Analysis of Passenger Car Unit (PCU), at Signalized Intersection on Sinhgad Road, Pune

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Abstract— Now days the traffic problem become complicated and tedious. We all familiar with a thing, that the India is developing country and densely populated. In India traffic is a measure problem, we have been going through. From last 30 years it has been observed that, the traffic is detrimental to people, all over the world. Among the million plus cities in Maharashtra, Pune has the maximum ratio of vehicles per thousand persons. There are some basic issues of measure cities like Pune needs awareness and solution as soon as possible so as to maintain proper growth in terms of basic development. The problem concern with traffic in Pune city is increasing with every passing day. In this paper an attempt is made to find passenger car unit (PCU) value for sinhgad road intersection. Passenger car unit (PCU) value of each type of vehicle is very essential for any miscellaneous traffic flow. These may be regarding traffic flow parameters, capacity, signal design, parking lots etc. The work holds into account the influence of mixing of traffic, speed and headway. These PCU values (devised in developed countries)are not suitable for Indian miscellaneous traffic conditions, where traffic is more diverse in nature, and driver do not follow lane discipline. This paper existing basic methods and their suitability for Indian traffic system. This paper also establishes the gaps in research areas which needs further research in Indian traffic condition. In a mixed traffic condition, where different types of vehicles share the same roadway space without any physical separation, the amount of collaboration is expected to change with the mix characteristics. The interaction among the vehicles is greatest during peak period on urban roads. The common practice to analyze mixed traffic flow is to transform all vehicles into equivalent numbers of passenger car units (PCUs). A mathematical equation relating PCU for a vehicle type to the influencing variables is suggested in this paper.

Keywords— Passenger car unit (PCU), Flow parameters, Traffic flow studies, Vehicles.

I. INTRODUCTION

The aftermaths on transportation sector are entirely major due to rapid development of urbanization, mostly because of urban vehicular growth. Effects of urbanization are detect appreciably in terms of traffic congestions, delays, road safety, pollution, and transport efficiency. As the population of country is increasing the demand for vehicles of all types is also increasing, e.g. car and motor cycles for personal use, heavy vehicles for goods transport and etc. Effectively addressing the congestion issue means not only adding new lanes (capacity) to the roadway system, it also means finding ways to make the existing roads work better. In the last 10 years, the population of four wheelers on Pune's roads has increased by 243 per cent and the number of two wheelers has seen a rise of over 144 percent. Pune city's population during the same period has increased by 24 per cent. On the other hand, the city's road length has failed to increase even slightly.

Traffic in the country is of the assorted nature. To approach the different types of vehicles on common basis, concept of passenger car unit developed. Passenger car unit (PCU) is thus a metric used to assess traffic-flow rate on a highway. In 1965 Highway Capacity Manual introduced the term Passenger Car Equivalent for the first time. PCE defined as "The number of passenger cars displaced in the traffic flow by a truck or a bus, under the prevailing roadway and traffic conditions". This definition of PCE was for relative homogeneous traffic conditions (only bus, car and trucks) succeed in developed countries. Many methods being for resolving passenger car units like those based on headway, delay, density, extra vehicle hours, etc..

a) Pcu values depends on the following factors:

1.Vehicle Characteristics: Physical and mechanical, such as length, width, power, accelerations, deceleration and braking characteristics of the vehicles.
2. 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.
3. Roadway characteristics:
a) Horizontal alignment.
b) Location: rural, urban, and semi-urban.
c) Stretch: mid-block, signalised intersection, police controlled intersection, uncontrolled intersections.
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.
4. Environmental characteristics:

a) Surroundings and local factors.
b) Obstructions.
c) Roadway location - embankment, cut, underpass, overpass, tunnel.
d) Terrain conditions: plain, rolling, hilly, mountainous.
5. Climatic conditions:
a) Fog, mist.
b) Rainy, dry.
6. Control conditions:
a) Posted speed limit.
b) Segregation of slow and fast moving vehicles.
c) Free access, control of access.[2]

II. PCU STUDIES IN INDIAN TRAFFIC CONDITIONS

Indian traffic streams consist of assorted traffic which also includes non-standard vehicles. Nonstandard vehicles refer to non-conventional vehicles that exhibit abnormal stream and queuing behaviour usually assumed in analysis. Effect of non-standard vehicles on Indian traffic cannot be neglected. Lane discipline is quite weak which makes lane by lane analysis impossible and incorrect. Next few paragraphs describe the pcu studies carried out for traffic similar to India.

a) Pcu by Indian roads congress (IRC)

Indian roads congress (IRC) suggested pcu values and their usages the pcu variation with terrain is adjusted as per the capacity of roads. IRC 70-1977 states that segregation in the form of physical, time-based, or by one way systems or a combination of these can effectively reduce interference due to slow moving vehicles in a mixed traffic situation.

b) Pcu studies in urban areas:

They are characterized by higher intersections and less length of mid-block sections. Traffic can be of all the levels of service. Predominant research on urban heterogeneous traffic conditions include.

- PCU of bicycles on urban road intersections:

Wang et al. made an analysis of interaction between bicycles and motor vehicles. A set of models of bicycle conversion factor were established for different situations. The suggested PCU values (i)for through bicycle at intersections was0.28; (ii) for left-turning bicyclewas0.33; (iii) for bicycle on the road section without physical separation was 0.24; and (iv) for bicycle on the road sections with physical separation was 0.22. For left turning vehicles, PCU was calculated as a ratio of average delay caused due each bicycle and average headway for successive vehicles. For other types, the PCU was calculated on basis of ratio of saturation flow rates of bicycles and other vehicles for the same road width. However, the study included only three sites and hence effect of road width and ratio of road widths of each road of intersection is not studied satisfactorily.

- ### Pcu of cycle rickshaw at mid-block section

Rahman and Nakamura studied the PCU of non-motorized rickshaw (or cycle rickshaw) of mid-block sections of non-congested road in Dhaka, Bangladesh; by speed reduction method. Average stream speeds were calculated from 12 hr field video data. Basic speed calculation is done from those one-minute intervals video data which contained only cars. Effect of decrease in speed due to increase in rickshaws was studied. However, effect of buses and trucks (4 to 5 % of total traffic) was neglected. The study showed a linear relationship between PCU of rickshaw and traffic volume as well as percentage of rickshaws.

- ### Pcu of non-standard vehicles at saturated conditions at intersections

Sahaet al. had performed the calculation of PCU at a saturated intersection of Dhaka city (in Bangladesh) by headway ratio method. The roads had no entry for trucks, no bus stoppages nearby and no parking zone. PCU values of 0.86, 1.42, and 2.16 were obtained for auto rickshaws, minibuses and buses respectively.[6]

III. DETERMINATION OF PCU

Traffic in many parts of the world is varied, where road space is united among many traffic modes with different physical dimensions. Loose lane castigation conquers; car following is not the norm. This complicates calculating of PCU. Some of the methods for determining passenger car units (PCU) are following:

- Modified Density Method
- Chandra's method
- Method Based on Relative Delay
- Headway method
- Multiple linear regression method
- Simulation method

It may be appropriate to use different values for the same vehicle type according to circumstances like volume of traffic, speed of vehicle, lane width and several external factors.

a) Method based on relative delay

The 1965 HCM used relative speed reduction to define PCUs for two lane highways and quantified this by the relative number of passing known as the Walker method. For multi-lane highways, PCUs were based on the relative delay due to trucks. PCUs for multi-lane highways based on relative delay may be found as

$$E_t = \frac{D_{ij} - D_b}{D_b}$$

Where D_{ii} is the delay to passenger cars due to vehicle type i under condition j and D_b is the base delay to standard passenger cars due to slower passenger cars.

PCUs in the 1965 HCM were reported for grades of specific length and percent, proportion of trucks, and LOS grouped as A through C or D and E. As expected, the highest PCU was reported for the longest and steepest grade with the highest

proportion of trucks and the lowest LOS. However, in many cases the PCU for a given grade and LOS decreased with increasing proportion of trucks. PCUs in the 1965 HCM were reported for grades of specific length and percent, proportion of trucks, and LOS grouped as A through C or D and E. As expected, the highest PCU was reported for the longest and steepest grade with the highest proportion of trucks and the lowest LOS. However, in many cases the PCU for a given grade and LOS decreased with increasing proportion of trucks.

b) Multiple linear regression model

Multiple linear regression method tries to represent the speed of a traffic stream as function of number of variables. For example, the percentile speed v_p can represented as:

$$v_p = v_f + c_1 \times V_c + c_2 \times V_t + c_3 \times V_\tau + c_4 \times$$

Where, $VP = v_f$ is the free speed, V_c is the number of passenger cars, V_c is the number of trucks V_τ is the number of recreational vehicles, V_τ is the number of other types of vehicles, V_a is the number of vehicles moving against the current stream, C_1 to C_5 are coefficient representing the relative sizes of speed reductions for each vehicle type. Although this model was formulated for two lane highways with opposing traffic flow, it could be applied to multi-lane highways by setting the coefficient C_5 to zero. Using the speed reduction coefficients, E_n the PCU for a vehicle type n is calculated as:

$$E_n = \frac{C_n}{C_1}$$

where C_n is the speed reduction coefficient for vehicle type n and C_1 is the speed reduction coefficient for passenger cars.

c) Method based on headway

Realizing one of the primary effects of heavy vehicles in the traffic stream is that they take up more space; headways have been used for some of the most popular methods to calculate PCUs. In 1976, Werner and Morrall suggested that the headway method is best suited to determine PCUs on level terrain at low levels of service. The PCU is calculated as

$$E_t = \frac{\left(\frac{H_m}{H_b}\right) - P_c}{P_t}$$

where H_m is the average headway for a sample including all vehicle types, H_b is the average headway for a sample of passenger cars only, P_c is the proportion of cars, and P_t is the proportion of trucks.

d) Chandra's method

Chandra and Sikdar (2000) proposed a methodology to estimate PCE values for mixed traffic conditions. They have estimated the PCE values as a function of vehicle area and speed. This method uses two factors: namely, velocity of vehicle type and its projected rectangular area to calculate the PCU value. According to their methodology PCE of any particular vehicle is formulated as follows:

$$(PCU)_i = \frac{(V_c/V_i)}{(A_c/A_i)}$$

where V_c and V_i are mean speeds of car and vehicle of type i respectively and A_c and A_i are their respective projected rectangular area length * width on the road.[3]

- ### Gaps in pcu research pertain to indian traffic condition

Pertaining to Indian conditions, research on the following areas may be looked upon for further research:
(i) Effect of grade on PCU on Indian roads/highway for saturated traffic and car-following conditions: This study is important for analyzing capacity of roads/highways in hilly regions of India. The accuracy of data shall be used for road improvements and future road widening schemes. Work done by Arasan and Arkatkar is limited to free flow conditions and wider roads only. (ii) PCU values of Para transit vehicles in semi urban areas:Para transit vehicles are mostly used in fringe areas of Indian cities- plying on the main roads, their routes and trips per day are mostly fixed. Vehicles such as six seatersVikrams, transit vans (like Tata magix models), and transit jeeps (with open doors) have never been studied although they have a significant share of traffic in and near Indian cities. Most of these vehicles are classified as „Light commercial vehicles‟ in a single group and assigned a PCU value of 1 in IRC codes. (iii) The PCE for vehicles in heterogeneous traffic at rotaries is not investigated till date. (iv) Similarly, PCE for vehicles in heterogeneous traffic at merging sections on highways is also not explored. Thedensity method used by Ahuja can be used in this context. (v) Effect of land use on the PCU factors can be established based upon vehicle composition and vehicle speed changes as per different land use. (vi) For calculating PCU values of vehicles for noting capacity of Indian highway tunnels, the method adopted by Feng-Bor Lin et al. in Taiwan‟s undersea tunnel may be extended for use in Indian highway conditions for trucks as well as buses assuming standard vehicles.[6]

IV. CASE STUDY AT ANAND NAGAR INTERSECTION

In the present work a signalised intersection located on sinhgad road of Pune is studied. A three phase signal is chosen. The details of the roads meeting at the intersection are depicted in fig.1

	2wheeler	4wheeler	3wheeler	Lcv/mini bus
Cycle	15	2	2	0
	8	0	3	1
	6	3	0	0
	6	0	2	0
	9	3	2	0
	10	2	0	0
Total	183	34	30	4
PCU	61	34	24	7

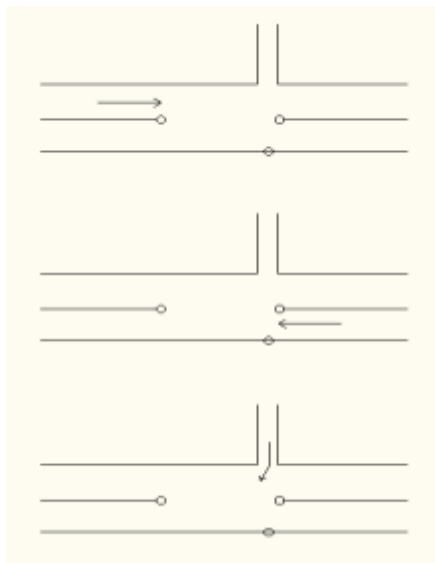|	2 wheeler	4wheeler	3wheeler	bus/truck	medium load vehicles
Cycle	118	27	23	2	4
	113	35	18	3	4
	122	27	25	6	2
	114	24	11	3	5
	108	33	13	4	2
	96	22	11	3	5
Total	2284	571	343	71	74
PCU	760	571	274	160	130

PCU (total)
2567

Road-2

Road-3

Fig. 3 Phases For Through Traffic At The Intersection Considered In Case Study.[5]

PUC Equivalents for signal computations:[3]

Types of vehicle	PCU Equivalents
Heavy or median goods vehicles	1.75
Light goods vehicle	1.00
bus	2.25
Motor cycle, moped or scooter	0.33
Pedal cycle	0.20

Obervations taken at intersection
Timing : 5.30-6.30

Road-1

	2wheeler	4wheeler	3wheeler	bus/truck	medium load vehicles
Cycle	160	35	23	5	3
	156	33	32	3	8
	180	32	31	3	4
	210	37	27	4	5
	100	22	25	4	6
	164	35	28	5	4
Total	3289	659	564	81	102
PCU	1096	659	451	183	178

PCU (total)	PCU (total)
1895	126

V.   CONCLUSION

Passenger Car Equivalent has been provided. Out of the various methods discussed, headway ratio method is currently the most commonly used method for PCE estimation Measurement over a intersection is may be one of the easiest field parameter that can be measured. Various types of volume counts and counting techniques have been discussed in brief. Out of the various methods discussed, Chandra's Method is only method that can be applied to the Indian condition of mixed traffic that is characterized by loose lane discipline. All the other methods are primarily based on homogeneous traffic conditions mainly prevailing in developed. All the other methods are primarily based on homogeneous traffic conditions mainly prevailing in developed countries. Some of the studies resulted in non-constant PCE, they did not establish direct relationships among PCE, traffic volume and percentage of heavy vehicles.

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