Ⅳ - 393 MACROSCOPIC METHOD OF ESTIMATING PASSENGER CAR EQUIVALENTS FOR UNCONGESTED FLOW REGIME

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1. Introduction

A macroscopic method of estimating Passenger Car Equivalents (PCE) for uncongested flow regime is discussed. The first part includes a brief introduction of the theoretical aspects, followed by an analytical method of forming the data base and finally the estimation procedure.

2. Theoretical Considerations

As discussed by Sthapit and Okura[2], the mathematical model of estimating PCE introduced by Huber[1], considers the estimation by comparing flow rates at equal average travel time (equal average speed) criteria or equal total travel time (equal density) criteria for the traffic streams under ideal and the prevailing conditions. The PCE values near the boundary, i.e. either free flow condition or jam condition were undefined for respective cases.

The basic equation of Highway Capacity Manual (HCM) with the same notations,

$$SF_i = MSF_i * N * f_w * f_{HV} * f_p$$

can be written as,

$$q_M = q_B * f_{HV}$$

after applying all other factors, where q_M and q_B are the flow rates per lane for LOSi for mixed flow (with passenger car and truck) and basic flow (passenger car only) respectively and f_{HV} is the heavy vehicle factor. The PCE can then be calculated as,

$$PCE = 1/p\ (q_B/q_M - 1) + 1$$

where, p is the percentage of heavy vehicles. From the above equations, corresponding to a full range of Level of Service (LOS) under ideal conditions there should exist a full range of LOS under prevailing conditions also. A new approach is proposed with the assumption that the two flows q_B and q_M will produce the same LOS when the normalized speed as well as the normalized density for the two flows are equal, i.e.

$U_B/U_{FB} = U_M/U_{FM}$ and $k_B/k_{JB} = k_M/k_{JM}$

or, $U_B/U_M = U_{FB}/U_{FM}$ and $k_B/k_M = k_{JB}/k_{JM}$

$$\therefore PCE = \frac{1}{p}\left[\frac{U_B\, k_B}{U_M\, k_M} - 1\right] + 1 \quad ..eq.(1)$$

$$= \frac{1}{p}\left[\frac{U_{FB}}{U_{FM}}\,\frac{k_{JB}}{k_{JM}} - 1\right] + 1 \quad ..eq.(2)$$

For a straight line Greenshield's model of traffic flow between speed and density, equal normalized speed and equal normalized density results in equal volume-to-capacity ratio and the PCE value is constant for all range of lane volume.

3. Data

One month data from the vehicle detector of Tomei Expressway with two lanes in each direction has been used. From the scatter plots of q-U, k-U and k-q, speed is chosen as the criteria to separate the uncongested and the congested flow regime. The data lying above this speed has been taken for analysis. In the uncongested flow regime also, two regions of flow, the absolute free flow case and the case with higher flow rate (lower LOS) are considered further. For the absolute free flow case, the data near capacity is deleted by some upper limit criteria of occupancy where as, for the case with higher flow rate the data near free flow is deleted by lower limit criteria of occupancy.

4. Method of Analysis

As given by eq.(1), if we consider absolute free flow case, when k_B and k_M both tend to zero, the limiting ratio k_B/k_M is unity, such that,

$$PCE = \frac{1}{p}\left[\frac{U_{FB}}{U_{FM}} - 1\right] + 1 \quad ..eq.(3)$$

Similarly, for the case with higher flow rates, from eq.(2),

$$PCE = \frac{1}{p}\left[\frac{q_{oB}}{q_{oM}} - 1\right] + 1 \quad ..eq.(4)$$

where, q_{oB} and q_{oM} are for optimum case. After classifying the data according to different percentage of heavy vehicle

groups, the traffic flow parameter relationships are obtained by regressing the data assuming Greenshield's model of traffic flow.

When PCE is estimated for absolute free flow condition by using eq.(3), the free flow speeds for different 'p' to be used in equation, are calculated by regressing speed(U) against density(k) such that the error in estimating speed is minimized and is of the form,

$$U = c - a*k$$

Where as, for higher flow rates, when eq.(4) is applied, the regression is done to minimize the error in estimating flow rate and is of the form,

$$q = A*U + B*U^2$$

The PCE for various percentage of heavy vehicle groups are estimated with same procedure for shoulder lane and median lane independently and also for day and night time conditions separately,hence, obtaining a relationship between PCE and percentage of heavy vehicle for the respective cases.

5. PCE for whole roadway section

The passenger car equivalents for the whole roadway section in one direction, PCE_d, with total percentage of heavy vehicle, P (considering both lanes) is calculated after following steps.

a) Relationships between total percentage, P, of heavy vehicle in one direction to the percentage of heavy vehicle in shoulder lane alone (p_1) and the percentage of heavy vehicle in median lane alone (p_2) are established as,

$$p_1 = a_1 P + b_1 P^2$$

$$p_2 = a_2 P + b_2 P^2$$

from which, the percentage of heavy vehicle in the respective lanes can be calculated for a known percentage of heavy vehicle in one direction.

b) The passenger car equivalents, PCE_1 for shoulder lane with percentage of heavy vehicle p_1, and PCE_2 for median lane with percentage of heavy vehicle p_2, are calculated from the relationship of PCE to respective percentage of heavy vehicle.

c) PCE_d for the whole roadway section in one direction with total percentage of heavy vehicle P, is then calculated from,

$$P * Q * PCE_d = q_1*p_1*PCE_1 + q_2*p_2*PCE_2$$

where, $Q = q_1 + q_2$

$$\therefore \quad PCE_d = \frac{1}{P}\left[\left(\frac{q_1}{Q}\right) \times p_1 \times PCE_1 + \left(\frac{q_2}{Q}\right) \times p_2 \times PCE_2\right] \quad eq.(5)$$

The values of q_1/Q and q_2/Q can be obtained from the plot of lane utilization rate against the total volume Q, as,

$$q_1/Q = X*Q + Y*Q^2 + Z = 1 - q_2/Q$$

6. Results

The PCE values at higher flow rates for shoulder lane and median lane and for day and night time conditions are shown in Fig.1 against the percentage of heavy vehicle for the corresponding lane. It is to be clear that although the PCE values (in Fig.1) for individual lanes are constant over all range of lane volume, the PCE values for the whole roadway section vary with total directional volume as given by eq.(5).

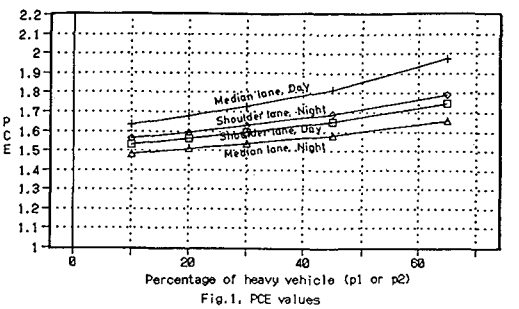

Fig.1, PCE values

From the results on PCE values and also from the scatter diagrams of basic traffic flow parameters, a large difference between the data sets of day and night time conditions as well as shoulder lane and median lane, are observed. The results from this analysis also show that it is possible to estimate the PCE values after forming the relationship between traffic flow parameters for different percentage of heavy vehicles from statistical method of regression analysis and will be investigated further.

7. References

1. HUBER (1982), Est. of PCE of Trucks in Traffic Stream, TRR No.869, pp.60-70.
2. STHAPIT and OKURA (1992), Est. of Effect of Heavy Vehicles on Motorway Traffic Characteristics, JSCE, Proc. of Infra. Planning No.15(1), pp.299-304.
3. TRB (1985), Highway Capacity Manual, Special Report 209, National Research Council, Washington D.C.