Vladislav Křivda*

CALCULATION OF CAPACITY RESERVES OF SMALL ROUNDABOUTS ARMS USING CAPACITY CALCULATIONS OF DIRECT INTERSECTIONS & T-JUNCTIONS

VÝPOČTY REZERV KAPACIT RAMEN MALÉ OKRUŽNÍ KŘIŽOVATKY S VYUŽITÍM KAPACITNÍCH VÝPOČTŮ PRŮSEČNÝCH A STYKOVÝCH KŘIŽOVATEK

Abstrakt

Příspevěk se zabývá hypotézou využití výpočtů rezerv kapacit průsečných a stykových křižovatek s použitím kritických a následných mezer pro výpočty rezerv vjezdu do malé okružní křižovatky. Teoretický základ je doplněn výpočty pro konkrétní křižovatku a konkrétní intenzity dopravních průvodů.

Abstract

The paper deals with a following hypothesis: application of direct intersections and T-Junctions capacity reserves for calculating entrance reserves into small roundabout with usage of critical and subsequent intervals. Theoretical fundamentals are supported by computations for a specific intersection and traffic flow intensity.

1 Introduction

Road transport, especially automobile transport, is booming for last 15 years in the Czech Republic. Number of vehicles is increasing, while the traffic safety is decreasing. There are lot of reasons, for instance poor operating conditions of vehicles and roads, unsatisfactory legislation and – last but not least – driver’s aggressiveness.

This is the reason why small roundabouts might help to calm down the traffic; first of all if they are suitably designed, for instance in transition from urban areas to extra-urban areas etc. Crucial condition is meeting desired and designed objectives, such as capacity of traffic flow etc.

It’s possible to imagine a small roundabout as four T-junctions with one-way traffic. Among other known methods for roundabout capacity calculations is theoretically possible to use theory of non-controlled intersections even for calculation of roundabout-arms capacity reserves. The following text will validate this theory in the practice.

2 Theory of Non-Controlled Intersections

According to theory of non-controlled intersections are fundamentals for their calculating separation of main and neighbouring traffic flows into flows from 1st up to 4th grade, depending on the traffic priority, in accordance with the Highway Code No. 361/2000. 1st grade traffic flows are superior to all others, 2nd grade traffic flows gives way only to 1st grade traffic flows, 3rd grade traffic flows gives way to 1st and 2nd grade traffic flows and, finally, 4th grade traffic flows gives way to 1st, 2nd and 3rd grade traffic flows on a T-junction.

Another fundament is so-called critical interval $t_c$ and consecutive interval $t_p$. A critical interval among the vehicles in the main traffic flow is described [Medelská, 1991] as an interval being accepted by 50% of drivers as suitable and being declined by other 50% of drivers for manoeuvring...

* Ing., Ph.D., Institute of Transport (342), Faculty of Mechanical Engineering, VSB - Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, +420 59 732 5210; vladislav.krivda@vsb.cz; http://www.id.vsb.cz/krivda
(i.e. crossing or joining the main traffic flow). All other intervals smaller than \( t_g \) are se marked as “bloc” and bigger than \( t_g \) as “anti-bloc”. A critical interval might be determined (for instance by J. R. Dorfwirth [Medelská, 1991]) by lining-up exploited and idle intervals according to their dimensions and plotting them on a graph. The point of intersection then shows desired value of a critical interval.

If exist any time intervals in the main traffic flows, which are bigger than the critical interval, then this interval maybe utilized by several vehicles from the neighbouring traffic flow. Logically, the biggest time-claim gains the first vehicle and the intervals of other vehicles are substantially smaller. Time interval among vehicles entering the T-junction from the neighbouring traffic flow is called as “subsequent interval” \( t_f \). It is determined by the average value and represents time interval between two consecutive vehicles.

Interval occurrence among vehicles in the main traffic flow is stochastic process and is determined by the exponential (Poisson) distribution as follows:

\[
P(t_{co} \geq t) = e^{-\frac{M}{3600} t} = e^{-q t} \quad \text{while} \quad q = \frac{M}{3600} \quad [\text{car.s}^{-1}]
\]

where \( P(t_{co} \geq t) \) Interval occurrence probability bigger or equal to \( t \)

\( M \) Hour intensity \([\text{car.h}^{-1}]\)

\( q \) Second intensity \([\text{car.s}^{-1}]\)

Final equation for performance of the neighbouring traffic flow by Harders is:

\[
C_m = \frac{M}{e^{\frac{M}{3600} t_f} - e^{\frac{M}{3600} t_f + q t_f}} \quad [\text{car.h}^{-1}]
\]

where \( t_g \) Critical interval \([\text{s}]\)

\( t_f \) Subsequent interval \([\text{s}]\)

It is essential to take into account also vehicle “arising” on a T-junction, case of traffic flows with the common integrating etc. during these calculations, see [Křivá, 2002]. The authors of this theory (Harders and Siegloch) recommend for T-junctions in urban areas following values:

- for the 2\textsuperscript{nd} grade traffic flow: \( t_g = 5.2 \text{ s}; t_f = 2.7 \text{ s} \)
- for the 3\textsuperscript{rd} grade and higher traffic flows: \( t_g = 6.0 \text{ s}; t_f = 3.2 \text{ s} \)

3 Calculations of Reserves on a Small Roundabout

Having used the above mentioned theory for non-controlled intersections some calculations on a small roundabout in Prokeš’s square in Ostrava (see Pic.1) have been made. This intersection has been designed with 4-arms but the fourth arm serves only for resident traffic with a very small intensity about 1-2 vehicles per hour. That’s why this arm has not been considered in the calculation. This roundabout contains only 1\textsuperscript{st} grade traffic flow (on a roundabout ring) and traffic flows on roundabout’s entrances.

As input data were applied following values:

- Intensity on intersection arms:
  - arm A: 645,0 unit vehicles/h
  - arm B: 604,5 unit vehicles/h
  - arm C: 268,5 unit vehicles/h

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Intensity on a roundabout ring (before arm entrance):

arm A: 94,0 unit vehicles/h
arm B: 135,0 unit vehicles/h
arm C: 498,0 unit vehicles/h

- critical interval: $t_g = 5,2$ s
- subsequent interval: $t_r = 2,7$ s

Picture. 1: Air view on the small roundabout on Prokeš's square in Ostrava

**Arm A:**

Capacity:

$$C_m = \frac{94}{\frac{94,5,2}{3600} - e^{\frac{94,5,2 - 2,7}{3600}}} =$$

$= 1206$ unit vehicles / h

**Arm C:**

Capacity:

$$C_m = \frac{135}{\frac{135,5,2}{3600} - e^{\frac{135,5,2 - 2,7}{3600}}} =$$

$= 1154$ unit vehicles / h

Reserve:

$$R = 1206 - 645 = 561 \text{ unit vehicles} / h$$

Reserve:

$$R = 1154 - 640,5 = 513,5 \text{ unit vehicles} / h$$
Arm D:

Capacity:

\[ C_n = \frac{498}{\frac{498.5.2}{3600} - e} = R = 778 - 268.5 = 509.5 \text{ vehicles/h} \]

\[ = 778 \text{ vehicles/h} \]

Results of calculations are listed in Table 2. Reserves at all entrances are satisfactory. According to ČSN 73 6102, which determines what kind of obstacle is intersection for given traffic flow based on reserves, is small roundabout only an imperceptible obstacle for all entrances (see Table 1).

Table 1: Obstacle grades and capacity reserves of intersection flows by ČSN 73 6102 Intersection designing on public roads:

<table>
<thead>
<tr>
<th>Obstacle grade</th>
<th>Reserve [vehicles.h⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>characteristics value</td>
</tr>
<tr>
<td></td>
<td>range</td>
</tr>
<tr>
<td>overloaded intersection</td>
<td>0</td>
</tr>
<tr>
<td>very huge obstacle</td>
<td>50</td>
</tr>
<tr>
<td>huge obstacle</td>
<td>100</td>
</tr>
<tr>
<td>medium obstacle</td>
<td>150</td>
</tr>
<tr>
<td>small obstacle</td>
<td>200</td>
</tr>
<tr>
<td>imperceptible obstacle</td>
<td>400</td>
</tr>
<tr>
<td>no obstacle</td>
<td>600</td>
</tr>
</tbody>
</table>

Table 2: Traffic flow output on small roundabout

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>645,0</td>
<td>1206,0</td>
<td>561,0</td>
<td>46,5</td>
<td>imperceptible obstacle</td>
</tr>
<tr>
<td>B</td>
<td>640,5</td>
<td>1154,0</td>
<td>513,5</td>
<td>44,5</td>
<td>imperceptible obstacle</td>
</tr>
<tr>
<td>C</td>
<td>268,5</td>
<td>778,0</td>
<td>509,5</td>
<td>65,5</td>
<td>imperceptible obstacle</td>
</tr>
</tbody>
</table>

Remark: Reserves are expressed in percentages by (3).

\[ Reserve [\%] = \frac{Reserve [\text{vehicles/h}]}{Output [\text{vehicles/h}]} \times 100 \]  \hspace{1cm} (3)

4 Comparison of results given by theory of non-controlled intersections with results given by the classical methods for capacity calculations of small roundabouts

Due to the restricted size of this paper any specific equations for reserve calculations and entrance capacity into small roundabouts will not be presented here. These methods are described in detail for instance in [Křivda, 2002], but first of all in the technical conditions TP 135.

These 3 methods have been used:
1. Brilon and Stuwe method
2. EPFL method (Ecole Polytechniques Fédérale de Lausanne)
3. VSS method (Vereinigung Schweizerische Strassenfachleute)

Capacities and reserves of individual entrances have been calculated by each method. Detailed calculations are presented in [Křivda, 2002]. Results are shown in table 3.
Table 3: Capacity and reserves calculated by Brilon, EPFL and VSS methods and by theory of non-controlled intersections

<table>
<thead>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brilon</td>
<td>EPFL</td>
<td>VSS</td>
<td>Brilon</td>
</tr>
<tr>
<td>A</td>
<td>645,0</td>
<td>1010,0</td>
<td>1190,0</td>
<td>1224,0</td>
</tr>
<tr>
<td>B</td>
<td>640,5</td>
<td>979,0</td>
<td>1102,0</td>
<td>1193,0</td>
</tr>
<tr>
<td>C</td>
<td>268,5</td>
<td>748,0</td>
<td>925,0</td>
<td>920,0</td>
</tr>
</tbody>
</table>

*) Theory of non-controlled intersections

5 Conclusions

Reserves in percentages were plotted on a graph (see Pic.2). It’s clear that the biggest reserves give VSS method, while the smallest ones are given by Brilon. All methods give satisfactory reserves for the case of observed small roundabout.

Additionally, it’s very interesting to compare reserves calculated according to the theory of non-controlled intersections. Capacity reserves of the entrance arms are similar, which proves hypothesis from the beginning of this paper – even for calculation of capacity reserves of a small roundabout is possible to apply theory of non-controlled intersections.

![Graph showing reserve comparison](image)

Pic. 2: Comparison of entrance capacity reserves calculated by Brilon, EPFL and VSS methods with a theory of non-controlled intersections (TNK)

References


