TRAFFIC SIGNAL EVALUATION USING A MODIFIED PASSENGER CAR EQUIVALENT UNIT

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Abstract: Mixed road traffic with a high proportion of motorcycles is a typical vehicle composition in Hochiminh City, Vietnam. Due to the nature of such a traffic stream, the method commonly used in evaluating the efficiency of traffic signals cannot be adopted here. Motorcycles are performing differently to traffic signals compared with passenger cars; in particular, their advanced mobility and flexibility resulted in a failure of the application of traditional traffic signal evaluation tools. This paper attempts to report a new approach for the issue; using a modified Passenger Car Equivalent unit (PCE) to convert motorcycles into standard car unit. Then aaSIDRA is applied to conduct a standard evaluation process on the performance of traffic signal designs; a range of output from aaSIDRA can be used to compare the differences with different signal settings. Finally, using the developed PCE factor, queuing and delay measured from aaSIDRA can be converted back into motorcycle delays.

Key Words: Mixed traffic, Passenger car equivalent unit, Traffic signal

1. INTRODUCTION

Similar as other cities in the developing countries, traffic congestion, delay, safety and environmental issues have been big problems in Hochiminh City, where mixed traffic flows are dominated by motorcycles. Considering the composition of vehicles in a traffic stream, approximately 90% of them are motorcycles. Due to the compact dimensions, advanced mobility and flexibility, motorcycles are a popular choice for many users. Motorcycles can easily creep in front of queued vehicles when traffic signal is red. They can also overtake other vehicles even in a same lane. Therefore the maneuver of vehicles and resulted traffic conditions are different from passenger car dominated traffic streams. This makes it difficult to apply traditional evaluation methods in measuring traffic performances. On the other hand, many of the software used in traffic engineering and transport planning are mainly dealing with motor vehicle related issues. Some researchers attempted to apply traffic/transport engineering software to investigate heterogeneous traffic streams. However, no study has been reported of using aaSIDRA, an analytical evolution tool specially developed for studying roundabouts, intersections and signalized intersections, to conduct research for mixed traffic flows, in particular, for motorcycle dominated traffic stream.

This paper reports a new approach, of which aaSIDRA is applied to evaluate mixed traffic flows at signalized intersections in Hochiminh City, Vietnam. Data were collected at an intersection using a video camera, and then a number of measures were extracted from the video taps. The motorcycle data were then converted into through car unit (tcu), prior being
used by aaSIDRA, a Passenger Car Equivalent (PCE) value for motorcycles was developed. This value is achieved through a calibration process to find the best PCE for the intersection. The outputs from aaSIDRA include measures such as the degree of saturation flow, delay and queue lengths. These measures can be used to adjust the intersection geometry designs and the traffic signal settings in order to improve its performance in the near future.

2. OBJECTIVES

aaSIDRA is an analytical software for the design and evaluation of signalized intersection, roundabout and other traffic control devices. It has been widely used in the world, the input to the software are mainly vehicular parameters. The objective of this study is to develop a Passenger Car Equivalent (PCE) value for motorcycles via calibration process using aaSIDRA software package. Then, this value is used to evaluate the performance of signalized intersections under the condition of mixed-traffic flows with a high proportion of motorcycles. In this study, the proportion of motorcycles is considered as high when their share in traffic flows is more than 50%. This is because, at this share of level, motorcycles will affect performance of traffic flows significantly.

3. REVIEW OF PAST STUDIES

Most traffic/transport engineering models are primarily developed for dealing with motor vehicle traffic flows. There has been little progress in using software to investigate mixed traffic flows for “non-standard vehicles”, mainly motorcycles and bicycles.

Matsuhashi et al (2005) applied VISSIM – a microscopic simulation model developed by PVT AG (Germany), to conduct traffic simulation analysis in Hochiminh City, Vietnam. Two scenarios were simulated to predict the effect of future changes in traffic compositions and traffic volumes on the performance of traffic streams. The data used in simulation analyses are obtained through image processing techniques. The results revealed that the speed of all vehicles in a traffic stream reduces when the share of cars increases, while the share of motorcycles decreases. The average speed of all vehicles would considerably increase when there was an increase in the share of public transport.

However, at some specific periods of time, traffic volume obtained via image processing is significant higher than the real traffic volume. This is because the shadows of the vehicles are also extracted as vehicles extracted by the image processing techniques. Furthermore, the two scenarios mentioned in the study represented hypotheses of the future traffic conditions. These may not reflect the real situations in Hochiminh City.

Julianto (2002) also used VISSIM to simulate a signalized intersection in the city of Surabaya in Indonesia. In the study, four different models that represented a group of two, three, four motorcycles and combination of two and four motorcycles were tested to find the most appropriate model with the results closest to the observed data. The study was based on the investigation of characteristics of a group of motorcycles including width, length, speed, acceleration/deceleration, and stopped gaps. The simulated results including queue length, travel time, number of stops and delay. They were then compared with the observed data to evaluate the accuracy of the model.
This study provided a notable approach in modeling a mixed traffic situation with high proportion of motorcycles at signalized intersections. Consistent outputs with high accuracy demonstrated that VISSIM micro is capable for that situation. However, it is quite difficult and confusing to adequately group motorcycles into packets in traffic data collection in the field. It may require considerable time for data extraction and analysis. Moreover, the method considered the motorcycles themselves only, and did not take account of the mixed traffic stream as a whole, either the interactions between motorcycles or other vehicles.

Oketch (2000) studied the lateral and longitudinal movements for a mixed traffic stream simulation. In the study, the author described that the process of lane changing when motorcycles overtaking each other. This process included three steps namely identification of available options, evaluation of the options by using Fuzzy logic and testing the safety condition (available gaps) before deciding to change lane and overtake lead vehicles. The microscopic simulation model was run under windows and DOS environments.

This model appears to be an appropriate measure to simulate mixed traffic flows with acceptable errors (the maximum error was only 5.3%). Nevertheless, because the model was done by manual, it does not have user friendly interface and the capacity is limited in implementing for a large network. Furthermore, the traffic streams used in the model include a low proportion of motorcycles. The appropriateness of this method should be tested for the case of high proportion of motorcycle traffic streams.

In the aspect of passenger car equivalent (PCE), a few studies were to find an appropriate PCE value for motorcycles. Wigan et al (2000) defined PCE value for a particular vehicle as the number of cars that bring the same effect on the capacity and performance at an intersection. These values depend on the specific conditions and may vary from one place to another.

Powell (2000) used the terminology of QFLIER, motorbike which sets off from the front of a queue before the end of the first 6 seconds of effective green time, to estimate the PCE value of motorcycles for the situation in Bangkok, Thailand. The study was based on the estimation of the number of QFLIERs. The finding was that the PCE values for motorcycles is 0 for those passing the stop line in the first 6 seconds of effective green time, and from 0.53 to 0.65 for those passing the stop line later. The results showed that the PCE value of motorcycles varied significantly depending on the time that motorcycle crossed the stop line during a signal cycle. It may be appropriate for specific short period of time, but it may not be used to reflect specific conditions for the overall observed period.

Minh et al (2003) estimated the passenger car equivalent (PCE) for motorcycles and buses in mixed traffic conditions at signalized intersections in Hanoi and Bangkok respectively. The method was based on saturation flow rate estimation. The saturation flow rate was assumed as a function of the number of vehicles discharging from the stop line during green time.

<table>
<thead>
<tr>
<th>City</th>
<th>Motorcycle</th>
<th>Car, van, taxi</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanoi</td>
<td>0.24</td>
<td>1.00</td>
<td>2.26</td>
</tr>
<tr>
<td>Bangkok</td>
<td>0.18</td>
<td>1.00</td>
<td>2.18</td>
</tr>
</tbody>
</table>

Regression method was used with an assumption that the relationship between the saturation flow rate and the number of vehicles was linear. Then the PCE values were determined as a...
coefficient of motorcycle and bus divided by the coefficient of passenger car unit. The results are shown in table 1.

From table 1, it can be seen that the PCE values for car, van and taxi are the same for both cities. For bus the variation is marginal but for motorcycles the differences are significant. The different PCE values for motorcycle may be due to the differences in vehicle compositions in the two cities.

In another approach, Minh and Sano (2005) converted other vehicle types into motorcycle units (MCU) recognizing the dominant factor of motorcycles. This method is based on the speed and occupied spaces of different vehicles in a traffic stream. The results showed that the MCU value for cars is from 3.6 to 3.9. This method opens a new approach and appears to be useful in the case of motorcycles are dominating the mixed traffic flows such as those in cities of Vietnam and Nevertheless, this method requires to be verified for its adequacy.

Similarly, Nakatsuji et al (2001) investigated the impacts of motorcycles on saturation flow rate at signalized intersections in Hanoi and Bangkok. But the method was based on different relative positions of motorcycles to passenger cars in traffic streams. The values of passenger car equivalent (PCE) for motorcycle were estimated as 0.60 and 0.63 for Hanoi and Bangkok respectively. Those values are quite different from the ones developed by Minh et al (2003) for the same cities.

In order to evaluate the effect of lane width on road capacity, Chandra (2003) investigated ten locations with various lane widths in India. The PCE values were estimated based on the level of service (LOS) that is defined in terms of operating speed. The PCE value of a vehicle type is determined by the following equation.

\[ PCE_i = \frac{V_c / V_i}{A_c / A_i} \]  \hspace{1cm} (1)

Where:

- \( V_c \) and \( V_i \) - The mean speeds for cars and type i vehicles, respectively.
- \( A_c \) and \( A_i \) - The rectangular areas of vehicles on the road.

The results showed that the PCE value for a vehicle type is directly proportional to lane widths, of which the PCE for motorcycle ranges from 0.25 to 0.3. However, this method did not consider the characteristics of motorcycles in mixed traffic streams.

Based on the discussions on the past researches, it can be seen that there is no applicable PCE values can be adopted. Those PCE values were developed for converting factor only. No efforts were made to develop a PCE value for the use in common computer software and evaluate the performance of a signalised intersection.

4. DATA COLLECTION PROCEDURES

This study aims to develop a range of PCE values and evaluate the performance of traffic signals in mixed-traffic condition at intersections in Hochiminh city. However, due to the constraint of time and budget, only one junction, which is typical intersection in the city, is
investigated. Twelve hours of traffic flows at the intersection are recorded and extracted, but only one hour of traffic data at afternoon peak hour is used in the study.

The Intersection and traffic signals: The selected junction is a four approach signalized intersection. The approaches and exits in the north-south direction include two 4.5-meter lanes, while the approaches and exits in the east-west direction has only one 4.5-meter lane. All the approaches have no median, slip lane or short lane. The grades at the intersection are negligible.

It can be seen from Figure 1, the intersection is in the North West part of the city. The major road carries traffic from central city to the airport.

The studied intersection has simple two phases fixed time signals with a cycle time of 50 seconds. The green times for phase A and phase B are 26 seconds and 18 seconds respectively. The inter-green time is 3 seconds for each direction. The speed limit is set at 40 km/h in almost all areas in the Central Business District (CBD) of Hochiminh City including the studied intersection.

Traffic volumes: The traffic flows were gathered by collecting the number of vehicles on a cycle by cycle basis, vehicle types were recorded separately. Due to the time constraint, only two hours of traffic data, from 4pm to 6pm, are studied. To investigate the peak hour operation, for the time from 4.40 pm to 5.40 pm, detailed traffic data is documented. Then, the traffic data is extracted for modeling purposes.

Figure 1 Study Location
The traffic flows for all 4 approaches were collected by extracting from replaying video files and manually counting the volumes for different vehicles. The data were classified in terms of vehicle types including motorcycle, car, bus and heavy vehicle; and in term of movement types: go through, right turn and left turn.

The results are presented in table 2. As mentioned before, motorcycle volumes are significant for all the movements, around 90%. This table provides the basic data for calculating the traffic volume for each approach. In a late process, the traffic volumes for motorcycles will be converted into PCE for the use of aaSIDRA.

### Table 2 Traffic Volume from 4.40pm to 5.40pm

<table>
<thead>
<tr>
<th>Approach</th>
<th>Go through</th>
<th>Right turn</th>
<th>Left turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorcycle</td>
<td>Car</td>
<td>Bus</td>
<td>Motorcycle</td>
</tr>
<tr>
<td>South</td>
<td>3208</td>
<td>393</td>
<td>23</td>
</tr>
<tr>
<td>North</td>
<td>3218</td>
<td>456</td>
<td>21</td>
</tr>
<tr>
<td>East</td>
<td>1646</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>West</td>
<td>1249</td>
<td>19</td>
<td>0</td>
</tr>
</tbody>
</table>

### Saturation flow:

Saturation flows were measured on a lane by lane basis in order to reflect the mixed traffic factor for the intersection. In this study, Akcelik (1994) method was employed for the measurement of saturation flows. In which, vehicles were counted in three separated intervals:

- First interval: the first ten seconds of the green period;
- Middle interval: the rest of the green period while saturated; and
- Last interval: the period after the end of the green.

Table 3 represents the measurements for the saturations for the intersection. Of which, all vehicles can be converted into through car unit using Passenger Car Equivalent (PCE) values.

### Table 3 Saturation flow measurement for the centre lane

<table>
<thead>
<tr>
<th>Cycle Number</th>
<th>Departures from Queue</th>
<th>Saturation Time (s)</th>
<th>Green Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Interval</td>
<td>Middle Interval</td>
<td>Last Interval</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>X2=186</td>
<td>X3=11</td>
<td>X4=971</td>
</tr>
<tr>
<td>Samples</td>
<td>n2=51</td>
<td>n3=7</td>
<td>n4=54</td>
</tr>
</tbody>
</table>

From this table, the saturation flow of centre lane can be determined by using following formula:

\[
S_C = \frac{x_2}{x_4 - 10n_4} \times 3600 = \frac{186}{971 - 10 \times 54} \times 3600 = 1554 \text{ pcu/h}
\]

(2)

Where:

- \(x_2\) and \(x_4\) - the total number of vehicles departing from the queues during the middle intervals and the total saturation time respectively in the studied period.
the total number of cycles which have a saturation time which lasts equal to or longer than ten seconds.

And their capacity is:

\[ Q = s \frac{g}{c} = \frac{1493 \times 26}{50} = 808 \text{ pcu/h} \]  \hspace{1cm} (3)

Where:

- \( s \) – Saturation flow rate
- \( g \) – Green time
- \( c \) – Cycle time

The saturation flows for other lanes are estimated later based on the saturation flows in the south approach and depend on PCE value.

Number of stopped vehicles: There are other measures such as delay, number of stops, queue length, capacity and degree of saturation that can be used to evaluate intersection performance. In this study, the number of vehicles in queue was observed as motorcycles were moved to the front of the cars; queue length in vehicles appears to be the most appropriate measure to evaluate the intersection performance.

In order to estimate the PCE value for motorcycles in running status, it is necessary to make an assumption of the PCE value in static condition. From traffic flow observations at the site, it could be seen that stopped motorcycles queued in groups of three to seven motorcycles.

As a result, it is reasonable to assume that one group of five motorcycles can be treated as a single passenger car. In this case, the PCE value of a motorcycle in the static condition in a queue is assumed to be equal to 0.2. The queue lengths, corresponding to this value, in south approach that can be extracted from video files are 5.37 and 3.26 vehicles for centre lane and side lane respectively.

Lane utilization ratio: The lane utilization ratio is determined by the following formula:

\[ R_{LU} = \frac{x_s}{x_c} \times 100 \text{ (unit in %)} \]  \hspace{1cm} (4)

Where:

- \( x_s \) is the degree of saturation of the side lane
- \( x_c \) is the degree of saturation of the centre lane

The lane utilization ratio depends on the PCE value. Therefore, it will be determined later corresponding to each of the specific PCE value.

5. MODELLING AND VERIFICATION

As aaSIDRA can only be used to deal with standard vehicles for all the input and output, all the traffic data should be converted into through car unit (tcu) by using the Passenger Car Equivalent (PCE) values for motorcycles and buses. In this study, in order to determine the
PCE value for motorcycles, the PCE value of 2.26 for buses, which is adopted from the study of Minh and Sano (2003), is used for modeling the intersection. The PCE value for motorcycles depends on the geometric characteristics, specific traffic conditions of the intersection, and especially on motorcycle behavior in mixed-traffic flow at an intersection. Motorcycle behavior at the intersection was carefully studied by observing motorcycle movements at the site and watching on the computer screen. As it can be seen when replaying the video files, motorcycles are very flexible, and sometime behave unpredictably.

- They usually do not follow the “first in first out” rule in queues, but try to creep to the front of the queue during red time period.
- Motorcycles do not stop one after another, but they usually stop in parallel, spread over the lane crossing the lane section with about three to five motorcycles in each row, and do not follow one after another but interpose themselves between each other.
- Motorcycles always react quicker than cars when the traffic signals turn to green. They also have higher acceleration rate, and thus quickly depart from the queue in comparison to cars and other vehicles.

As a result from the above discussions, and from site observation of traffic stream, during a moving condition such as departing from queues and being clear of the intersection, about ten motorcycles can be approximately assumed to be equal to one passenger car. In this case, the PCE value for motorcycles is recommended as 0.1, and this value is used as the first PCE value in the calibration process. From the traffic data in table 2, the traffic volumes for all approaches in the case $PCE_m=0.1$ are determined and presented in table 4.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Light vehicles (tcu/h)</th>
<th>Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Go through</td>
<td>Right turn</td>
</tr>
<tr>
<td>South</td>
<td>714</td>
<td>56</td>
</tr>
<tr>
<td>North</td>
<td>778</td>
<td>12</td>
</tr>
<tr>
<td>East</td>
<td>175</td>
<td>28</td>
</tr>
<tr>
<td>West</td>
<td>144</td>
<td>79</td>
</tr>
</tbody>
</table>

Note: $PCE_m$ is the PCE value for Motorcycle

Also, the number of vehicles departing from the queue is converted into tcu value, and is listed in table 5.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Departures from Queue</th>
<th>Saturation</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>First</td>
<td>Middle</td>
<td>Last</td>
</tr>
<tr>
<td>Interval</td>
<td>Interval</td>
<td>Interval</td>
<td>(s)</td>
</tr>
<tr>
<td>Total</td>
<td>X1=71</td>
<td>X2=17</td>
<td>X3=0</td>
</tr>
<tr>
<td>Samples</td>
<td>n1=28</td>
<td>n2=34</td>
<td>n3=0</td>
</tr>
</tbody>
</table>

The saturation flow of the side lanes for north-south direction and the lanes of east-west direction can be calculated as below:

$$s_s = \frac{x_2}{x_4-10n_4} \times 3600 = \frac{17}{321-10\times28} \times 3600 = 1493 tcu / h$$

And the capacity of side lane is:
\[ Q = s \times g / c = 1493 \times 26 / 50 = 776 \text{ tcu/h} \quad (6) \]

Where:

\( s \) – Saturation flow rate  
\( g \) – Green time  
\( c \) – Cycle time

From the traffic data collected, the lane utilization ratio for the side lane can be determined and it is presented in Table 6.

Finally, all the input data can be summarized in the input data preparation form as shown in figure 2. From this form, all the required data can be inputted into aaSIDRA to run the model, of which, the basic saturation flow is initially set up at 1800 tcu/h due to the environment class and lane type. The output of lane saturation flow is \( s = 1532 \text{ tcu/h} \) which is significantly different from the measured values (1554 tcu/h and 1493 tcu/h for centre lane and side lane respectively). Therefore the basic saturation flow has to be adjusted for calibration in the following way.

<table>
<thead>
<tr>
<th>Table 6 Lane utilization ratios for side lanes (PCE(_m) = 0.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South Approach</strong></td>
</tr>
<tr>
<td>Centre Lane</td>
</tr>
<tr>
<td>Traffic volume (tcu/h)</td>
</tr>
<tr>
<td>Saturation Flow (tcu/h)</td>
</tr>
<tr>
<td>Capacity (tcu/h)</td>
</tr>
<tr>
<td>Degree of Saturation</td>
</tr>
<tr>
<td>Lane Utilization (%)</td>
</tr>
</tbody>
</table>

The basic saturation flow for centre lanes:

\[ s_{b}' = \frac{1800 \times 1554}{1532} = 1826 \text{ tcu/h} \quad (7) \]

The basic saturation flow for other lanes:

\[ s_{b}' = \frac{1800 \times 1493}{1532} = 1754 \text{ tcu/h} \quad (8) \]

Then aaSIDRA is using these values as the new basic saturation flows. The output values of saturation flows for centre lane and side lane are 1554 tcu/h and 1493 tcu/h which are the same as the measured values. It is considered these input saturation flows are appropriate.

In order to assess the accuracy level of the modeling procedures, the output data estimated by aaSIDRA are compared with the observed data. In this study, the average back of queue in number of vehicles is used for the comparison. The differences between the estimated values and observed values, which is equal to or less than 10%, is considered to be acceptable.

In order to make the comparison, all the estimated and observed average backs of queues are represented in the Table 7. The difference is expressed in percentage. As can be seen in this table, only the mean back of queue of the east approach shows significant difference (29.34%) between the estimated value (4.1 through car units (tcu)) and the measured value (3.17 tcu)). The reason for this phenomenon may be because there were a large number of motorcycles.
turning left (104 tcu/h), which bring big effect on the vehicles going through and turning right from the opposite direction. As a result, the capacity of the intersection decreases, and delay and number of stopped vehicles increase.

![Figure 2 aaSIDRA input Preparation Form](image)

Table 7  Back of queues for all the lanes ($\text{PCE}_m = 0.1$)

<table>
<thead>
<tr>
<th></th>
<th>South Approach</th>
<th>North Approach</th>
<th>East Approach</th>
<th>West Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Centre lane</td>
<td>Side lane</td>
<td>Centre lane</td>
<td>Side lane</td>
</tr>
<tr>
<td>Average back of queue (tcu)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td>5.37</td>
<td>3.26</td>
<td>5.63</td>
<td>2.88</td>
</tr>
<tr>
<td>Estimated</td>
<td>5.50</td>
<td>3.40</td>
<td>6.00</td>
<td>2.90</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>2.42</td>
<td>4.29</td>
<td>6.57</td>
<td>0.69</td>
</tr>
</tbody>
</table>

In all the other lanes, the estimated values are quite similar to the observed values. The differences range from 0.69% in the side lane of north approach to 6.57% in the centre lane of the same approach. Therefore the results of back queues for all the lanes except the East approach are acceptable. As a consequence, it can be said that the PCE value of 0.1 is appropriate for modeling this intersection.

To gain confidence on the PCE of 0.1 is the most appropriate value for the specific condition with the selected intersection; the model is verified by using a calibration process. Of which, lower PCE value of 0.09 and the upper value of 0.11 for motorcycles are used for modeling the mixed traffic flow for the intersection.

The processes of modeling in these cases are the same as the process in the case of PCE=0.1. The results show that, in these cases (PCE equals to 0.09 and 0.11), the differences between estimated values and observed values are larger than in the case PCE=0.1. This demonstrates that the PCE=0.1 is the most appropriate value for the studied intersection.
6. CONCLUSION AND RECOMMENDATION

Mixed-traffic flow predominated by motorcycles is an emerging characteristic of all traffic flows in Hochiminh City as well as other cities in Vietnam. This study attempts to model mixed traffic flows for a four-leg signalized intersection in the CBD of Hochiminh City, Vietnam using aaSIDRA software. The traffic data were collected at the field in January, 2006 using video recording method, where a video camera was set up on the first floor of a building located at the north-west corner of the intersection, which can cover most of the intersection. Due to time constraint, although twelve hours of traffic were recorded in video tapes, one hour of traffic data in the afternoon peak period was extracted to be used for the study. The required traffic data were extracted in a laboratory by replaying the video files and manually counting traffic on the computer screen with the assistance of PowerDVD software.

In the study, a passenger car equivalent (PCE) value was developed to be used to convert motorcycles into passenger car unit. This value was subjected to a number of calibration processes. Of which, motorcycle behavior in mixed traffic stream at signalized intersections could be investigated.

The modeling process shows that aaSIDRA estimated values (queue lengths in vehicles) on almost all lanes (except the east approach) are quite similar to the observed values. In other words, the PCE value reflects quite accurately the real conditions of the studied intersection. aaSIDRA outputs include all the required data such as degree of saturation, queue lengths, delays, stop rates, movement speeds, and the level of service, which are clearly presented in both graphical and tabulate forms. All these indicators of performance, which are adequately shown in the aaSIDRA outputs, demonstrate that the intersection satisfactorily operates for the mixed traffic flows. This could be verified by observing the traffic flows at the site.

As mentioned before, due to time limitations the traffic data were from one signalized intersection only and over a short time period. It is recommended that more signalized intersections should be involved in the study and the observation times should extended to guarantee the results can reflect the real conditions of these intersections as well as in a certain area in Hochiminh City.

Because the PCE values for motorcycles vary depending on specific conditions at intersections, in the future studies, intersections in Hochiminh city should be divided into different types regard to different traffic signal configurations (cycle, green and amber time), different geometry (the number of lanes, lane width, short and slip lane). The PCE values should be validated and calibrated using aaSIDRA and use data from field observations. Then, the results of PCE values should be summarized in a matrix, which will be used for further studies in the future.

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