ANALYSIS OF TRAFFIC SAFETY ON ROUNDABOUT JADRANSKA AVENUE – AVENUE DUBROVNIK IN ZAGREB

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ABSTRACT

Although roundabouts have been applied in Croatia for thirty years, from the standpoint of traffic safety they have not been sufficiently investigated. The traffic police, road administration and insurance companies are those who are mostly engaged in dealing with the consequences of traffic accidents, so that the recorded accidents can be explored from their inspections, surveys of damage and annual reports. More intensive researches of traffic safety at roundabouts began only in the last 2-3 years, and based on the research carried out at 30 roundabouts in the City of Zagreb, we have presented a systematic analysis of accidents at the Jadranska Avenue - Avenue Dubrovnik roundabout.

KEYWORDS: roundabout, traffic flow, traffic safety, design elements, survey and verification of damage

1 INTRODUCTION

The intersections are the most sensitive points in road network, which have to provide sufficient traffic capacity and safety. Special attention should be paid to intersections with circular traffic flows (roundabouts) because the characteristics of their traffic flows have been least studied. Since the designers faced first of all the problems of determining capacities and dimensioning of these intersections, it was justifiably assigned the status of priority [3]. On the contrary, the problem of traffic safety has been assigned secondary significance due to the lack of dramatic accidents with fatal consequences, but in the recent 3-4 years it has been given priority in the studies [1, 4, 5, 6]. Monitoring of these issues is usually within the scope of work of the traffic police, road administration and insurance companies, and the reported accidents can be studied from their investigations and standardized annual reports [2]. Based on the results of scientific research at thirty roundabouts in Zagreb [1, 4], the most important safety and design properties of Jadranska Avenue – Avenue Dubrovnik roundabout in the city of Zagreb will be evaluated.

2 CORRELATION OF TRAFFIC SAFETY AND DESIGN

The main advantage of single-lane roundabouts (compared to the classical three-leg and four-leg intersections) lies in the elimination of the conflicting area and the conflicting points with crossing and weaving and in the reduction of the number of conflicting points of merging and diverging. Theoretically, classical four-leg intersection has 32 conflicting points (16 crossings, 8 merging and 8 diverging), and a single-lane four-leg roundabout has only 8 conflicting points of lower order (4 merging and 4 diverging) which is presented in Figure 1 [8].

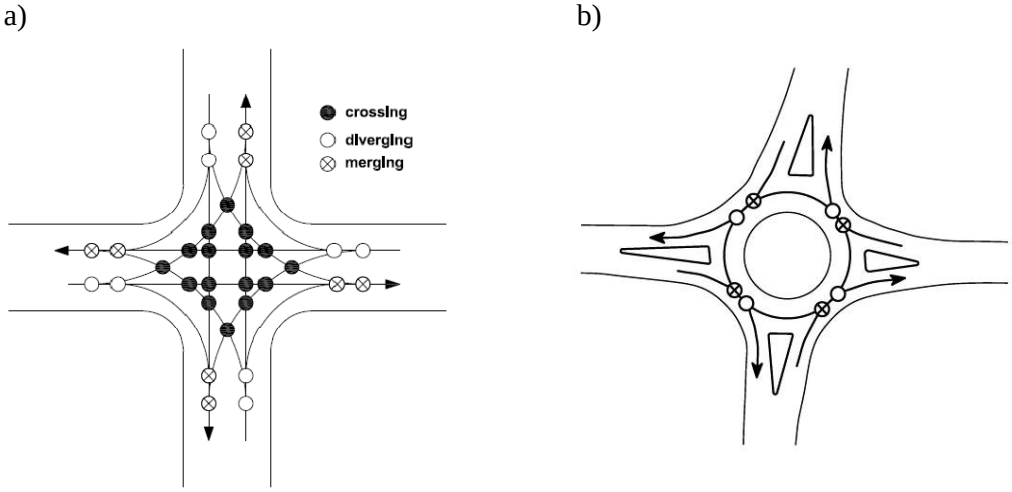

Figure 1: Conflicting points at a) classical intersection and b) roundabout [8]

The consequences of traffic accidents are not so serious and there are no fatalities and seriously injured. The cause lies in lower driving speeds and the fact that in roundabouts there are no head-on collisions. In the majority of cases the collisions of vehicles are lateral, at a sharp angle or due to rear collision. Collisions between motor vehicles and non-motor vehicle, that cross the intersection leg, are the same as at classical intersections, only the collision consequences are much smaller (due to reduced speed at entries and exits).

The traffic safety of non-motorized traffic at a roundabout depends first of all on the method of their guidance in the area of the roundabout, proper design of traffic signalization, and design method of dividing islands. In our country and in the world there are three methods known for guiding the bicycles in the area of roundabouts: non-segregated (combined) guidance of motor and bicycle traffic; parallel guidance (along the external edge of the circular roadway) and independent-segregated guidance (parallel with the kerb or in the form of concentric circles).

The traffic safety of pedestrians in the roundabouts depends on the pedestrian crossings and the visibility in the roundabout and somewhat less on the design method of dividing islands and traffic signalisation. The pedestrians should be able to see on time vehicles entering or exiting the roundabout [7].

3 ANALYSIS OF TRAFFIC SAFETY AT JADRANSKA AVENUE – AVENUE DUBROVNIK ROUNDABOUT

3.1 General data

The Jadranska Avenue – Remetinečka Road – Avenue Dubrovnik – Jadranski Bridge roundabout is located at the south-western entry into the City of Zagreb. It was opened to traffic on 9 September 1985. Before the reconstruction it had been designed as signal-controlled intersection at level with the grade-separated pedestrian traffic and without tram traffic. Fast urbanization, insufficient number of bridges over the river Sava, and increased traffic load of the south-western entry into the city have resulted in increased traffic load of the traffic network. In order to increase the traffic safety, capacity and introduction of tram traffic on the intersection, the roundabout was constructed as the optimal solution in the upper level as well as the passage for trams with passing sidings at the lower level [1].

a) b)

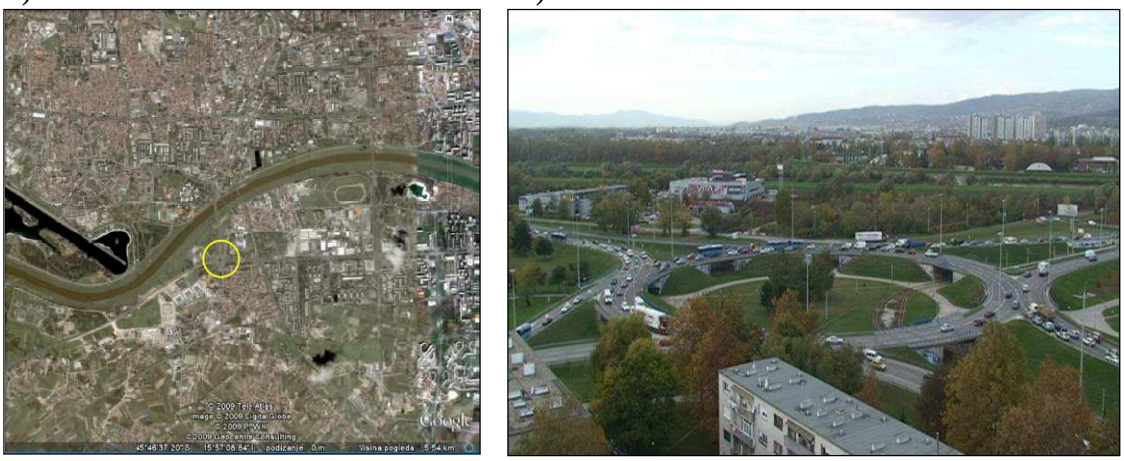

Figure 2: Jadranska Avenue – Avenue Dubrovnik roundabout; a) disposition in urban network; b) photo from south-eastern side [1]

3.2 Design and traffic flows

The intersection has the form of a big roundabout with four approaches: Jadranska Avenue, Avenue Dubrovnik, Jadranski Bridge and Remetinečka Road (Figure 2). The intersection is located on flatland with no major limitations, whereas the approach routes are at the following gradients: approach 1 (Jadranska Avenue) has a gradient of +2%, approach 2 (Remetinečka Road) has a gradient of +3%, approach 3 (Avenue Dubrovnik) has a gradient of +2.97%, whereas approach 4 (Jadranski Bridge) has a gradient of +1%. The external diameter (D_v) amounts to 148 metres, whereas the internal diameter (D_u) is 124 metres. The roadway is divided into three traffic lanes each 4 metres wide whereas the approaches are also organized with three traffic lanes, but of 3.5 metres width. They merge with the roundabout with a radius (R) of 80 metres except for the northern approach which merges with a radius (R) of 200 metres. The circular roadway has a gradient of about 2% towards the centre of the structure because of the rainfall drainage.

In order to present the traffic load of the intersection the latest measurable data collected in 2008 (Figure 3) have been used. More marked load was registered at all

approaches except on approach 2. From the registered intersection traffic load in the value of Q_k = 70230 veh./day and estimated throughput power/capacity C_k = 75,000 veh./day, results the level of utilization I_k = 0.94 (94%). Quantitatively, the traffic consists of passenger cars (about 80%), and the rest are semi-freight or freight vehicles (about 15%), and vehicles of public urban transport (about 5%) [1, 4].

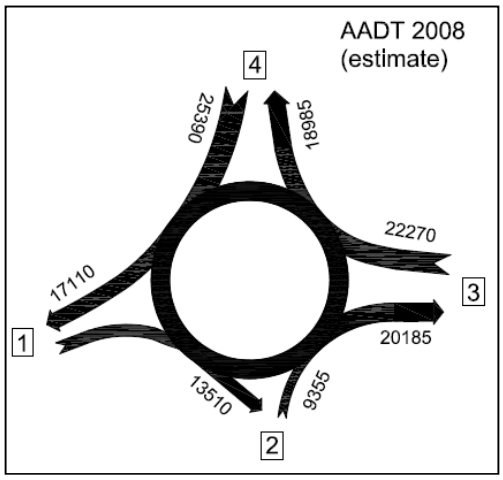

Figure 3: Traffic flows (AADT 2008 - estimate) [1]

3.3 Traffic safety and design

The analysis and the verification of the level of traffic safety has been carried out on the basis of video-recordings, data by HOK insurance (damage surveys and reports), and on the analysis of approaching speeds, visibility and equipment of the intersection.

- Speed recording was carried out in cooperation with the traffic police (MUP), on Tuesday, 7 July 2008 in the time period from 8.30 – 8.35h on Jadranska Avenue and from 8.45 – 8.50h on Avenue Dubrovnik. Meteorological conditions were almost ideal, mainly sunny with light clouds enabled good visibility at all the intersections. Regarding the specific characteristic of the analyzed intersection, the desired knowledge about the flow speeds and the technical characteristics of the device, MULTINOVA 6F has been selected and used. For the needs of recording an unmarked police car and a plain-clothes police officer were engaged, in order to reduce the possibility of being recognized thus acting on the drivers' awareness. On the Jadranska Avenue (approach 1) the measuring instrument was located on the southern part of the road on the merging lane 150 metres before the intersection (Figure 4), westwards in front of the parked unmarked police car. The speed limit on this section of the road is 50km/h and marked by an installed traffic sign. During the measured time the device registered 150 vehicles, and the results for 20 vehicles are given in Table 1 [1, 4, 5].

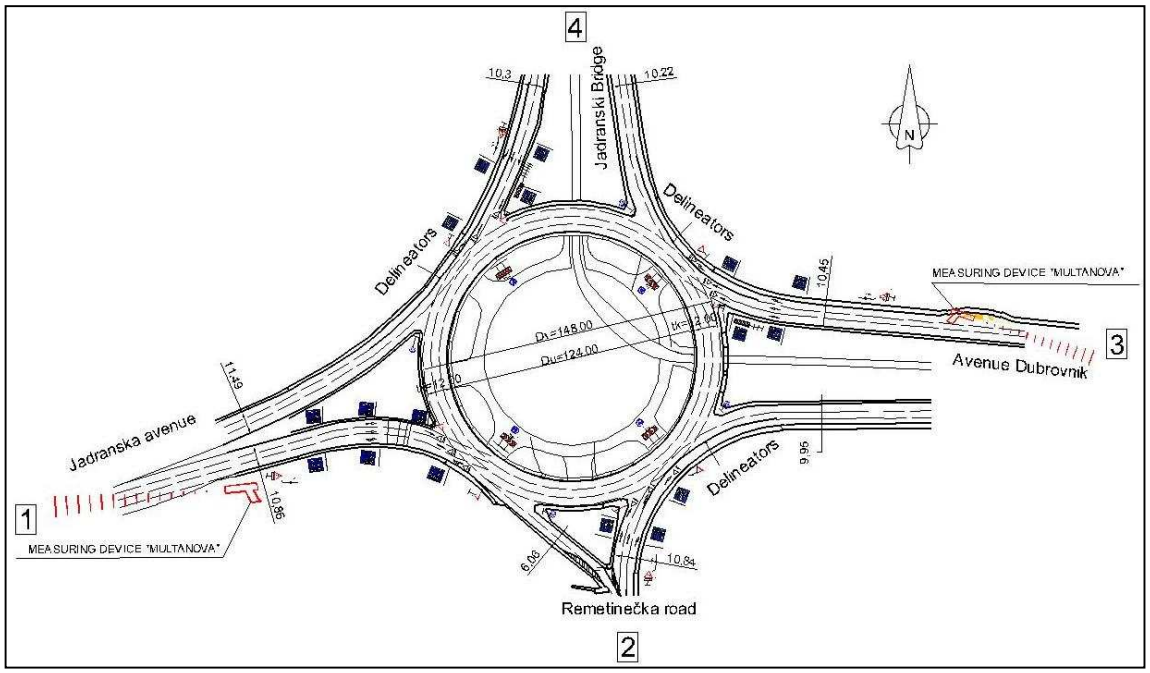

Figure 4: Layout design elements, and the position of measuring instruments of the speed of approaches at Jadranska Avenue – Avenue Dubrovnik intersection [4, 5]

Table 1: Registered speeds at approaches to Jadranska Avenue – Avenue Dubrovnik intersection [4, 5]

	Approaches 1 i 3	
	Jadr. Av.	Av. Dubro.
Time	8,30-8,35 h	8,45-8,50 h
Vehicle	SPEED (KM/H)	
1	72	66
2	97	63
3	93	62
4	76	51
5	72	66
6	83	76
7	*60*	90
8	**100**	70
9	93	69
10	96	70
11	83	88
12	90	88
13	79	67
14	93	**100**
15	79	**102**
16	85	85
17	95	77
18	92	55
19	77	*45*
20	65	53
Sum	1680	1443
Average speed	**84**	**72,15**

Table 1 shows that there are significant deviations from the limited speed. Maximal recorded speed of a passenger car is **100 km/h**, average speed **84 km/h**, and the minimum speed *60 km/h* which indicates the alarming information that the drivers do not respect the speed limit at all. On the Avenue Dubrovnik (approach 3) the measuring device was located on the

northern part of the road at the bus stop of public urban transport 120 metres eastwards in front of the parked unmarked police car. The speed limit on this section of the road is 50km/h and marked by an installed traffic sign. During the measuring period the device registered 104 vehicles, and the results are given in Table 1. Also, from the Table one can see that it comes to significant deviations from the speed limit. Maximal recorded speed of the passenger car is **102 km/h**, average speed is **72.15 km/h**, and the minimum is *45 km/h* which also indicates the alarming information that the drivers do not respect the speed limit at all. The approach speeds that are much higher than the speed limit directly influence the traffic safety, i.e. these are one of the main reasons of two types of accidents – rear-end collision, and collision with the vehicle in the roundabout [1, 4].

- The analysis of all types of visibility was done by means of a field inspection using video-recordings and recordings. The following has been checked: front visibility (Figures 5 and 6), visibility to the left, visibility in the roundabout, and all forms of traffic disturbances and visibility when exiting the intersection.

Approach 1 (Jadranska Avenue)

Approach 2 (Remetinečka Road)

Figure 5: Registered recordings of visibility at approach 1 (Jadranska Avenue) and approach 2 (Remetinečka Road) [1, 4]

- Regarding horizontal and vertical signalization the intersection is equipped in compliance with the stipulated regulations. The lighting, drainage and landscape are designed correctly and functionally. The delineators were added subsequently.
- The data on traffic accidents, in the period from 2008 to 2011 were collected by the HOK insurance. The methodology of data processing and analysis was taken over from the

previous research [1, 4], and reports and damage surveys were supplied by HOK insurance [2].

Approach 3 (Avenue Dubrovnik)

Approach 4 (Jadranski Bridge)

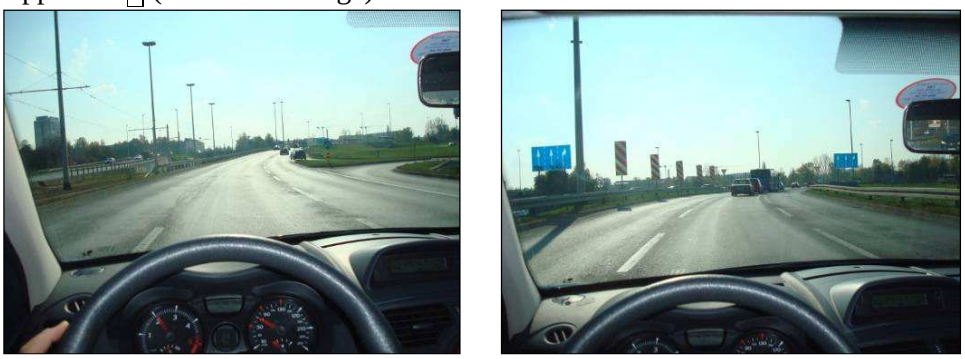

Figure 6: Registered recordings of visibility at approach 3 (Avenue Dubrovnik) and approach 4 (Jadranski Bridge) [1, 4]

Table 2 shows thirty analyzed traffic accidents which occurred in the area of the Jadranska Avenue – Avenue Dubrovnik roundabout in Zagreb. The traffic accidents have been processed according to the time, place, type, consequences, and cause of occurrence. Table 3 shows the overall analysis of the processed traffic accidents expressed in percentages (%), whereas the layout of the intersection area with the highest number of traffic accidents is given in Figure 7.

Table 2: Analysis of traffic accidents at Jadranska Avenue – Avenue Dubrovnik roundabout [2]

Year 2008					
Reg. No.	TIME (date /hour)	PLACE	TYPES	CONSEQUENCES	CAUSE
3200800360	21.07. / 10.00 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
0320-0800620	20.09. / 10.45 h	right approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
10510801228	29.11. / 20.45 h	middle lane of circular roadway between approaches 1 and 2	collision in merging	material damage	driver' s error, road drawbacks
3200900094	18.12. / 21.10 h	right lane of circular roadway between approaches 1 and 4	collision in merging	material damage	driver' s error, road drawbacks
Year 2009					
Reg. No.	TIME (date /hour)				
10510900464	22.01. / 15.50 h	right lane of circular roadway between approaches 1 and 4	collision in merging and rear-end collision	material damage	driver' s error, road drawbacks
10510900409	22.01. / 17.00 h	right lane of circular roadway between approaches 3 and 4	collision in diverging	material damage	driver' s error, road drawbacks
10510900636	23.03. / 12.45 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
10510900695	06.04. / 12.30 h	right lane of circular roadway between approaches 3 and 4	weaving in circulatory roadway	material damage	driver' s error, road drawbacks
1051-0901888	18.09. / 18.30 h	right approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
1051-0902129	12.10. / 13.00 h	right lane of circular roadway between approaches 1 and 2	weaving in circulatory roadway	material damage	driver' s error, road drawbacks
10510902757	18.12. / 18.50 h	right lane of circular roadway between approaches 1 and 4	collision in diverging	material damage	driver' s error, road drawbacks
Year 2010					
Reg. No.	TIME (date /hour)				
1051-1000164	17.01. / 13.30 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
0320-1000540	17.02. / 16.30 h	middle approach lane 4	collision in merging	material damage	driver' s error, road drawbacks
1051-1000496	19.02. / 7.30 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
0320-1001861	05.07. / 11.43 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
1051-1000590	02.03. / 8.30 h	right lane of circular roadway between approaches 2 and 3	weaving in circulatory roadway	material damage	driver' s error, road drawbacks
1051-1000996	12.04. / 7.15 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
1051-1001201	09.05. / 10.00 h	middle lane of circular roadway between approaches 3 and 4	collision in diverging	non-material damage material damage	driver' s error, road drawbacks
10511001304	19.05. / 8.00 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
10511001356	21.05. / 13.00 h	right approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
1051-1001430	29.05. / 22.15 h	right lane of circular roadway between approaches 1 and 4	weaving in circulatory roadway	material damage	driver' s error, road drawbacks
1051-1002099	12.08. / 16.57 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
1051-1002132	16.08. / 12.45 h	right approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
1051-1002140	20.08. / 12.45 h	right lane of circular roadway between approaches 3 and 4	weaving in circulatory roadway	material damage	driver' s error, road drawbacks
1051-1002141	23.08. / 7.45 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
1051-1003554	23.12. / 20.05 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
0320-1003468	30.12. / 14.30 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks
Year 2011					
Reg. No.	TIME (date /hour)				
1051-1100147	15.01. / 15.00 h	middle approach lane 2	rear-end collision	material damage	driver' s error, road drawbacks
0320-1100177	16.01. / 02.15 h	middle approach lane 1	rear-end collision	material damage	driver' s error, road drawbacks

Note:

- traffic accident – reg.no. 10510900464 of 22.01.2009. consists of two types of traffic accidents

Table 3: Overall analysis of traffic accidents at Jadranska Avenue – Avenue Dubrovnik roundabout

Number of analyzed traffic accidents		30	
TIME			in percentages
Day		20	67%
Night		10	33%
PLACE			
Approach 1 Jadranska avenue	right lane of approach 1	4	13%
	middle lane of approach 1	7	23%
Total at approach 1		11	37%
Approach 2 Remetinečna Road	middle lane of approach 2	6	
Total at approach 2		6	20%
Approach 4 Jadranski Bridge	middle lane of approach 4	1	
Total at approach 4		1	3%
Circular roadway	right lane of circular roadway between approaches 1 and 2	1	3%
	middle lane of circular roadway between approaches 1 and 2	1	3%
	right lane of circular roadway between approaches 2 and 3	1	3%
	right lane of circular roadway between approaches 3 and 4	3	10%
	middle lane of circular roadway between approaches 3 and 4	1	3%
	right lane of circular roadway between approaches 1 and 4	5	17%
Total on circular roadway		12	40%
TYPES			
collision in merging		4	13%
weaving in circulatory roadway		5	17%
rear-end collision		18	60%
collision in diverging		3	10%
CONSEQUENCES			
material damage		29	97%
non-material damage (injured)		1	3%
fatalities		0	0%
CAUSE			
driver' s error, road drawbacks		30	100%

Tables 2 and 3 lead to the following conclusion:

- the highest number of traffic accidents occurred during the day (67%);
- according to the place of occurrence, the highest number of traffic accidents occurred on the circular roadway (40%);
- according to the type of accidents, the highest number of accidents is rear-end collision (60%), and collision in interweaving (17%);
- according to consequences the highest number of accidents is mostly material damage (97%);
- the biggest cause of traffic accidents is the driver's error, and road drawbacks (100%).

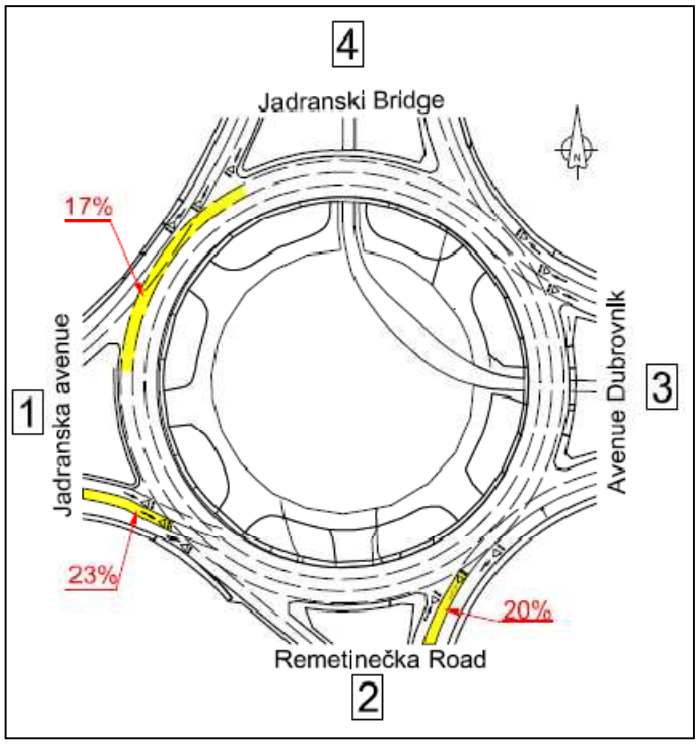

Figure 7: The area of roundabout zone Jadranska Avenue – Avenue Dubrovnik with highest rate of traffic accidents (%)

3 CONCLUSION

The roundabout has been designed for lower traffic loads than the present ones and according to obsolete design and safety requirements. Because of its position and role in the traffic network over time it became undercapacitated and causes significant congestions.

In order to determine the cause of occurrence of the highest number of traffic accidents during the day, further research is necessary, which would contain data on the meteorological conditions and the visibility. The most significant cause of a large number of accidents on the circular roadway (collisions in interweaving) is the existence of three lanes in the circular roadway, which causes confusion for some drivers.

Long sections in front of the roundabout (approaches 1, 3 and 4), and tangential merging from the approaches allows high approaching speed (Table 1), and the higher level of the intersection i.e. the gradients of the approaches in combination with safety fence and vertical signalization have caused reduced visibility at arrival and merging into the intersection (Figures 5 and 6). These design elements are the main cause of the majority of accidents – rear-end collisions (Table 3).

All the mentioned design elements are the main cause of all the traffic accidents at the observed intersection, since with their inadequate characteristics they directly influence the driving conditions. Consequently, they cause drivers' errors, which subsequently cause a large number of traffic accidents with material damage, without fatalities.

Due to all the mentioned drawbacks, urgent reconstruction of the respective roundabout is necessary. The reconstruction would significantly reduce the number and the consequences of traffic accidents, and it would increase its throughput capacity.

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