CETRA[2016]

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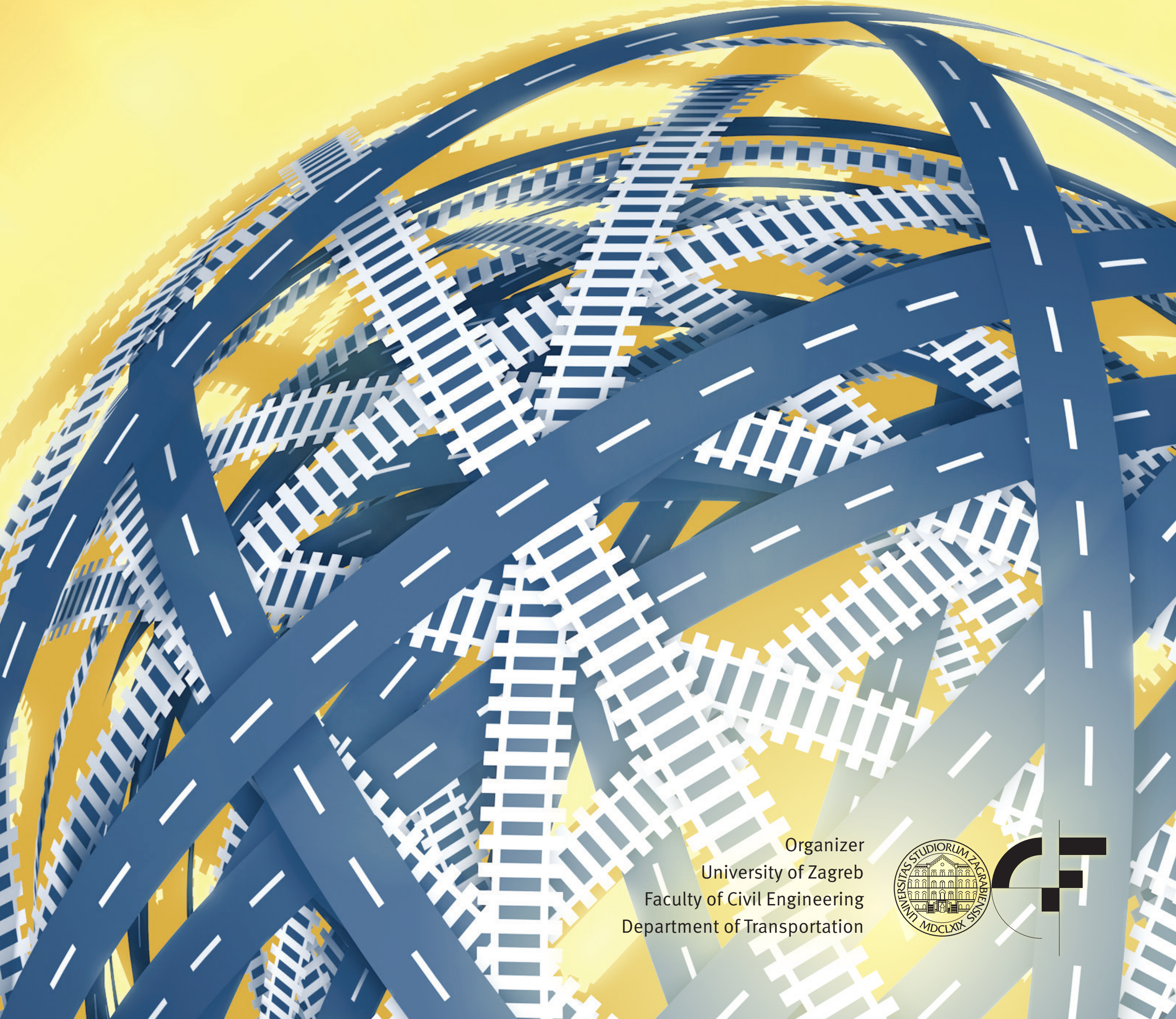
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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COMPARISON OF SOME CAPACITY AND CONTROL DELAY MODELS ON ROUNDABOUTS

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Abstract

In the capacity analysis of roundabouts, correctly determining of the degree of saturation and control delay is of the highest importance, because these parameters are the main indicators of traffic flow quality. This paper briefly describes models of compute control delay on roundabouts that are currently most widely used in practice, such as: HCM, Akcelik, Brilon. In conclusion, will be recommended the guidelines for calibration process of these methods.

Keywords: roundabout, control delay, calibration

1 Introduction

Correct determination of capacity-to-volume ratio and delays, which are basic indicators for quality of traffic movements at intersections, is crucial for roundabout analysis. In practice, there are many methods for determination of level of service at roundabouts, with high dissipation in results. Differences in results are occur because of different approaches in capacity and delay methodologies. In this paper, we give briefly description of capacity and delay models according to Highway Capacity Manual 2010 (HCM 2010), Akcelik (Sidra Intersection) and Brilon, which are the most used methodologies for this purpose.

2 Capacity and delay prediction models

Driver delay consists of a many factors relating to traffic control, roundabout geometry, traffic flow and accidents occurancy. Total delay is the difference between travel time in real conditions and travel time when there is no traffic control, geometric restrictions or any accidents. Delay control includes time that driver spent during deceleration, time when car is completely stopped and acceleration time. This kind of delay interpretation is presented on Figure 1.

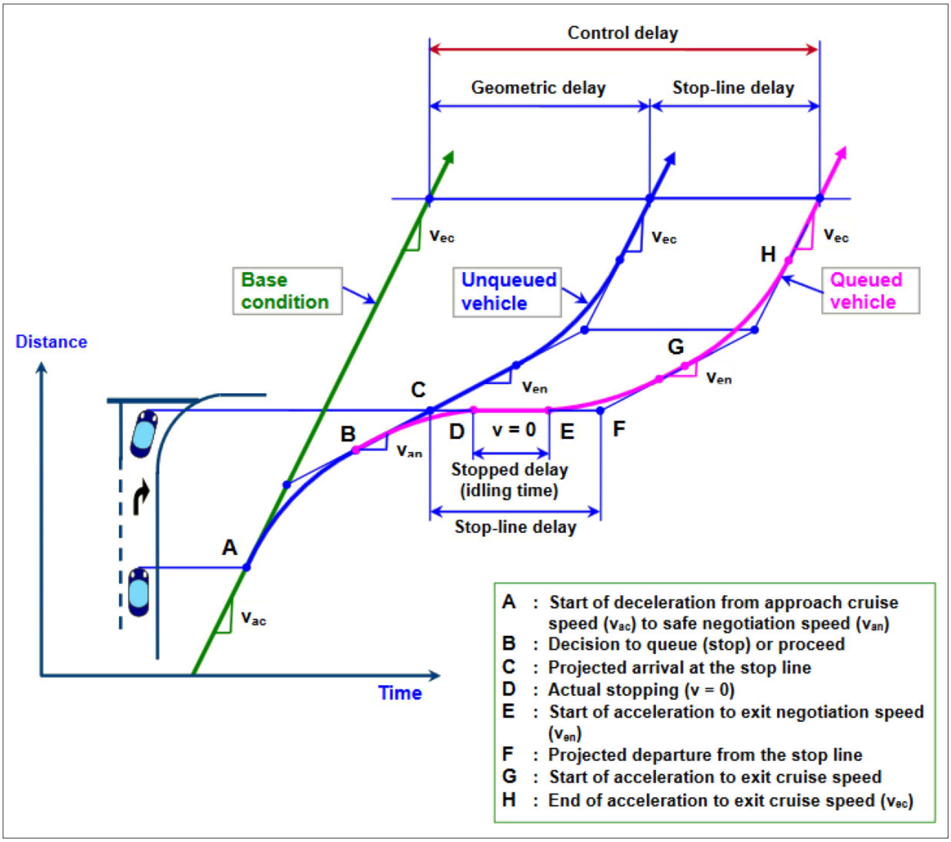

Figure 1 Definition of control delay, geometric delay, stop – line delay and stopped delay (Source: Sidra Intersection – User Guide) [3]

2.1 HCM 2010 metodology

Highway Capacity Manual 2010 is based on many years researches of roundabouts in the United States of America. Capacity for single-lane roundabouts, according to this method, can be calculated with following equations:

$$C_{e,pce} = 1130 \cdot e^{(-1.0*10^{-3})V_{c,pce}} \tag{1}$$

Where:
$C_{e,pce}$ – lane capacity, adjusted for heavy vehicles [pce/h], and
$V_{c,pce}$ – conflicting flow rate [pce/h].

Analytical model for delay control prediction is:

$$d = \frac{3600}{C} + 900T\left[x - 1 + \sqrt{(x-1)^2 + \frac{\left(\frac{3600}{C}\right)\cdot x}{450T}}\right] + 5\min[x,1] \tag{2}$$

Where:
d – average control delay [s/veh],
x – volume-to-capacity ratio of t he subject lane [veh/h],
$c_{m,x}$ – capacity of the subject lane [veh/h],
T – time period [h] (T=0,25h for a 15-min analysis).

2.2 Akcelik metodology (Sidra Intersection 5.1)

In this paper, we only consider Akcelik M3D model. Equation (3) is used for the capacity calculation based on Rahmi Akcelik researches in Australia:

$$Q_c = \frac{3600}{\beta} \cdot \left(\left(1 - \Delta_c \cdot q_c \right) + \left(0{,}5 \cdot \beta \cdot \Phi_c \cdot q_c \right) \right) \cdot e^{-\lambda \cdot (\alpha - \Delta_c)} \quad (3)$$

Where:
β – follow up headway [seconds/vehicle],
α – critical gap [seconds/vehicle],
Δ_c – intrabunch headway [seconds/vehicle],
q_c – circulating flow at entry [pce/hour],
Φ_c – proportion of unbunched vehicles in the circulating stream,
λ – parameter in the exponential arrival headway,
Q_e – capacity of a single entry lane [pce/hour].

Two elements of this equation, Φ_c and Δ_c, are fixed parameters. Φ_c represents the proportion of unbunched vehicles in the circulating stream. Used as a calculated variable in Akcelik's capacity equation, this will be a fixed parameter with the value of 0,55 for this formulation. This is done to maintain simplicity in this paper. In Sidra Intersection User Guide exact equation for Φ_c can be found, although it does not have a big influence on final result [2].
Akcelik gives a value of two seconds for Δ_c parameters, for circulatory roadway with one lane. The remaining element for this equation is λ. This is a parameter in the exponential arrival headway, that according to Tanner (1962, 1967) can be assumed to be equal to the circulating flow [2]. Method for delay calculation according to Akcelik in Sidra Intersection, is the same like in HCM 2010. The main difference is that this method directly takes geometric characteristics into account, while HCM 2010 considers roundabout geometry through regression part of equation (1). Adjusted delay equation by Akcelik is:

$$D = \frac{3600}{Q_e} + 900 \cdot T_f \left(x - 1 + \left((x-1)^2 + \frac{8 \cdot K_d \cdot x}{Q_e \cdot T_f} \right) \right)^{0{,}5} \quad (4)$$

Where:
D – average yield line delay [seconds],
Q_e – capacity of a single entry lane [pce/h],
T_f – duration of the analysis [hours],
x – degree of saturation and
K_d – overflow parameter [K_d = 1].

2.3 Brilon metodology

The capacity of roundabouts in Germany is studied for many years by numerous researches. For all types of roundabouts, except mini roundabouts, entry capacity is not under influence of vehicle flow at other entries. Following equation is used for capacity calculation by German research Werner Brilon:

$$C=3600\cdot\left(1-\frac{t_{min}\cdot q_k}{n_c\cdot 3600}\right)^{n_c}\cdot\frac{n_e}{t_f}\cdot e^{-\frac{q_k}{3600}\cdot\left(t_g-\frac{t_f}{2}-t_{min}\right)} \qquad (5)$$

Where:
C – basic capacity of one entry [veh/h],
q_k – traffic volume on the circle [veh/h],
n_c – number of circulating lanes [-],
n_e – number of entry lanes [-],
t_g – critical gap [s],
t_f – follow-up time [s], and
t_{min} – minimum gap between succeeding vehicles on the circle [s].

As can be seen from this equation, entry capacity depends on number of circulating lanes and number of entry lanes. Other geometric parameters did not show a significant impact on capacity. The values for parameters t_g, t_f and t_{min} depends on type of roundabout and can be calculate using following equations (Table 1).

Table 1 Parameters for capacity calculation in Brilon metology [4]

Type of roundabout	Number of lanes		Parameters		
	n_e	n_c	t_g	t_f	t_{min}
1/1 26 ≤ d ≤ 40m	1	1	$t_g=3{,}86+\frac{8{,}27}{d}$	$t_f=2{,}84+\frac{2{,}07}{d}$	$t_{min}=1{,}57+\frac{18{,}6}{d}$

Roundabout diameter used in this example is 29 m. The formula developed by Brilon for average delay estimation at roundabout entry is:

$$D=\frac{3600}{C}+\frac{900}{C}\cdot\left[\sqrt{(R\cdot T-2)^2+8\cdot C\cdot T}-(R+T+2)\right] \qquad (6)$$

Where:
d – average delay (queueing delay) [veh/s],
C – capacity [veh/h],
T – duration of the peak period [h],
R – reserved capacity [veh/h],
q – total volume [demand] [veh/h].

3 Basic differences in described models

Methodologies presented here have been applied to single-lane roundabout with different values for circulating flow at entry (from 100 to 600 veh/h), while critical gap and follow up headway are taken in accordance with recommendations for each methodology (Table 2). We take three different cases for Akcelik calculation:

1) Akcelik – default values for critical gap and follow up headway which can be found in Sidra Intersection software,
2) Akcelik* – Akcelik methodology with recommended values for critical gap and follow up headway by HCM 2010,
3) Akcelik** – critical gap and follow up headway values recommended by [2].

For Brilon methodology, critical gap and follow up headway are calculated using equations from Table 1 and given roundabout diameter. Comparing different equations for delay, it is clear that differences between them are negligible. Equations for capacity are also based on similar approach, and in all of them critical gap, follow up headway and circulating flow are key parameters. The results are presented in the following Figures 2 and 3.

Table 2 Different values for critical gap and follow up headway

	Akcelik M3D	Akcelik M3D*	Akcelik M3D**	Brilon
Critical gap (sec)	4	4,3	3,5	4,145
Follow up headway (sec)	2	2,85	3	2,911

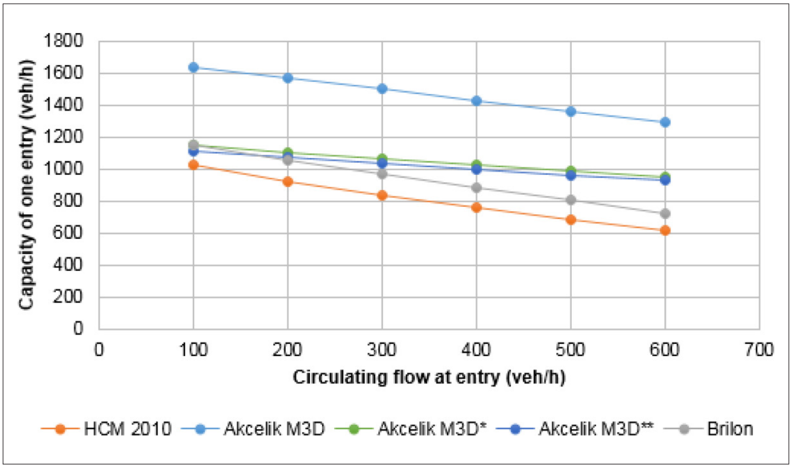

Figure 2 Comparison of roundabout capacity for different metodologies

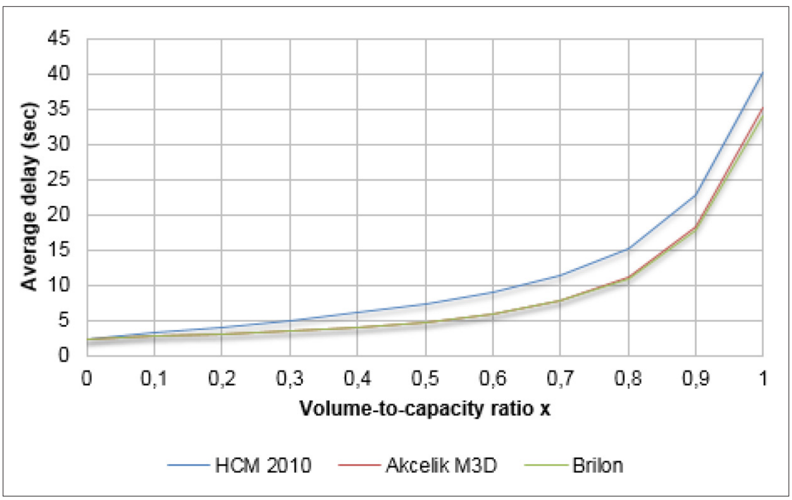

Figure 3 Comparison of average delay for different metodolgies

4 Conclusion

The main conclusions according to obtained results and presented figures are:

- Differences between delay models are negligible (HCM 2010 provides some higher results because of additional part of delay).
- Akcelik's diagram for delay (Figure 1) completely explained methodology for delay calculation and it can be used like a methodology for practical determination of delay in real conditions, on the field.
- Figure 2 shows that the highest values for capacity gives Akcelik and they much depends on critical gap and follow up headway. Hence, it is easiest to make a mistake using this methodology, specially using Sidra Intersection software where capacity is very sensitive to ''environment factor''.
- HCM 2010 method uses fixed values for gap acceptance parameters, while Sidra standard model gap acceptance parameters depend on the geometry and flow rate.
- The capacity has much bigger impact on level of service analyses, because delay models are equal. The most important parameters for capacity determining in all methodologies are critical gap and follow up headway. Recommended values for these parameters are different for all methodologies, so their determination is crucial for quality and correct analysis.

Further researches must be focused on correct calibration process all of these methodologies. Only then, results will match real conditions.

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