Determination of Equivalent Passenger Car Units for Motorcycles, Buses and Minibuses at Urban Signalized Intersections in Iran, Case Study: Isfahan and Yazd Cities

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1. Introduction

Passenger Car Equivalent (PCE) is a factor that indicates the number of equivalent passenger cars that can be substituted with other vehicle types in traffic stream with the same effect on the roadway and traffic conditions. Differences at the performance characteristics of heavy vehicles and motorcycles cause a number of changes in traffic flow characteristics. One of the main methods, which creates a unified procedure in traffic flow analysis is to convert all types of vehicles to one equivalent type. This concept was first introduced in the 1965 edition of Highway Capacity Manual to estimate the impact of heavy vehicles on traffic flow. Since then, several methods have been proposed in different studies to estimate the PCE values for different vehicle types, that is, methods based on vehicles headway, volume-to-capacity ratio, speed, delay, optimization techniques, density-flow relationship, and regression analysis. In the absence of widespread studies on this subject and despite different prevailing traffic conditions in Iran in comparison to other countries and especially western countries, the previous traffic studies in Iran have mainly relied on the PCE values obtained from the highway codes of western countries. In this study, the PCE values are calculated for motorcycles, buses, and minibuses at urban signalized intersections of two major Iranian cities, namely, Isfahan and Yazd. For this purpose, the regression analysis method was chosen for estimating PCEs at signalized intersection under prevailing heterogeneous traffic conditions. The main purpose of this study was to estimate the appropriate PECs used for estimating saturation flow, determining the level of service and capacity at signalized intersections.

2. Data collection

In this study, Cochran formula was used to determine the sample size for an infinite population. Then data were collected from 8 entry approaches of 5 signalized intersections in Isfahan and Yazd cities. Vehicle entries (including passenger cars, buses, minibuses, and motorcycles) were videotaped for 425 cycles at saturated green intervals. Data were collected during peak traffic periods (07:30 to 08:30 and 19:30 to 20:30).

3. Data analysis

Multiple linear regression analysis was used for the calculation of the PCE values. For this purpose, a multiple variable linear relationship was established between different types of passing vehicles and their corresponding saturation green times using SPSS software. First, the green phase was divided into 5-second intervals per cycle and vehicles, motorcycles, buses, and minibuses were counted, separately. Then the intervals, in which more than 3 PCE crossed the stop line, were considered as saturated green interval. At this step, the PCEs values, which are proposed by the Indian Road Guidelines were used. Then, the sum of saturation green time intervals per cycle, and the vehicle numbers passing through the approach during this intervals were calculated separately. Finally, a multiple relationship was established between this data as shown in Equation 1.

$$t = n_1 a_1 + n_2 a_2 + n_3 a_3 \quad (1)$$

Where,

n_i is the number of type i vehicles passed through the intersection in each cycle,

a_1, a_2, a_3 are regression analysis coefficients for passenger car, motorcycle and heavy vehicle, respectively, and t is total saturated green time per cycle.

All PCE values for heavy vehicles and motorcycles have been obtained at a %95 and %80 confidence levels, respectively. This motorcycle's reliability level is acceptable for saturation flow rate estimation.

The coefficients of the fitted model also indicate a strong correlation between the passing vehicles and the effective green time intervals at all approaches.

The F-test was also used to ensure the significance of the regression models (Sig.<0.05). The Pearson correlation test was used to illustrate the relationship between paired variables. The results indicated that the variables are negligibly or weakly correlated. According to the results and considering the results of previous studies, the interactive effect between variables was ignored and it was assumed that all parameters operate independently.

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In the next step, PCEs were calculated using Equation 2. Then the average of PCEs were proposed for each types of vehicles.

$$\boldsymbol{p_i = \frac{a_i}{a_1}} \quad (2)$$

where, p_i is the passenger car unit value of the i^{th} vehicle type, and a_1 , a_2, a_3 are the regression analysis coefficients for passenger car, motorcycle and heavy vehicle, respectively.

Then the one-sample t-test was used to determine whether our samples come from a population with a specific mean. The significance level of the test (sig.) indicated that the proposed mean PCE values are valid for each vehicle type.

4. Results

The results show that, multiple linear regression analysis is an appropriate method to calculate the PCEs in heterogeneous traffic conditions prevailing traffic flow in Iranian cities. In this study, PCE values for buses, minibuses, and motorcycles were estimated as 2.53, 1.45 and 0.46, respectively. It should be noted that when the proportion of passing buses and minibuses in traffic composition is low, they can be aggregated as "heavy vehicles" with an average PCE value of 2.13. Finally, the PCE values obtained from this research were compared with the corresponding PCE values suggested in the highway capacity manuals of several countries located in three different continents. This comparison indicated that the PCEs obtained in this research for the two Iranian cities are generally higher than those countries.