DEVELOPMENT OF PASSENGER CAR UNIT (PCU) VALUES FOR MALAYSIA

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Abstract: Passenger Car Unit (PCU) value of each class of vehicle is very important for any mixed traffic flow studies. These may be concerning traffic flow parameters, capacity, signal design, parking lots etc. Though the PCU values to be used for different classes of vehicles has been proposed for Malaysian roads, research work were conducted to validate. The work took into the effect of mixing of traffic, speed and headway. A set of PCU values was then derived.

1. INTRODUCTION

1.1 Need for PCU Values

The unrestricted mixing of various classes of vehicles along a road without their physical segregation creates various complex problems. To the traffic engineer both in the design of traffic facilities and also in the management of vehicles operations. Each class of vehicle in the traffic stream cannot be considered as equivalent to any other vehicle class as there is considerable difference in the vehicular and flow characteristics of each vehicle class. The vehicular characteristics refer to dimensions, power, speed, acceleration, braking and maneuverability of the vehicles. The traffic flow characteristics refer to transverse and longitudinal spacing between the vehicles of the same class and between different classes at various speed ranges. This depends on the vehicle characteristics as well as driver characteristics

1.2 Factors affecting PCU Values

Passenger Car Unit (PCU) value has been defined by the TRRL as "On any particular section of road under prevailing traffic conditions, the addition of one vehicle of a particular type per hour will reduce the average speed of the remaining vehicles by the same amount as the additional of say, x cars of average size per hour. One vehicle of this type is equivalent to x PCU. In the case of a bottleneck, and particular in an intersection, if a particular type of vehicle under saturated conditions requires x times as much time at the intersection as is required by an average car, then that type is equivalent to x PCU".

If the addition of one vehicle of a particular class in the traffic stream produces the same effect as that produced by the addition of one passenger car, then that vehicle class is considered equivalent to a passenger car. Hence, this value may be considered as a measure of relative space requirement of a vehicle class compared to that by a passenger car under a specified set of roadway, traffic and other conditions.

PCU values depends on the following factors:

(i) Vehicle Characteristics: Physical and mechanical, such as length, width, power, accelerations, deceleration and braking characteristics of the vehicles.

(ii) Stream Characteristics:

a) Mean stream speed
b) Transverse gap or lateral clearance distribution of vehicles at different speeds of flow
c) Longitudinal gap distribution of vehicles at different speeds of flow
d) Speed characteristics of the stream such as speed distribution, dispersion and speed differences between different adjoining vehicles in longitudinal and transverse directions
e) Stream composition, i.e., percentage composition of different classes of vehicles
f) Traffic volume to capacity ratio
g) Pedestrian volume
h) Flow conditions

(iii) Roadway characteristics

a) Horizontal alignment
b) Location: rural, urban, semi-urban
c) Stretch: mid-block, signalised intersection, police controlled intersection, uncontrolled intersections, rotary
d) Skid resistance of pavement surface
e) Traffic flow regulations such as one-way, two-way, divided and undivided roads
f) Number of lanes and pavement width
g) Sight distance
h) Pavement surface , unevenness, type and structural condition

(iv) Environmental characteristics

a) Surroundings and local factors
b) Obstructions
c) Roadway location – embankment, cut, underpass, overpass, tunnel
d) Terrain conditions: plain, rolling, hilly, mountainous

(v) Climatic conditions

a) Fog, mist
b) Rainy, dry

(vi) Control conditions

a) Posted speed limit
b) Segregation of slow and fast moving vewhicles
c) Free access, control of access

1.3 Basic Principle to estimate PCU Values

Two basic principles should be applied to the estimation of PCU Values for any of the roadway types identified in capacity analysis procedures. The first principle links the concept of PCU to the level of service (LOS) concept and the second emphasizes the consideration of all factors that contribute to the overall effect of trucks on the traffic stream performance.

Level of service is s quantitative measure of the effect of number of factors, which includes speed and travel time, traffic interruptions, freedom to maneuver safety, driving comfort and convenience to various categories of roads.

Passenger car Unit (PCU) value of each class of vehicle has been found to be of prime importance in the study of mixed traffic particularly in studies concerning traffic flow parameter, capacity, signal design, parking lots etc.

1.4 Scope of this study

In this study, urban mid block section has be considered to find the PCU values. With all the various factors influencing the PCU values as discussed above, the main factors which has been considered here are

(i) Average speed of each class under different set of prevailing conditions
(ii) Average longitudinal gap
(iii) Average Effective width

2. DATA COLLECTION

Different locations were selected to conduct the traffic study using the video camera. The locations were for different category of roads and for different composition of traffic. All the traffic movement details were recorded by the video camera.

Width and Lateral clearance

On most of the roads, vehicles are travelling behind each other in more or less as a lane. Since, this lane concept holds good, there will not be much change in the PCU value from this factor. Hence, the effective width and transverse clearance was not considered.

Speed and Volume measurement

Speed of different classes of vehicle was measured using the video camera. Classified traffic volume counts were also obtained form the video.

Time Headway Measurements

Time headway of different classes of vehicles was measured. This was done by observing the time headway of a queue of same class of vehicle, number of vehicles in the queue and the speed of that vehicle class in the queue.

3. DATA ANALYSIS

3.1 Speed Distributions

The PCU factor is based on the mean speed values of different vehicle classes. This is calculated by dividing the mean speed value of passenger cars by the mean speed value of any vehicle class. the value are given in Table-1.

$$F_u = \frac{U_c}{U_v}$$

Where
F_u = PCU factor for speed for vehicle class v
U_c = Mean speed of car
U_v = Mean speed of the vehicle class v

Table 1: PCU Factor for Speed

Class of Vehicle	Mean speed U_v kmph	Speed Factor $F_u=U_c/U_v$
Car	27.15	1.00
Motorcycle	32.84	0.827
Van	27.02	1.01
Small Lorry	26.79	1.013
Big lorry	22.59	1.202
Bus	28.89	0.94

3.2 Headway Distributions

If T sec is the elapsed time for n vehicles in the queue of a particular class if vehicle moving at a desired speed, to cross a line from head to head, the mean time headway t sec is given by:

$$t = \frac{T}{(n-1)}$$

Time headway is a stochastic variable. It follows a certain probability distribution. In this work, mean lower time headway for different classes of vehicles have been determined by rejecting a part of the higher values of time headway. A vehicle driver may feel free to allow any value of space or time headway with respect to the lead vehicle while moving at any given speed. This is true particularly when the density and volume of flow are low and free flow condition exit. However, as the flow increases ands approaches the maximum possible value at a particular sped the time headway will decrease. Therefore, it is desirable to consider the lower values of time headway at each stream speed corresponding to compact flow and ignore the higher value of headway which correspond to only scattered flow.

To obtain this, a cumulative relative frequency curves of time headway distribution for different classes of vehicle were drawn. A typical headway distribution graph is as shown in Figure 1. A tangent is drawn at the portion of the ogive. Another tangent point is drawn at the higher time headway range after the point of inflection. The intersection of these tangents was taken as the cut-off point t_I. Mean lower time headway t_v was calculated using the relation:

$$t_v = \frac{\sum_{i=1}^{n} t_i}{n}, t_i \le t_i'$$

Where t_v = mean lower time headway of any vehicle class
t_i = individual time headway of the vehicle class
t_I = Cut-off point for time headway distribution of vehicle class
n = Number of individual time headway under consideration.

This method was adopted to find the mean lower time headway for other classes of vehicle. The PCU factor based on this headway for any class F_t was obtained by dividing the mean time headway of this vehicle with the mean time headway of car. Table-2 shows the PCU factors for different vehicles.

$$F_t = \frac{F_v}{F_c}$$

Where
F_t= PCU factor for time headway for vehicle class v
F_c= Mean lower time headway for cars
F_v= Mean lower time headway for vehicle class v

Table 2: PCU Factor for Time Headway

Class of Vehicle	Mean Lower Headway t_v sec	Headway factor $F_t = t_v/t_c$
Car	2.124	1.00
Motorcycle	1.574	0.74
Van	3.306	1.56
Small Lorry	4.106	1.93
Big lorry	4.564	2.15
Bus	5.269	2.48

3.3 Lateral clearances

In most of the roads considered, the traffic is following each other in a lane and there is not much of disturbance within the lane. Hence the factors like the average length and width of each vehicle class and the average transverse gap between vehicles has not been considered. The effect of this is assumed to be unity as the equivalent factor for width.

$$F_w = \frac{W_v}{W_c}$$

Where
F_w= PCU factor for Lateral clearance for vehicle class v
W_c= Transverse gap for cars
W_v= Transverse gap for vehicle class v

3.4 Determination of PCU values

As discussed, the PCU value of a vehicle at urban mid-block depends upon the (i) average effective width W_v, (ii) the mean speed U_v and the (iii) mean lower time headway t_v.

With the increase in mean speed of vehicle U_v the time spent by the vehicle decreases. Lesser the speed, greater is the hindrance to the other vehicles. When other factors remain constant, PCU_v is inversely proportional to U_v. Thus,

$$PCU_v \propto \frac{1}{U_v}$$

where K_u = constant of variation in mean speed.

$$PCU_v = \frac{K_u}{U_v}$$

Similarly, the moving space occupied by the vehicle in traffic stream increases with the increase in the mean time headway, t_v maintained by the vehicle. and hence, PCU_v is directly proportional to t_v.

$$PCU_v = K_v.t_v$$

Where K_v = constant of variation in mean time headway.

Generalising these, when all jointly vary and other remaining factors remain constant. The

$$PCU_v = K\frac{W_v t_v}{U_v}$$

Hence if the ratio is taken with respect to the car,

$$\frac{PCU_v}{PCU_c} = \frac{W_v t_v}{U_v} \div \frac{W_c t_c}{U_c}$$

If $PCU_c = 1$, then the PCU values of other classes can be obtained using the following equation and the results is shown in Table 2.

$$PCU_v = \frac{W_v}{W_c} \times \frac{U_c}{U_v} \times \frac{t_v}{t_c} = F_w \times F_u \times F_t$$

Table 3: PCU Values for Mid Block Sections

Class of Vehicle	Width Factor $F_W = W_v/W_c$	Speed Factor $F_u = U_c/U_v$	Headway factor $F_t = t_v/t_c$	PCU= $F_w * F_u * F_t$
Car	1.00	1.00	1.00	1.00
Motorcycle	1.00	0.827	0.74	0.61
Van	1.00	1.01	1.56	1.58
Small Lorry	1.00	1.013	1.93	1.92
Big lorry	1.00	1.202	2.15	2.58
Bus	1.00	0.94	2.48	2.33

4. RESULTS & CONCLUSIONS

4.1 Discussions:

The analysis is based on the field studies conducted on typical urban roads in Kuala Lumpur and Petaling Jaya considering almost all classes of vehicles commonly found in Malaysia. Hence, the PCU value obtained can be used for urban roads. The PCU value of each vehicle is not a constant but varies with several factors such as proportion of other classes, level of service, volume to capacity.

The speeds of individual vehicles in the queue need not be precisely equal, but may vary slightly from vehicle to vehicle and similarly the time headway of individual vehicles in the queue. In this study, the average value of speed and time headway is taken.

4.2 Conclusions:

The model represented is a step in determining the PCU values on urban roads. The methodology adopted can be extended to determine the equivalents of any other type of vehicle and also under different traffic and roadway conditions. Comparing the results (Table-4) with those adopted by Jabatan Kerja Raya (JKR), the obtained results are on the lower side.

Table-4: Comparison of PCU Values

Class of Vehicle	PCU Values derived	PCU Values by JKR
Car	1.00	1.00
Motorcycle	0.61	0.75
Van	1.58	2.00
Small Lorry	1.92	2.50
Big lorry	2.58	3.00
Bus	2.33	3.00

4.3 Scope for further work

The effect of the lateral clearance or the effective width can be studied. Research can be extended by considering the distribution of headway and lateral clearances as functions of speed and vehicle interference. In this study, the headway calculated is for the vehicle following the same class. The behaviour of a class of vehicle following other class can be further studied. Similarly studies can be extended to rotary and signalised intersections.

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