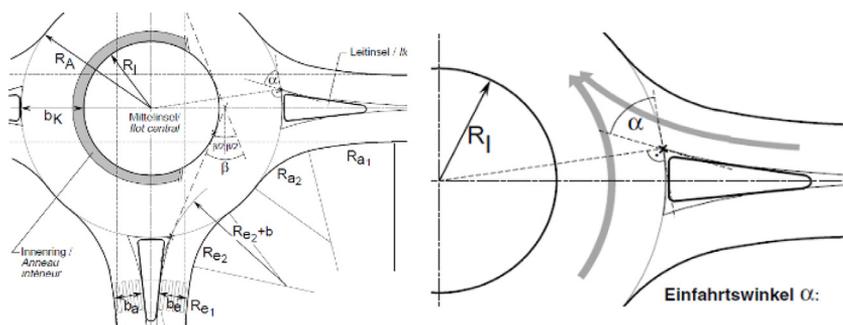


Figure 3 Design elements and entry angle at Swiss roundabouts

2.5 USA guides

All the geometric components are interrelated in order to provide basic features of roundabouts, i.e. safety and road capacity. In the design of the intersection characteristics have to be tested through the fastest path for all the directions.

The Table 4 shows the basic design characteristics and the Figure 5 shows types of roundabouts according to the American guides.

Table 4 Basic design characteristics

Design elements	Mini roundabouts	Single-lane roundabouts	Multi-lane roundabouts
Desirable maximum entry design speed	25–30 km/h	30–40 km/h	40–50 km/h
Number of entering lanes per approach	1	1	2+
External diameter	13–27 m	27–55 m	46–91 m
Central island treatment	Fully traversable	Raised (may have traversable apron)	Raised (may have traversable apron)
Typical daily capacity (veh/day)	≤ 15000	≤ 25000	≤ 45000 (for two lane roundabout)

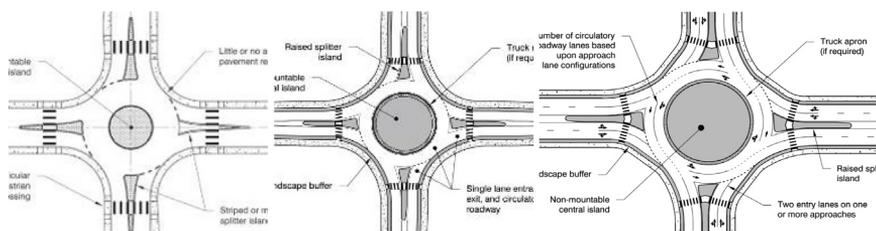


Figure 4 Types of roundabouts according to the American guides

Mini-roundabouts are most commonly used in urban environment with low speed entries. Splitter islands have to be raised, traversable or only marked. The design according to design vehicle. The width of circulatory lane in single-lane roundabouts varies from 4.8 m to 6 m. Circular shape of a central island is recommended, but oval, irregular or raindrop shapes can also be used. The entry radius is from 15 m to 30 m and the exit radius is from 15 m to 60 m. The traversable portion of a central island is 50–75 mm raised.

Multi-lane roundabouts have at least one entry with two or more lanes which requires a wider roadway in circulating part of the intersection so that at least two vehicles can travel side by side. When driving through multi-lane roundabout lanes do not need to be changed. When entering and exiting a multi-lane roundabout, vehicle must travel by its natural path in order to avoid overlap path. Reaching appropriate deflection along natural vehicle path represents an optimally designed multi-lane roundabout. The width of circulating double lane is from 8.5 m to 9.8 m and of circulating triple lane is from 12.8 m to 14.6 m. Firstly an entry is designed with a smaller radius of 20 m to 35 m, and then with a radius of 45 m and more. The entry lane can be moved to the left in order to obtain increased deflection which reduces it at exit (Figure 5 left). Radius of the fastest path is between 53 m and 84 m which results in design speed of 40–50km/h in the intersection. Determining of the fastest path in a multi-lane roundabout are shown in the Figure 5 right.

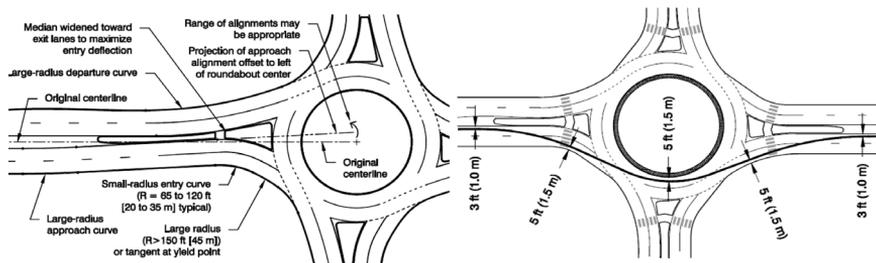


Figure 5 Design of multi-lane entry and determining the fastest path

3 Roundabouts in the Varaždin county

The advantages of roundabouts have been recognized by the institutions dealing with management, maintenance and construction of road infrastructure. In the last 10 years City offices, County road offices and the Croatian roads ltd. have been using roundabouts in reconstructing and building intersections.

12 roundabouts are already built and two more are planned. It is important to point out that 79 % of γ and τ junctions were covered to roundabouts and the rest 21 % of them are new intersections. According to the types they are small roundabouts with one circulating lane, one entry and one exit lane. In 36% of intersections a bypass lane was designed to increase the road capacity and to take right turning vehicles outside of a circulating lane (Figure 6). The geometric design analysis shows the implementation of modern design elements (Table 5).



Figure 6 Single-lane roundabout with additional lanes for the right turn

Table 5 Design elements of roundabouts in the Varaždin county

	Single-lane roundabouts	
	urban	rural
External diameter	29 m – 33 m	36 m– 48 m
Entry radius	12 –16 m	12 m–20 m
Exit radius	14 m –16 m	14 m –20 m
Circulatory lane width	7 m–8.5 m	6.5 m–7.5 m

Vehicle distance from the central island by the value of two lanes provides low speed in the circulatory lane in all the roundabouts. Although 90% of roundabouts are designed to have traversa-

ble central island only 40% of them are built as paved surfaces (granite blocks) when related to asphalt circulatory lane. It is recommended for the central island to be made of different material and raised up by apron which increases the safety conditions from a number of aspects. The Figure 7 shows the roundabout in Ludbreg with splitting and central island raised by blocks and a mound covering the view of the opposite entry lane. The central ring is made of granite blocks which provide the circulating traffic to stay in the lane and it provides additional width to be used only by larger vehicles.



Figure 7 The roundabout in Ludbreg

4 Conclusion

The insight into achievements in roundabouts design is characterized by the basic principle of speed controlling through the geometric design resulting in the improved safety of intersection. Different types and their basic characteristics show uniformity in all the countries that were considered. Single-lane roundabouts represent a standard solution. There are different elements of geometric design defining the basic characteristics of single-lane roundabouts. The Swiss guides define an entry angle and a deflection angle while the American guides test the fastest path speed. In all the countries mini-roundabouts are used with a diameter of 27 m and less and a traversable central island.

There are some differences in the design approach with multi-lane roundabouts. The German guides allowing only one exit lane at double-lane roundabouts have a restrictive approach. In the American guides the entry and exit radius are increased due to the principle of a natural path in order to avoid path overlap while entering and exiting.

Disadvantages of multi-lane roundabouts can be eliminated by using turbo roundabouts. The design of roundabouts in the Varaždin county follows the modern guides. The solution of the traffic safety also has to be found in the use of other types of roundabouts. Creating the national guides based on positive experiences from all around the world could significantly contribute to the safe and unified use of roundabouts.

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