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ROUNDABOUT APPROACHING SPEED ANALYSES

Mirna Klobučar[1], Aleksandra Deluka-Tibljaš[1], Sanja Šurdonja[1], Tiziana Campisi[2], Robert Maršanić[3]
[1] University of Rijeka, Faculty of Civil Engineering, Croatia
[2] University of Enna Kore, Faculty of Engineering and Architecture, Italy
[3] Road Administration Primorje-Gorski Kotar County & University of North, Koprivnica, Croatia

Abstract

Roundabouts are very often implemented as a measure for speed control at the intersections where there is a problem with traffic safety. Although the approaching speed is emphasized in some research as relevant for operational speed in the roundabout, there are no detailed analyses of the effects of geometric and traffic elements on approaching speed that can be used to design safer roundabouts. The experimental study presented in this paper was done on six different roundabouts, on 22 approaches, located at a regional road network. The outer radii of analyzed roundabouts were from 15 to 22 m. The speed was measured for 24 hours at every approach. As operational speed, v_{85} - speed up to which 85 % of vehicles are moving was included in the analyses. The impact of main geometric elements – lane width, slope, and length of the straight part of the road before entrance to the roundabout was analyzed. As a traffic parameter, the impact of the posted speed limit at the approach on the operational speed was also analyzed. Some preliminary recommendations regarding speed control were generated as a conclusion of this study.

Keywords: roundabouts, approaching speed, operational speed, traffic safety

1 Introduction

Roundabouts are commonly used to control intersections of different geometry by facilitating low to moderate traffic flows. Numerous studies have been conducted on the safety and traffic benefits of roundabouts for cars and trucks, proving that roundabouts are the safest and most effective form of traffic control for most intersections [1, 2]. Compared to signalized intersections and controlled stop intersections, roundabouts can usually offer better overall safety performance, smaller queues, fewer delays, and higher throughput. Also, in some cases, the expensive widening of an intersection approach required for a signalized intersection can be eliminated by the use of roundabouts [3]. Roundabouts are increasingly becoming the intersection of choice in many countries due to the positive and recognized operational advantages deriving from their geometrics [2].
The design process of selecting roundabout geometric parameters is an iterative process – after the preliminary selection of geometric parameters, it is necessary to check vehicle trajectories, visibility, and operational speed. Finally adopted layout must enable the passage of large vehicles but also prevent the development of excessive speed by cars [4, 5]. Therefore, it is crucial to analyze which geometric or traffic elements can help in speed control at roundabouts.

Operational speed is most important for ensuring appropriate safety and capacity conditions at roundabouts. Measured operational speed often exceeds the intended speed based on the design speed or posted speed limit (PSL) [6]. In studies in which operational study models are developed, PSL limit is often emphasized as the most critical parameter [7,8]. The geometry of the roundabout, and thus the vehicle's trajectory through the roundabout, also has a significant influence on the operational speed [9]. Analyses of operational speed measured at the entrance and exit of roundabouts showed that operational speed at the roundabout entrance can be higher than at the exit [5]. As the entrance to the roundabouts is more complex than the exit, it is important to release better parameters that affect entrance speed.
Regarding traffic safety, available research shows that accidents related to roundabouts primarily result from exceeding operational speed. Analyzes of traffic accidents in the United States show that most accidents occur when assessing the roundabout entrance situation or loss of control at entry. The accidents are different, but the problem is related to the inappropriate operating speed at entry in most cases [10]. As the entrance to the roundabout is, therefore, a critical point, the idea is to analyze if this speed, and to what extent, depends on the design of the roundabout approach.
This paper presents research conducted to determine the impact of main geometric elements and posted speed limit at the approach of the roundabouts on the operational speed at the approach. The elements analyzed in this case are lane width, approach slope, and length of the straight part of the road before the roundabout entrance. Some preliminary correlations between approaching speed and defined parameters were set.

2 Methodology and field measurements results

Data for the present study were collected on six single-lane roundabouts located on the border of the urban area in the municipalities of Viškovo and Kastav near the city of Rijeka, Croatia. Given the radii between 15 m and 22 m, they are classified as medium-sized urban roundabouts [11]. The speed up to which 85 % of all passing vehicles drive is accepted as operating speed (v_{85}).
To ensure the quality and integrity of the database, field measurements were conducted using Datacollect SRD radar traffic counters without interrupting the traffic flow. Traffic counters were placed on a street light pole or traffic sign pole at the height of 2,20 m. The approach speed was recorded at each approach at two positions: at a distance of 15-30 m (Position 1) and 49-62 m (Position 2) from the stop line of the roundabout, depending on the position of the existing pole. Positions and labels of traffic counters are shown in Figure 1. Speed data was recorded in continuation for 24 hours, as well as the day-time speed from 6 to 22 hours and the night-time speed from 22 to 6 hours in stable weather conditions. All data were collected on Wednesday and Thursday. The sample consisted of:

- 2 regular three-leg (I-II) and 4 regular four-leg (III-VI) roundabouts
- 14 cross-sections on which posted speed limit (PSL) is 40 km/h, 26 with PSL 50 km/h and 4 with 70 PSL 70 km/h
- Analyzed approaches are two-way

Traffic data collected in the field are presented in table 1 for every roundabout (RB) and every approach (AP) as follows: daytime speed (DS v_{85}); night-time speed (NS v_{85}); 24-hour speed (24h v_{85}); vehicles exceeding the speed limit (v_{exc}); lane width (LW); approach slope; length of the straight part of the road before entrance to the roundabout (LSP); posted speed limit at the approach outside the roundabout zone (PSL); outer radii (R).

Figure 1 Positions of the traffic counters on the approach

Table 1 Geometric and traffic characteristics of selected approaches

RB	AP	DS v_{85} [km/h]	NS v_{85} [km/h]	24h v_{85} [km/h]	v_{exc} [%]	LW [m]	Slo [%]	LSP [%]	PSL [km/h]	R [m]
I	A.1	49	62	50	13,3	3,0	3,0 %	40	50	15
	A.2	52	66	51	15,5					
	B.1	52	54	52	19,6	3,0	-7,0 %	100	50	
	B.2	41	45	41	1,5					
	C.1	34	39	34	0,0	3,0	-2,1 %	150	50	
	C.2	43	50	43	1,7					
II	A.1	47	55	48	7,7	3,0	-4,6 %	130	50	16
	A.2	46	53	47	6,0					
	B.1	29	36	29	0,0	3,2	0,9 %	130	50	
	B.2	54	64	55	32,7					
II	C.1	34	41	35	0,1	3,0	0,9 %	150	50	16
	C.2	62	72	62	59,2					
III	A.1	50	56	50	12,8	3,5	-3,0 %	60	40	22
	A.2	44	49	44	1,9					
	B.1	30	33	30	0,0	3,0	4,0 %	0	40	
	B.2	44	52	44	2,4					
	C.1	41	42	41	0,5	3,5	1,7 %	50	40	
	C.2	29	31	29	0,0					
	D.1	36	41	36	0,0	3,25	-6,6 %	150	40	
	D.2	37	41	37	0,0					

Table 1 Geometric and traffic characteristics of selected approaches - continuation

RB	AP	DS v_{85} [km/h]	NS v_{85} [km/h]	24h v_{85} [km/h]	v_{exc} [%]	LW [m]	Slo [%]	LSP [%]	PSL [km/h]	R [m]
IV	A.1	28	30	28	0,0	3,5	-9,7 %	260	40	16
	A.2	37	39	37	5,0					
	B.1	52	56	52	21,6	2,5	-0,9 %	0	50	
	B.2	52	55	52	22,6					
	C.1	48	53	49	59,1	3,5	-0,6 %	50	40	
	C.2	46	48	46	46,3					
	D.1	44	48	44	4,0	3,25	10,9 %	0	50	
	D.2	41	44	41	1,1					
V	A.1	66	68	66	6,2	3,25	0,7 %	80	70	17
	A.2	85	89	86	59,1					
	B.1	29	33	29	0,0	3,0	2,0 %	170	50	
	B.2	64	71	65	77,3					
	C.1	56	60	56	0,6	3,25	0,7 %	700	70	
	C.2	80	86	80	45,1					
	D.1	51	57	51	19,5	2,75	-5,0 %	0	50	
	D.2	58	64	59	51,6					
VI	A.1	37	45	38	0,4	3,3	-2,4 %	200	50	15
	A.2	48	60	48	9,2					
	B.1	41	49	42	1,5	3,5	3,8 %	150	50	
	B.2	53	62	54	27,5					
	C.1	32	39	32	0,0	2,9	-0,7 %	75	50	
	C.2	48	58	48	11,1					
	D.1	58	69	58	41,5	3,5	-0,5 %	530	40	
	D.2	60	74	60	45,4					

3 Analyses of the results

According to data in Table 1, night-time speeds are greater than day-time speeds at all locations, by an average of 6 km/h. Approaching speed collected for 24 hours doesn't deviate a lot from the daytime speed, as shown in Figure 2.
According to the Guidelines [11], medium-sized urban roundabouts must be designed to allow a maximum speed of 40 km/h. A posted speed limit sign is placed at approximately 35 m from the entrance to the roundabout, as shown in Figure 1.
Figure 3 shows that the speed limit (40 km/h) was exceeded on 13 approaches in the case of day-time speed (the speed is higher for 10 km/h on average) and for as many as 16 approaches looking at night-time speed (the speed is higher for 14 km/h on average). The average percentage of vehicles exceeding the posted speed limit is 30 %.

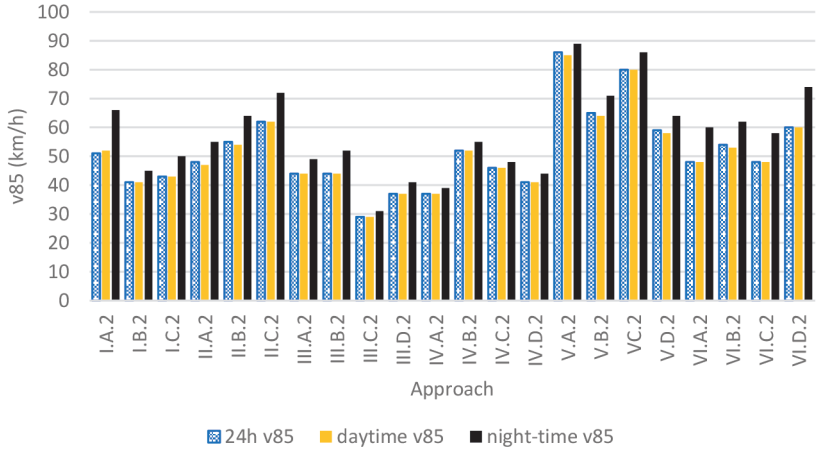

Figure 2 Comparison of v_{85} approaching speed at Position 2

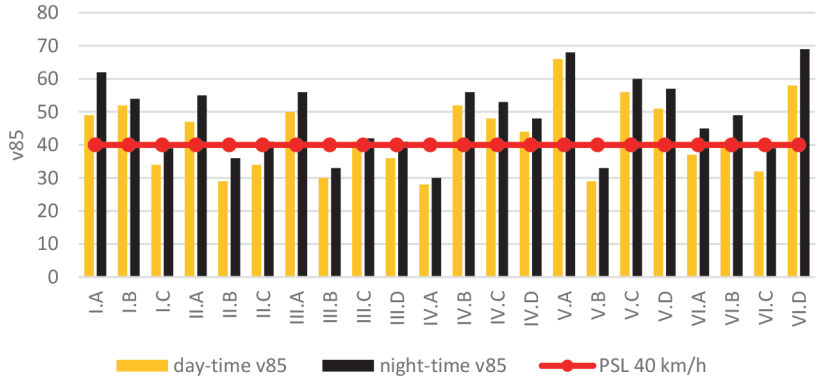

Figure 3 Operational speed at Position 1 (15-30 m from the entrance)

The correlation between collected geometric parameters (lane width, slope, length of the straight part of the road before entrance to the roundabout), posted speed limit and measured 24 h approaching speed was analyzed. The results are presented in Tables 2 and 3.

Table 2 Correlation between selected parameters and measured approaching speed at Position 1

	LW [m]	**Slope** [%]	**LSP** [m]	**PSL** [km/h]	**24h v_{85}** [km/h]
LW [m]	1				
Slope [%]	0,03534	1			
LSP [m]	0,33998	-0,13646	1		
PSL [km/h]	-0,25943	0,19884	0,30049	1	
24h v_{85} [km/h]	0,03423	0,01616	0,18447	0,43224	1

Table 3 Correlation between selected parameters and measured approaching speed at Position 2

	LW [m]	**Slope** [%]	**LSP** [m]	**PSL** [km/h]	**24h v_{85}** [km/h]
LW [m]	1				
Slope [%]	0,03534	1			
LSP [m]	0,33998	-0,13646	1		
PSL [km/h]	-0,25943	0,19884	0,30049	1	
24h v_{85} [km/h]	-0,14619	0,19678	0,43107	**0,79736**	1

As proved in other research [5, 7] there is a strong positive correlation between approaching operational speed and posted speed limit. Similar results are confirmed in the results of this study for Position 2, located app 50-60 m before the entrance. At the same time, based on the analyses of this relatively small database, there is no significant correlation between approaching operational speed and geometric elements.
As a positive correlation between PSL and approaching operational speed was established, a simplified regression model was developed to describe the relationship between approaching operational speed at 49 – 62 meters from the entrance (Position 2) and PSL.

Table 4 Regression statistics

Multiple R	0,797361082
R Square	0,635784695
Adjusted R Square	0,61757393
Standard Error	8,371923111
Observations	22

Model for the approaching speed (v_{85}) as a function of posted speed limit (PSL) can be defined as follows:

$$v_{85} = 11.667 + 1.295 \cdot v_{PSL} \quad (1)$$

The correlation is valid for the roundabout with a radius of 15 to 22 m, at a distance of 49 to 62 m from the entrance to the intersection.

4 Conclusions

Speed control at the roundabout entrance is an important element of roundabout traffic safety. In this paper, approaching operational speed data collected at different roundabouts are analyzed. The goal was to establish parameters that affect approaching operational speed and possibly define some measures which can be implemented to control entrance speed. The results show that the geometric elements analyzed in this paper (lane width, approach slope, length of the straight part of the road) do not significantly affect approaching speed.
According to this limited study, the posted speed limit set outside roundabout zone resulted as the only relevant parameter that affects approaching operational speed measured app 50-60 m before the entrance. In order to lower speed in the roundabout entrance zone, the distance of the location of the PSL sign should be increased to more than 35 m which was applied presently at the analyzed location. That would affect approaching operational speed

at Position 2 and subsequently at Position 1, 15-30 m from the entrance, and have a positive impact on the entrance safety, especially for pedestrians and cyclists.

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