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WAITING TIME ON LARGE ROUNDABOUT - CASE STUDY

ČAS ČAKANIA NA VEĽKEJ OKRUŽNEJ KRIŽOVATKE - PRÍPADOVÁ ŠTÚDIA

Abstract

Many studies showed, that waiting time of vehicles is important characteristic – has a significant effect on critical gap and capacity of roundabout. The results of analysis of waiting time of road vehicles and trams and its evaluation especially on a large roundabout are presented in the paper. The values of waiting time estimated from the results of a special traffic survey as well as calculated using HCM formula are compared.

Keywords

Large roundabout, traffic volume, waiting time, capacity.

Abstrakt

Mnohé štúdie ukázali, že čas čakania vozidiel je dôležitá charakteristika – má významný dopad na kritickú medzeru a kapacitu okružnej križovatky. V článku sú prezentované výsledky analýzy času čakania vozidiel a električiek a ich hodnotenie, špeciálne na veľkej okružnej križovatke. Hodnoty času čakania stanovené z výsledkov špeciálneho dopravného prieskumu sú porovnané s hodnotami výpočtu podľa HCM.

Kľúčové slová

Veľká okružná križovatka, intenzita, čas čakania, kapacita.

1 INTRODUCTION

Ever-increasing traffic volumes on road networks cause problems with solution of neuralgic points - intersections. Their design is a challenging task for the designers - the need to ensure sufficient capacity and quality – level of service. Currently the roundabout are frequently applied alternative solutions intersections, especially in urban conditions. Quality services on these intersections will be provided with the correct geometry design - depending on the rate crossed communications to intersection, which has sufficient capacity. A direct consequence of optimal design is then reducing the delay of vehicles passing through the intersection. Vehicle delay at the intersection is particularly important, especially for public transport vehicles. The situation at the roundabout is more complicated in the case of tram vehicles passing such a crossroads. For technical reasons, railroad cannot be led circuit so tram crossing with the traffic flow of motor vehicles at the intersection is a potential accident site, but also, due to the right of way of vehicles on the circuit, the source delay trams.

The capacity is decisive in the choice of type intersection for the traffic engineering designer; therefore knowledge of actual characteristics that affect it has an important role.

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2 THEORY OF SOLVING PROBLEM

Most of the models to calculate of capacity of the roundabout are base on the theory of critical gaps - capacity is an exponential function and is heavily dependent on the critical gap, assuming that all drivers are homogeneous - they will only accept gaps bigger than the critical gap and reject smaller [1]. Also, according to [2], about the current draft for design of roundabouts in Slovakia, the entrance capacity is defined as the maximum number of vehicles, which use appropriate gaps. It depends on the number of lanes on the circle, the number of lanes on the entrance, traffic volume on the circle and is expressed as follows:

$$G = 3600 \cdot \left(1 - \frac{t_{min} q_{\mathrm{k}}}{3600\, n_{\mathrm{k}}}\right)^{n_{\mathrm{k}}} \frac{n_{\mathrm{z}}}{t_{\mathrm{f}}} e^{-\frac{q_{\mathrm{k}}}{3600}\left(t_{\mathrm{g}} - \frac{t_{\mathrm{f}}}{2} - t_{\mathrm{min}}\right)} \tag{1}$$

where:

G – is the basic entrance capacity [p.veh/h];

q_k – the traffic volume at circle [p.veh/h];

t_g – the critical time gap [s], may be used $t_g = 4{,}1$ s;

t_f – the follow-up time gap [s], may be used $t_f = 2{,}9$ s;

n_z – the number of lanes at the entrance to the intersection [-];

n_k – the number of lanes at circle [-];

t_{min} – the minimum time gap between vehicles at circle [s] may be used value $t = 2.1$ s [2].

Uniformed and recommended values of critical gap are used into calculations of the capacity. Some foreign studies show that the waiting time for entrance to circle (w) affects the behavior of the rider - his critical gap is dependent on the waiting time - with increasing waiting time the critical gap is reduced. This can cause the real entrance capacity is higher than gives [1, 3].

The average waiting time is a quality behavior of the traffic movements at the intersection - Figure 1.

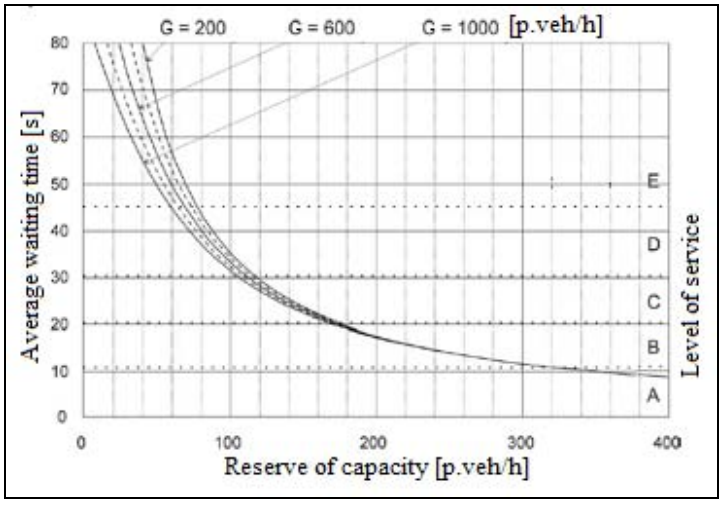

Fig.1: The average waiting time depending on the capacity and reserve of capacity [2]

Waiting time can be quantitatively expressed by theoretical calculation [2, 4] or experimental measurements.

This paper presents the example of a large roundabout demonstrated the results of the analysis of traffic-engineering features as parameters affecting the critical gap and, ultimately, the capacity of

the intersection - volumes, composition of traffic flows and the waiting time obtained from direct measurement - traffic survey.

3 EXPERIMENT – THE TRAFFIC SURVEY

The aim of the experiment was to determine the actual traffic-engineering features of roundabout for evaluation of roundabout capacity. It was therefore conducted a special survey of automobile traffic and tram traffic in a typical working day of the week during peak hour - morning and the afternoon (the time the survey was selected on the basis of long-term monitoring of traffic volumes). Transport survey methodology (TS) was chosen in order to obtain information on:

- traffic volume on circle and all entrances and exits of intersection,
- traffic volume on separate lanes to turn right,
- composition of traffic flows at the intersection,
- routing traffic through the junction area,
- waiting time of vehicles at entrances to circle and
- trams' waiting time at the entrance / exit to / from the circle.

3.1 Geometrical parameters of intersection - intersection description

For experiment was chosen roundabout Tr. SNP - Moldavská cesta - Alejová with tram in Kosice - aerial photo see Figure 2 - with an outside diameter D = 103 m with two lanes at circle lane. Four lanes roads are coming into the intersection. The configuration is following: two lanes going into intersection and one separate lane for vehicles to turn right. Particularity intersection is that tram road going through in all directions. Movement of pedestrian is provided by crossings at all entrances to the intersection. Diagram of intersection geometry is in Figure 3.

Fig.2: Intersection aerial image

3.2 Transport Survey Methodology

Traffic survey was conducted by two methodologies: dash-and-dot method for direct right turn and number plates recording method and special transport survey of waiting time. Direct method was studied for the type and number of vehicles used to separate right turn lane. The number plates recording method was found direction of movement vehicles at intersection, composition of traffic

flows and traffic volume on the entrance and exits to/from circle. By special survey was determined waiting time of vehicles before entering the circle. The survey was conducted on a working day - Tuesday, during the morning (7:00 to 8:00) and afternoon (16:00 to 17:00) peak hours. Designation of entrances:

1. Moldavská cesta – Z. Štadión.
2. Tr. SNP.
3. Moldavská cesta – OC Optima.
4. Alejová.

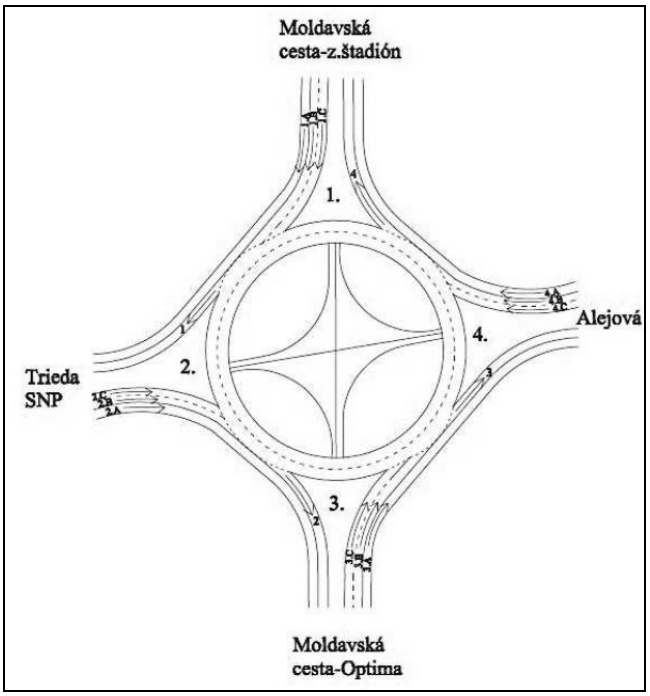

Fig.3: Schematic junctions with labeled entrances for TS

The tram traffic survey was conducted by recording the number and direction of trams and by the research using method for direct recording time waiting.

3.3 Geometrical parameters of intersection - intersection description

Traffic volumes on all entrances are relatively high, because it is the main entrance radials to Kosice - I/50 road in the direction from Rožňava (Bratislava), and collection local roads - Tr. SNP and Moldavská cesta.

The volume of the pedestrian crossings was very low, therefore not monitored.

Volumes and direction of vehicles crossing the area at the time of the survey is shown in Tables 1 and 2.

Tab.1: Volumes – morning hour [p.veh/h]

FROM	TO				∑ 1
	1.	2.	3.	4.	
1.	6	12	221	424	663
2.	318	14	14	120	466
3.	192	529	8	42	771
4.	23	229	452	2	706
∑ 3	539	784	659	588	

Tab.2: Volumes – afternoon hour [p.veh/h]

FROM	TO				∑ 1
	1.	2.	3.	4.	
1.	4	18	314	531	867
2.	447	6	17	177	647
3.	214	460	6	26	706
4.	18	124	483	5	630
∑ 3	683	608	820	739	

Load is shown graphically in the form of cartograms in Figures 4 and 5.

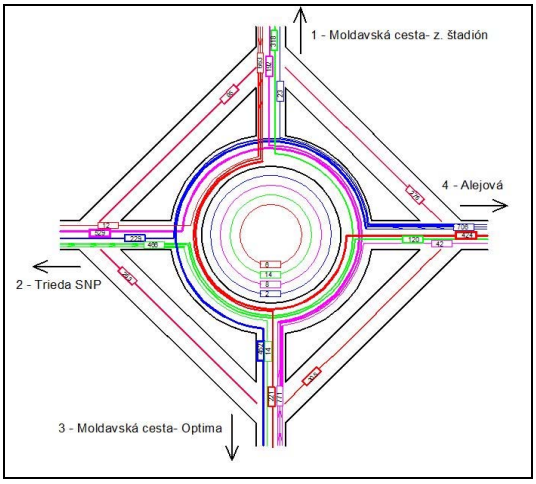

Fig.4: Cartogram of volumes - morning peak hour (7:00 to 8:00) in [p.veh/h]

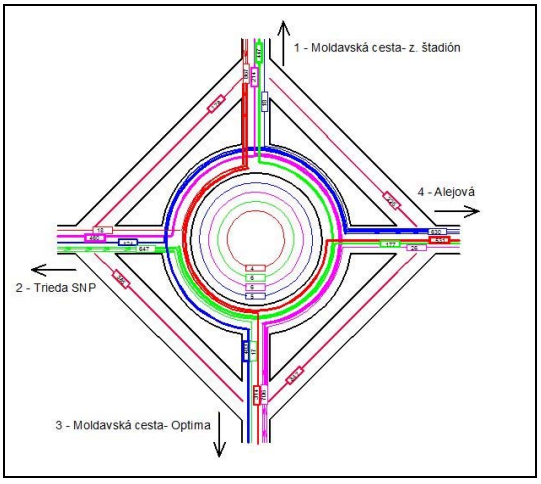

Fig.5: Cartogram of volumes - afternoon peak hour (16:00 to 17:00) in [p.veh/h]

Waiting times determined from traffic survey in the morning peak hour are shown in Table 3 for vehicular traffic, for trams in Table 4 in the afternoon peak hour in Tables 5 and 6. There is number of delayed vehicles and the number of vehicles at the entrance.

Tab.3: Observed waiting times of vehicles - morning peak hour

The entrance	Volume of the entrance [veh/h]	*w* [s]		
	Delayed vehicles/total	Max.	Min.	Average
1.	220/611	19.9	1	5.65
2.	350/422	22	1	7.1
3.	269/731	108	1	14.55
4.	417/665	40	1	10.6

Tab.4: Observed waiting times of trams - morning peak hour

Direction	Volume of the entrance [trams/h]	*w* [s]					
	Delayed trams/total	Max.		Min.		Average	
		input	output	input	output	input	output
1.-2.	6/6	12	4	2	1.2	5.16	2.68
1.-3.	2/2	42.1	17	12	2.3	27.05	9.65
1.-4.	0/0	-	-	-	-	-	-
2.-1.	6/6	18	19.7	1.5	2.9	7.25	10
2.-3.	1/1	5.5	5.2	5.5	5.2	5.5	5.2
2.-4.	6/6	24	32.7	4	1.4	9.92	18.23
3.-1.	1/1	5.5	2.7	5.5	2.7	5.5	2.7
3.-2.	4/5	8	10	2	4.9	5.45	6.45
3.-4.	0/0	-	-	-	-	-	-
4.-1.	0/0	-	-	-	-	-	-
4.-2.	6/6	25.6	17	2	2	7.45	10.15
4.-3.	1/1	21	5	21	5	21	5

During the morning peak hour crossing went through 2 429 vehicles, of which 177 heavy vehicles (buses and trucks), that is 7.3%. The most loaded (30.1%) was the entrance number 3 Moldavská cesta - OC Optima and most loaded (30.8%) exit was number 2 - Tr. SNP. The least loaded were the entrance (17.4%) at station number 2 Tr. SNP and the least loaded exit (19.8%) was the exit on the station number 1. Moldavská cesta - Z. Štadión.

From all amount of the 2429 cars there were 1256 cars delayed which is 51.7%. Most delays vehicles (62.7%) were recorded at the entrance number 4 Alejová and the least (36%) at the entrance number 1 Moldavská cesta - Z. Štadión. The highest average waiting time was at the entrance number 3 Moldavská cesta - OC Optima 14.55, the lowest at station 1 Moldavská cesta - Z. Štadión. The highest measured waiting time (108 s) was recorded at the entrance number 3. Moldavská cesta - OC Optima.

During the morning, it was out of a total of 34 trams 33trams were delayed (97%). High time waiting for entrance (42.1 s) was measured at the direction of the 1 - 3 Moldavská cesta - Z. Štadión

and Moldavská cesta - OC Optima, the highest waiting time was measured for exit (32.7 s) at the direction of the 2 - 4 from Tr. SNP to Alejová.

Tab.5: Observed times of vehicles waiting at the intersection - afternoon hour

The entrance	The volume of the entrance [veh/h]	*w* [s]		
	Delayed vehicles/total	Max.	Min.	Average
1.	280/807	44.8	1	8.85
2.	231/615	30	1	6.45
3.	234/676	39	1	9.5
4.	465/592	60	2	12.25

Tab.6: Found trams waiting times at the crossroads - afternoon hour

Direction	Volume of the entrance [trams/h]	*w* [s]					
	Delayed trams /total	Max.		Min.		Average	
		entrance	exit	entrance	exit	entrance	exit
1.-2.	5/5	34.4	18	4.2	4.3	22.15	8.24
1.-3.	1/1	56.9	36	56.9	36	56.9	36
1.-4.	0/0	-	-	-	-	-	-
2.-1.	5/5	9.3	72.2	4.2	4.4	6.16	26.72
2.-3.	0/0	-	-	-	-	-	-
2.-4.	5/5	26.3	15.3	4	7.9	12.88	10.7
3.-1.	2/2	7	34.6	7	16	7	25.3
3.-2.	1/1	7.4	8.5	7.4	8.5	7.4	8.5
3.-4.	1/1	3.9	12.1	3.9	12.1	3.9	12.1
4.-1.	0/0	-	-	-	-	-	-
4.-2.	5/5	20.1	4	8.9	2.4	14.5	3.38
4.-3.	0/0	-	-	-	-	-	-

During the afternoon peak hour 2,690 vehicles went through crossing, of which 160 heavy vehicles (buses and trucks), which is 5.9%. The most loaded entrance (30%) was 1st entrance Moldavská cesta - Z. Štadión and most loaded exit (28.6%) was the exit number 3 Moldavská cesta - OC Optima. The least loaded entrance (22%) was number 4 Alejová and the least loaded was the exit (21.6%) number 2 Trieda SNP.

From all amount of the 2690 cars there were 1210 cars delayed which is 45%. Most delays vehicles (38.4%) were recorded at station number 4 Alejová and the least (19.1%) at station number 2 Trieda SNP. The highest at the entrance number 4 Alejová 12.25 s and the lowest entrance average waiting time was at number 2 Trieda SNP. The highest measured waiting time (60 s) was recorded at the entrance number 4 Alejová.

For comparison, the waiting time of vehicles is calculated according to equation (1), and time gap values given in [2] were used in the calculation. Calculation results and service level determination by figure 1 are shown in Tables 7 and 8, and also results compared with data obtained from traffic surveys.

Tab.7: Comparison of average waiting time of vehicles - morning peak hour

The entrance	Average *w* [s] from TS	Level of service	Average *w* [s] according to [2]	Level of service
1.	5.65	A	20	B
2.	7.1	A	< 10	A
3.	14.55	B	< 10	A
4.	10.6	A	12	B

Tab.8: Comparison of average waiting time of vehicles - afternoon peak hour

The entrance	Average *w* [s] from TS	Level of service	Average *w* [s] according to [2]	Level of service
1.	8.85	A	28	C
2.	6.45	A	32	D
3.	9.5	A	18	B
4.	12.25	B	11	B

From Tables 7 and 8, it is clear there are different values of waiting time and the evaluation of the service level. The results by [2] and traffic survey were compared. The actual waiting times are often below as calculated.

4 CONCLUSION

The results give a picture of the real load of roundabout with an emphasis on waiting time of vehicles and trams on a large roundabout with a tram. Forasmuch as that is the only one intersection of this type in Slovakia it was impossible compared the results. This type of intersection occurs abroad [5]. The analysis shows that the calculated average waiting times for some of the entrances are higher than those actually measured. It can mean that drivers entering the circle using shorter time gaps. To speak exact findings from the evaluation of the impact of time waiting for the critical time gap and the capacity of the large roundabouts in Slovakia will be necessary to perform a variety of other measurements.

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