Determination of PCU values for mixed traffic conditions along the hilly road of East Sikkim

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Abstract

The road space in India is shared by different travel modes with different physical dimensions. On top of this, lane discipline is also not followed in India. All these factors influence the evaluation of traffic characteristics, roadway capacity, defining model for traffic flow and other transportation design factors. Passenger car unit (PCU) is a frequently used unit for calculating and expression of heterogeneous traffic volume to a simpler equivalent traffic unit where a passenger car is taken as a standard vehicle and all other classes of vehicle are expressed in terms of the standard car. For the present study, 11 km stretch of NH-10 in East Sikkim was taken into consideration. Data collection was done by video graphic survey. PCUs of different classes of vehicle are estimated using the speed area method by using traffic volume data. The PCU is calculated by multiplying the speed and area ratios of standard cars by the PCU of the subject vehicle type. The methodology adopted in this study is very much suitable for making proper PCU model under different conditions of heterogeneous traffic and road conditions of the study area.

Keywords: PCU; traffic volume; undivided roadway; hilly terrain; speed area.

1. Introduction

Mixed traffic condition is a big problem in evaluation of traffic characteristics, roadway capacity, defining model for traffic flow and other transportation design factors. For solving this problem of heterogeneity in traffic analysis, a generalized factor is used which is known as PCU. This value is always in a dynamic form because different vehicles have different PCU values. These values are affected by many factors such as vehicle conditions, roadway conditions and environmental factors. Therefore PCU makes the evaluation of traffic volume easy. There are different methods available to evaluate PCU value such as speed area method, Chandra et al. [1], modified density method, area occupancy method, etc. Mallikarjuna et al. [2] estimated PCE under heterogeneous traffic conditions using a simulation model. Fuzzy based model using MATLAB for calculation of PCU for public transport, Bus was used by P. Aggarwal [3] were the results when compared with the standard results had strong correlation. Srikanth et al. [5] determined PCU of multilane highways using speed factor method, headway factor method and area factor method. Sharma and Biswas [9] have discussed the various methods which are used to determine the PCU values for a heterogeneous traffic conditions. The aim of their study was to provide an appropriate method to find PCU for different circumstances. Apart from the above mentioned methods, the paper also discussed the homogeneous coefficient model, Walker’s method, multiple linear regression analysis method, simultaneous equation method and Huber method. Space occupancy method, Kumar et al [6] of estimation of PCU is also a new method in urban multilane road with heterogeneous traffic conditions.

The hilly regions of India along the Himalayan Belt, has a different traffic conditions as compared to the rest of India. Most roads of these regions are undivided with width as 5.5m also known as intermediate lane road. The effect

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of this lane width on the PCU value was studied by M. Mardani N et al [4]. A study was done by Gautam, et al [7] for estimating the PCE values for hill roads of Meghalaya. They found that the PCU values are affected by the environmental conditions, natural landscape and roadway conditions.

Sikkim, is a Himalayan state in the North East part of the country. This study aims to determine the PCU values for the mixed traffic conditions along the undivided stretch of National Highway 10, in the hilly region of Sikkim. The scope of the study is limited to determining the PCU values in mixed traffic conditions of the study area.

2. Data collection and Methodology

The study area considered for this study is NH10 from Rangpo Gate to Singtam, in the state of Sikkim. A total of around 11 kms road stretch was considered for the study. Different sections of National Highway-10 were identified and the road was divided into a number of sections of length 500 m each. First of all, RLs of the road alignment were calculated along the NH-10 starting from Rangpo Gate to Singtam. In each section, video graphic method was used for collecting the traffic data. The Speed radar gun was used to estimate speed of the vehicles. The vehicle were divided into six groups namely Two Wheeler (TW), Standard Car (CS), Big Car (CB), Light Commercial Vehicles (LCV), Heavy Commercial Vehicles (HCV) and Bus(B). The dimensions of each vehicle types were taken from the given literature Srikanth et al [5] and shown in the Table 1. The shoulder width has been neglected at some locations.

| Vehicle Type | Length (m) | Width (m) | Area (m²) |
|--------------|------------|-----------|-----------|
| 2W           | 1.97       | 0.74      | 1.4578    |
| CS           | 3.6        | 1.6       | 5.76      |
| CB           | 4.6        | 1.7       | 7.82      |
| LCV          | 4.3        | 1.56      | 6.708     |
| HCV          | 6.7        | 2.3       | 15.41     |

A vehicle's PCU is calculated by factors such as traffic flow, roadway length, environmental factors, climate factors, vehicular areas, and so on. The different factors considered in the study are the mean speed of different vehicle type and their mean rectangular projected area. The PCU value of the subject vehicle types is calculated using speed area method also known as speed modeling, Pooja et al [8]. The speed area method is used as this is the simplest method and data collection is relatively easier. The calculation of factors and equations for PCU value is discussed in detailed in the upcoming paragraphs.

2.1 Speed factor

When a vehicle's average speed increases, the amount of time it spends stuck in traffic decreases. Speed factor is defined as the ratio of mean speed of a standard car (\(V_c\)) to the mean speed of the subject vehicle (\(V_i\)).

\[ F_v = \frac{V_c}{V_i} \]

where,
\(F_v\) is the speed factor of the vehicle under consideration,
\(V_c\) is the average speed of the standard car,
\(V_i\) is the mean speed of the vehicle under consideration.

2.2 Area factor

The PCU of a vehicle type is determined by the vehicle's dimensions. The PCU is inversely proportional to the vehicle's area. Area factor is calculated by taking the ratio of the projected area of the subject vehicle (\(A_i\)) to the area of the standard car (\(A_c\)).

\[ F_a = \frac{A_c}{A_i} \]

where,
Fa is the area factor of the vehicle under consideration
Ac is the projected area of the standard car
Ai is the projected area of the vehicle under consideration

2.3 PCU values

The PCU value of the concerned vehicle is calculated as the product of the speed factor and the area factor of the corresponding vehicle under consideration.
\[ PCU = F_v \times F_a \]
where,
PCU is the Passenger car unit value of the vehicle under consideration
Fv is the speed factor of the vehicle under consideration
Fa is the area factor of the vehicle under consideration.

3. Data analysis and Discussion

Video graphic data was analyzed and the graph is plotted between projected area and vehicle type, Fig. 1. It is observed that the vehicle type Bus and Two-Wheeler has highest and lowest projected area respectively. From the Table 2., it is clearly visible that the speed distribution of every vehicle type is non uniform. The time spent by the HCV vehicle to cross over the section is maximum as compared to other vehicle type.

![Fig. 1. The projected area (m²) of different types of vehicles.](image)

Speed data collected were analyzed and from Table 2. It is obvious that the speed distribution of each vehicle type is not standardised. The time spent by the HCV vehicle to cross the section is maximum as compared to other vehicle type. The composition of the different type of vehicle with calculated average speed is tabulate as Table 3 and explained by Fig. 2.
Table 2. Speed (Kmph) data at the study section

|   | 2W | Standard car | Big car | LCV | HCV | Bus |
|---|----|--------------|---------|-----|-----|-----|
| 52| 45 | 45           | 43      | 49  | 43  |
| 49| 45 | 45           | 33      | 45  | 46  |
| 42| 48 | 48           | 35      | 41  |
| 70| 55 | 36           | 40      | 26  |
| 59| 59 | 59           | 50      | 52  |
| 58| 55 | 55           | 41      |
| 48| 47 | 40           | 35      |
| 56| 62 | 36           | 55      |
| 45| 52 | 58           | 48      |
| 41| 49 | 51           | 40      |
| 55| 44 | 55           | 53      |
| 52| 59 | 38           | 36      |
| 48| 48 | 35           |
| 52| 50 | 47           | 45      |
| 47| 48 | 56           | 37      |
| 40| 67 | 49           |
| 38| 56 | 49           |
| 21| 62 | 28           |
| 39| 50 | 28           |
| 41| 45 | 28           |
| 41| 46 | 38           |
| 52| 28 | 42           |
| 68| 28 | 29           |
| 39| 45 | 37           |
| 40| 39 | 44           |
| 34| 43 | 52           |

Fig 2: Average speed of different types of vehicle.
Table 3: Average speed and traffic composition at study section

| Vehicle Type | Composition (%) | Average speed (Kmph) |
|--------------|-----------------|----------------------|
| 2W           | 16              | 47.44                |
| CS           | 33              | 49.24                |
| CB           | 35              | 48.8                 |
| LCV          | 6               | 42.28                |
| HCV          | 7               | 42.96                |
| B            | 3               | 39.96                |

Fig 3. The composition of different vehicle type at different time intervals.

The product of the speed factor and the area factor is used to calculate the PCU values of various vehicles. The PCU values obtained from this method is found to be more precise.

Table 4. PCU values of different vehicle types

| Vehicle Type | Area factor | Speed factor | PCU     |
|--------------|-------------|--------------|---------|
| 2W           | 0.253       | 1.038        | 0.263   |
| CS           | 1           | 1            | 1       |
| CB           | 1.358       | 1.009        | 1.37    |
| LCV          | 1.164       | 1.165        | 1.356   |
| HCV          | 2.675       | 1.146        | 3.065   |
| B            | 4.417       | 1.232        | 5.441   |

3.1 Calculation of PCU values

A Standard Car (CS) was taken as standard or reference vehicle and Bus (B) as subject vehicle. The projected area of different vehicle types is in table 1. The projected area of Bus and Standard Car are 25.44 m² and 5.76 m² respectively. The area factor of Bus is calculated as the ratio of the bus's projected area to the regular car's projected area, which is approximately equal to 4.417. From the data collected the mean speed of Bus and the Standard Car are 39.96 km/hr and 49.24 km/hr respectively. The speed factor of Bus is the ratio of the mean speed of Standard Car (CS) to the mean speed of Bus (B) which is approximately equal to 1.232. The PCU value of Bus is equal to the
product of speed factor and area factor of Bus which is approximately equal to 5.441.

Table 5. Comparison between PCU values of different vehicle as obtained from the study and as per Indo-HCM (2017)

| Vehicle type | PCU obtained from study | PCU as per Indo HCM (2017) |
|--------------|-------------------------|----------------------------|
| 2W           | 0.263                   | 0.25                       |
| CS           | 1                       | 1                          |
| CB           | 1.37                    | 1.60                       |
| LCV          | 1.356                   | 1.20                       |
| HCV          | 3.065                   | 4.80                       |
| B            | 5.441                   | 5.00                       |

Similarly, the PCU value of 2W is equal to the product of speed factor and area factor of 2W which is approximately found out to be equal to 0.263. The PCU value of CB is found to be equal to 1.37. That of LCV is 1.356 and the PCU value of HCV is calculated as 3.065. The PCU values of the different vehicles determined are tabulated in Table 4. A comparison of the obtained PCU values with the Indo HCM (2017) values is presented in Table 5.

4. Conclusions

It is seen from the study that the traffic condition has less or no influence in the PCU values when speed area method is used. As there are no guidelines in India for calculation of traffic capacity for hill roads, therefore this study provides an insight to traffic capacity determination. For hilly terrain, the speed area method is found to be more suitable for determination of PCU. It is also seen that two wheeler has minimum PCU value and CB and LCV have almost same PCU.

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