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DETERMINING THE CRITICAL HEADWAYS BY OBSERVATION THE ROUNDBOUDT’S TRAFFIC FLOWS IN RUSSIAN FEDERATION

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Abstract

This paper describes the results of the critical headways surveys at roundabouts in the Russian Federation. The project is finished in 2017 and its main target is to improve the capacity and delays estimation technique. In the period of the USSR the manual of traffic circles and roundabouts design was prepared in the middle of the 80th of last century. The former manual contained the capacity estimation technique considering conflict points and weaving zones. In 40 years have changed a lot of things: daily volumes, structure of traffic flows, cars and tracks dynamic, as well as drivers behavior. The results of current project allowing to consider the actual traffic conditions at roundabouts in Russia and feature of driver’s behavior. During processing of the obtained data there was a problem of the choice of the critical headways estimation technique. During the observation we got a lack of saturated conditions which are continuous queuing on the minor road entering the roundabout. So Siegloch’s method which requires saturated conditions has been rejected and Ruff’s method was chosen. Raff’s method is based on simple technique of the accepted and rejected intervals consideration and no iterative procedures are required. Received results confirm that the general equations of roundabout’s capacity estimation (HCM 2000 and HCM 2010) are applicable in Russia.

Keywords: roundabouts, gaps assumption, critical gaps estimation

1 Introduction

Over the last years, the Federal Road Agency of the Russian Federation has been working on updating the design manuals including the preparation of a draft preliminary national standard “Public roads. Rules of roundabouts design”. This paper will deal with the compact turnarounds, which basic parameters for calculating the capacity are critical gaps and follow-up times. At the same time, the roundabout capacity calculation method, which was used previously, was based on the estimation of the traffic flow in weave zones, which was the result of the common practice for a long time of designing the large-diameter circles with 3 and, sometimes 4, lanes on the circulatory roadway.

2 Objective

The research work objectives were to establish the characteristics (parameters?) of traffic flows on the roundabouts including which are classified as compact ones. In accordance with this, the critical gaps became one of the most important characteristics of the interaction of traffic flows in the zone of their confluence at the entries to the circulatory roadway.
3 Methodology

Nine roundabouts were selected in the Moscow region and the city of Moscow for the research, and the main principle of site selection was the complete absence of the pedestrian impedance. The aerial video recording with quadcopter (Figure 1) was used for the field survey. The range of values of the characteristics of the investigated roundabouts is shown in Table 1.

![Image of roundabout](image)

**Figure 1** One of the investigated intersections, Uspenskoye – 1st highway, (Moscow region) and the traffic flow interaction area considered on it

<table>
<thead>
<tr>
<th>Characteristics of the roundabouts</th>
<th>Range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lanes on the circulatory roadway</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Number of lanes on the entries</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Circulatory roadway traffic volume, vehicles/hour</td>
<td>234 – 1146</td>
</tr>
<tr>
<td>Circulatory roadway traffic volume per lane, vehicles/hour per lane</td>
<td>117 – 573</td>
</tr>
<tr>
<td>Traffic volume on the entries, vehicles/hour</td>
<td>288 – 870</td>
</tr>
<tr>
<td>Traffic volume per entry lane, vehicles/hour per lane</td>
<td>96 – 732</td>
</tr>
</tbody>
</table>

The peculiarity of the sample of the investigated intersections was that it included only very contrast situations. The highest values of the circulatory roadway traffic volumes were combined with the low values on approaches to them, and vice versa, the case of maximum traffic load on the approach of 732 vehicles/hour corresponded to the insignificant circulatory roadway traffic volume of 776 vehicles/hour (388 vehicles per lane). The obtained values of the circulatory roadway traffic volumes made it possible to conclude that in the cases under consideration the headways distributions can be described by an exponential distribution and there is no need to use a shifted exponential distribution and Cowan 3M distribution [1-3]. While processing the video records the gaps in the main flow and the follow-up times in the secondary flow were defined in accordance with the schemes shown in Figure 2.
Critical gaps cannot be determined directly by field surveys. There are several methods to calculate the critical gaps based on essentially different statistical estimates: Siegloch’s Method; Ashworth’s Method; Raff’s Method et al [2-5]. From the practical point of view, Siegloch’s Method is most attractive as it allows constructing the regression model, which allows determining two parameters at once: critical gap and follow-up time. According to Siegloch’s Method the \( t_c \) critical gap is determined as:

\[
t_c = g_o + 0.5 t_f
\]

(1)

Where \( g_o \) is minimum accepted gap (s); \( t_f \) is follow-up time in minor stream (s).

To apply the method under consideration the condition that there is a vehicle queue on the approach to the turnaround at the secondary direction throughout the measurement period should be met. The survey data analysis showed that in most examined cases the vehicle queue included 2-3 vehicles and the set values of follow-up time vary greatly from 2.36 to 6.01 (s). The obtained values vary significantly from the results of earlier studies that examined the case of saturated approaches [6]. In this regard, Siegloch’s Method had to be abandoned. It should also be noted that absence of queues on the entries to the roundabouts did not allow obtaining the regression models of capacity estimation as it was done in HCM 2010.

Raff’s Method seems to be more effective under the conditions of unsaturated flows at the secondary directions (e.g. roundabout entries). Determination of the critical gap using the Raff’s Method is based on the proposition that there is a sum of two probabilities [4, 5]:

\[
F_a(g) + F_r(g) = 1
\]

(2)

Where \( g \) is gap of major stream; \( F_a(g) \) is cumulative probability of accepted gap; \( F_r(g) \) is cumulative probability of rejected gap.

The critical gap estimation procedure using the Raff’s Method has simple geometric interpretation according to which the critical gap \( t_c \) is a point of intersection of cumulative probabilities \( F_a(g) \) and \( F_r(g) \). This method was used to determine critical gaps on all investigated intersections (Figure 3).
Figure 3  Critical gap estimation (Golovinskoye Highway)

4 Results

The estimation results using Raff’s Method are presented in Table 2. The obtained values varied greatly, which required analysis and explanation. A part of results shown in Table 2 ($t_c = 16.56 \text{ s}$ and $t_c = 11.68 \text{ s}$) is explained by insignificant values of the circulatory roadway traffic volume, when, correspondingly, the critical lags acceptance should be considered instead of critical gaps acceptance. In case of approach with two lanes, the value $t_c = 2.8 \text{ s}$ is obtained on the entry to the 4 lane circulatory roadway and explained by the fact that the secondary flow entering at high speed and at an acute angle into the main flow on the circulatory roadway of large diameter. The latter case has nothing to do with the roundabouts traffic mode and is not considered. After the case with low values of the circulatory roadway traffic volume have been excluded from consideration the final result of the study is as follows (Table 3).

<table>
<thead>
<tr>
<th>Critical gap, $t_s$</th>
<th>Number of lanes</th>
<th>On the roundabout entry</th>
<th>On the circulatory roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.56</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11.68</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5.13</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>10.2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6.22</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8.21</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3.89</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6.12</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6.50</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.18</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>8.32</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3.25</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.16</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4.16</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2.80</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2  Critical gaps according to exam. results

<table>
<thead>
<tr>
<th>Critical gap, $t_s$</th>
<th>Number of lanes</th>
<th>On the roundabout entry</th>
<th>On the circulatory roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>8.6</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6.2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4.2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3  Critical gaps depending on the no. of lanes
It was interesting to analyze the traffic volume effect on the value of the critical gap accepted by drivers. The traffic load effect on the ring carriageway was discovered.

\[ t_c = 10,48 - 0,0069v_r; R = -0,47 \]  

(3)

Where \( v_r \) is traffic volume on the circulatory roadway, vehicles/hour.

Correlation of relationship “critical gap — traffic volume on the circulatory roadway and the roundabout entry” is slightly higher:

\[ t_c = 13,14 - 0,48v_r - 0,23v_a ; R = 0,53 \]  

(4)

Where \( v_r \) is traffic volume on the circulatory roadway, vehicles/hour, \( v_a \) is the roundabout entry, vehicles/hour.

The results obtained are similar to the research data of other countries [2, 3, 7, 8]. At the same time, the high value of the critical gap \( t_c = 9 \) s obtained for the combination “one lane on the approach – 1 or 2 lanes on the ring” draws attention. More such roundabouts should be included in the further examinations when planning the experiment.

5 Conclusion

As a result of the research, critical gap values were obtained for different combinations of the number of lanes at the roundabouts and entries to them. Further researches should be aimed at studying the cases of saturated flows in the secondary directions, which will allow obtaining the required statistical material to evaluate the follow-up time. This will require expanding the surveys geography, i.e. the roundabouts should be considered in as many regions of the country as possible.

References

