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.

Keywords: Roundabout; Entry capacity estimation; Pedestrian 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).

$$c_e = q_{cir} \int_0^\infty h(t)E(t)dt$$ (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 $\tau$ 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.
3. Methodology

3.1. Basic concept of entry capacity modeling

A standard single-lane roundabout with four legs under the left-hand traffic rule is assumed, which includes crosswalk, physical splitter island and the space of one-vehicle length between crosswalk and yield line at every leg. Entry capacity of Approach A $c_A$ is estimated considering two cases of circulating flow in front of Entry A. Circulating vehicles are assumed to be flowing in Case (a) whereas they are assumed to be queuing in circulating roadway in Case (b). Illustrations of Cases (a) and (b) are shown in Figs. 1(a) and (b), respectively.

Case (a)
Under the condition of flowing circulating vehicles, entry capacity $c_a$ is determined by pedestrians across Entry A, circulating flow passing in front of Entry A and several influencing factors, i.e., physical splitter island, pedestrian approaching side and distance between crosswalk and yield line.

Case (b)
On the other hand, vehicles exiting to Exit B, C or D which are blocked by pedestrians across at these exits may lead to a queue in circulating roadway. When the queuing vehicles reaches up to front of Entry A, vehicles at Entry A are prevented from entering roundabout due to these queuing vehicles. Thus, entry capacity $c_b$ is equal to zero under this condition since vehicles cannot enter roundabout at all.

$P_{\text{flowing}}$ is defined as the probability of circulating vehicles flowing in front of Entry A in Case (a), and $P_{\text{queue}}$ is defined as the probability of queuing vehicles reaching up to front of Entry A in Case (b). Accordingly, entry capacity $c_A$ considering Cases (a) and (b) is estimated by Eq. (2).

\[
c_A = P_{\text{flowing}} \cdot c_a + P_{\text{queue}} \cdot c_b
\]  \hspace{1cm} (2)

Since the situations of circulating flow in case (a) and (b) are independent, $P_{\text{flowing}} + P_{\text{queue}} = 1$. In addition, $c_b$ is equal to zero as described in case (b). Thus, Equation (2) is changed to Eq. (3).

\[
c_A = (1 - P_{\text{queue}}) \cdot c_a
\]  \hspace{1cm} (3)

3.2. Estimation of $c_a$

Based on HBS (2005) and HCM (2010), a standard roundabout is generally designed with the distance of one-vehicle length between downstream edge of crosswalk and yield line. For entry vehicles, this space has a function of storage to wait for an available gap of circulating vehicles before entering roundabout. Thus, entering procedure is divided into two separate parts due to this storage space, first crossing pedestrian flow and then merging into
circulating flow. The similar process can also be observed at two-stage unsignalized intersections, where major road is divided into two separate parts by some storage space. The capacity of minor flow at two-stage unsignalized intersection was estimated considering the length of storage space (Brilon et al, 1996). When applying this estimation method to roundabout, \( c_a \) is calculated by Eq. (4).

\[
c_a = \frac{n_a}{n_a + 1} f(q_{cir}) + \frac{1}{n_a + 1} g(q_{ped}, q_{cir})
\]

(4)

Here \( n_a \) is defined as the maximum number of vehicles which can be stored between crosswalk and yield line; \( f(q_{cir}) \) is the maximum entry flow considering circulating flow only which is estimated by existing methods referring to \( c_e \) in Equation (1); \( g(q_{ped}, q_{cir}) \) is the maximum entry flow considering both circulating and pedestrian flows which is estimated based on Wu’s theory (2001) as follows.

Wu (2001) developed a model for estimating capacity of minor flow in a certain period \( T \) through classifying situation of major flow into four items, “queuing”, “bunching”, “single vehicle” and “free space”. Period \( T \) is assumed to have the probability of 1. Headway distribution of a single flow in major road is assumed to follow Cowan’s M3 model. “Queuing” happens under the congested situation; headway of vehicles in “bunching” and “single vehicle” item is assumed to be equal to minimum headway \( \tau \) and the intercept gap size \( t_0 \) in \( E(t) \), respectively, and “free space” is denoted as the situation of no vehicle. According to gap acceptance theory and Siegloch’s model (1973), minor flow can only cross major flow under the condition of “free space”. In period \( T \), many short periods of items will occur and each of them has a probability. Since each item is independent, by summing up all small periods of one item to a large period, four large periods are finally included in period \( T \). Dependent on the definition of the conditioned probabilities, the probability of “free space” \( P_F \) is calculated under the condition of \{“no single vehicle \( P_{0,S} \)”, “no bunching vehicle \( P_{0,B} \)”, “no queuing vehicle \( P_{0,Q} \)”). \( P_F \) is expressed by Eq. (5).

\[
P_F = P_{0,S} * P_{0,B} * P_{0,Q}
\]

(5)

Thus, capacity of minor flow \( c_{minor} \) is estimated by the probability of free space \( P_F \) multiplying saturation capacity of minor flow \( c_{max} \) which is calculated by follow-up time of minor flow \( t_{f,minor} \).

Probability of “queuing” \( P_Q \) is calculated by degree of saturation \( x \) of the flow, then \( P_{0,Q} \) is calculated by Eq. (6).

\[
P_{0,Q} = 1 - P_Q = 1 - x
\]

(6)

The probability of “bunching” \( P_B \) is calculated dependent on average minimum headway \( \bar{\tau} \) and flow demand \( q \) [veh/s]. Thus, the probability of “no bunching vehicle” \( P_{0,B} \) is calculated by Eq. (7).

\[
P_{0,B} = 1 - P_B = 1 - q * \bar{\tau}
\]

(7)

\( P_{0,S} \) is the probability of headway \( t \) in the major flow larger than \( t_0 \) under the condition that headway \( t \) is larger than minimum headway \( \tau \), which is calculated by Eq. (8).

\[
P_{0,S} = P(t > t_0 | t > \tau) = \frac{P(t > t_0)}{P(t > \tau)} = \frac{1 - F(t = t_0)}{1 - F(t = \tau)}
\]

(8)

Here, \( F(t) \) is the distribution function of headway \( t \) in major flow.

Since the headway of major flow is assumed to follow the shifted-negative exponential distribution, \( F(t) \) regarding \( t_0 \) and \( \tau \) is calculated by Eq. (9) and (10).
When \( m \) major flows which are independent of each other exist, e.g., major flows from two directions, the probability of “free space” of \( m \) major flows \( \mathbf{P}_k^m \) becomes the product of the probabilities of “free space” of all flows as shown in Eq. (11).

\[
\mathbf{P}_k^m = \prod_{k=1}^{m} P_k^m = \prod_{k=1}^{m} P_{0,5}^k \cdot \prod_{k=1}^{m} P_{0,B}^k \cdot \prod_{k=1}^{m} P_{0,Q}^k, \quad m \in N = \{1, 2, 3, \ldots, n\}, \quad k \in N = \{1, 2, 3, \ldots, m\}
\]

Accordingly, the capacity of minor flow under this condition \( c_{\text{minor}} \) is estimated by Eq. (12).

\[
c_{\text{minor}} = c_{\text{max}} \cdot \mathbf{P}_k^m = c_{\text{max}} \cdot \prod_{k=1}^{m} P_k^m
\]

Entry vehicles cross pedestrian flow through available gaps of pedestrians, which is similar to merging into circulating flow. Thus, the impact of pedestrians is estimated based on gap acceptance theory. Several assumptions are made as follows.

- Pedestrians walk on crosswalk in the straight line parallel to the crosswalk;
- Pedestrians from different directions walk in different lines;
- Pedestrians in one walking line are independent of ones in another line;
- Pedestrians do not change the line during walking;
- Pedestrian overtaking behavior does not occur in each walking line;
- Headway of pedestrians in each walking line is assumed to follow negative exponential distribution.

Based on these assumptions, pedestrians are assigned to cross in different walking lines, which are independent of each other. \( n_{wl} \) is defined as the maximum number of walking lines in crosswalk, which is determined by the width of crosswalk \( w_c \) and social distance between pedestrians. \( s_R, s_L \) is defined as right and left distance when a pedestrian keeps to each other, which is assumed to be 0.5m in this study. Thus, \( n_{wl} \) is calculated by Eq. (13).

\[
n_{wl} = \left[ \frac{w_c}{s_L} + 1 \right] \quad \epsilon I = \{2, 3, \ldots, n\}
\]

Pedestrian approaching side is classified into near-side and far-side based on direction of entry flow as shown in Fig. 1. \( \alpha_N \) is defined as the proportion of pedestrian demand from near-side in total pedestrian demand, and \( 1 - \alpha_N \) is the proportion of pedestrian demand from far-side in total pedestrian demand. Accordingly, maximum number of walking lines for near-side pedestrian \( N_{wl} \) is calculated by this proportion \( \alpha_N \) as shown in Eq. (14).

\[
N_{wl} = \left[ \alpha_N \cdot n_{wl} \right] \epsilon I = \{0, 1, 2, 3, \ldots, n_{wl}\}
\]

Pedestrian demand in each walking line is assigned by \( \alpha_i \) or \( \alpha_j \), which is defined as the proportion of pedestrian demand in walking line \( i \) (\( j \)) in total near-side (far-side) pedestrian demand.

At roundabout, pedestrian and circulating flows are major flows. Thus, an entry vehicle will at most cross \( N_{wl} \) near-side pedestrian flows, \( F_{wl} \) far-side pedestrian flows and one circulating flow before entering roundabout and all flows are assumed to be independent. Dependent on Wu’s theory (2001), \( g(q_{ped}, q_{cir}) \) can be estimated by Eq. (15).
3.3. Estimation of $P_{queue}$

At downstream Exit X (referring to B, C or D), exiting vehicles have conflict with pedestrians and cross pedestrian flow by available gaps of pedestrians. Thus, exiting vehicles may be queuing in circulating roadway when there is no available gap in pedestrian flow. Exiting vehicles and pedestrians form a queuing system, which pedestrian flow plays a role of service centre. Both headway distributions of exiting vehicles and pedestrians are assumed to follow negative exponential distribution. $P_{queue}$ is the probability of the queuing vehicles reaching up to the front of Entry A. For Exit X, $n_{b}^{X,A}$ is defined as the maximum number of vehicles which can be stored between downstream Exit X and Entry A. $\text{Prob}(n_{b}^{X,A})$ is defined as the probability of number of vehicles queuing in circulating roadway. $P_{queue}$ is calculated as the maximum value of $\text{Prob}(n_{b}^{X,A})$ in all downstream exits as shown in Eq. (16).

$$P_{queue} = \max \{ \text{Prob}(n_{b}^{X,A}) \}$$ (16)

According to queue theory, $\text{Prob}(n_{b}^{X,A})$ is calculated by Eq. (17).

$$\text{Prob}(n_{b}^{X,A}) = \left(1 - \frac{\lambda_{X}}{\mu_{ped}^{X}}\right)^{n_{b}^{X,A}} \left(\frac{\lambda_{X}}{\mu_{ped}^{X}}\right)^{n_{b}^{X,A}}$$ (17)

where $\lambda_{X}$ is arrival rate of vehicles exiting the downstream Exit X and $\mu_{ped}^{X}$ is the service rate which is the reciprocal value of the average service time.

$\lambda_{X}$ is related to the circulating flow $q_{cir}$ passing in front of Entry A. $\alpha_{X}^{b}$ is defined as the proportion of demand of vehicles exiting the downstream Exit X in circulating flow $q_{cir}$. Thus, $\lambda_{X}$ is calculated by Eq. (18).

$$\lambda_{X} = \frac{\alpha_{X}^{b} \cdot q_{cir}}{3600}$$ (18)

Since pedestrian flow plays a role of service centre and exiting vehicles cross pedestrian flow dependent on available gaps of pedestrians, service time is defined as the total time of rejected gaps between two acceptable gaps. Dependent on Siegloch’s model (1975), exiting vehicles cannot cross pedestrian flow when headway $t$ of pedestrians is shorter than $t_{b,ped}^{X}$. Service rate $\mu_{ped}^{X}$ is calculated by the probability of headway $t$ under the condition $t < t_{b,ped}^{X}$. The same assumptions regarding pedestrians across Entry A are given to pedestrians across Exit X as well and dependent on Wu’s theory (2001), $\mu_{ped}^{X}$ is calculated based on the probability of “free space” $P_{f}^{X}$ as shown in Eq. (19).

$$\mu_{ped}^{X} = 1 - P_{f}^{X} = 1 - \prod_{j=1}^{N_{f}^{X}} P_{0,0}^{j} \cdot \prod_{j=1}^{N_{f}^{X}} P_{0,B}^{j} \cdot \prod_{j=1}^{N_{f}^{X}} P_{0,F}^{j} \cdot \prod_{j=1}^{N_{f}^{X}} P_{0,0}^{j} \cdot P_{0,B}^{j} \cdot P_{0,F}^{j}$$ (19)

Finally, based on Eqs. (3), (4) and (16), roundabout entry capacity $e^{A}$ including Cases (a) and (b) can be estimated.
4. Results and Discussion

The proposed model is examined under the following assumptions.

- Exit B is assumed to have the highest probability to generate a queue reaching up to the front of Entry A in all downstream exits;
- Pedestrian flow at Exit B: 300ped/h and all pedestrian from near-side;

- Except pedestrian demand, all parameters regarding pedestrians at Exit B are assumed to be same as those regarding pedestrians across Entry A, i.e., $w^A_c = w^B_c$, $n^B_w = n^B_w$, $t^A_{ped} = t^B_{ped}$, $t^A_{far} = t^B_{far}$, $t^A_{ped} = t^B_{ped}$, $t^B_{far} = t^B_{ped}$;
- Number of walking lines is assumed to be nwl;
- Proportions of pedestrian demand in walking lines for one approaching side are assumed to be identical:
  \[ \alpha^A_i = \frac{1}{N^A_w}, \quad \alpha^A_j = \frac{1}{F^A_w}, \quad \alpha^B_i = \frac{1}{N^B_w}, \quad \alpha^B_j = \frac{1}{F^B_w}; \]
- Critical gap of pedestrians in each walking line for one approaching side is assumed to be identical:
  \[ t^A_{ped(i)} = t^A_{ped(i+1)} = t^B_{ped(i)}; \]
- All entry vehicles are assumed to stop at the moment when pedestrians are about to cross the curb regardless pedestrian approaching side, and wait until pedestrians arrive at the curb of the other side;
- $f(q_{cir}) = \frac{3600}{t_{cir}} \left( 1 - \tau_{cir} \right) * \exp \left\{ \frac{q_{cir}}{3600} \left( t_{ped} - t_{cir} + 2 \tau_{cir} \right) \right\}$;
- Circulating flow: 0~1200veh/h with interval of 100veh/h;
- Pedestrian flow at Entry A: 0~500ped/h with interval of 100ped/h.

4.1. Estimation result of entry capacity under given parameters

The given parameter values are shown in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
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<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n^A_w$</td>
<td>1 vehicle</td>
<td>$t^A_{ped} = t^B_{ped}$</td>
<td>1s</td>
<td>$\alpha^A_i$</td>
<td>0</td>
<td>$\alpha^B_i$</td>
<td>1</td>
</tr>
<tr>
<td>$n^B_w$</td>
<td>2 vehicles</td>
<td>$t^B_{ped}$</td>
<td>5s</td>
<td>$\alpha^B_i$</td>
<td>1</td>
<td>$\alpha^B_i$</td>
<td>0</td>
</tr>
<tr>
<td>$t_{cir}$</td>
<td>2s</td>
<td>$t^A_{far}$</td>
<td>5s</td>
<td>$\alpha^A_i$</td>
<td>0</td>
<td>$\alpha^B_i$</td>
<td>0.2</td>
</tr>
<tr>
<td>$t_{ped}$</td>
<td>3.5s</td>
<td>$t^B_{ped}$</td>
<td>2.25s</td>
<td>$\alpha^B_i$</td>
<td>0.2</td>
<td>$\alpha^B_i$</td>
<td>0</td>
</tr>
<tr>
<td>$t_{circ}$</td>
<td>2.25s</td>
<td>$w^A_c = w^B_c$</td>
<td>2m</td>
<td>$\alpha^B_i$</td>
<td>0.2</td>
<td></td>
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</tr>
</tbody>
</table>

Fig. 2 shows the estimation result of entry capacity under the conditions in Table 1. It is found that estimated entry capacity is reduced with increase of circulating flow and pedestrian flow, which follows the results described in other existing methods (e.g., HCM, 2010).

4.2. Sensitivity of physical splitter island

Kang, et al (2013) analyzed empirical data on a real roundabout in Japan and found that, the critical gap of pedestrians from far-side under the condition without physical splitter island $\epsilon^A_{far \ without \ ped}$ is longer than that under the condition with physical splitter island $\epsilon^A_{far \ with \ ped}$. Entry capacity is reduced more under the condition without physical splitter island. $\epsilon^B_{far \ without \ ped}$ and $\epsilon^B_{far \ with \ ped}$ are input with the value of 10s and 5s, respectively. Other input conditions are shown in Table 1. Fig. 3 shows the estimation results of entry capacity with/without physical splitter island and pedestrian demand of 100ped/h, 300ped/h and 500ped/h from far-side only across Entry A were selected as examples shown in Figs. 3(a), (b) and (c), respectively. It is found that estimated
entry capacity has a lower performance under the condition without physical splitter island in each level of pedestrian demand. This sensitivity can be obtained in previous analysis as well (Kang et al, 2013).

4.3. Sensitivity of pedestrian approaching side

Kang, et al (2013) also found that under the condition without physical splitter island, the critical gap of pedestrians from far-side $t_{\text{far,without}}^{\text{ped}}$ is longer than that from near-side $t_{\text{near,without}}^{\text{ped}}$ under the assumption that all entry vehicles stopped at the moment when pedestrians are about to cross at the curb of crosswalk and wait until pedestrians complete crossing. Entry capacity is reduced more when pedestrians are from far-side only comparing to the case of near-side only. Accordingly, $t_{\text{near,without}}^{\text{ped}}$ and $t_{\text{far,without}}^{\text{ped}}$ is assigned to be 5s and 10s in the model, respectively. Some parameters, i.e., $\alpha_\text{g}, \alpha_\text{f}, \alpha_\text{tr}, \alpha_\text{fr}$ are accordingly changed for the estimation of the case of near-side pedestrians only. Fig. 4 shows the comparison of estimated entry capacity regarding pedestrians from near-side only and far-side only. The results under the pedestrian demands of 100ped/h, 300ped/h and 500ped/h across Entry A were selected as the examples shown in Figs. 4(a), (b) and (c), respectively.
It was found that under the condition without physical splitter island, entry capacity is reduced more significantly when all pedestrians are only from far-side in each level of pedestrian demand. The sensitivity of pedestrian approaching side follows the result in previous study (Kang et al, 2013).

4.4. Sensitivity of distance between crosswalk and yield at Entry A

Duran and Cheu (2011) found that under the condition of two-lane roundabout, entry capacity increases when the distance between the yield line and crosswalk is long enough for accommodating the vehicles waiting for acceptable gap. Thus, \( n_a \) which is defined as the maximum number of vehicles that can be stored between crosswalk and yield line is assigned to be 0, 1 vehicle and 2 vehicles for examination, and all pedestrians are assumed to be from far-side with 5s critical gap under the condition with splitter island. The results under the pedestrian demands of 100ped/h, 300ped/h and 500ped/h across Entry A were selected as the examples shown in Figs. 5(a), (b) and (c), respectively. It is found that entry capacity is reduced most significantly when \( n_a = 0 \) and then improved with increase of \( n_a \). This result is consistent with previous analysis such as Duran and Cheu, 2011, Kang, et al 2013.

![Fig. 5. Estimated entry capacity changing with \( n_a \)](image)

4.5. Sensitivity of \( P_{queue} \)

\( P_{queue} \) is simply examined by changing the value of \( P_{queue} \) to 0, 0.3 and 0.8. All inputting conditions and parameters are kept the same as in Table 1. The results under the pedestrian demands of 100ped/h, 300ped/h and 500ped/h across Entry A were selected as the examples, as shown in Figs. 6(a), (b) and (c), respectively. It is found that estimated entry capacity is reduced with increase of \( P_{queue} \).

![Fig. 6. Estimated entry capacity changing with \( n_a \)](image)

5. Conclusions and Future work

This study developed an estimation method on roundabout entry capacity considering pedestrian impact and several influencing factors, i.e., physical splitter island, pedestrian approaching side, distance between crosswalk and yield line and queuing vehicles blocked by pedestrians across downstream exits. In this proposed model, impact
of pedestrian is considered based on gap acceptance theory, instead of an adjustment factor, since in real world entry drivers cross pedestrian flow by available gaps of pedestrians which is similar to merging into circulating flow. The impacts of all influencing factors are realized through inputting parameters, e.g., \( tc_{ped} \), \( fa_{with} \), \( fa_{without} \) and so on. Through sensitivity analyses it was found that the proposed model can reflect impacts of these influencing factors and the sensitivity of each influencing factor on entry capacity is consistent with the results which have been obtained in previous analyses.

Although the impacts of influencing factors on entry capacity are successfully reflected in this study, the parameters in the model still need to be calibrated and modified by real world data in future.

References


