# Methodology for Motorcycle Equivalent Unit at Road-Segments in Urban Road

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**ABSTRACT**

This paper investigates the methodology of motorcycle equivalent unit (MCU) at road-segments in motorcycle dependent city. A methodology based on passenger car equivalent (PCE) approach previously developed by Chandra *et al*. (2003) is presented in this research. This methodology illustrates a more accurate method of MCU in mixed traffic flow by considering the characteristics of moving vehicles such as velocity and an effective space. In which, the effective space of each kind of vehicle is computed under considering influences of velocity and physical size of the subject vehicle and the surrounding motorcycles.

The proposed methodology was applied to field data collected at eight sections in four road-segments located in Hanoi city, Vietnam. The field data indicated that the effective space of each vehicle varies by the speed of moving vehicle, and MCU value increases slightly corresponding with the lane number of each urban road during the peak hour. Also, it was found that the MCU is a function of the mean speed, a mean effective space of each vehicle. The field data indicates that the MCU values of car, bus, minibus, and bicycle are 3.43, 10.48, 8.34 and 1.38, respectively at road-segments in urban road.

## INTRODUCTION

Heterogeneous traffic with the predominance of motorcycles is very common in many cities in southeast Asia, where motorization has developed speedily in the last few decades. In these areas, the term “motorcycle dependent city “has been used to indicate a city with low income, high density land use and motorcycles’ domination in traffic flow. While many developed countries confront troubles relating to vehicle traffic, southeast Asian coutries in general and Vietnam in particular are facing a serious situation in respect to the high volume of motorcycle traffic and congested motorcycle flows. Besides, the ownership of motorcycles is increasing significantly in many other southeast Asian coutries due to their high mobility and affordable price. Furthermore, motorcycle traffic, which has very distinguishable characteristics, significantly affects the traffic condition. Motorcycles may reduce the speed of other modes and make the traffic more congested due to their slim shapes, small size and maneuver behaviour. In addition, motorcycles tend to make use of every space on the carriageway in front and both sides of their locations when in motion.

The term passenger car equivalent (PCE) was introduced in the 1965 Highway Capacity Manual. Since 1965, considerable research effort has been directed toward the estimation of PCE value for various roadway types and the passenger car has been used as the basic vehicles for converting other vehicle into passenger car equivalent (PCE) in the traditional approach. However, PCE concept becomes hard to be suitable in traffic dominated by motorcycles in southeast Asian countries, including Vietnam. Hence, it would seem to make more sense in such case that the motorcycle is considered as the basic vehicle in this traffic flow. In order to account for other categories of vehicles in the traffic flow, the concept of motorcycle equivalent unit (MCU) value at urban mid block sections was introduced in this paper.

The objective of this study is to develop a methodology that accurately estimates the value of MCU for the other vehicles under considering the characteristics of moving vehicles in the traffic stream. These characteristics are the speed of the other vehicles with the surrounding motorcycles, the occupied space between motorcycles taken and a subject vehicle. In addition, this study illustrates and validates how the methodology accurately determines MCU values at mid block sections in urban street.

## LITERATURE REVIEW

There is the existence of many methods for determining passenger car units (PCUs) such as the homogenization coefficient method, the semi-empirical method, the Walker’s method, the headway method, the multiple linear regression method and the simulation method. PCU is also known as passenger car equivalent (PCE).

For motorcycle analysis, Lan *et al* (2003) analyzed the motorcyclist behaviors in a mixed traffic flow with passenger cars on 2.5(m) and 3.75 (m) lanes. They developed traffic volume-density relationships and speed-density relationships under different percentage of motorcycles. They concluded that under pure motorcycle condition, the maximum flow rates for 2.5 (m) and 3.75 (m) lane widths are 5,600 and 8,300 (Vph), respectively. The motorcycle equivalent unit (MCU) range from 2.63 (speed 14m/sec) to 5.27 (speed 4m/sec) for 10% ~ 100% of passenger cars. Some analyses have been done by Nakatsuji *et al.* (2001) so as to scrutinize the impact of motorcycles on capacity at signalized intersections in Hanoi and Bangkok. Such authors made a classification of some patterns, which were different relative positions of motorcycle to passenger car, then carried out regression analysis in order to estimate how different among these patterns were in terms of headway and start-up lost time. Similarity, Hai (1999) also evaluated effects of motorcycle on saturation flow rate in Hanoi. He estimated motorcycle's influence to car start-up lost time by separating two cases: position and number of motorcycles in front of first car in queue. Furthermore, Minh *et al* (2003) estimated then compared the PCU for motorcycles at some signalized intersections in Hanoi and Bangkok by using multiple linear regression analysis technique. The authors also estimated the saturation flow rates, and the changing of motorcycles and cars in the saturation flow rate. Chandra *et al.* (2003) considered speed to be a prime variable to determine the relative effect of individual vehicles on traffic stream in respect PCU described as follows:

$$PCU_i = \frac{V_c / V_i}{A_c / A_i} \quad (1)$$

Where

$V_c$ , $V_i$ = mean speed for cars and type *i* vehicles, respectively;

$A_c$ , $A_i$ = the respective projected rectangular area (length × width) of roads;

The physical size of a vehicle is an indicator of space occupancy, which is crucial in operational characteristics of traffic stream (Chandra *et al.*, 2003). Nevertheless, the value of the physical size of a vehicle is constant. It is unrealistic that the space occupancy on the road of a vehicle in reality is a function of many attributes, such as speed, surrounding traffic environment, etc. Minh (2005) addressed a comprehensive analysis of motorcycle behavior and operation through videotaping a few roads that have significant motorcycle proportion. Speed – flow relationships were developed for all locations, in which the adjustment factors for the present of vehicles other than motorcycles were based on motorcycle equivalent unit. In addition, a basic understanding of characteristics of motorcycle traffic was provided from the research. However, the calculating formula of motorcycle equivalent unit in Minh (2005) has the same limitations with that of Chandra *et al*. (2003). The concept of motorcycle unit (MCU) values was introduced by Hien *et al* (2007) at signalized junction in Hanoi, Vietnam. He investigated the variability of saturation flow and MCU values in traffic condition dominated by motorcycles. Besides, the MCU value of cars was also found to be constant and it was calculated as equivalent to 3.67 in his research.

As described above, the debate of previous research focuses on the concept of PCU and MCU value at signalized intersection or signalized junction. However, very little research has been conducted regarding the motorcycle equivalent unit under mixed traffic flow at road-segments in urban road. Therefore, this paper is continuous to developing and validating the methodology of MCU at road-segments under the traffic condition dominated by motorcycles.

## PROPOSED MCU METHODOLOGY

Motorcycle equivalent unit (MCU) is defined as the number of motorcycles that can be displaced for one vehicle of specified type running at the speed of that vehicle. MCU for each type of vehicle is developed by taking the consideration of dynamic characteristics of moving vehicles in this study. Such factors show the correlation of speed and occupied space between surrounding motorcycles taken and a subject vehicle. The modified formula that is applied for MCU conversion is depicted as follows:

$$MCU_k = \frac{\overline{V}_{mc}}{\overline{V}_k} \times \frac{\overline{S}_k}{\overline{S}_{mc}} \quad (2)$$

Where
$MCU_k$ = motorcycle equivalent unit of type *k* vehicle;
$\overline{V}_{mc}$, $\overline{V}_k$ = the mean speed of motorcycles and type *k* vehicle, respectively (m/s);
$\overline{S}_{mc}$, $\overline{S}_k$ = the mean effective space for motorcycles and type *k* vehicle, respectively ($m^2$);

In traffic with lane discipline, the occupancy is under control by the length of a vehicle (See Chandra *et al.,* 2003). However, under the conditions of mixed traffic where vehicles do not follow lanes strictly, the required space is better reflected by area. Therefore, total physical size of the vehicle and the required space has been considered in equation (2).

In order to calculate mean speeds of different types of vehicles ($\overline{V}_k$), the spot speed technique was applied. The speeds of traffic entities were determined by the time required for traveling a known distance (trap length). In this study, the trap length was measured as the distance between two consecutive electric poles. The time required to travel a given distance was captured by recording the entry and exit time of that length. The speed then obtained from the division between the trap length and the travel time for each vehicle.

Since it is assumed that each vehicle has a mean effective space ($\overline{S}_k$) for driving and this space might vary according to speed, traffic condition, driver characteristics (such as age, income or gender) or weather conditions. Therefore, to reduce the influence of these factors on the mean effective space, the weather condition is dry weather and the traffic condition is considered in peak time in this research. In addition, it is impossible to determine the driver characteristics because the data is collected from each video camera that is set on the eighth floor of high building. Therefore, the influence of driver characteristics is not considered in the scope of this paper. It is hypothesized that the mean effective space values might vary by the speed of vehicle in road segments. If this is so, the relation between the mean effective space and mean speed for type k vehicle could be written in the nonlinear function as below:

$$\overline{S}_k = a \times \overline{V}^2_k + b \times \overline{V}_k + c \quad (3)$$

Where
$\overline{V}_k$ = the mean speed of type *k* vehicle (m/s);
$\overline{S}_k$ = the mean effective space for type *k* vehicle ($m^2$);
$a, b, c$ = parameters of nonlinear function;

The effective space for a vehicle is defined as the necessary space needed by a vehicle to maintain its desired speed. In other words, it is the boundary around the subject vehicle, which is necessary for its maneuver regarding its speed. Therefore, this variable depends on vehicle speed, mode and other adjacent vehicles. The effective space of a subject vehicle is illustrated in Figure 1 and expressed as follows.

$$S_k = L_k \times W_k \quad (4)$$

Where
$S_k$ = effective space for vehicle type *k* ($m^2$);

$L_k$ = effective longitudinal distance of running vehicle inclusive of vehicle length (m);
$W_k$ = effective lateral distance of running vehicle inclusive of vehicle width (m);

The values of the effective space of each sample are calculated at section A and section B in the first 25 meters and the second 25 meters of road segments, respectively. These sections are illustrated in the Figure 3 and the mean effective space value of vehicle is measured based on the values of effective space at two these sections. In addition, it is straightforward to measure the effective longitudinal distance ($L_k$) value in the formula (4). However, the problem is how to determine the lateral boundary line of the effective lateral distance ($W_k$) for each running vehicle. In fact, the occupied space of vehicle is affected by the size of the subject vehicle and the surrounding motorcycles. Therefore, it is assumed that the lateral width of the subject vehicle is a function of the lateral width of motorcycles, the total physical size of subject vehicle and motorcycles. The lateral width of subject vehicle may be computed as follows:

$$D_k = \frac{Z_k}{Z_{mc}} \times D_{mc} \quad (5)$$

Where

$D_k$ = the effective space's lateral width of vehicle type *k* (m);
$D_{mc}$ = the effective space's lateral width of motorcycles (m);
$Z_k$ = the total physical size of vehicle type *k* ($m^2$);
$Z_{mc}$ = the total physical size of motorcycles ($m^2$);

The total physical size's values of vehicle type k and motorcycles are adopted from Chandra *et al.* (2003). These total physical size's values are chosen because the proposed method of motorcycle equivalent unit will be validated and compared with the method of Chandra. The other reason is the data used for Chandra's method also come from the developing countries, where the traffic condition is similar to Hanoi, Vietnam.

## PRELIMINARY FIELD DATA COLLECTION

Four approaches that belong to Kim lien Street (KL), Giai phong Street (GP), Cau giay Street (CG) and Hang bong Street (HB) were selected for data collection in Hanoi, Vietnam. Geometrically, these streets can be divided into four groups such as four-lane road, six-lane road, eight-lane road and eight-lane road with two lanes for bicycle only. All these roads are divided road with raised median within the city centre. The geometry and traffic properties of these approaches are shown in Figure 2 and Figure 3, respectively. The traffic data were collected in two weeks, from 9$^{th}$ to 13$^{th}$ and 16$^{th}$ to 20$^{th}$ March 2009. In addition, data were collected in dry weather and at peak time, from 6:00am to 8:00am and 4:00pm to 6:00pm in every weekday. The traffic flow was composed of passenger car, minibus, bus, motorcycle and bicycle; however, motorcycles make up the majority in the traffic stream in all locations.

The traffic flow data was gathered by using two video cameras that were set on the high building. The system consisted of two portable video cameras, two tripods, videodiscs, a measuring roller, and manual counters. Then, vehicle's positions were identified from image video files in laboratory. These positions regarding time events were calculated according to screen co-ordinates then converted into roadway co-ordinates by using Speed Estimation from Video data (SEV) software (Minh, et al. 2005).

Therefore, all data of the effective space and speed for each sample was analyzed by author with two laptops corresponding to two sections A and B at each road-segment. From field data it was found that the variation of the speed of subject vehicle and the surrounding motorcycles was little at each section (20 meters). Besides, the value of effective space also was the same for each vehicle at each section. Therefore, it was assumed that the value of speed and the effective space of subject vehicle and the surrounding motorcycles were constant at each section. However, the speed and the effective space of each vehicle changed a lot between two sections in road-segments. Hence, these values were computed at two sections A and B to estimate the correlation relationship between the effective space and speed of each subject vehicle in road-segments.

## RESULTS OF THE PROPOSED MCU METHODOLOGY

### The Relationship between Speed and Effective Space for Each Type of Vehicle

The values of the speed and the effective space of each type of vehicle were calculated at four selected road-segments. Then, the relationships between the effective space and speed of motorcycles, buses and cars were representative and illustrated in Figure 4. In addition, this relationship of bicycles and minibuses also were computed at each road-segment in this research.

From figure 5, it is straightforward to see the correlation relationship between speed and the effective space is high at all selected road-segments. This means that speed of subject vehicle is one of the most important factors which can create the strong influence on the effective space of that vehicle. The area of the effective space of vehicle is larger when the speed of subject vehicle increases in road-segment. In contrast, this area is smaller corresponding to the lower speed of subject vehicle. The results of this correlation relationship prove that the assumption of formula (3) is correct and appropriate in the traffic flow dominated by motorcycles.

Assume that the area of the effective space of subject vehicle is affected by the speed of a head motorcycle. To test the influence of the speed of a head motorcycle on the effective space of subject vehicle, the correlation relationship between the speed of a head motorcycle and effective space also was computed at two road-segments in GP Street and KL Street and illustrated in Figure 5. From the results, the values of the correlation coefficient are 0.059 and 0.106 in GP Street and KL Street, respectively. Therefore, the influence of the speed of a head motorcycle on the area of effective space of subject vehicle is low. Hence, this is the main reason that makes the speed of a head motorcycle is not available in formula (3).

The traffic flow condition is considered as well as the saturation flow at road-segments in this research. From figure 4a, 4b, and 4c, the average speed of motorcycles in KL, GP, CG and HB Streets are 7.64, 7.13, 7.14 and 6.71 (m/sec), respectively. Besides, the average speed of cars is 8.64, 6.63, 8.45 and 7.19 (m/sec) at four selected road-segments in figure 4b. The average speed of buses also is 8.55, 7.72, 7.35 and 6.96 (m/sec) in KL, GP, CG and HB Streets, respectively in figure 4c. In addition, the values of average speed of bicycles are 4.72, 4.65, 4.14 (m/sec) in each road-segment. This value of minibuses is 8.27, 7.85 and 7.41 (m/sec) in GP, CG and HB Streets, respectively and there is no minibuses route on KL Street. The figures of the relationship between speed and the effective space for bicycles and minibus are not shown in this paper. In general, the value of average speed of subject vehicle in the eight-lane road is much less higher than that of subject vehicle in four-lane road during the saturation flow condition in urban street.

Even though, there is the different of geometry among road-segments and this is the main reason that makes the value of speed, the effective space of subject vehicle is a little different among road-segments. However, to determine the value of the mean effective space ($\overline{S}_k$) that is appropriate for many road-segments in urban road. All the results of average effective space, mean speed for each sample at four road-segments can be considered as the input data for estimating the function (3) of the mean effective space ($\overline{S}_k$) by regression technique.

**Calibration of nonlinear regression model and MEU value for each kind of vehicle**

To calibrate equation (3), the mean effective space of subject vehicles for heterogeneous traffic is evaluated by using the nonlinear regression analysis. The output of mean effective space by the nonlinear regression analysis is presented in Table 1.

The results show that the influence of mean speed on the mean effective space of bicycles is lowest in traffic flow. This is easy to understand because all bicyclists prefer to run on the lane that nears pavement. Therefore, the influence of motorcycles on the effective space of bicycles is very weak and the area of the mean effective space of bicycles is normally large than the required space of mean speed. In contrast, this influence of buses and minibuses is very high in the mixed traffic flow. From the Table 1, the final nonlinear function predicting the mean effective space of each kind of vehicle at road-segments in mixed traffic flow dominated by motorcycles in urban road could be written as:

$$\overline{S}_{mc} = 0.07\overline{V}^2_{mc} + 0.66\overline{V}_{mc} - 1.72 \qquad (6)$$

$$\overline{S}_{Car} = 0.13\overline{V}^2_{Car} + 1.22\overline{V}_{Car} + 7.29 \qquad (7)$$

$$\overline{S}_{Bus} = 0.19\overline{V}^2_{Bus} + 5.12\overline{V}_{Bus} + 27.68 \qquad (8)$$

$$\overline{S}_{MiniBus} = 1.34\overline{V}^2_{MiniBus} - 9.21\overline{V}_{MiniBus} + 49.71 \qquad (9)$$

$$\overline{S}_{Bicycle} = 0.37\overline{V}^2_{Bicycle} - 1.61\overline{V}_{Bicycle} + 5.35 \qquad (10)$$

Where

$\overline{S}_{mc}, \overline{S}_{Car}, \overline{S}_{Bus}, \overline{S}_{MiniBus}, \overline{S}_{Bicycle}$ = mean effective spaces of motorcycles, cars, buses, minibuses and bicycles, respectively;

$\overline{V}_{mc}, \overline{V}_{Car}, \overline{V}_{Bus}, \overline{V}_{MiniBus}, \overline{V}_{Bicycle}$ = mean speeds of motorcycles, cars, buses, minibuses and bicycles, respectively;

The MCU values of vehicle type *k* are achieved after computing the mean effective space and mean speed of each type of vehicles in traffic stream. Table 2 expresses the values of MCU for different types of vehicles computed at the various locations. It is straightforward to see that there is a small difference in the value of MCU of each vehicle type among four selected road-segments. This difference could be explained by the different road width that becomes largely. From table 2, the value of MCU of buses and cars increases slightly when the lane number of each approach increases. In addition, the values of MCU of bicycle are reasonable within the real situation of traffic flow condition in the selected road-segments. In reality, bicyclists prefer to ride on the lane that is near by the roads' pavement; hence, the influence of motorcycles on the mean effective space of bicycles is weak. Therefore, the area of this mean effective space of bicycles is normally larger than that of the required space for riding at these road-segments. However, the value of MCU of bicycles will be more accurate with the saturation flow condition of mixed traffic flow that dominated by motorcycles.

Four selected road-segments was representative for the road-segments that belong to the four-lane road, six-lane road, eight-lane road in urban road. Therefore, the weighted mean method was used in this research to calculate the unique value of MCU that was acceptable for each kind of vehicle at road-segments. From table 2, MCU value of cars, buses, minibuses and bicycles are 3.43, 10.48, 8.34 and 1.38, respectively.

## Model validation

The proposal model was validated with the data of two approaches, namely HB Street and CG Street. In addition, the same data set also used to test Chandra's method. Chandra's method is used for validation because the data used for this method also comes from the developing countries, where the traffic condition is similar to Hanoi, Vietnam. The concept of validation was carried out based on the speed-flow curve that if the mean stream speeds at different time intervals are the same, the volume must be the same after converting into the MCU. Therefore, after calculating the mean stream speeds at the different time intervals, if two mean stream speeds are similar, the volumes at those intervals are converted into the MCU. If the volume after converting into the MCU is the same, the research methodology for calculating the MCU is correct. Otherwise, the method needs to be revised.

The relationships between mean stream speed and volume on HB Street and CG Street are plotted in Figure 6a and 6b, respectively. From these Figures, it is straightforward to see that mean stream speeds are inversely proportional to volume. The regression coefficient of the proposal model is higher than that of Chandra's model. Moreover, at the same mean stream speed, the traffic volume of the proposal model is better than that of Chandra's model. This means that when the samples have the same mean stream speed, the largest distance between the two samples of the proposal model is less than the largest distance of two samples of Chandra's model. Therefore, the proposal model is better than Chandra's model.

## CONCLUSION

The passenger car unit (PCU) of different type of vehicle under mixed traffic conditions was developed to estimate MCU of various type of vehicle at road-segments in urban road. Field data from eight sections in four selected road-segments in Hanoi, Vietnam were used to illustrate the proposed methodology. The field data showed that the correlation relationships between speed and the effective space of all vehicles were high at all selected approaches in urban road. The variation of the effective space mainly depends on the speed of subject vehicle at road-segments.

The proposed methodology was used to estimate the mean speed, the mean effective space and MCU of the other vehicles under mixed traffic condition that dominated by motorcycles in urban roads. The estimated MCU showed that a single car, a single bus, a single minibus and a single bicycle at road-segments replaces 3.43, 10.48, 8.34 and 1.38, motorcycle equivalent unit respectively. This methodology makes more sense in a mixed traffic flow in motorcycle dependent cities such as Hanoi, Vietnam in particular and the other cities in Asia in general. There might also be some other factors contributing to the variation of the effective space of subject vehicle but not included in the models such as the age, income or gender of drivers, traffic conditions. Thus, the models can be improved with bigger data size, larger range of variation and more predictor variables to be considered. Furthermore, capacity concept of road segments using the MCU for each type of vehicle should be dealt with the other study.

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**LISTS OF FIGURES**



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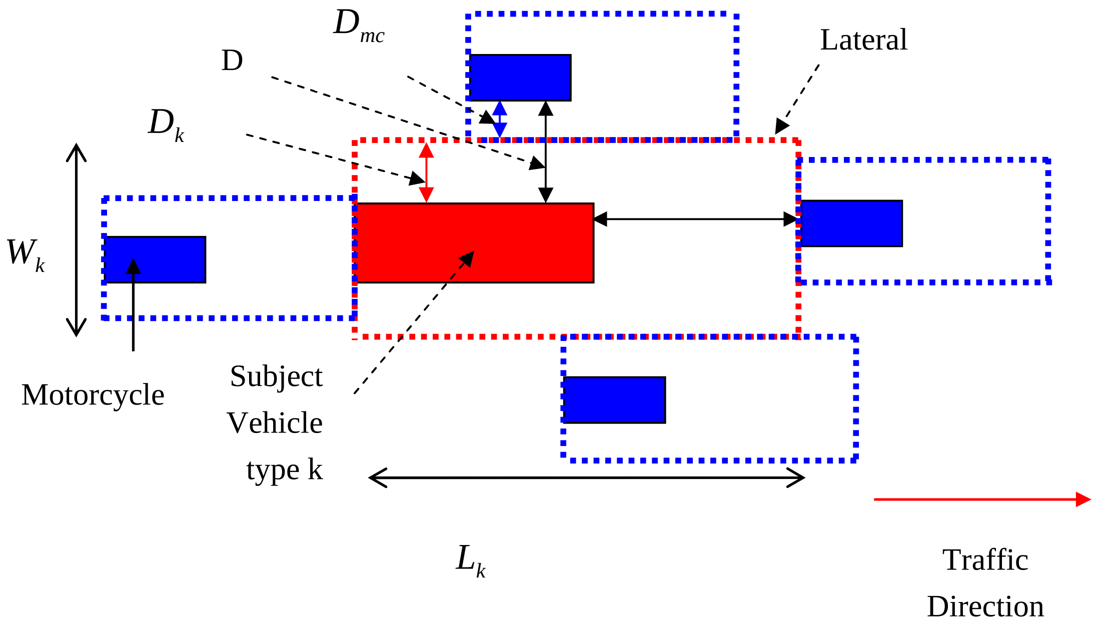


**FIGURE 1 The Effective Space of Subject Vehicle and the Surrounding Motorcycles**

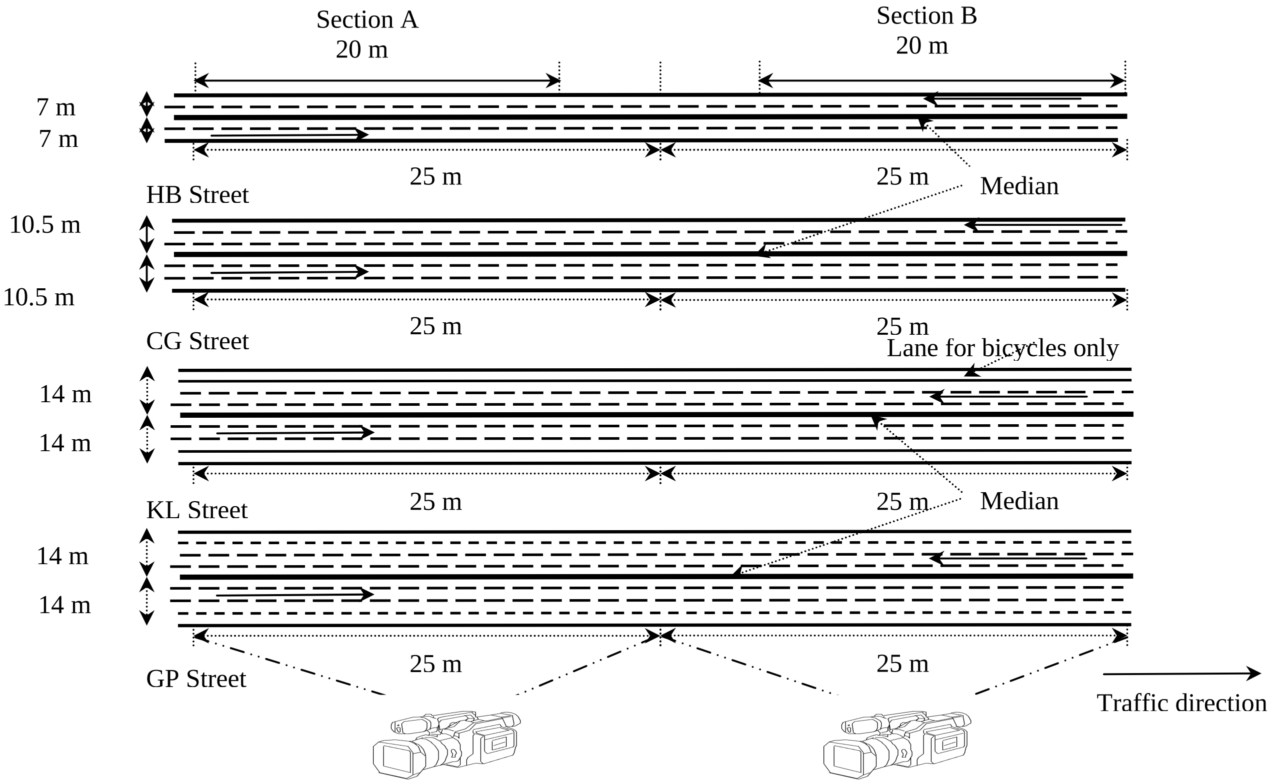


**FIGURE 2 Layouts of Four Road-Segments**

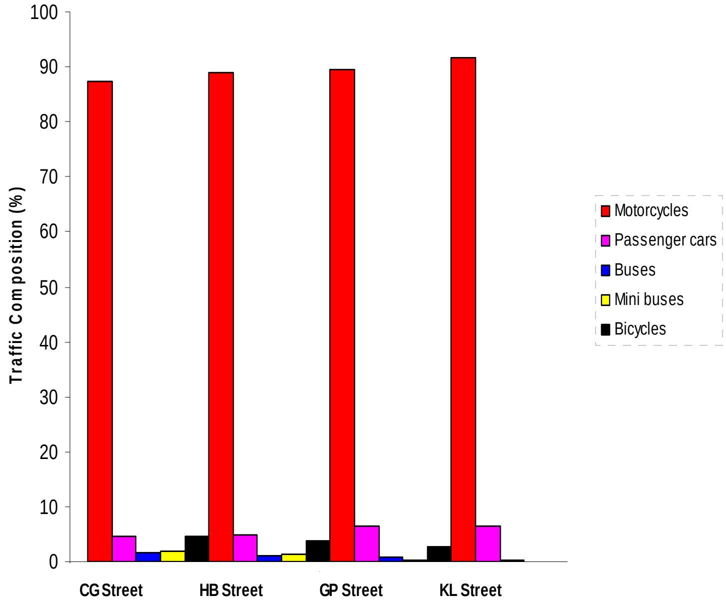


**FIGURE 3 Traffic Composition at Four Selected Road-Segments**

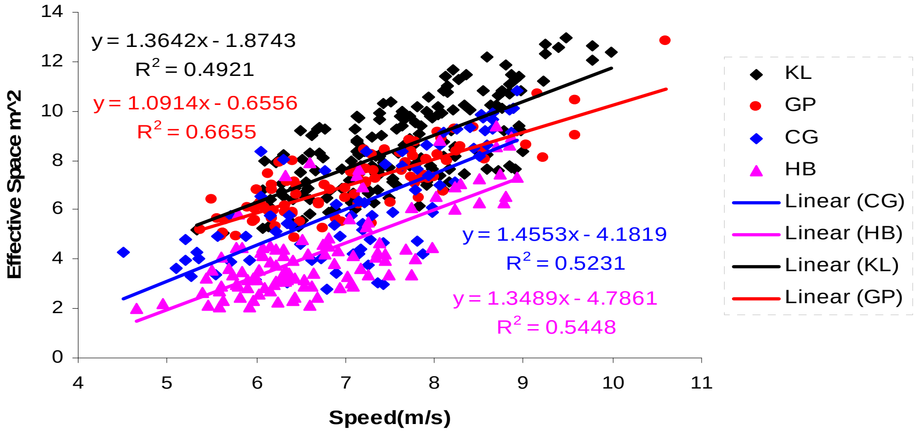


**FIGURE 4a The Relationship between Speed and Effective Space of Motorcycles**

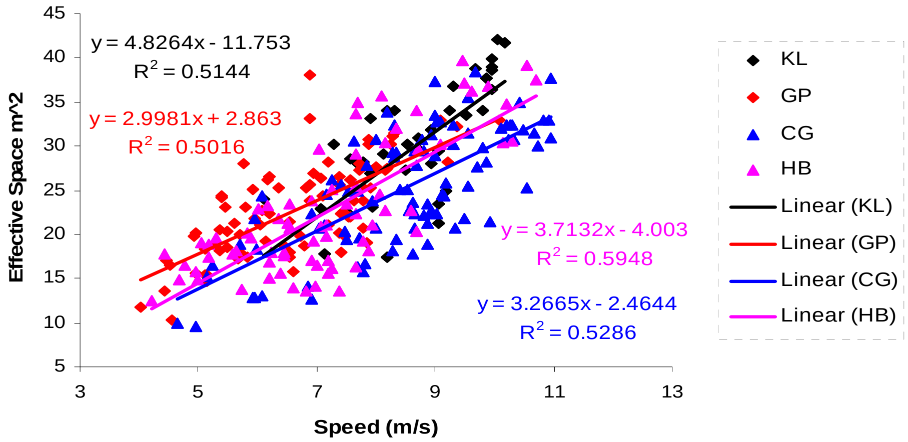


**FIGURE 4b The Relationship between Speed and Effective Space of Cars**

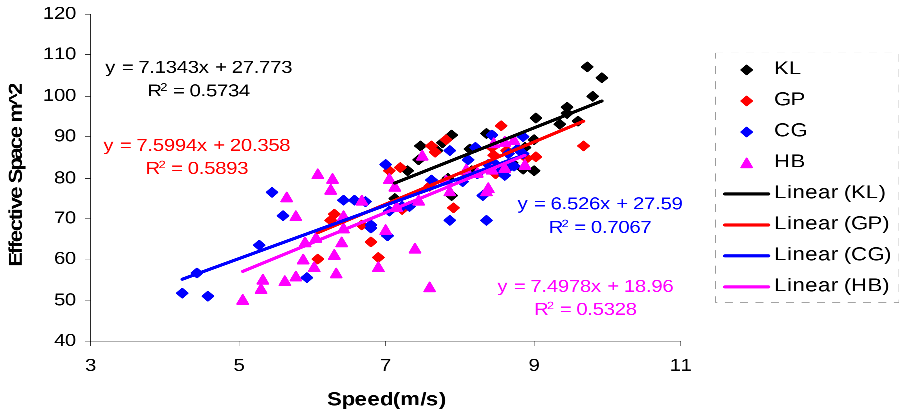


**FIGURE 4c The Relationship between Speed and Effective Space of Buses**

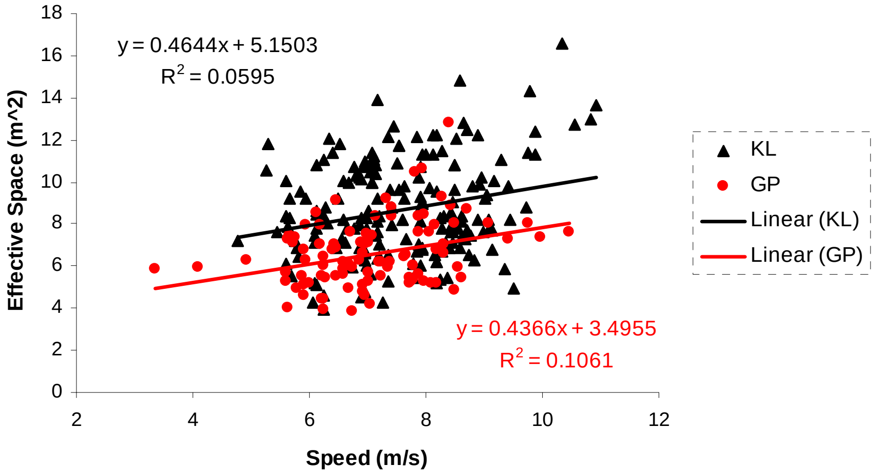


**FIGURE 5 The Relationship between Effective Space of Subject Vehicle and Speed of a Head Motorcycle**

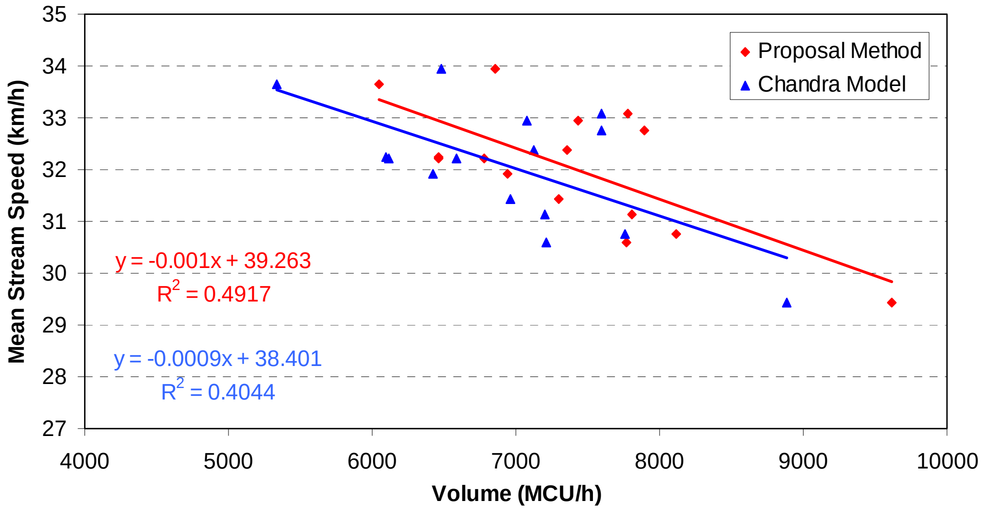


**FIGURE 6a The Relationship between Mean Stream Speed and Volume in HB Street**

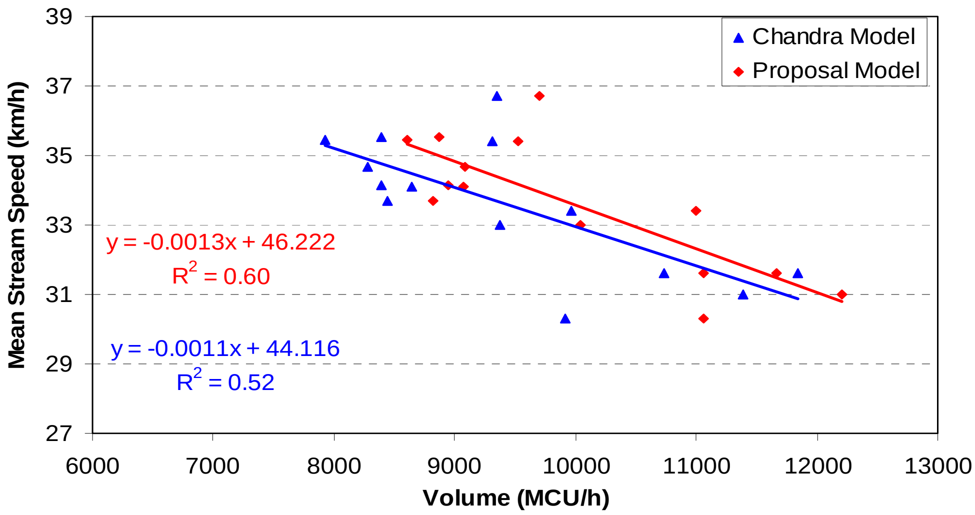


**FIGURE 6b The Relationship between Mean Stream Speed and Volume in CG Street**

**TABLE 1 Output of Mean Effective Space by Nonlinear Regression Analysis**

| *Subject Vehicle* | *Number of observation* | *Adjusted R square* | *Variable in formula (3)* | *Coefficients* | *Std Error* | *95% Confidence interval* | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| ***Motorcycle*** | *469* | *0.53* | | | | | |
| | | | $\overline{V}_{mc}$ | 0.66 | 0.86 | - 1.03 | 2.35 |
| | | | $\overline{V^2}_{mc}$ | 0.07 | 0.06 | - 0.04 | 0.19 |
| | | | (Constant) | - 1.72 | 3.12 | - 7.86 | 4.41 |
| ***Car*** | *311* | *0.54* | | | | | |
| | | | $\overline{V}_{Car}$ | 1.22 | 1.45 | - 1.64 | 4.1 |
| | | | $\overline{V^2}_{Car}$ | 0.13 | 0.09 | - 0.05 | 0.32 |
| | | | (Constant) | 7.29 | 5.41 | - 3.35 | 17.92 |
| ***Bus*** | *128* | *0.68* | | | | | |
| | | | $\overline{V}_{Bus}$ | 5.12 | 4.84 | - 4.47 | 14.71 |
| | | | $\overline{V^2}_{Bus}$ | 0.19 | 0.33 | - 0.46 | 0.85 |
| | | | (Constant) | 27.68 | 17.43 | - 6.83 | 62.19 |
| ***Minibus*** | *41* | *0.66* | | | | | |
| | | | $\overline{V}_{MiniBus}$ | - 9.21 | 6.22 | - 21.67 | 3.25 |
| | | | $\overline{V^2}_{MiniBus}$ | 1.34 | 0.42 | 0.51 | 2.17 |
| | | | (Constant) | 49.71 | 23.24 | 3.13 | 96.29 |
| ***Bicycle*** | *102* | *0.32* | | | | | |
| | | | $\overline{V}_{Bicycle}$ | -1.61 | 2.52 | - 6.62 | 3.39 |
| | | | $\overline{V^2}_{Bicycle}$ | 0.37 | 0.27 | - 0.17 | 0.92 |
| | | | (Constant) | 5.35 | 5.70 | - 5.96 | 16.67 |

**TABLE 2 The Result of MCU of Vehicles from Proposal Model**

| Subject vehicle | Location | KL | GP | CG | HB |
|---|---|---|---|---|---|
| ***Motorcycles*** | $\overline{V}_{mc}$ $(m/\sec)$ | 7.64 | 7.13 | 7.14 | 6.71 |
| | $\overline{S}_{mc}$ $(m^2)$ | 7.5 | 6.63 | 6.64 | 5.93 |
| | $MCU_{mc}$ | ***1*** | ***1*** | ***1*** | ***1*** |
| | Observation number | *195* | *89* | *84* | *110* |
| ***Cars*** | $\overline{V}_{Car}$ $(m/\sec)$ | 8.64 | 6.63 | 8.45 | 7.19 |
| | $\overline{S}_{Car}$ $(m^2)$ | 27.65 | 21.16 | 27 | 22.86 |
| | $MCU_{Car}$ | ***3.26*** | ***3.43*** | ***3.42*** | ***3.59*** |
| | Observation number | *58* | *85* | *96* | *72* |
| ***Buses*** | $\overline{V}_{Bus}$ $(m/\sec)$ | 8.55 | 7.72 | 7.35 | 6.96 |
| | $\overline{S}_{Bus}$ $(m^2)$ | 85.51 | 78.67 | 75.7 | 72.63 |
| | $MCU_{Bus}$ | ***10.18*** | ***10.96*** | ***11.07*** | ***11.8*** |
| | Observation number | *26* | *23* | *34* | *38* |
| ***Minibuses*** | $\overline{V}_{Minibus}$ $(m/\sec)$ | No data | 8.27 | 7.85 | 7.41 |
| | $\overline{S}_{Minibus}$ $(m^2)$ | | 65.27 | 60.05 | 55.1 |
| | $MCU_{Minibus}$ | | ***8.48*** | ***8.22*** | ***8.4*** |
| | Observation number | | 8 | 17 | 16 |
| ***Bicycles*** | $\overline{V}_{Bicycle}$ $(m/\sec)$ | No data | 4.72 | 4.65 | 4.14 |
| | $\overline{S}_{Bicycle}$ $(m^2)$ | | 6.07 | 5.94 | 5.08 |
| | $MCU_{Bicycle}$ | | ***1.38*** | ***1.37*** | ***1.4*** |
| | Observation number | | *30* | *35* | *37* |