The road traffic systems, travel patterns and other traffic characteristics are different for each country due to differences in geometric patterns of a country, available transport facilities for commuters, rate of development in the transport sector and so on. Consequently, many standard relations and factors used in one region may not be suited for others. Therefore, an issue comes up to determine the different traffic engineering parameters which are appropriate to local urban transport system characteristics. One such endeavor is to determine the passenger car equivalent (PCE) at signalized intersections for the Dhaka Metropolitan City in Bangladesh where traffic characteristics are completely different from any other cities of the world.

PCE currently used in Bangladesh is based on the values given in Geometric Design of Highways (MoC, 2001), which is the modification of the values given by Webster (1958) on the study performed in the United Kingdom in the 50’s and 60’s. But now-a-days, the situation is far different both for traffic and road user as the characteristics have changed from that time. Hence, in this paper an empirical study was carried out to determine the PCE of different types of vehicle that reflect the actual traffic conditions of Dhaka Metropolitan City. Data were collected from ten signalized intersections and the headway ratio method was used to estimate the PCE of different types of vehicle. The main vehicle compositions observed during the study period consist of passenger cars, auto-rickshaws, mini-buses and buses. The PCE obtained in this study were compared to the values established earlier. It was found that the estimated PCE are smaller than those being used in Bangladesh.

Key Words: Passenger car equivalent (PCE), Headway ratio method, Saturation flow rate, Through traffic, Signalized intersections
fines PCE as “the number of passenger cars that are displaced by a single heavy vehicle of a particular type under prevailing roadway, traffic and control conditions”. In Bangladesh, vehicle types are divided into several categories. Thus, the mixed traffic compositions encountered in Bangladesh, PCE of each category of vehicles has been found to be of major significance, particularly in the estimation of saturation flow at signalized intersections.

Passenger car equivalent (PCE) currently used in the design and analysis of signalized intersections in Dhaka Metropolitan City as well as in Bangladesh is based on the values given in the Geometric Design of Highways, Ministry of Communication6. The values of PCE in the Geometric design of Highways are the modification of the PCE given by Webster7. These PCE derived in those research are shown in Table 1. The values determined by Webster7 are based on the study performed in the United Kingdom in the 50’s and 60’s. But now-a-days, more powerful vehicles are introduced on the roads through the use of automatic transmissions and by increasing the power to weight ratios and also the driver’s behavior, traffic compositions and the roadway characteristics in Bangladesh are far different from that of the original publication. As a result these values may not be representative of local traffic conditions in Bangladesh.

Furthermore, the number of vehicles and their compositions in Dhaka Metropolitan City is increasing day by day with the increase of population. Statistics shows that the growth rate of motorized vehicles in Bangladesh is around 10 percent per annum8. Moreover, the compositions of the traffic at the studied intersections are very complex. Both motorized and non-motorized traffic moves through the intersections. There is no lane marking or lane restriction, no phase in the traffic signal for right turning vehicles, inadequate pedestrian facilities, poor parking facilities, poor road surface condition and so on. To reduce the effects of this increasing amount of vehicles and their compositions on the operational system of the signalized intersections and considering other factors, it is necessary to determine the PCE on the basis of current roadway and traffic conditions of Dhaka Metropolitan City, Bangladesh.

Therefore, the objective of this paper is to determine the PCE that reflects the local traffic conditions in Dhaka Metropolitan City, Bangladesh. Emphasis was placed on the through movement of different types of vehicle. The main vehicle compositions observed during the study consist of passenger cars, auto-rickshaws, mini-buses and buses. The performance of the signalized intersections can be improved by using these PCE.

### 2. STUDY APPROACH

Methods commonly used for deriving PCE fall into two groups, specifically the headway ratio method and regression method. Headway ratio method has been used by Brown & Odgen9, Cuddon & Odgen10, Hasan et al.11 and William H.K. Lam2 while the regression method has been used by Branston and van Zuylen12 and Kimber et al.1. In this study, the headway ratio method was used for the calculation of PCE. According to Leong13, the saturation flow rate based on PCE of the headway ratio method predicts better than the saturation flow rate based on PCE of regression analysis.

This procedure is recommended by examining the condition — ‘*necessary and sufficient condition for the effect of a certain type of vehicle to be independent of the type of vehicle preceding it and following it*’. The following condition should be satisfied if it is wanted to calculate PCE by the headway ratio method10. It involves a com-

<table>
<thead>
<tr>
<th>Vehicle categories</th>
<th>Webster7 (1958)</th>
<th>MoC6 (2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Light goods vehicle</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Heavy or medium goods vehicle</td>
<td>1.75</td>
<td>-</td>
</tr>
<tr>
<td>Truck</td>
<td>-</td>
<td>3.00</td>
</tr>
<tr>
<td>Bus</td>
<td>2.25</td>
<td>3.00</td>
</tr>
<tr>
<td>Tram</td>
<td>2.50</td>
<td>-</td>
</tr>
<tr>
<td>Auto-rickshaw</td>
<td>-</td>
<td>0.75</td>
</tr>
<tr>
<td>Motorcycle, moped, scooter</td>
<td>0.3</td>
<td>0.75</td>
</tr>
<tr>
<td>Pedal cycle</td>
<td>0.20</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Comparison of two sides of Equation (1) as below:

\[ h_{c,c} + h_{x,x} = h_{c,x} + h_{x,c} \]  

where,  
\( h_{c,c} \) = Average headway of a car followed by a car;  
\( h_{c,x} \) = Average headway of a car followed by a type \( x \) vehicle;  
\( h_{x,c} \) = Average headway of a type \( x \) vehicle followed by a car;  
\( h_{x,x} \) = Average headway of a type \( x \) vehicle followed by a type \( x \) vehicle.

For those headway samples that do not exactly fulfil the independence condition, a corrective factor needs to be applied. Scraggs\(^1\) has derived the proof of this condition and Kimber \(\text{et al.}\)\(^1\) and Brown and Ogden\(9\) have explained in detail. Scraggs\(^1\) derived the corrective factor (C) by using the least square method which is given in Equation (2):

\[ C = \frac{abcd(w - x - y + z)}{abc + abd + acd + bcd} \]  

where  
\( a \) = Number of headways for car following car;  
\( b \) = Number of headways for car following type \( x \) vehicle;  
\( c \) = Number of headways for type \( x \) vehicle following car;  
\( d \) = Number of headways for type \( x \) vehicle following type \( x \) vehicle;  
\( w \) = Mean headways for car following car;  
\( x \) = Mean headways for car following type \( x \) vehicle;  
\( y \) = Mean headways for type \( x \) vehicle following car; and  
\( z \) = Mean headways for type \( x \) vehicle following type \( x \) vehicle.

Equation (3) represents the adjusted mean headways for a car following a car:

\[ \bar{h}_{(c,c)} = U - \frac{C}{\text{No. of headways car following car}} \]  

where,  
\( \bar{h}_{(c,c)} \) = Adjusted mean headways for car following car;  
\( U \) = Uncorrected mean headway; and  
\( C \) = Correction factor

The adjusted mean headways for vehicle type X following vehicle type X can be represented as in Equation (4):

\[ \bar{h}_{(x,x)} = U - \frac{C}{\text{No. of headways vehicle type X following vehicle type X}} \]  

Note that passenger car equivalent (PCE) for through vehicles compares the headways for a given vehicle type with cars travelling straight through the intersection. Hence, the PCE is calculated using Equation (5):

\[ e_x = \frac{\bar{h}_{(x,x)}}{\bar{h}_{(c,c)}} \]  

### 3. SITE DESCRIPTIONS

The purpose of the site survey was to identify potential signalized intersections which are suitable for field data collection. The location of the intersections was in the Central Business District (CBD) area. The criteria for site selection have to accommodate significant flows of the selected vehicles (passenger cars, auto-rickshaws, minibuses and buses) during times of the day when it operated at saturation. It is important to ensure that the signalized intersections being studied are fully saturated or have adequately saturated portions of the green interval of longer than 20 seconds\(^15\).

The sites selected for data collection are shown in Table 2. In this table ten intersections are listed with their approaches. Each approach of the intersection is described with the parameters of the number of lanes, width of lanes and percentage of vehicle types. The types of vehicle included cars, auto-rickshaws, mini-buses and buses. The trucks were not included in this analysis because this type of vehicle was restricted to enter into the city during the day time (i.e. 8 am to 8 pm).

### 4. DATA COLLECTION AND METHODOLOGY

Data were collected from through lanes at several signalized intersections in Dhaka Metropolitan City in Bangladesh. The selection of intersections was based on the following criteria: high traffic volumes and significant queuing, through lanes with protected signal phase, no parking allowed, and no bus blockages permitted. Before starting data collection, the types of vehicle were divided into few categories, i.e. cars, auto-rickshaws, minibuses and buses. Data were collected in a similar fashion to the method used by Hossain\(^16\).
actual time headway of different vehicles passing through the stop line. Thus, by using a cassette recorder, events in the observed lane such as beginning of green interval, the passage of the rear axle of each passing vehicle over the stop line (the rear axle was used because the first vehicle in the queue frequently stops over the stop line) as well as the vehicle type, the end of saturation flow and the beginning of amber and red interval can be noted. This method was judged to be fast and accurate, because the observer had only one task to perform in the field. The geometric data of specific lanes at signalized intersections such as lane width, approach grade, and turning radius were measured.

Data were collected during peak periods on week days in dry weather when the intersections were saturated. It is important to make sure that the traffic flows at signalized intersections being studied is saturated. A fully saturated cycle is one which the queue has not fully discharged by the beginning of the red interval\(^2\). Then by using the software BancianVer 2003\(^17\), data were downloaded from the audio cassette to computer for analysis.

In order to estimate the PCE, headways for saturation flows were used and the first four vehicles crossing the stop line were excluded to eliminate the effects of queue start-up as vehicles accelerated.

5. RESULTS AND DISCUSSION

The processed data for through lanes with a level gradient were analyzed to estimate the passenger car equivalents (PCE) for cars, auto-rickshaws, mini-buses and buses using the headway ratio method. In the survey, a detailed record of vehicle departures was made by the observers with event-recording equipment. Hence, the inter-vehicle straight-ahead time headways can be calculated by vehicle type. The PCE computed based on the headway ratio method for auto-rickshaws, mini-buses and buses are shown in Tables 3, 4 and 5 respectively.

The summary of PCE derived using the headway ratio method for each type of vehicle is shown in Table 6. Comparison of PCE obtained from MoC\(^6\) was also made and is shown in Table 6.
In this study, the passenger cars, micro-buses and pickups were grouped together. The presence of many mini-buses in Dhaka Metropolitan City has prompted to classify them differently from ordinary buses because of their difference in size and operating characteristics.

The results summarized in Table 6 were obtained from several signalized intersections in Dhaka Metropolitan City. The PCE of buses was found to be 2.16 which is smaller when compared to MoC6 value. This may be due to the buses today having higher power to weight ratio when compared to buses in the 50’s and 60’s, as the PCE of MoC6 is the modification of Webster7.

The PCE of mini-buses was found to be 1.42 which is not close to the value suggested by MoC6. In MoC6, buses and mini-buses were grouped together. But in this study the mini-bus was considered separately from buses as the size of mini-buses is different compared to mini-buses in the 50’s and 60’s.

The PCE of auto-rickshaws was found to be 0.86 which is slightly higher than the suggested value by MoC6. The estimated PCE for auto-rickshaws in Bangladesh conditions is higher than that being used in practice in Bangladesh, indicating a greater individual effect on traffic in Bangladesh.

In order to get values that really represented the traffic condition of Bangladesh, data from other parts of the country are needed. Since a large sample size is used in this study, it can be assumed that the values obtained are representative of the current traffic condition of Bangladesh.

In this study, the passenger cars, micro-buses and pickups were grouped together and the PCE of those vehicles is estimated as passenger cars. It is recommended that in the future study, it should be considered separately to find out the PCE values of each of the vehicle types grouped as passenger cars. Moreover, this study was conducted to estimate the passenger car equivalent (PCE) at signalized intersections in Dhaka Metropolitan City. But there are many turning lanes in this city and unfortunately, to date no investigation has been carried out to estimate the PCE value on the turning lane. Hence, a study on the PCE on turning lanes is suggested for future research.

### 6. CONCLUSIONS

This paper has discussed the procedure of deriving the passenger car equivalent (PCE) for through vehicles according to the traffic conditions of Dhaka Metropolitan City, Bangladesh. The PCE for four vehicle types were derived using the headway ratio method. The estimated PCE for cars, auto-rickshaws, mini-buses and buses are 1.00, 0.86, 1.42, and 2.16, respectively. The comparison between the estimated PCE and the PCE currently used in Bangladesh is demonstrated in this paper.

The PCE presently used in Bangladesh considerably differs from the PCE obtained from this study, which has a significant impact on the calculation of the saturation flow rate and thus influences the design of signalized intersections. It is suggested that the values obtained in this study can be used as a guideline in the design and analysis of signalized intersections in Dhaka Metropolitan City as well as in Bangladesh.
REFERENCES


