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An Estimation Method of Roundabout Entry Capacity Considering Pedestrian Impact

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Abstract

Entry capacity is one of the most important indices for performance evaluation of roundabout. In addition to circulating vehicles, pedestrian flow is another key conflicting stream which has significant impact on entry capacity. The pedestrian impact is considered by an adjustment factor in the existing method (Brilon, et al, 1993) which was developed based on the roundabouts under the design with physical splitter island, crosswalk and distance of one-vehicle length between crosswalk and yield line. Some of them such as the physical splitter island and the distance between crosswalk and yield line cannot be always satisfied due to space limitation in some places, which are considered to have significant impact on entry capacity. Moreover, it is supposed that several other influencing factors also strongly affect entry capacity, e.g., pedestrian approaching side and queuing vehicles in circulating roadway due to pedestrians across downstream exits. Therefore, a theoretical model was developed in this study to estimate roundabout entry capacity considering pedestrian impact and these influencing factors, i.e., physical splitter island, pedestrian approaching side, distance between crosswalk and yield line and queuing vehicles in circulating roadway. Through conducting sensitivity analyses it was found that the impacts of the influencing factors on entry capacity can be expressed by the proposed model. Parameters in the proposed model which is used to reflect influencing factors should be calibrated and modified by empirical data in future.

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Keywords: Roundabout; Entry capacity estimation; Pedetrian impact; Theoretical model

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1. Introduction

Roundabout entry capacity is calculated as the maximum number of vehicles which can enter into roundabout in a certain period. Pedestrians and circulating vehicles are major conflict flows with entry vehicles before entering roundabout, which cause the reduction of entry capacity. Circulating flow is commonly considered as a parameter in existing estimation methods (FHWA, 2009), while pedestrian impact is estimated through an adjustment factor f_{ped} considering circulating flow and pedestrian demand (Brilon et al, 1993). This existing method was developed based on empirical data from the single-lane roundabouts which are under the standard design with physical splitter island, crosswalk and distance of one-vehicle length between crosswalk and yield line. Some of these conditions such as the physical splitter island and the distance between crosswalk and yield line cannot be satisfied in all places due to limited space, which are considered to have significant impact on entry capacity. In addition, it is supposed that such pedestrian behaviour as pedestrian approaching side which affects entry driver behavior also have significant impact on entry capacity. Moreover, exiting vehicles blocked by the pedestrians across downstream exit may lead to a queue in circulating roadway, which will prevent entry vehicles from entering roundabout and result in reduction of entry capacity. Therefore, this study aims to develop a method for estimating roundabout entry capacity considering the impacts of pedestrians and several influencing factors, i.e., physical splitter island, pedestrian approaching side, distance between crosswalk and yield line and queuing exit vehicles blocked by pedestrians across downstream exits.

2. Literature Review

From the view point of microscopic approach, roundabout entry capacity was estimated based on gap acceptance theory, which was originally developed for unsignalized intersection (FHWA, 2009). Accordingly, entry capacity c_e is estimated by Eq. (1).

$$c_e = q_{cir} \int_0^{\infty} h(t) \cdot E(t) dt \tag{1}$$

Here, q_{cir} is circulating flow; $h(t)$ is denoted as the headway distribution of the circulating flow, and $E(t)$ is the expected number of vehicles which can enter roundabout in one acceptable gap of size t of the circulating flow. At roundabout, circulating flow is major flow which has the priority whereas entry flow is minor flow. Regarding the headway distribution, M3 model which assumed a negative exponential distribution for headway was recommended to apply since it considered bunching flow with minimum headway τ in major flow (Cowan, 1975). On the other hand, a regression model was developed for $E(t)$ based on observed data (Siegloch, 1973). This model included two important parameters critical gap t_c and follow-up time t_f. t_c is defined as the minimum gap of major flow that one vehicle in minor flow can accept to cross major flow, and t_f is the headway of queuing vehicles in minor road. Another parameter t_0 is defined as the intercept of the gap size in this model which is calculated by t_c-t_f /2. According to this regression model, no vehicle in minor flow will cross or merge into major flow unless the gap between vehicles in major flow is greater than t_0.

Pedestrian impact is not considered in the estimation of c_e, while it is estimated through an adjustment factor f_{ped} considering circulating flow and pedestrian demand (Brilon et al, 1993). In addition, several influencing factors were examined through simulation and found to have significant impact on entry capacity, i.e., physical splitter island, pedestrian approaching side and distance between crosswalk and yield line (Duan and Cheu, 2011; Kang et al, 2013). Moreover, queuing vehicles in circulating roadway are considered to strongly affect entry capacity. Since the queue is generated by exit vehicles which are blocked by pedestrians across downstream exits, the time of the blocking events which occur at downstream exits was analyzed for estimating impact of the queue (Rodegerdts and Blackwelder, 2005). Taken together, these influencing factors are necessary to be considered in the estimation of entry capacity, especially in the places where roundabouts cannot be installed under standard design due to space limitation, e.g., Japan.