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Effect of Passenger Car Unit on Highway Capacity under Different Traffic Spectrum

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ABSTRACT. *Passenger car unit (PCU) is well known in traffic engineering, where passenger cars are often used as a measure or basis for converting different categories of vehicles. This research will show the importance of PCU on the same and different vehicles changing the effect of varying traffic spectrums (low-speed vehicles and non-motorized vehicles). This research discussed ten sections of various highways in Pakistan (one section of motorway, two sections of national highways, and the remaining seven sections of two-way roads). In this research, we calculated the speed of different vehicle types, the area of different vehicle types, the width of the highway, and traffic composition on ten sections of highways. After that, we estimated the value of the passenger car unit using the speed-based method. Now we shall be drawn a comparison between the value of passenger car unit of different vehicles on the different sections of highways. The importance of passenger car unit on the same and different vehicles changes the effect of different traffic spectrums. When we compare section number 1 and the remaining all other nine sections of highways, we can easily see the impact of low-speed vehicles (non-motorized) on the value of passenger car unit. Because only section number 1 is the motorway section, and there are no low-speed vehicles (Motorbikes) present on the motorway in Pakistan. Low-speed vehicles exist in the remaining other sections. All these effects are discussed in this paper.*

Keywords: Passenger car unit, Traffic spectrum, Low-speed vehicle, Non-motorized vehicle, Highway

1. INTRODUCTION

Passenger car unit is a general term in traffic engineering. It tells us how a vehicle travels on the road. It depends upon three main factors. The first factor is the speed of the vehicle. When the vehicle's speed increased compared to the standard car, its value as a passenger car unit also increased. Similarly, a vehicle has a larger projected area than the smaller projected area of the vehicle; the value of the PCU of the large vehicle will be more than that of a smaller car. In this research, the importance of PCUs on the same and different vehicle changes is affected by different traffic spectrums (low-speed vehicles and non-motorized vehicles) [6]. Another element that influences the passenger car unit of the automobile is the breadth of the road. The road breadth is greater than the increases in the values of passenger car unit for large cars and light traffic vehicles; heavy traffic vehicles, as well as BUS, are also higher when undivided segments are used [9]. For undivided roads, this pattern is a bit more complicated. Passenger car unit for large car tractors, buses, and bus trailers on the undivided highway is greater than on the divided highway. Due to undivided highways, smaller cars have more flexibility, which can result in a greater velocity ratio for mini cars to kinds of vehicles with smaller sizes. For buses, similar reasoning could use. All these trends are discussed in this paper.

1.1. Literature Review

Passenger car unit is a term utilized in highway engineering to determine traffic-flow density on the road. Many engineers also work in this field in America, Europe, and Asia. Huber (1982) estimated the PCU of a vehicle using average driving time. In high-traffic situations, the same proportion of trucks has been found to significantly affect mean travel time more than a lower volume [1]. Giuffre (2015) approved similar methods and validated that there is a direct connection between truck passenger car unit and traffic intensity [2]. Mondal (2017) also appeared that the passenger car unit of different automobile types has a positive linear relationship with traffic volume and the v/c ratio. A decreasing linear trend was noted for motorized bikes and rickshaws [4]. Rao and Yadav (2018) observed that a fall in traffic formation of 3 W causes a rise in passenger car unit for a traffic flow [5]. Biswas (2018) winded up that increasing the percentage of heavy automobiles reduces the value of passenger car unit of three-wheeled and two-wheeled vehicles but also increases the PCU of other vehicles. However, increasing the proportion of small automobiles, such as two-wheelers, leads to a lower passenger car unit for big automobiles and a rise in other automobile types [9]. Arasan and Arkatkar (2010) used a simulation method to determine the PCU along an urban highway. Subotic (2016) used a procedure-based method to calculate the passenger car unit of large automobiles in a city unit with two lanes. The speed-based method is straightforward and suitable for heterogeneous traffic flows formed by any of the vehicles (Biswas et al. 2020) [6].

1.2. Methodology

We have required a method that covers the heterogeneous nature of traffic situations, bidirectional traffic situations, low-speed automobiles, and non-motorized vehicles. For this situation, only a speed-based method will be suitable. The approach is straightforward, and it is suitable for heterogeneous traffic flows. Finally, we selected the speed-based method for calculating the passenger car unit for this case study. According to the speed-based method, here we have required the speed of vehicles and area of vehicles to calculate passenger car unit and achieve the objective of my research. All these parameters were calculated manually on the ten sections of different highways in Pakistan. Two other parameters (width of highways and traffic composition on highways) were also calculated manually.

$$PCU = \frac{V_s}{V_r} \div \frac{A_s}{A_r}$$

Vs and Vr mean velocity of car and automobile type r respectively, while As and Ar are their covered area by the automobile onto the road.

2. DATA COLLECTION & EXTRACTION

This research discussed ten sections of different highways in Pakistan (one section of motorway, two sections of national highways, and the remaining seven sections of undivided roads). On these ten segments, we surveyed the various kinds of cars (Meharan, Rickshaws, xli vehicles, vans, motorbikes, multi-axle trucks, tractor-trailers, etc.). Each vehicle is classified into eight distinct categories. Here the small car is taken as a standard car. The PCU for the other vehicles was calculated from this vehicle. To determine the passenger car unit values, consider how much area each car is projected to have. The area ratio of the vehicle was calculated in table 2.

Table-1: Display the width of ten road sections

Section Number	Road Sections Detail	Road Width (m)
1	Multan to Sukkur motorway M-5 (divided road)	11.35
2	Torkham to Karachi N-5 (divided road)	8.25

3	Peshawar to Hyderabad N-55 (undivided road)	8.5
4	Muzaffargarh to Mianwali road (undivided road)	8.25
5	Multan to Leiah road (undivided road)	8.15
6	Muzaffargarh to Jhang road (undivided road)	8
7	Leiah to DG khan road (undivided road)	7.85
8	Multan to Vehari road (undivided road)	7.75
9	Shujaabad to Jalalpur road (undivided road)	7.5
10	Gailywal to Jalal pur road (undivided road)	4.5

Table-2: Display area ratio (As/Ar) to standard car (SC)

Automobile type	**Automobile included**	**L (m)**	**W (m)**	**Area (sq.m)**	**As/Ar**
Standard car (SC)	Meharan car	3.3	1.4	4.6	1
Large car (LC)	XLI	4.5	1.7	7.7	0.6
Motorbike (MB)	Motorbike	1.8	0.8	1.5	3.05
Rickshaw (RS)	Three wheeler	3	1.2	3.6	1.28
LTV	Mini trucks and vans	4.8	1.8	9.1	0.51
HTV	Multi axle trucks	11.5	2.4	28.1	0.16
Bus	Buses	10.6	2.5	26.6	0.17
Tractor Trailers (TT)	Tractor and trailers	9.4	2.4	22.7	0.2

After the estimation of the velocity of the vehicle, it is divided by the velocity of the standard car; we then get Vs/Vr. The ratio of Vs/Vr is divided by the ratio of As/Ar for the standard car type, and then we get the passenger car unit value for the car. Table 4 provides the passenger car unit for various vehicles in the data stream segments where data collection is completed.

Traffic volume is an essential parameter of this case study. It is calculated manually with the speed of the vehicle. We can be noted the type of vehicle and the number of vehicles. From the number of the vehicle, we get the traffic volume of each vehicle per hour. After getting the traffic volume per hour of each vehicle divided by the total traffic volume of all vehicles, we get traffic composition in percentage.

Table-3 : Display the traffic composition of every vehicle categories at each segments

TRAFFIC COMPOSITION (%)								
Section Number	**SC**	**LC**	**MB**	**RS**	**LTV**	**HTV**	**BUS**	**TT**
1	31.35	25	0	0	17.3	16.5	9.87	0
2	22.1	13.1	17.7	6.55	16.4	13.6	8.2	2.33

3	20.5	14.7	16.1	4.21	19.3	15.1	7.9	2.2
4	18.4	13.4	19.1	7.9	18.4	17.1	3.1	2.6
5	24.1	18.2	23.2	5	16.2	9.1	2.5	1.7
6	21.2	16.4	20.2	6.2	15.1	12.3	7.1	1.5
7	27.2	12.7	22	6.7	15.8	11.4	2.8	1.4
8	25.1	16.1	22.2	5.7	13.2	9.9	5.9	1.9
9	27	12.1	26.3	7.1	12.7	7.2	4.8	2.8
10	19.8	8.1	41.2	15.1	5.1	0.5	0.2	10

Table-4: Displays mean speed ratio & Passenger Car Unit value of different vehicles

Mean speed values Vs/Vr									**Passenger Car Unit Values**							
Section Number	**Standard Car**	**Large Car**	**Motor Bike**	**Rickshaw**	**Light Traffic Vehicles**	**Heavy Traffic Vehicles**	**BUS**	**Tractor Trailers**	**Standard Car**	**Large Car**	**Motor Bike**	**Rickshaw**	**Light Traffic Vehicles**	**Heavy Traffic Vehicles**	**BUS**	**Tractor Trailers**
1	1	0.78			1.06	1.29	0.9		1	1.3			2.07	7.79	5.14	
2	1	0.78	1.4	1.75	1.08	1.37	0.88	2.33	1	1.29	0.46	1.36	2.11	8.32	5	11.4
3	1	0.82	1.38	1.86	1.07	1.44	0.96	2.6	1	1.36	0.45	1.45	2.09	8.75	5.46	12.7
4	1	0.79	1.27	1.82	1.09	1.41	0.9	2.58	1	1.32	0.41	1.42	2.13	8.54	5.13	12.7
5	1	0.78	1.24	1.84	1.1	1.36	0.86	2.19	1	1.29	0.41	1.43	2.15	8.23	4.94	10.7
6	1	0.73	1.31	1.67	1.12	1.22	0.81	1.96	1	1.21	0.43	1.3	2.2	7.41	4.62	9.63
7	1	0.72	1.18	1.68	1.13	1.18	0.74	1.93	1	1.2	0.39	1.31	2.21	7.16	4.24	9.44
8	1	0.71	1.06	1.56	1.11	1.22	0.79	2	1	1.18	0.35	1.22	2.17	7.39	4.54	9.8
9	1	0.69	1.2	1.58	1.07	1.32	0.8	1.75	1	1.14	0.39	1.23	2.08	8.03	4.59	8.58
10	1	0.77	1.18	1.74	1.15	1.74	1.34	2.35	1	1.28	0.38	1.36	2.24	10.5	7.67	11.5

3. DISCUSSION OF RESULTS

Figures 1 show the value of passenger car unit and their modification for various vehicle kinds on divided and undivided roads. Because the bus is more significant in size than a passenger car, it can keep its velocity if any other automobile were simultaneously on the highway. For undivided roads, this pattern is a bit more complicated. Passenger car unit for large car tractors, buses, and bus trailers on the undivided highway is greater than on the divided highway. Due to undivided highways, smaller cars have more flexibility, which can result in a greater velocity ratio for mini cars to kinds of vehicles with smaller sizes. For buses, similar reasoning could use. Passenger car unit, value disturbed by the traffic formation. In this case, segment 10 (4.5 m of roadway) has the highest amount of bikes. Here the passenger car unit values for BUS (7.67), light traffic vehicle (2.24), tractor-trailer (11.5), and heavy traffic vehicle (10.5) are at their highest in comparison to the other segments. Due to the diverse traffic formation (bikes are 41.2

percent in this segment), less highway breadth and the largest value for passenger car unit found for nearly all kinds of automobiles.

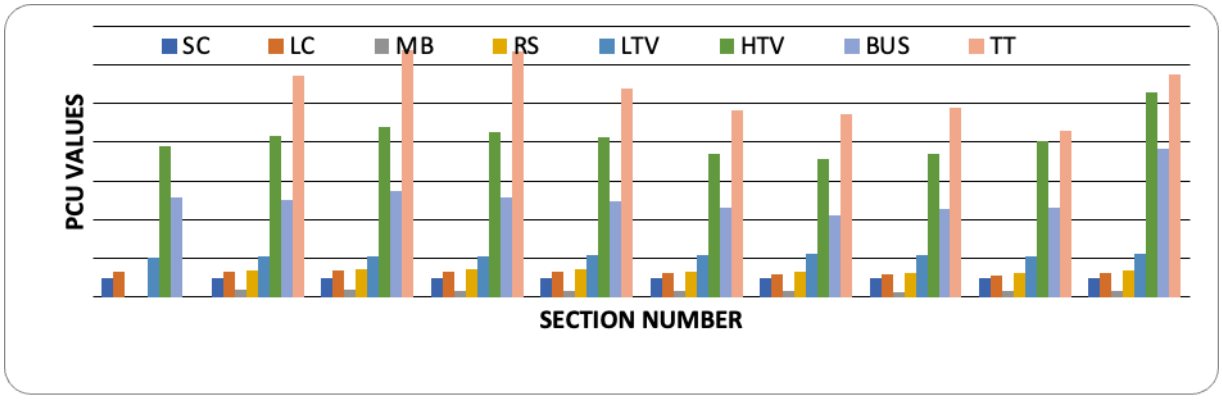

Fig-1: Displays comparison of passenger car unit of vehicle with ten highways

According to the counter, the impact of the density of traffic, the passenger car unit, and values for all kinds of vehicles has to consider that the number of automobiles in an hour is nearly identical for the three segments. For a 647 vehicle/hour, the passenger car unit, values for large cars, light traffic vehicles, heavy traffic vehicles, bikes, and LC have been steadily increasing. This could be due to the increasing carriageway width. The greater the carriageway's width, the greater the drivers' confidence to overtake, cross or keep their speed. This is not the case with LC. Their PCU value for LC has a greater increase for undivided roads. This could be due to the formation of traffic.

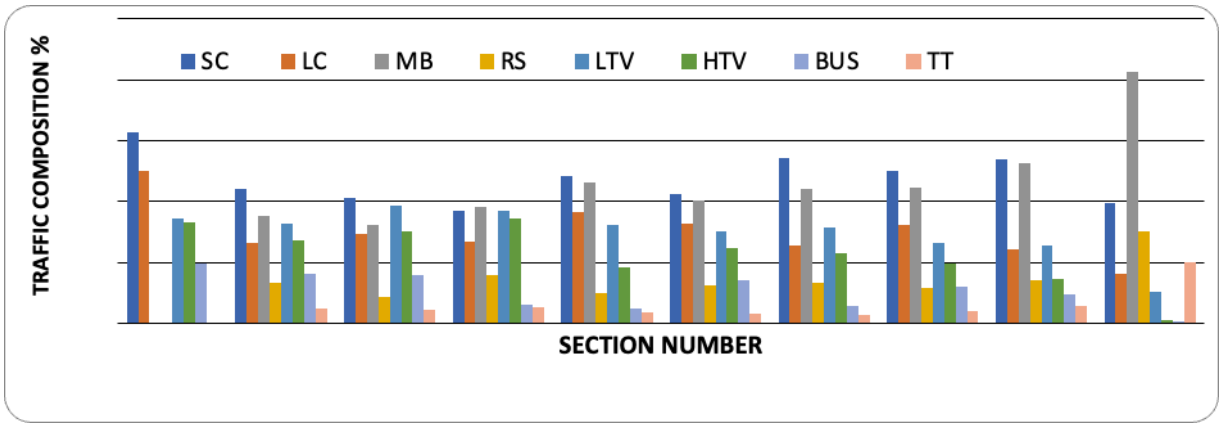

Fig-2: Display the graph between ten highway and their traffic composition

4. CONCLUSIONS

The results reveal how the passenger car unit of automobile changes based on the density of traffic, traffic formation, traffic moving in two or one directions, and the road breadth. On an undivided highway, the other driver's side frequently affects the driver. The significance of PCU across all vehicle types is higher for undivided segments than for divided segments. However, for BUS, this pattern reversed. Because BUS speed is higher on motorways (divided segment) than on an undivided segment, its velocity is the dominant factor. The value of passenger car unit for the large cars for the divided segment (1.3, 1.29) diminished when road breadth was reduced for a two-way segment; this will be similar to the large cars (1.36, 1.32). It is also dependent on how traffic is composed.

The passenger car unit value for the large cars in the 6-9 section is less because of various traffic compositions. The dimension of the car is the essential factor. Road width is also a factor in the PCU value of all kinds of vehicles. If roads are wider, the more congested the freedom will be, and there will be more places for automobiles to reach their highest speed. The passenger car unit, value for the large cars,

heavy traffic vehicles, and BUS rise by increasing the breadth of the road. This is not the case for less congested roads in the village. Since, in segment 10, the passenger car unit, the value for the entire automobile is highest; however, the road width is 4.5 meters. Because of diverse traffic, composition percentages and large size vehicles cannot reach the speed required in this section. Therefore, the speed ratio for big automobiles has increased in this area.

The findings of this research will benefit the national highway authority Pakistan and Punjab's communication and work department. The department could use these results to study future road capacity and traffic flow analysis.

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