JOURNAL OF TRANSPORTATION
SYSTEMS ENGINEERING AND INFORMATION TECHNOLOGY
Volume 14, Issue 5, October 2014
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com

ScienceDirect

Cite this article as: J Transpn Sys Eng & IT, 2014, 14(5), 15−22.

RESEARCH PAPER

Review and Outlook of Roundabout Capacity

QU Zhaowei, DUAN Yuzhou, SONG Xianmin*, XING Yan

College of Transportation, Jilin University, Changchun 130022, China

Abstract: Capacity is an important part of the operation efficiency at roundabouts. Through analyzing existing capacity models of roundabout, this paper focuses on the problem research principles and methods such as empirical regression model, gap acceptance model and model based on simulation software. The key technologies of modeling are also analyzed. Then the general approaches of modeling roundabout capacity are proposed, combined with some problems easily overlooked in previous study. Determining the interaction mechanism among each traffic flow and considering the significant impact factors, the capacity model is established on the whole. Finally, combing with the control objectives of roundabouts, an outlook is proposed for future studies on roundabout capacity.

Key words: traffic engineering; roundabout; capacity model; gap acceptance theory; critical gap

1 Introduction

As an important parameter of transportation system, capacity is the basis of the analysis of delay, level of service and queue length. It is obvious that capacity is closely related to traffic status. Roundabouts are received more attention increasingly due to the advantages of accident-decreasing and efficiency-increasing. According to statistics, the number of roundabouts in U.S. and Canada has been over 2000 by 2010[1]. Roundabout capacity is the maximum possible throughput per unit time under given road geometry and traffic conditions. As the premise of evaluating operating efficiency, the capacity has become a hotspot of roundabout research.

Unsignalized intersection theory provides a solid foundation for the research of roundabout capacity[2, 3]. With the rise of modern roundabouts, research methods of two-way-stop-controlled (TWSC) intersection and two-way-yield-controlled (TWYC) intersection have been successfully applied into analyzing operational efficiency of roundabouts[4]. However, driving behaviors have been changed at roundabout due to the differences of geometrical characteristics and traffic conditions. Moreover, the theoretical transferability must meet with the traffic flow characteristics highly. Therefore, the method of capacity calculation which adequately considered the operational characteristics of roundabout needs to be proposed.

Four typical capacity models of roundabout are analyzed in the paper from the perspective of system analysis. The pros and cons of different models have been systematically discussed based on previous study. Then the general approaches and key factors of modeling roundabout capacity are studied. Finally, an outlook is proposed for future studies on roundabout capacity with the control objectives of roundabouts.

2 The models and methods of roundabout capacity

In the initial stage of constructing roundabouts, Wardrop[5] regarded the maximum throughput in weaving sections as the capacity of roundabout. With "give way" rule presented in modern roundabout, the entrances are more prone to emerge bottlenecks[6]. Thus the weaving section model is not applicable any more. In addition, three modeling methods are discussed in this paper in detail, namely, empirical regression model, gap acceptance model and simulation-based method. Different methods have their own applicable conditions and will be elaborated in the following subsections.

2.1 Weaving theory model

Weaving section is the zone where the traffic bottlenecks probably occur at the traditional roundabout. Regarding the maximum possible throughput in this area as the capacity of entire roundabout, Wardrop[5] proposed the weaving theory model (Eq.(1)). However, its application should match some

Received date: Dec 19, 2013; Revised date: Mar 17, 2014; Accepted date: Mar 25, 2014
*Corresponding author. E-mail: songxm@jlu.edu.cn

DOI: 10.1016/S1570-6672(13)60141-5

certain conditions, such as D>40m, w=6.1~18.0m (where D is the diameter of the central island, and w is the width of weaving section), so it is limited. And the circulating vehicles have priority over entry ones with the "give way" rule proposed. Therefore, the UK Department of the Environment put forward an improved model[7] (Eq.(2)).

$$Q = 280(1+\frac{e}{w})(1-\frac{p}{3})/(1+\frac{w}{l}) \quad (1)$$

$$Q = \frac{160l(w+e)}{w+l} \quad (2)$$

where, Q is roundabout capacity, e is average width of approach ($e=(e_1+e_2)/2$, m), w is width of weaving section (m), p is the proportion of weaving traffic in weaving section (%), l is length of weaving section (m), e_1 is width of access approach (m), and e_2 is circulatory width in front of splitter island (m).

Based on weaving section, weaving theory model only applies to medium-to-large-scale roundabout with multilane. The model mainly considers the static feature and ignores time-variant characteristics of traffic flow. Because of less weaving behaviors at modern roundabout caused by the reduction of central island's diameter, the weaving theory model may be not suitable for current operational mode[8].

2.2 Empirical regression model

Empirical regression model，also known as conflicting volume model, predicts the capacity by means of establishing the regression equation between entry capacity and circulating volume. The prediction is significant under saturated flow condition, besides this methodology could take into account the "pseudo conflict" caused by exiting vehicles[9]. Many countries use empirical regression model, such as UK, Switzerland, Germany and France[6, 10, 11]. In addition, Federal Highway Administration (FHWA) [12, 13] also proposed this type of model. In summary, some typical models are listed in Table 1.

Table 1 Some typical empirical regression models

Country	Model
UK（Kimber）	$C_e = F - f_c Q_c$, $f_c = 0.29 + 0.116e$, $F = 329e + 35u + 2.4D - 135$
Switzerland（Bovy）	$C_e = \frac{1}{\gamma}[1\ 500 - (\frac{8}{9})(\beta Q_c + \alpha Q_{exit})]$, $\alpha=\alpha_0(1\frac{1}{3}-\frac{2}{3}\sqrt{\frac{Q_{exit}}{C_{exit}}\frac{Q_{exit}}{Q_t}})$ and $Q_t = Q_c + Q_{exit}$
Germany（Stuwe）	$C_e = Ae^{\frac{-BQ_c}{10\ 000}}$
U.S.（FHWA）	$C_e = 1\ 218 - 0.74Q_c$
Jordan	$C_e = e\frac{A - BQ_c}{10\ 000}$

NOTE: C_e is entry capacity, Q_c is conflicting volume, Q_{exit} is exiting volume. In Switzerland's model：γ is effect of number of entry lanes: one lane=1, double lane=[0.6,0.7]. β is effect of number of circulatory lanes: one lane=[0.9,1.0], double lane =[0.6,0.8]. α is effect of exiting vehicels; α_0 is mid-value of α. A, B is intercept and slope constants, respectively.

Considering the effects of geometry, some scholars have put forward the improved regression models. Polus et al.[14] introduced the diameter into regression model (Eq.(3)), but the data were collected at the small-to-medium-scale single-lane roundabout, without taking the number of lanes into account. Through analyzing the integrated effects of circulating flow, lane width, central island's diameter and distance between entrance and exit, Al-masaeid et al.[11] also established a capacity model (Eq.(4)). And the prediction values are similar to other models' under low volume conditions.

$$C_e = 394D^{0.31}e^{-(0.000\ 95Q_C)} \quad (3)$$

$$C_e = 168.2D^{0.312}S^{0.219}e^{0.071EW+0.019RW}e^{-5.602Q_C/10\ 000} \quad (4)$$

where, D is diameter of central island, S is distance between entrance and exit, EW is entry width, and RW is the circulatory width.

Furthermore, Wei et al.[15] proposed the streamline process to estimate capacity via video data. Due to the difficulties in capturing and extracting videos at multi-lane roundabout, this method is limited to single-lane roundabout. Al-Madani[9] put forward an empirical model aiming at heavy demand conditions and compared with other models. Considering the influences of slow traffic, Martijn et al.[16] proposed the improved model based on Bovy's(Eq.(5) - Eq.(7)).

$$C_e = C_{e,h}F_{exit}p_e \quad (5)$$

$$F_{exit} = 1 - p_{blocking} = 1 - (x^{N+1} - 0.14x) \quad (6)$$

$$p_e = e^{-q_{c,b}t_0} 且 t_0 = t_{cr,b} - 0.5t_{f,b} \quad (7)$$

where, x is virtual V/C ratio, N is space between roundabout and cycle facility expressed in number of cars, $p_{blocking}$ is probability of exiting vehicles blocking the roundabout, $q_{c,b}$ is volume of circulating cyclists (bic/s), $t_{cr,b}$ is critical gap to cyclists (s), and $t_{f,b}$ is follow-up headway, C_e is entry capacity (pcu/h) , $C_{e,h}$ is entry capacity due to the main conflicts (pcu/h), F_{exit} is reduction factor caused by downstream exit , p_e is probability that exit is not blocked by cyclists.

Above all, the empirical regression model is relatively easy