Ⅳ－452 PASSENGER CAR EQUIVALENTS OF TRUCKS FROM MICROSCOPIC APPROACH

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1. Introduction

The estimation of Passenger Car Equivalents (PCE) usually considers either the microscopic or the macroscopic behavior of traffic flow. The microscopic approach considers the estimation of typical four headway pairs involving truck and passenger cars, whereas, in the macroscopic approach, the relationships of macroscopic traffic variables are examined.

2. Theoretical Considerations

The basic equation for PCE is generally obtained from the definition of Passenger Car Equivalents as given in the Highway Capacity Manual, such that,

$$PCE = \frac{1}{p}\left(\frac{q_B}{q_M} - 1\right) + 1 \qquad ..(1)$$

where, q_B and q_M represent the passenger car only flow and the mixed flow with percentage of heavy vehicle 'p' respectively for the same level of service (LOS). The detailed procedure for estimating PCE from macroscopic approaches have been discussed by Sthapit and Okura [1,2] elsewhere.

From the fundamental relationship between flow rate (q) and average time headway (h),

$$q(vph) = \frac{3600}{h(sec)}$$

If the flow rates in equation (1) are substituted by corresponding headways, then,

$$PCE = \frac{1}{p}\left(\frac{h_M}{h_B} - 1\right) + 1 \qquad ..(2)$$

If the four headway pairs (lagging headway in this study) are expressed as h_{ij} where 'i' is the vehicle type of interest and 'j' is the leading vehicle type, then the average headway in a mixed stream can be expressed as,

$$h_M = (1-p)^2 h_{M_{PP}} + p(1-p) h_{M_{PT}} + p(1-p) h_{M_{TP}} + p^2 h_{M_{TT}}$$

This expression assumes that the sequence of headway types in the mixed stream is random. Also, since the basic stream contains only passenger cars, $h_B = h_{B_{PP}}$ (the first subscript 'B' or 'M' stands for basic or mixed respectively). Substitution in equation (2) results,

$$PCE = \frac{1}{p}\left[\frac{(1-p)^2 h_{M_{PP}} + p(1-p) h_{M_{PT}} + p(1-p) h_{M_{TP}} + p^2 h_{M_{TT}}}{h_{B_{PP}}} - 1\right] + 1 \qquad ..(3)$$

If it is assumed that $h_{B_{PP}} = h_{M_{PP}}$, the equation for PCE after simplification becomes,

$$PCE = (1-p)\left(\frac{h_{M_{PT}}}{h_{M_{PP}}} + \frac{h_{M_{TP}}}{h_{M_{PP}}} - 1\right) + p\,\frac{h_{M_{TT}}}{h_{M_{PP}}} \qquad ..(4)$$

In the above formulation for PCE there are few things that should be considered before estimating the PCE values from headway data.

The first thing is that, although equation (4) involves with the microscopic headway pair, it was derived from the ratio of flow rates. If the PCE values were estimated by equation (1) from macroscopic approach, the data of five minutes or fifteen minutes averages would have been used. Again, average of longer duration may not reflect the adequate situation for percentage of heavy vehicle to be used in equation (4). Thus, averaging several hours' data may not give enough information for a comparison of results from microscopic and the macroscopic approaches. In the contrary, if shorter duration is used, the number of data in each pair of headway type will be too small to take an average. Besides, when the flow rate is low, the data will include headway from about one second to greater than twenty seconds. It will then be difficult to define the maximum headway to be considered, as there has been virtually no theory regarding this problem.

The second thing to be considered is the assumption of randomness of the sequence of headway types in the mixed stream. From actual data, the effect of this assumption in the estimated PCE value can be checked and should be modified if other appropriate relationships can be derived.

The assumption of $h_{B_{PP}} = h_{M_{PP}}$, (for same LOS as from equation 1) is conceptually very important and should be made clear. From this assumption, it

is made possible to use the data from the mixed-flow-only, while estimating PCE values. However, this assumption does not state how the LOS is defined and the cases for which it would be applicable. For different range of flow rates, or percentage of truck in mixed stream, or speed, this assumption may not be adequate. If this assumption could not be verified, then $h_{B_{PP}}$ has to be calculated from the stream with basic-vehicles-only, which corresponds to the same LOS as $h_{M_{PP}}$. In such situation, it would again be necessary to define LOS either by the speed, or density or the volume-to-capacity ratio, for which the headway for basic-stream and mixed-stream are calculated.

3. Analysis and Results

The traffic detector data for each vehicle from a site in Tomei expressway which was collected for about two days were used for analysis. The average headway of fifteen minutes for each headway pair type was calculated at five minute moving interval. The data include a large range of heavy vehicle (10% - 85%), mostly in the free flow region, and data near capacity were very few.

The average headway for each headway pair seems to have no relation with flow rate if only the followers headway (less than five seconds) is considered. So, all headway data were used for averaging. From the available data, the assumption of randomness in the sequence of headway type was verified for all the range of percentage of heavy vehicle.

The average headway for each pair of headway type was calculated by regressing with flow rate and the passenger car equivalent was estimated from equation (4). The result is as shown in Figure (1) (darker symbols represent higher flow rate). The PCE value seems to increase with the increase in the flow rate for the same percentage of truck in the available data. But the PCE seems to decrease with the increase in percentage of heavy vehicle for lower flow rates. This result could not be confirmed for higher flow rates as data near capacity were not available for different percentage of heavy vehicle classes. Moreover, higher percentage of truck occured during night time and hence, the decrease in PCE with the increase in percentage of truck is not clear, whether it is due to the different light condition or due to the presence of truck alone.

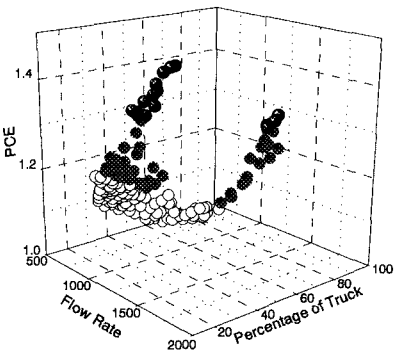

Fig. 1, PCE values

At lower flow rates, the headway for T-T pair was less than that for P-P pair mainly because most of the trucks travel with lower speed and travel in platoons more often, thus decreasing the average headway (hence decreasing PCE). However, difference in speed between truck and passenger car diminishes at higher flow rates (also supported from the data). The headway for T-P pair was higher than that for P-P pair for all volume range and the headway for P-T pair was almost equal to P-P pair for all volume range. The headway for T-T and T-P pair were almost equal at highest volume range, both higher than that for P-P pair.

Near the free flow region (highest LOS), there is more concern of decrease in speed rather than decrease in flow rate (or increase in headway) due to presence of truck. Therefore, headway approach may not be suitable to estimate PCE or to estimate the change in LOS due to presence of truck at this flow region. However, before drawing any concrete conclusions, strong support from extensive data is required and is further planned to be investigated.

4. References

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