ESTIMATION OF MOTORCYCLE UNITS FOR MOTORCYCLE DOMINATED TRAFFIC: A CASE STUDY OF AHMEDABAD

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ABSTRACT

India, just like many south Asian countries, is an emerging economy. The traffic in Indian urban areas is of 'heterogeneous' nature with 2-wheeler vehicles dominating the traffic flow by around 70%. Passenger Car Unit (PCU) in used commonly to convert each class of vehicles for estimating capacity of a road. But in mixed traffic condition, there is absence of lane discipline and presence of different classes of vehicles. Further, the proportion of passenger cars in the traffic stream is considerably less as compared to 2-wheeler vehicles. Therefore, the aim of this paper is suggest equivalency factors in terms of motorcycles for Ahmedabad city. Motorcycle Unit (MCU) for each class of vehicles has been estimated using speed and effective space parameters. Data collection was carried out by videography method on two urban mid-block sections in Ahmedabad city. It was found that the effective space for each vehicle increases with increase in its speed. Final MCU results were 1.54, 15.16, 3.86, 8.32, 1.00, and 2.34 for bicycle, bus, car, LCV, motorcycle, and rickshaw respectively. The values obtained from this study can be used to evaluate roadway capacity with increased accuracy for design, planning, operation, and layout of road sections. Besides, the same approach can be applied for estimation of PCUs accurately by dynamic effective space parameter.

Keywords: Mixed Traffic, Effective Space, Motorcycle Unit, Passenger Car Unit

1. INTRODUCTION

In Ahmedabad, total registrations of the two-wheeler vehicles were recorded as 1,948,844 units when opposed to cars, recorded as only 594,679; motorcycles being more than thrice the number of cars (Ahmedabad Regional Transport Office, Government of Gujarat)[1]. It has been observed that the sale of 2-wheeler vehicles is increasing every year. Reasons contributing to this are its affordability, high mileage, easy maintenance, maneuverability, etc. In general, total traffic in the Ahmedabad city comprises 70% of 2-wheeler vehicles. Therefore, it becomes irrelevant to consider ‘passenger car’ as a base vehicle for the calculating equivalency factors of other classes because of the dominance of 2-wheeler vehicles in traffic composition. The concept of Passenger Car Equivalent (PCE) was introduced in Highway Capacity Manual (1965), and since then, extensive research has been conducted for estimating PCE or PCU values for different traffic conditions accurately. However, PCU values are not suitable in Indian urban roads due to the heterogeneous mix of traffic, absence of lane discipline, and variations in each class of vehicles itself. Therefore, road designs might not be sufficient in urban areas when designed using these PCU values.

Traffic condition in India is very different from that of developed countries. The latter is dominated by passenger cars and can be recognized as almost homogeneous traffic, but the former is composed of different classes of vehicles, particularly in urban roads, dominated by motorcycles (a majority in

[1] From the year 2005 to November 2020

the range of 100cc to 150cc). In this research, the category of motorcycles consists of geared bikes, electric bikes, non-geared scooters, geared scooters, and mopeds. "The wide variety of vehicles and the disparity in their size and speed create a number of problems for traffic operations. Vehicles do not respect the lane markings and tend to utilize every possible lateral or longitudinal gap" (Chandra and Kumar, 2003). The vast difference in static and dynamic characteristics of all vehicles occupying the same right of way (ROW) results in non-uniform motion of vehicles on road. Most of the studies are carried out in developed countries, and there exist fewer studies taking into account the mixed nature of traffic on Indian roads. High-performance vehicles in mixed traffic conditions are obstructed by slow-moving vehicles, resulting in a platoon of traffic with a similar speed in a cluster. Furthermore, in urban roads of Ahmedabad city, the proportion of passenger cars was comparatively less than motorcycles, which was observed from the classified volume count study conducted in the selected sites for MCU study.

It is more logical to use a motorcycle as a base vehicle considering its high proportion in mixed traffic of Ahmedabad city. The dominance of motorcycles in a traffic flow affects the traffic condition differently than passenger cars. Due to its easy maneuverability, it can slow down other classes of vehicles present in the mixed flow and their smaller size allows them to fill the gaps between other classes of vehicles causing traffic congestion. "Most motorcycles don't follow strictly the lane discipline of the road in mixed traffic flows" (Cao and Sano, 2012). The problem of measuring the traffic capacity of roads with mixed nature of traffic is often resolved by converting all classes of vehicles into an equivalent unit. Vehicle capacity of a roadway is defined as the maximum number of vehicles passing a given point on the roadway within a specific period, usually taken as one hour, under currently existing conditions. To estimate the equivalency factor of all classes of vehicles in urban areas with the dominance of motorcycles, the concept of Motorcycle Unit (MCU) is studied in this paper.

The PCU values have been estimated previously using various parameters such as speed, headway, density, etc. Chandra and Kumar (2003) adopted a model to estimate PCU with the help of mean speed and projected area. The projected area is a constant value, unlike mean speed. But space requirement for a vehicle on the road depends on the speed of the vehicle, mode, surrounding nature of traffic, driver characteristics, etc. Therefore, to estimate the more dynamic values of MCU, the effective space of vehicles were considered. Effective space is the space requirement of a vehicle to maintain its desired speed on road. Regression analysis was adopted to establish the relationship between speed and effective space for each class of vehicles.

1.1 Objectives

Following are the objectives of this research:

1. To develop a methodology for estimating MCU values for traffic in Ahmedabad city accounting for its mixed nature.
2. To establish a relationship between dynamic characteristics such as speed and effective space for different classes of vehicles.
3. To estimate MCU values of different classes of vehicles using effective area and speed.

2. METHODOLOGY

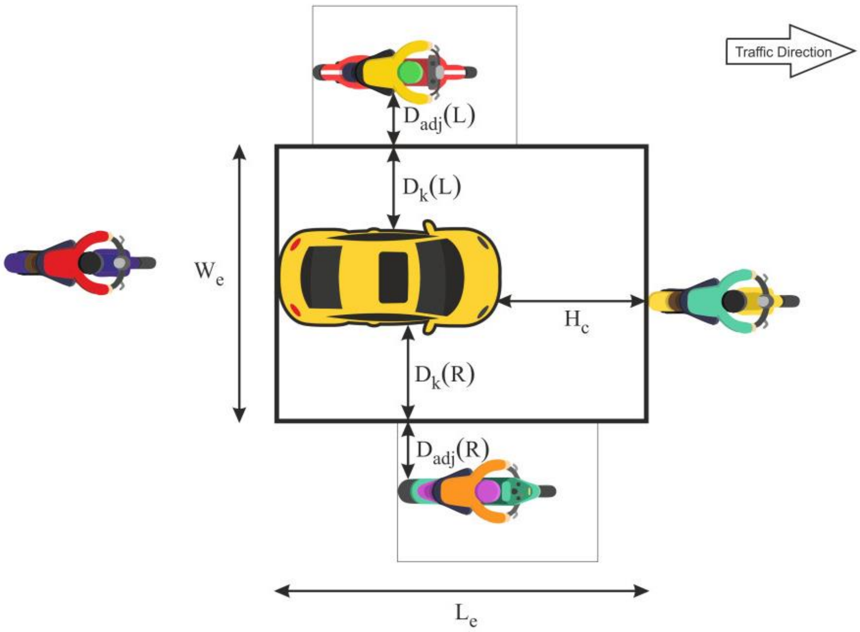
"The definition of [MCU] is the number of motorcycles that can be displaced for one vehicle of a specified type running at the speed of that vehicle" (Cao and Sano, 2012). Dynamic characteristics of the moving vehicles in mixed-traffic are taken in consideration for estimating MCU for each class of vehicles. Chandra and Kumar (2003) considered speed as the prime variable for estimation on PCU values.

$$PCU_i = \frac{V_C \;/\; V_i}{A_C \;/\; A_i} \qquad [1]$$

Where, V_c and V_i = mean speed for cars and type i vehicles respectively, and
A_c and A_i = their respective projected rectangular areas (*length ×width)* on the road.

However, the projected area in this model is constant based on average dimensions of that vehicle class, but the area occupancy is a dynamic factor affected by speed of that subject vehicle, speed of surrounding vehicles, driver characteristics etc. Therefore, effective space is considered in this study instead of projected area. Effective space is the space required by a vehicle to maintain its desired speed on road. Evidently, saturation flow is necessary for calculating effective space; on a road without saturation flow, very few samples will have motorcycles surrounding it and; hence, sufficient data cannot be collected. Effective space will be calculated as illustrated below.

Figure 1 Effective Space; Source: Vyas and Anovadia, 2021



From figure 1, Effective Space= $L_e \times W_e$
Where, L_e = Effective length and W_e = Effective width.
Here, effective length can be calculated simply by addition of headway clearance to the projected length of the subject vehicle. So, L_e = projected length L + headway clearance H_c

But, there stands a problem in determining effective width for the subject vehicle. It is tricky to measure lateral clearances on both sides of the subject vehicle. Furthermore, the lateral clearances depend on the size of subject vehicle and adjacent vehicles on both sides. As assumed by Cao and Sano (2012), the lateral width of the subject vehicle is divided proportionately in accordance with a physical size ratio of the subject vehicle and adjacent vehicles and lateral width of adjacent motorcycle. Hence, the lateral clearance for the subject vehicle can be calculated as below.

$$Dk^{(R/L)} = \frac{L_k \times W_k}{L_{adj} \times W_{adj}} \times Dadj^{(R/L)} \qquad [2]$$

Where, (R/L) is for right or left.
Dk = Lateral clearance for subject vehicle k.

Dadj = Lateral clearance for adjacent vehicle (motorcycles).
L_k and W_k= Average length and average width of subject vehicle respectively.
L_{adj} and W_{adj}= Average length and average width of adjacent vehicles respectively.

Average length and width of various vehicle classes have been adopted from Chandra and Kumar (2003) because they are very accurate with respect to Indian traffic and also widely adopted in studies of various developing economies.

Table 1: Average Dimensions of considered vehicle classes

	Vehicle Classes	Average Length (m)	Average Width (m)
1	Bicycle	1.9	0.45
2	Bus	10.1	2.43
3	Car	3.72	1.44
4	LCV	6.1	2.1
5	Motorcycle	1.87	0.64
6	Rickshaw	2.7	0.95

Source: Chandra and Kumar, 2003

From the figure 1,

$$W_e = Dk(L)+W_k+Dk(R) \quad [3]$$

From the table 1 and equation [3], we can calculate effective width, and finally obtain effective space for a subject vehicle. After calculating effective spaces for each sample we need to estimate MCU values using dynamic characteristics i.e. speeds and effective spaces for each class of vehicles. The equation [1] for estimating PCU, as mentioned earlier is modified as below:

$$MCU_k = \frac{V_{mc} \ / \ V_k}{Ae_{mc} \ / \ Ae_k} \quad [4]$$

Where, V_{mc} and V_k= mean speed for cars and type k vehicles respectively
Ae_{mc} and Ae_k= their respective mean effective spaces on the road
MCU_k= MCU for class k vehicle

3. LITERATURE REVIEW

Chandra and Kumar (2003) estimated the values of PCU for various classes of vehicles in mixed traffic condition in India. Mean speed and their respective projected area on ground were used in their model for estimating PCU values. It was found that the values of PCU increase linearly to the width of carriageway because narrow lanes do not provide adequate margin of error and, therefore, speed of individual vehicles drop. However, in this research, projected areas are static values and in actual scenario, the area requirement by each vehicle on road depends on several factors such as speed of subject vehicle, speed of surrounding vehicle, driver characteristics etc.

Cao et al. (2007) studied the impacts of effective space on speed of various vehicles. Effective space approach is used here instead of projected area to estimate MCU values more dynamically. Relationship between speed and effective space for each class of vehicle is established at three locations in Hanoi city, Vietnam. Videography method was employed for data collection and SEV software developed by Minh et al. (2005) was used for analysing the collected data. MCU values obtained were used to convert heterogeneous traffic stream in homogeneous equivalent. Mean stream speed was calculated in km/hr to plot speed-volume relationship.

Asaithambi and Mahesh (2016) adopted the similar methodology for urban roads in India using effective space approach. Study was conducted on mid-block sections of four-lane divided urban roads in Chennai and Mangalore. The MCU values were validated with previously developed methods. It is suggested that these values can be used for speed-flow relationship, estimation of highway capacity and formulating effective traffic control and management measures.

Cao and Sano (2012) published a paper for estimating MCU values more accurately in mixed traffic flow considering the characteristics of moving vehicles, such as velocity and effective space. Moreover, the values obtained are more accurate because they are computed by taking consideration of physical size of subject vehicles and surrounding motorcycles. It was suggested that the effective space is affected by size of subject vehicle and motorcycles on its left and right side, and hence it is assumed that lateral width of subject vehicle is a function of lateral width of motorcycles and the total physical size of subject vehicle and motorcycles. Field data were collected in Hanoi city, Vietnam by videography.

Srikanth (2019) applied space occupancy method to determine PCU values for Ongole city. To obtain the effective dimensions, the space headway of a sample vehicle was added to its physical length for effective length; however, to obtain effective width, a multiplication factor of 1.1 was multiplied with the physical width. Distinct PCU values were calculated for several speed ranges.

Vyas et al. (2021) modified the effective area approach to include the speed of adjacent motorcycles in the model to estimate effective area for each sample. The final Motorcycle Equivalent Units (MEUs) were suggested for Ahmedabad city based on data collected from two mid-block sections. These equivalency factors were recommended, for they were considered to be more accurate.

Sai Kiran and Verma (2016) reviewed various traffic studies with respect to its relevance to mixed traffic flow as found in developing economies. The ways in which traffic scenario in developing countries are different from developed countries are acknowledged. The unsynchronised movement of vehicles, absence of lane discipline, and variation in sizes and manoeuvring abilities in mixed traffic is also ascertained. This paper aims to provide review of studies on various mixed traffic characteristics in developing economies, identifying limitations and suggest future scope for research.

IRC: 106 (1990) published by The Indian Road Congress is referred to study the guidelines for capacity of urban roads in plain areas. PCU values are recommended in Table-1 for various vehicle types found in mixed traffic condition in India.

4. DATA COLLECTION AND ANALYSIS

4.1 Criteria for Site Selection

Following criteria were taken into consideration while selecting site for surveying:

- Both the ends of trap length fairly away from any intersection or diversion.
- Presence of a high building to mount video camera setup.
- Minimum obstruction to traffic flow due to speed breakers, parking, bus stops etc.
- Major urban road with high traffic volume during peak hours.
- Considerably mixed traffic with adequate proportion of motorcycles.
- Saturation flow during peak hour.

4.2 Selected Sites

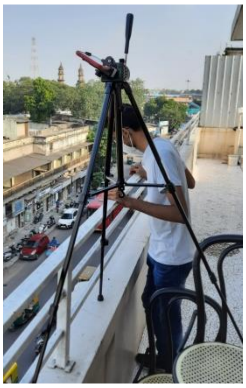
1. Gulbai Tekra (Panjarapol Char Rasta- L.D. College of Engineering)

2. Kalupur Road (Kalupur Railway Station- Kalupur Darwaja)

Videography survey was conducted at both locations to record the data for further analysis. First survey was conducted on 3rd September 2020, 8:30 A.M. to 10:30 A.M. (2 hours). Second survey was conducted on 30th September 2020, 5:30 P.M. to 8:00 P.M. (2.5 hours). Video recording was started just before peak hours and was recorded for some time after peak hour. Peak hours were identified by the traffic volume studies.

Figure 2 Videography at Gulbai Tekra

Figure 3 Videography at Kalupur Road



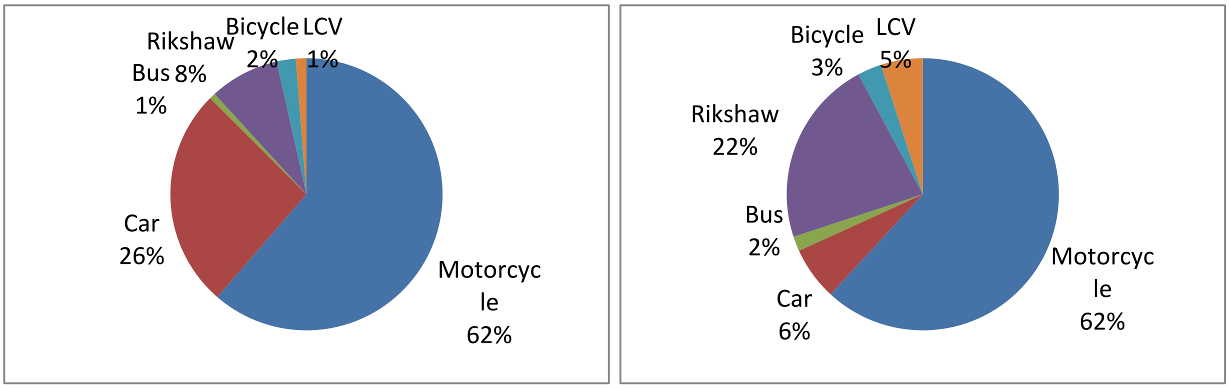
4.3 Data Collection and Extraction

All the traffic data was collected by videography method on selected locations. Videos were recorded on working days in dry weather condition to study the peak hour flow with maximum traffic. The traffic volume was measured for the interval of every 15 minutes and charts for traffic composition were worked out from the data of both survey location.

Gulbai Tekra will be addressed as location-1 and Kalupur Road will be addressed as location-2 in our study.Location-1 was a 6-lane road divided by 2-lanes of exclusive bus lane with median separations and location-2 was a 2-lane one way road with additional parallel parking space on either side. Figure 2 depicts the traffic composition at both study locations.

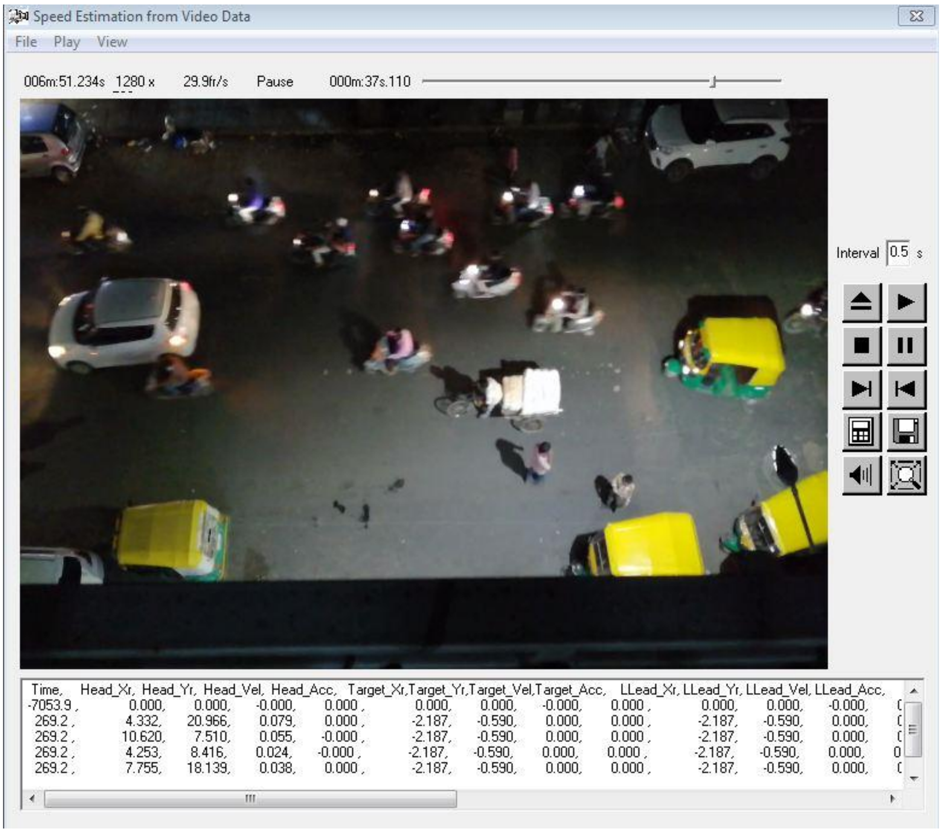
Video camera was mounted on a tripod on top of the buildings with the camera tilted downward towards road and necessary measurements were taken on road for trap length and four base points. 25m trap length was recorded in videos. Recorded videos were later converted in AVI format in order to play it in Speed Estimation from Video Data (SEV) software. In SEV software, the base points were established and speed data was extracted simultaneously to the position co-ordinates of sample vehicles. Speeds and effective spaces were calculated and recorded in a spreadsheet to plot the relationship for speeds and effective spaces for each class of vehicles. It must be noted that only those samples were examined in this study which were surrounded by motorcycles considering the motorcycle dominated traffic and uniformity in measuring effective spaces. Finally, regression analysis was used to obtain a non-linear equation for relation of speeds and effective spaces and to find the coefficient of determination for the same.

Figure 4 Traffic Composition at locations 1 and 2 respectively



SEV software (figure 5) gives readings for speed for each vehicle by right clicking on the sample vehicle. In addition, SEV software easily converts screen co-ordinates into roadway co-ordinates, which are useful in calculating effective space around subject vehicle. A reading can be measured several times and, hence; it can be verified. The speed of each sample vehicle was calculated at 0.5 sec interval.

Figure 5 SEV Software Interface



Traffic in Ahmedabad city is of mixed nature; it is important to identify all the classes of vehicles present at the study location in considerable proportion. Hence, the following classes of vehicles were selected after classified volume study and only those classes were considered for analysis from video data.

Table 2: Vehicle classes considered

	Vehicle Classes	Types Included
1	Bicycle	Bicycles
2	Bus	Buses
3	Car	Cars, Jeep
4	LCV	Tempos, Transit Mixer, Mini-buses
5	Motorcycle	Motorbikes, Scooters, Mopeds
6	Rickshaw	Rickshaws

5. DATA ANALYSIS AND RESULTS

Data for speeds and effective spaces were obtained from SEV software and were recorded in a spreadsheet. These values were then plotted on charts for each vehicle class separately as shown below. Charts for both locations are illustrated distinctively on the same graph. A non-linear line of regression is also obtained in each chart to show a positive increase in effective spaces with increase in speed of vehicles. A value of non-linear equation in the form of '$y = ax^2 + bx + c$' and the coefficient of determination (R^2) is in each graphs for both locations, where y = mean effective space of class 'k' in (m^2); x = mean speed of class 'k' in (m/s); a, b & c are constants of that non-linear function.

Figure 6 Relation between speeds and effective spaces at location 1 and 2 for Bicycle

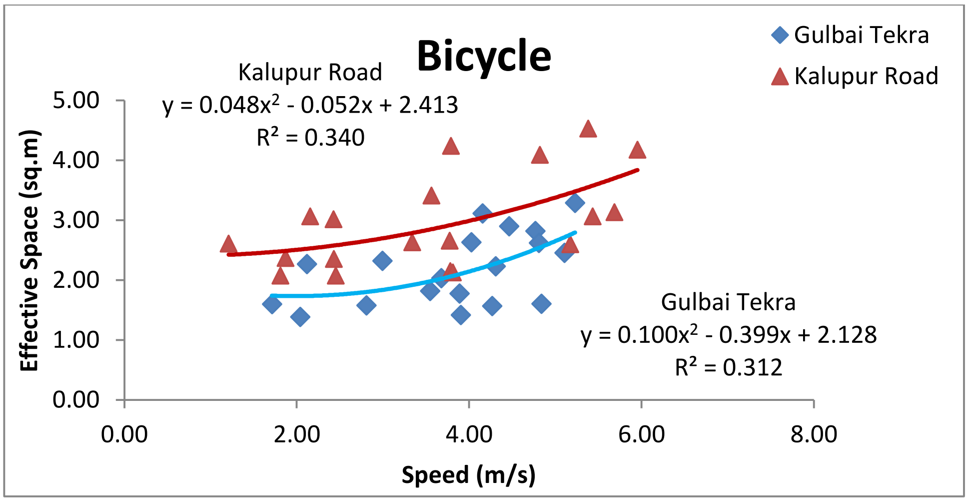


Figure 7 Relation between speeds and effective spaces at location 1 and 2 for Bus

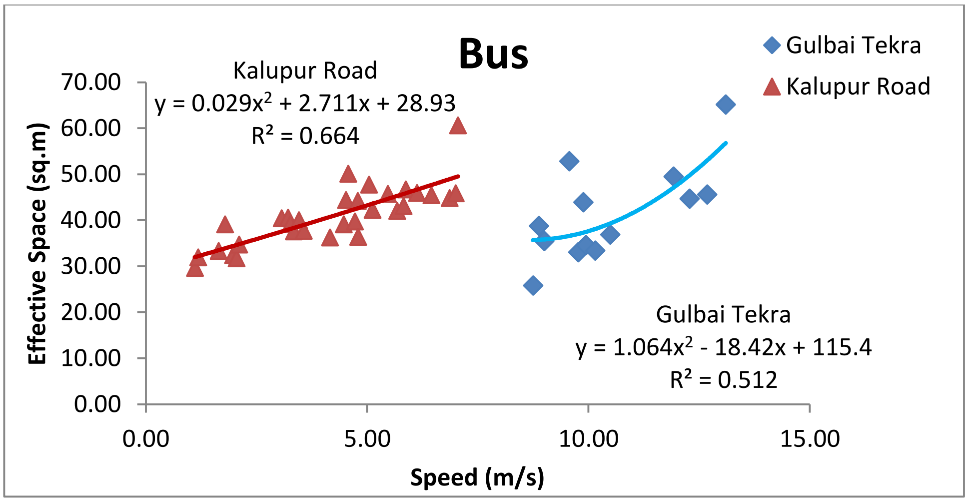


Figure 8 Relation between speeds and effective spaces at location 1 and 2 for Car

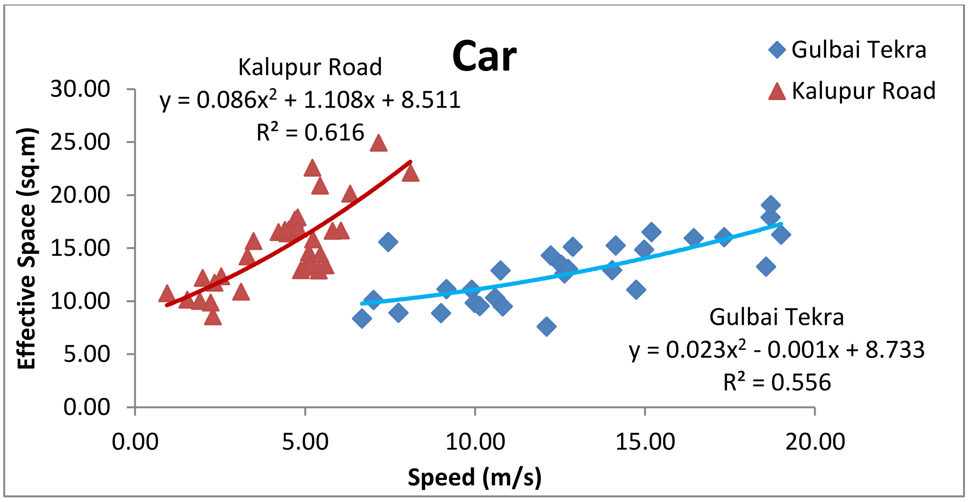


Figure 9 Relation between speeds and effective spaces at location 1 and 2 for LCV

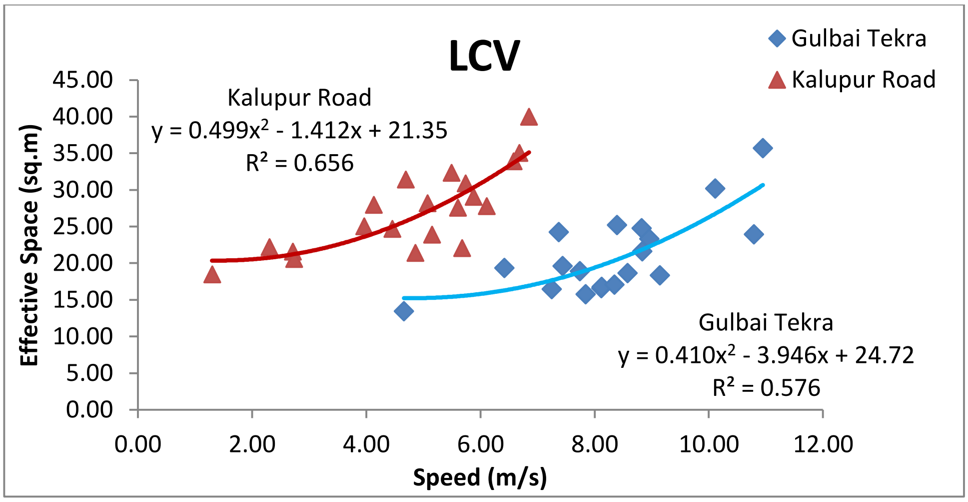


Figure 10 Relation between speeds and effective spaces at location 1 and 2 for Motorcycle

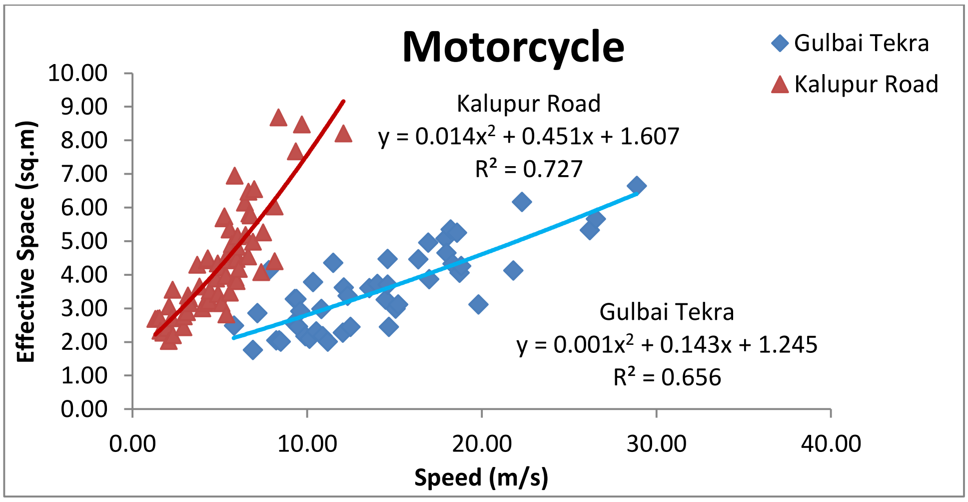
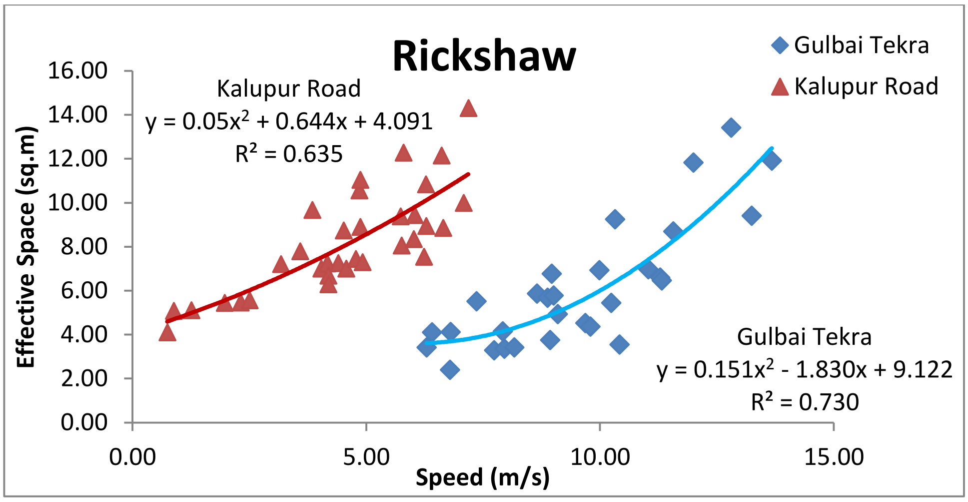


Figure 11 Relation between speeds and effective spaces at location 1 and 2 for Rickshaw



From the regression analysis for both the locations (figure 6, 7, 8, 9, 10, and 11), it can be clearly observed that there is a high R^2 value, except for bicycles. Therefore, it can be suggested that effective space of subject vehicle is affected significantly by its speed and it increases with the speed of the vehicle. On the contrary, in case of bicycles, the R^2 values at locations 1 and 2 are 0.312 and 0.340 respectively. This is because bicycles are slow moving vehicles and usually run on the outermost side near kerbs/footpath. They are not much affected by motorcycles or any other class because drivers of other classes of vehicles usually prefer to drive close to median at higher speeds.

Furthermore, Cao and Sano (2012) studied the correlation between effective space of the subject vehicle and speed of head motorcycle at 3 locations in Hanoi city, Vietnam to identify the influence of speed of head motorcycle on effective space. The R^2 values obtained were 0.23, 0.15 and 0.12. It was found that the effective space has very low effect by the speed of motorcycle in front of it. Hence, it is assumed the same in Ahmedabad city and we have studied only the effect of position of surrounding vehicles on the subject vehicle.

MCU values for all the vehicle classes considered in this study are estimated by equation [4] based on the values of speeds and effective spaces from both locations. These equivalent units are calculated for both the study locations and also a combined final value is given after integrating all the data of both study locations in the same data set; hence, final MCU values are more appropriate as to represent Ahmedabad city. Discernibly, more similar surveys can be conducted to obtain these data for mid-block sections in entirely different locations so as to determine MCU values for Ahmedabad city with increased accuracy.

Table3: Estimated MCU values

Vehicle Class	MCU 1	MCU 2	Final MCU
Bicycle	2.26	0.95	1.54
Bus	15.70	11.36	15.16
Car	4.03	4.08	3.86
LCV	10.07	6.61	8.32
Motorcycle	1.00	1.00	1.00
Rickshaw	2.53	2.10	2.34

It is interesting to observe the final MCU value of bicycle as 1.54; as is more than that of motorcycle. These can be explained by its low speed, high effective space and very poor relation between these two variables. Also, there is significant variation in MCU values of Bus and LCV at both locations. It shows that there is considerable difference between the behaviours of both classes at these two study locations and; therefore, even more accurate value for MCU for those two classes can be determined by obtaining same data for another location and combining it to the existing dataset.

6. CONCLUSION

The basic objective of this paper is to estimate MCU values for Ahmedabad city in particular and areas with predominance of motorcycles in general by consideration of dynamic characteristics such as speeds and effective areas. The MCU values estimated can be used for calculating roadway capacity by speed-volume relationships, which are useful for design, planning, operation, and layout of urban road sections.

The MCU values obtained from this study for bicycle, bus, car, LCV, motorcycle, and rickshaw are 1.54, 15.16, 3.86, 8.32, 1, and 2.34 respectively. These values are obtained from the data of two study locations; the accuracy of these values for Ahmedabad city can be improved by addition of more data from different study locations inside the city.

Limitation of this study is regarding the accuracy of the MCU values; the values are estimated based on the data analysis through a video in software, thus, measuring various parameters to their exactness is difficult. Also, inclusion of other factors that affect the effective area of a sample vehicle should be recognised and the model can be modified further to incorporate those factors. These factors can be speeds of adjacent vehicles, driver characteristics, local conditions etc. and this can be considered as the future scope of the studies.

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