An Analysis of Heavy Vehicle Impact on Roundabout Entry Capacity in Japan

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Abstract
Impact of heavy vehicles on roundabout entry capacity is generally considered through a heavy vehicle adjustment factor \(f_{HV}\) which is calculated by heavy vehicle percentage and passenger car equivalent (PCE hereafter) value. The PCE value of trucks is generally set as 2.0 and estimated based on several considerations such as entry capacity and move-up time. All of these considerations are influenced by local driver behavior and geometry conditions. Thus, this paper aims to estimate entry capacity considering the characteristics of heavy vehicle behavior in Japan by microscopic simulation. Then based on the simulation results, the PCE value is also examined. Through the simulation study it is found that entry capacity is reduced when heavy vehicle percentage increases. Moreover, estimated PCE results show that the PCE value of entry flow increases when circulating flow increases but decreases when circulating flow is in high level. Also it is found that PCE of entry flow is lower than that of circulating flow which has priority at roundabouts.

Keywords: Roundabout, Capacity, Heavy vehicle, Simulation, PCE

1 Introduction

Heavy vehicles perform differently from passenger cars due to their characteristics such as size and acceleration. At roundabouts, entry capacity is usually estimated in a unit of passenger cars and the impact of heavy vehicles is generally considered through the adjustment factor \(f_{HV}\). In Highway Capacity Manual (HCM hereafter) 2010 (HCM, 2010), this adjustment factor is considered for entry flows (after entering roundabout) which form circulating flow in front of the subject entry. Since circulating flows have priority at roundabout entries, SIDRA (SIDRA for roundabouts, 2011) also considers the impact of heavy vehicle on the entry flow of the subject entry through adjusting the gap acceptance parameters (critical gap and follow-up time) under the condition with heavy vehicles.

The adjustment factor \(f_{HV}\) is generally estimated by two parameters, heavy vehicle percentage \(P_T\) which is calculated by field data and passenger car equivalent (PCE hereafter). The PCE represents the number of passenger cars that one heavy vehicle is equivalent to. For applying in practice, PCE is commonly recommended to be a fixed value, i.e. in HCM 2010, PCE=2.0 for trucks. The PCE can be

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estimated from several approaches such as flow rate, density and move-up time. All of these considerations are influenced by local driver behavior. Moreover, since vehicles enter roundabouts based on gaps available in the circulating flow, the PCE of subject entry flow should have different value from the PCE of circulating flow. Thus, it is necessary to examine the PCE value at roundabouts based on Japanese situations considering the applicability of PCE.

This paper first aims at estimating roundabout entry capacity considering the impact of heavy vehicles through applying microscopic simulation. Input parameters of the simulation such as speed of vehicles and gap acceptance behavior are calibrated by using field data observed in Japan. Based on the estimated entry capacity from the simulation study, PCE values of heavy vehicles under the Japanese conditions are calculated.

2 Literature Review

In HCM 2010 (1), the entry capacity of single-lane roundabout is estimated by Equation (1).

\[ c_{e,pce} = 1.130 \exp(-1.0 \times 10^{-3})v_{c,pce} \]  

where \( v_{c,pce} \) : circulating flow rate (pc/h)  
\( c_{e,pce} \) : lane capacity, adjusted for heavy vehicles (pc/h)

Circulating flow is formed by flows from other entries. The impact of heavy vehicle is considered on these entry flows as shown in Equation (2).

\[ v_{i,pce} = \frac{v_i}{f_{HV}} \]  

where \( v_{i,pce} \) : demand flow rate for movement i (pc/h) of other entries  
\( v_i \) : demand flow rate for movement i (veh/h) of other entries  
\( f_{HV} \) : heavy vehicle adjustment factor

Then, circulating flow is directly counted as pc/h. The factor \( f_{HV} \) is estimated by heavy vehicle proportion and passenger car equivalent which is shown in Equation (3).

\[ f_{HV} = \frac{1}{1 + P_T (E_T -1)} \]  

where \( P_T \) : proportion of demand volume that consists of heavy vehicles  
\( E_T \) : passenger car equivalent (PCE) for heavy vehicles

In HCM 2010, \( E_T \) is set as 2.0. By using the adjusted circulating flow (pc/h), entry capacity is counted as pc/h. However, the impact of heavy vehicles on the subject entry flow is not considered.

SIDRA estimated the impact of heavy vehicles also on the subject entry flow through adjusting gap parameters of critical gap \( t_c \) and follow-up time \( t_f \) under the condition with heavy vehicles. The adjusting formulas are shown in Equations (4) and (5).

\[ t_f' = \frac{t_f}{f_{HV}} \]  
\[ t_c' = \frac{t_c}{f_{HV}} \]  

where \( t_f' \) : follow-up headway adjusted for heavy vehicle effects in the entry stream
The adjusted critical gap $t'_c$ and follow-up time $t'_f$ are input in the estimation model which is used in SIDRA. In addition, the default values of the passenger car equivalent $e_{HV}$ of heavy vehicles for circulating and entry flows are defined to be 2.0 and 1.5, respectively.

Based on Equations (3) and (6), for a certain value of heavy vehicle percentage, $f_{HV}$ which represents the impact of heavy vehicles is determined by PCE. However, PCE is influenced by local behavior which means the value of 2.0 in the existing manuals such as HCM 2010 may not be applicable for Japanese situation.

Many researchers proposed PCE values based on observations in various places. Akcelik (1998) also proposed PCE to be 1.7 and 1.9 for circulating flow and entry flow, respectively based on the data observed in the UK. Tanyel (2001, 2005) proposed a PCE value to be 1.15 for minibuses and PCE values in the range of 1.50 to 1.65 for buses in the circulating flow at roundabouts. Also, Tanyel et al (2013) conducted an investigation for identifying heavy vehicle effect on traffic circle and by focusing on buses which are the most typical heavy vehicle on traffic circles in urban area of Turkey. They calculated PCE values for minor and major flows and found that the PCE values should be used differently for different flows. Otherwise, the same value may lead engineers to overdesign traffic circles. Lee (2015) calculated PCE values for heavy vehicles at roundabouts based on observed headways of various following sequence of passenger cars and heavy vehicles. The experiment was done at several roundabouts in the U.S. They proposed that the range of PCE values for heavy trucks and light trucks were 1.5-2.5 and 1.0-1.5, respectively for the entry flow. Through applying these proposed PCE values, it was found that entry capacity showed more accurate results than the case PCE=2.0 which is recommended in HCM 2010.

Thus, the PCE value should be examined considering characteristics of heavy vehicle behavior in Japan. The PCE value is calculated from the viewpoint of capacity which is estimated by applying gap acceptance behavior in this analysis. Based on Lee’s research (2015), headway parameters ($t_c$, $t_f$ and $\tau$) varies with the following sequences of vehicles, e.g. heavy vehicle following passenger car or converse sequence. However, entry capacity estimation formula such as Equation (1) cannot reflect this following sequence. Thus, the entry capacity is estimated by applying the microscopic simulation VISSIM 5.40 in this analysis.

Regarding the microscopic simulation, the authors conducted simulation analysis for estimating roundabout entry capacity considering pedestrian impacts (Kang and Nakamura, 2015). The case of simulation without pedestrians in previous analysis is applied as the base case (without heavy vehicles) in this paper.
3 Methodology

3.1 Observation Site

In order to reflect the local characteristics of heavy vehicle behavior in Japan in the simulation study, input values of simulation parameters are calibrated by using field data observed in Japan. Thus, several empirical analyses such as speed and gap acceptance behavior are first done. Field data were observed at a roundabout located in Hitachitaga City, Ibaraki Prefecture, Japan as shown in Figure 1. It is a four-leg single lane roundabout which is implemented in front of a railway station of this city and Entry/Exit 2 is connected to a bus terminal where a considerable frequency of bus services can be expected. A video survey was conducted at this site from 6am to 4pm on 17th October, 2014. Vehicle speeds (passenger cars and heavy vehicles) and gap parameters (critical gap $t_c$, follow-up time $t_f$ and minimum headway $\tau$) are collected and analyzed. The details of empirical analysis are not explained in this paper, but the results are introduced in the next section as the input values to simulation.

![Figure 1: Layout of observation site (roundabout in Hitachitaga City, Ibaraki Prefecture, Japan)](image)

3.2 Simulation Study

VISSIM 5.40 is applied in this analysis for estimating roundabout entry capacity.

Geometric Layout

Considering the application and consistence of the research, a four-leg single lane roundabout with a diameter of 27m which is the minimum requirement for the standard four-leg single lane roundabout is assumed in this analysis. The angle of two adjacent legs is set to be 90 degrees. Crosswalks and physical splitter islands are hypoththesized to be present at all entries/exits, and the distance between yield line and crosswalk is assumed as 5m which can accommodate one passenger car. The geometric layout is shown in Figure 2. Since the geometry layout hypothesized in the simulation study is similar to the observation site; such as the diameter, the observations of headway are applied in the simulation site. And due to the limited number of study sites, the impacts of geometric elements cannot be considered in this analysis.

Traffic Flows

In this analysis, vehicle traffic flows are assigned from all entries. Entry S is assumed to be the subject entry for observing entry capacity and a constant flow of 1600veh/h is input for representing a saturated condition for capacity observation at this entry. The roundabout is assumed to be located under the condition that the ratio of traffic demand between major road and minor road is equal to 8:2. The E-W direction is assumed to be the major road as shown in Figure 2. Additionally, the fixed
turning ratios \( r \) (left-turn traffic “L”, through traffic “Th” and right-turn traffic “R”) of each entry are assumed. For Entries E and W, \( r_L:r_{Th}:r_R=1:8:1 \), and for Entries N and S, \( r_L:r_{Th}:r_R=4:2:4 \). No pedestrian flow is assumed in this study, although the hypothetical roundabout equips crosswalks.

![Figure 2: Basic Information of a hypothesized Roundabout in Simulation Analysis](image)

**Speed**

Based on empirical analysis, free vehicles reduce speed when approaching the yield line of roundabout regardless of vehicle type, and keep low speed in circulatory roadway, then accelerate after exiting roundabout. The speeds of passenger cars and heavy vehicles in entry roadway are almost the same at an upstream position from the roundabout (over 40m from the yield line), but near the yield line and in the circulatory roadway the average speed of heavy vehicle is approximately 3km/h lower than that of passenger car. Thus, dependent on the empirical results both of the average speeds of passenger cars and heavy vehicles in entry roadways are assumed to be 30km/h. Speed reduction is realized by a function “Reduced Speed Areas” in VISSIM 5.40. Several reduced speed areas are drawn near the yield line and in the whole circulatory roadway. Since equal entry speed is set regardless of vehicle types, speed reduction on entry road is represented by differing deceleration for heavy vehicles and passenger cars as 1.3 \([\text{m/s}^2]\) and 2.0 \([\text{m/s}^2]\), respectively under the condition of uniform deceleration. In the end, median of circulating speed are adjusted to 17 [km/h] for heavy vehicles and 20 [km/h] for passenger cars. Furthermore, the minimum and maximum circulating speeds, 18 [km/h] and 25 [km/h], are set for passenger cars, and those speeds for heavy vehicles are set so as to be 3 [km/h] smaller than them, respectively.

**Parameter Settings for Gap Acceptance Behavior**

Three parameters are included in the gap acceptance theory, critical gap \( t_c \), follow-up time \( t_f \) and minimum headway \( r \). The function “Priority Rule” is selected to reflect critical gap \( t_c \) and “Wiedemann 74 model” is used to reflect the other two parameters.

In the function “Priority Rule”, parameters “minimum gap time” and “minimum headway (distance)” are necessary to be calibrated. The illustrations regarding gap times and headways are shown in Figure 3. The parameter “minimum headway” stands for the “length” of conflict area. Gap time in this function is defined as the time duration which a subject in the major roadway passes the distance between the current position and the end of the conflict area by using the current travel speed. Subjects in the minor roadway judge these gap times to decide whether cross or merge into major road. When the gap time is longer than the input “minimum gap time”, the vehicle at the stop line in minor road shown in Figure 3 will decide to merge into major road, otherwise the vehicle will wait until available gap time appears.
The parameter “minimum headway” is input by the default value of 5m, while the parameter “minimum gap” is calibrated based on the empirical results of critical gap \( t_c \). As shown in Figure 3, Critical gap is formed by minimum gap and the time passing the distance of vehicle length \( L_v \) and front distance \( D_f \). The value of \( L_v \) is assumed to be 4.4m which is the average value of vehicle length dependent on simulation input. And \( D_f \) is assumed to be 1.5m in this analysis.

For the calculation of \( t_c \), it is categorized dependent on combinations of vehicle types. In Figure 3, the major and minor roads correspond to the circulatory roadway and an entry roadway of roundabout, respectively. Here, the circulating and entry vehicles are denoted as \((c_1, c_2)\) and \((e_1, e_2)\), and \( P \) and \( H \) represent passenger cars and heavy vehicles, respectively. Critical gap data are recorded by the form of e.g. \( c_1c_2-e_1 \). Based on the field data, four types of critical gaps were observed, PP-P, HP-P, PH-P and PP-H. Additionally, normalized values \( R \) of HP-P, PH-P and PP-H were calculated referring to \( t_c(PP-P) \approx 4.7 \). It is assumed that the impact of heavy vehicle is independent. Thus, the critical gap values of PP-H, HP-H, PH-H and HH-H are calculated by the critical gap value of PP-P and normalized values of other three types which include heavy vehicles. For example, the critical gap of HH-P is calculated by Equation (7) as follows.

\[
 t_c(HH-P) = t_c(PP-P) \cdot R_{HP-P} \cdot R_{PH-P} \cdot R_{PP-P}
\]  

The values of critical gap of all combinations are shown in Table 1.

<table>
<thead>
<tr>
<th>Combinations</th>
<th>PP-P</th>
<th>HP-P</th>
<th>PH-P</th>
<th>PP-H</th>
<th>HP-H*</th>
<th>PH-H*</th>
<th>HH-H*</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_c ) (sec)</td>
<td>4.7</td>
<td>5.9</td>
<td>5.1</td>
<td>5.5</td>
<td>7.5</td>
<td>6.6</td>
<td>8.0</td>
</tr>
</tbody>
</table>

*calculated by \( t_c(PP-P) \) and normalized value \( R \)

Table 1: Critical gap \( t_c \) from field data

Since the diameter of the hypothesized roundabout is slightly smaller than the observed one and the critical gap is assumed to decrease when diameter reduces, the \( t_c(PP-P) \) is adjusted to be 4.5 sec in this analysis. All other \( t_c \) values including heavy vehicles are calculated by using the normalized value which is obtained from the empirical results. Accordingly, the adjusted \( t_c \) values are summarized in Table 2.

<table>
<thead>
<tr>
<th>Combinations</th>
<th>PP-P</th>
<th>HP-P*</th>
<th>PH-P*</th>
<th>PP-H*</th>
<th>HH-H*</th>
<th>HP-H*</th>
<th>PH-H*</th>
<th>HH-H*</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_c ) (sec)</td>
<td>4.5</td>
<td>5.4</td>
<td>5.0</td>
<td>5.3</td>
<td>5.9</td>
<td>7.0</td>
<td>6.4</td>
<td>7.7</td>
</tr>
</tbody>
</table>

*calculated by \( t_c(PP-P) \) and normalized value \( R \)

Table 2: Adjusted critical gap \( t_c \)
The parameter “minimum gap time” is calibrated to reflect $t_c$. Thus, the input values of “minimum gap time” are shown in Table 3.

<table>
<thead>
<tr>
<th>Combinations</th>
<th>PP-P</th>
<th>HP-P</th>
<th>PH-P</th>
<th>HH-P</th>
<th>PP-H</th>
<th>HP-H</th>
<th>PH-H</th>
<th>HH-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum gap time (sec)</td>
<td>3.7</td>
<td>4.2</td>
<td>5.1</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:** Input value of “minimum gap time”

Since “Priority Rule” can only reflect the conflict between entry vehicle and the approaching circulating vehicle which is $c_2$-$e_1$, for the same vehicle type of $c_2$ and $e_1$, the input values of “minimum gap time” are identical, i.e. PP-P and HP-P.

The gap parameter $t_f$ and $\tau$ are reflected by the “Wiedemann 74 model”. The distance between two vehicles can be adjusted by three parameters in the model, which are “average standstill distance”, “additive part of desired safety distance” and “multiple part of desired safety distance”. It is assumed that the distance between two queued vehicles does not vary with different combinations of vehicle types. Since the “Wiedemann 74 model” cannot be used for different combinations of vehicle types, parameters are calibrated by using the $t_f$ and $\tau$ of two passenger cars. Accordingly, the input values are shown in Table 4.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>average standstill distance (m)</th>
<th>additive part of desired safety distance (m)</th>
<th>multiple part of desired safety distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For $t_f$</td>
<td>2.1</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>For $\tau$</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Table 4:** Input values of Wiedemann 74 model

### Simulation Scenarios

Heavy vehicles are assigned from entries based on three cases; (1) only from the subject entry; (2) only from other three entries with the same $P_T$ and (3) from all the entries with the same $P_T$. Cases (1) and (2) represent the extreme situations and case (3) reflects the ordinary situation. In this analysis, $P_T$ is arranged from 0 to 1 with the interval of 0.1 for every case for examining the tendency of heavy vehicle impact. Circulating flow is controlled in the range between 0 and 1200veh/h for 7 levels. For every combination of input conditions, the VISSIM model was run for 10 times with a unique random number seed. Thus, in total 2,100 combinations were computed and each of them was run for 1h15min simulation time with a 15min warm-up time. Data from the first 15min of warm-up time were excluded from the results. Performance statistics were measured at a 15min interval. The measured entry flow (veh/h) was averaged based on 10 simulation runs.

### 4 Results and Discussions

#### 4.1 Estimated entry capacity from simulation study

Figure 4 shows the estimated entry capacity changing with circulating flow (horizontal axis) under different values of $P_T$. Figure 4(a), (b) and (c) represents the cases (1), (2) and (3), respectively. In each figure, the results of $P_T=0$, 0.2, 0.4, 0.6, 0.8 and 1 are shown as examples. Additionally, the units of circulating and entry flows are shown as veh/h and pc/h under the conditions with and without heavy vehicles, respectively.
Basically, it is found that in all the figures entry capacity is reduced when heavy vehicle percentage increases. Due to the larger size of heavy vehicles, the number of vehicles which can enter roundabout is reduced when more heavy vehicles are included.

4.2 Calculation of PCE value based on Simulation Results

Based on a macroscopic viewpoint of traffic flow, the adjustment factor $f_{HV}$ under the condition $P_T = \theta$ ($f_{HV}(P_T=\theta)$) is estimated through comparing flow rate including heavy vehicles $Q_{P_T=\theta}$ and the flow without considering heavy vehicles $Q_{P_T=0}$ at the similar circulating traffic flow conditions as shown in Equation (8).

$$f_{HV}(P_T=\theta) = \frac{Q_{P_T=\theta}}{Q_{P_T=0}}, \quad \theta \in [0,1]$$  \hspace{1cm} (8)

On the other hand, the adjustment factor $f_{HV}$ can also be estimated by using $P_T$ and PCE as shown in Equation (3) which is also applied in HCM 2010. Based on Equation (3), PCE can be transferred to Equation (9) as follows.

$$E_T = \frac{1}{P_T} \left( \frac{1}{f_{HV}} - 1 \right) + 1, \quad E_T = \text{PCE}$$  \hspace{1cm} (9)

By Equations (8) and (9), $E_T$ under the condition $P_T = \theta$ can be calculated as shown in Equation (10).

$$E_T(\theta) = \frac{1}{r} \left( \frac{Q_{P_T=\theta}}{Q_{P_T=0}} - 1 \right) + 1$$  \hspace{1cm} (10)
PCEs of case (1) and (3) are calculated and the results are shown in Figures 5 and 6, respectively.

(a) Relationship between circulating flow and PCE by $P_T$ of entry flow

(b) Relationship between $P_T$ of entry flow and PCE by circulating flow level

**Figure 5:** PCE estimation of case (1) based on simulation results

For case (1), the results of $P_T=0.2$, 0.4, 0.6, 0.8 and 1 are shown as examples. The value $Q$ is defined as the entry capacity and the similar traffic condition represents the similar level of circulating flow. Figure 5(a) shows the results of PCE changing with circulating flow under different conditions of $P_T$. It is found that the values of PCE are distributed in the range of 1.5 and 1.9. Moreover, regardless of values of $P_T$, PCE increases with the increase of circulating flow but decreases when circulating flow is over 600pc/h. Since the PCE represents the number of passenger cars which a heavy vehicle is equivalent to, it can be considered as a kind of expression of heavy vehicle impact. PCE becomes higher when the impact of heavy vehicle is greater. Thus, the reduction of PCE when circulating flow is high in Figure 5(a) can be explained that the significance of heavy vehicle impact on entry capacity becomes subordinate when circulating flow becomes high.

Figure 5(b) shows the results of PCE changing with $P_T$ at certain levels of circulating flow. It is found that PCE is slightly reduced when $P_T$ increases. This can be explained by the calculation process. In Equation (10), the degree of $1/r$ reduction ($10^{-1}$) is much greater than the increase of $Q_{PT\text{=0}}/Q_{PT\text{=r}}$ (1.1~1.5). Thus, PCE decreases as $P_T$ increases. On the other hand, Equation (10) is the estimation formula for basic road segment without considering the priority. Thus, it may be not appropriate to use this formula to calculate PCE for entry flow which should give priority to circulating flow. Moreover, in Figure 5(b) the PCE curve of $q_{cir}=876\text{pc/h}$ is lower than that of $q_{cir}=634\text{pc/h}$. This tendency corresponds to the results shown in Figure 5(a) that PCEs are reduced when circulating flow is in the high level.
Figure 6 shows the estimation results of PCE of case (3). Since circulating flow also includes heavy vehicles, only two traffic conditions are considered, circulating flow=0 ($Q$ represents entry capacity under this condition) and entry capacity reduced to the minimum value ($Q$ represents maximum circulating flow under this condition). It is found that the PCE of circulating flow at any level of $P_T$ is higher than that of entry flow. This tendency can also be obtained in SIDRA where PCE values of circulating flow and entry flow are 2.0 and 1.5, respectively. It can be explained that circulating vehicles have priority to entry vehicles which is similar to travel in basic road segment, while entry vehicles are travelling based on gap acceptance behavior so that the impact of heavy vehicle may be reduced due to gap acceptance behavior. This result demonstrates that heavy vehicle impact should also be considered on entry flow before entering roundabout.

Also, similar to the results shown in Figure 5(b), the PCE value of either entry flow or circulating flow decreases with the increase of heavy vehicle percentage.

Moreover, PCE of circulating flow has the same definition to the values which is applied in HCM 2010 and SIDRA (for circulating flow in SIDRA). Under the condition of case (3), the maximum estimated PCE value of circulating flow in this analysis is approximately 1.8, which is lower than that used in HCM 2010 and SIDRA. On the other hand, the estimated PCE value of entry flow approaches to the value applied in SIDRA which is 1.5.

5 Conclusion and Future Work

This paper estimated roundabout entry capacity considering heavy vehicle impact under the Japanese conditions by applying microscopic simulation in which input parameters were calibrated by using field data observed in Japan. Heavy vehicle assignment was considered in three cases: (1) from subject entry only; (2) from other entries only and (3) from all entries with the same increase of heavy vehicle percentage. Based on simulation results, PCE values of entry and circulating flows were also calculated. It was found that entry capacity is reduced when heavy vehicle percentage increases. The results are realistic considering the characteristic of heavy vehicles such as larger size comparing to passenger cars.

Then, regarding the results of PCE in case (1) it was found that PCE of entry flow increases with the increase of circulating flow while decreases after circulating flow exceeding 600pc/h. It can be explained that the significance of heavy vehicle impact is weakened when circulating flow is high since entry vehicles should give priority to circulating flow. Also under the certain level of circulating flow, PCE of entry flow is found to decrease with the increase of heavy vehicle percentage. Since entry flow is the minor flow, the PCE value may also be influenced by gap acceptance behavior. Future work should be done from this viewpoint.
Moreover, regarding case (3), it was found that PCE of circulating flow is higher than that of entry flow at any level of heavy vehicle percentage. The same tendency is found in SIDRA. The result demonstrated that the significance of heavy vehicle impact is reduced when the traffic flow is in the minor approach. Moreover, the PCE values regardless for circulating flow and entry flow which are calculated in this analysis are smaller than 2.0 used in HCM 2010. It implies that by using PCE=2.0, entry capacity may be underestimated.

Since only three specific cases of heavy vehicle assignment were examined in this analysis, simulation study will also be done for the other more general cases. Moreover, since heavy vehicle impact on entry capacity is significantly influenced by several factors such as geometric elements and previous exits, their impacts will be additionally considered in future. Also since this analysis focused on the tendency of heavy vehicle impact, the scenario of heavy vehicle percentage $P_T$ is assumed to be in a full range ($0 \leq P_T \leq 1$) which may not be realistic in the real world. Thus, in the future work, the range of $P_T$ will be narrowed down dependent on observations. Another work to be considered in future is consideration of types of heavy vehicle. In this analysis, since buses and trucks were observed at the study site, only these two types of heavy vehicles were considered in the simulation study. The impacts of other types of heavy vehicle such as trailer are expected to be examined through some experiments in future.

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