Passenger Car Units for Heterogeneous Traffic Using a Modified Density Method

GEETAM TIWARI
Transportation Research Injury Prevention Program, IIT Delhi, India
JOSEPH FAZIO
Illinois Institute of Technology, Chicago, USA
SRI PAVITRAVAS
Civil Engineering Department, IIT Delhi, India

ABSTRACT

The upcoming *Highway Capacity Manual* (HCM) 2000 will use density method to derive its new, passenger-car equivalences (PCEs) for trucks. These PCEs appear as "E_T" in HCM tables. The density method assumes homogeneous traffic. Strict lane discipline characterizes homogeneous traffic. By adjusting the density method to handle heterogeneous traffic, one can derive more accurate passenger car units for Indian conditions. Very loose lane discipline describes heterogeneous traffic. Measuring the distribution of each Indian traffic type across the pavement width from different highway types allowed the adjustment. Motorized two-wheelers, cars, bicycles, farm tractors, trucks and other traffic types comprise Indian traffic. Data showed the 85th percentile distribution width of each traffic type can serve as a more accurate measure than the marked lane width when traffic is heterogeneous. The project team collected speed, flow and lateral placement data at 34 rural and suburban highway sites throughout India. These sites comprised six highway types. One can compare two "only passenger car" traffic streams with one being homogeneous and the other heterogeneous. This comparison occurs when the streams have equal average speed and demand. The area density of the heterogeneous traffic stream will be different from the homogeneous traffic stream area density because the pavement widths that each stream uses will be different. This difference results in a "passenger car unit" adjustment factor, f_{PCU}, to convert a passenger car in heterogeneous traffic into its homogeneous traffic counterpart. The study also rendered passenger car units for each Indian traffic type in relation to an Indian passenger car. Preliminary results show the adjustment necessary to convert Indian passenger cars in heterogeneous traffic into U.S. passenger car equivalents for homogeneous traffic. Derivations of passenger-car-unit adjustment factors showed that a car is equivalent to 2 cars in homogeneous traffic on single-lane highways, two-lane highway types without paved shoulders, with 1.5 meter shoulders and with 2.5 meter shoulders. On 1.5 lane highways and four-lane divided highways f_{PCU} value is 1, i.e., performance of heterogenous traffic and homogenous traffic are similar. These equivalents happen when the Indian cars move at the same space mean speed as cars in homogeneous traffic. The modified density method can be used to determine passenger car units for various traffic entity groups on rural and suburban roads in India.

1. INTRODUCTION

Many methods exist for determining passenger car units (PCUs), e.g., homogenization coefficient, semi-empirical method, Walker's method, headway method, and multiple linear regression method and simulation method (*1*,*2*). PCU is also known as passenger car equivalent (PCE). Another method is the density method. However, the PCU values derived from the density method are based on underlying homogeneous traffic concepts such as strict lane discipline, car following and a vehicle fleet that does not vary greatly in width. However, Indian highways carry heterogeneous traffic, where road space is shared among many traffic modes with different physical dimensions. Loose lane discipline prevails; car following is not the norm. Therefore methods based on homogeneous traffic concepts have limited applicability for heterogeneous traffic.

The density method proved most applicable to the study because it uses field data collected from National Highway and State Highway sites in India. However, since road traffic in India is quite heterogeneous when compared with the West's, one must modify the density method to account for heterogeneity.

Figure 1 illustrates the density method used for homogeneous traffic. An idealized traffic mixture of only passenger cars is equivocated with another 100 percent, homogeneous, traffic stream. This traffic stream consists of other traffic entity type, e.g., truck, bicycle, motorcycle, etc. The space means speed of the passenger-car traffic stream is 60 km/h (50 mph) in Figure 1(a). This mean speed implies that cars will maintain a specific, average gap. As mean passenger-car speed changes, the average spacing changes, i.e., density. Average spacing is the inverse of density. One converts density into average spacing using the following equation:

$$\bar{h}_{space} = \frac{1}{k} \tag{1}$$

where k is density (entities/km), and h_{space} is average front-bumper to front-bumper spacing (km). Base conditions for Indian multilane rural and suburban highways have the following characteristics:

- Level terrain, with grades no greater than 2 percent in the up or down directions,
- 3.5 meter (11.5 feet) lane widths,
- 1.5 meter (5 feet) paved shoulder widths low-design highway types,
- 2.5 meter (8.2 feet) paved shoulder widths for high-design highway types,
- No direct access point along the roadway,
- Only Indian passenger cars in a traffic stream and
- A free-flow speed that varies by highway type.

Comparing Figure 1(b) to Figure 1(a), one notices how the density method uses homogeneous traffic ideas. Figure 1(b) has the same lane width and length as Figure 1(a). It also has the same conditions, but Figure 1(b) has only trucks in its traffic stream. The passenger-car and truck streams have equal space mean speeds when using density method. One can equivocate the density of trucks to the density of passenger cars under homogeneous conditions to find the PCUs for trucks,

$$PCU_{truck} = \frac{k_{car} / W_L}{k_{truck} / W_L} \tag{2}$$

where k_{car} is the density of cars in pure homogeneous traffic (cars/km), W_L is the lane width (m) of the lane in homogeneous traffic, k_{truck} is the density of trucks in pure homogeneous traffic (trucks/km) and PCU_{truck} is the passenger-car unit for trucks given homogeneous traffic behavior. In the density-based PCU method for homogeneous traffic where car-following and lane-discipline behavior prevails, all traffic entities use an equal W_L.

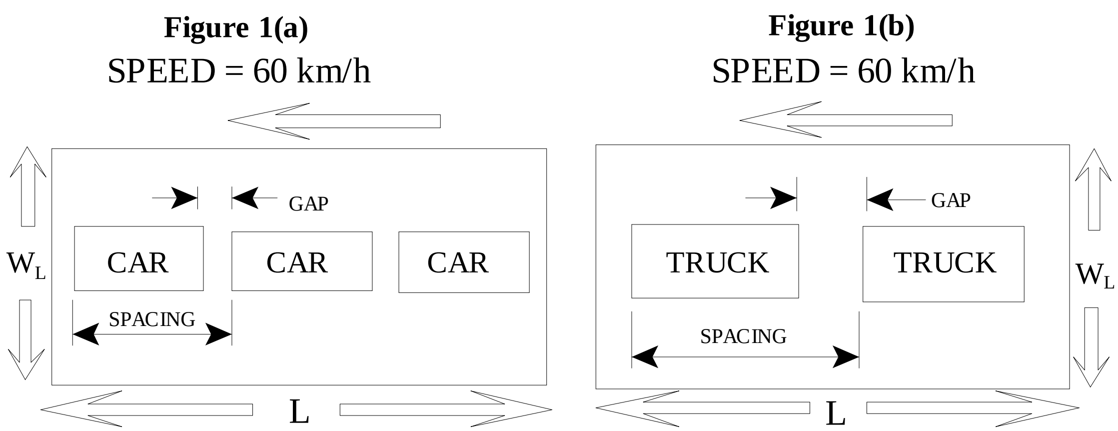

FIGURE 1 Homogeneous Traffic Density for PCU Estimation.

The average spacing or density of trucks changes depending on the grade and length of the grade according to the *U.S. Highway Capacity Manual* (*3*). For uniform upgrades, PCU_{truck} may go as high as 15.0. On uniform downgrades, PCU_{truck} can go as high as 7.5. However, all Indian study sites lay on level terrain; the effect of grade and grade length is negligible. For similar conditions and space mean speeds, the average truck gap approximately equals the average car gap. The following equation renders the truck equivalent (E_T) based on homogeneous traffic concepts.

$$PCU_{truck} = \frac{L_{truck}}{L_{car}} \tag{3}$$

Where L_{truck} is the average length of trucks (m), and L_{car} is the average length of the passenger car (m). In United States homogeneous traffic, the minimum PCU value is 1.5 for trucks on level terrain as shown in Figure 1 (*1*).

Figure 2(b) illustrates the base heterogeneous traffic conditions on Indian National Highways and State Highways. One characterizes heterogeneous traffic as having lane discipline that is relaxed. Complicated lane-changing and car-following behavior also characterizes heterogeneous traffic conditions. Heterogeneous traffic meets one of two conditions. One condition is that the peak-hour volume has less than 85 percent passenger cars. The other one is that the peak-hour volume has less than 90 percent cars, trucks and buses (4).

Figure 2(a) **Figure 2(b)**

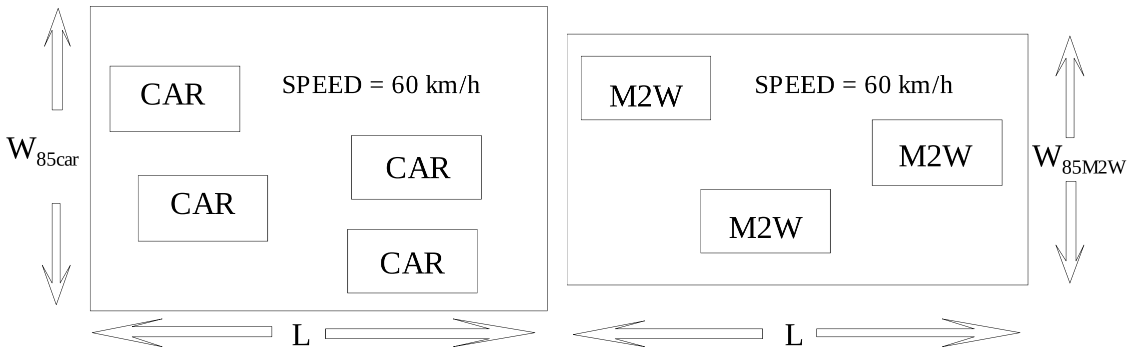

FIGURE 2 Car Density of Homogeneous Traffic for Estimating PCU of Car in Heterogeneous Traffic Stream.

One can modify the density method to adjust for heterogeneity in PCU calculations by making Figure 2(a) equivalent to Figure 2(b). In heterogeneous traffic, passenger cars do not use width as in homogeneous traffic. One uses the 85th percentile distribution width used by Indian passenger cars to reflect density over a highway area instead of just length. Table 1 shows an example of how 85th percentile traffic-entity distribution (the width utilized by 85 percentile traffic) is determined. Forty-eight such figures were examined based on a two-dimensional matrix, i.e., six highway types by eight traffic entity types. Twenty-three of the 48 figures showed that the rate of change stabilized at the 85th percentile distribution width. The 90th percentile tire distribution width came in second with 20 out of the 48 figures. Thus, holding space mean speeds equal, the 100 percent, homogeneous, traffic stream of passenger cars will, in general, have a higher density than passenger cars in heterogeneous traffic because the 85th percentile width is usually wider than a lane. Making homogeneous case equivalent to heterogeneous case produces the following relationship:

$$(f_{CPU})_j = \left[\frac{k_{car}/W_L}{k_{car}/W_{85car}}\right]_j \tag{4}$$

where, for highway type j, k_{car} is the density of passenger cars in heterogeneous traffic (entities/km), W_l is the base line width for passenger cars in homogeneous traffic conditions, W_{85car} is the 85th percentile car distribution width, i.e., 3.7 m (12 feet), and f_{pcu} is the passenger-car-unit adjustment factor. To determine PCUs for local Indian conditions one must make an Indian passenger car equivalent to one car in homogeneous traffic as shown in Figure 4. Translating the above equivalence using measures from data reduction yields the following relationship:

$$(PCU_{Xi})_j = \left[\frac{k_{car}/W_{85car}}{(q_{Xi}/u_{Xi})/W_{85Xi}}\right]_j \tag{5}$$

where, for the highway type j,q_{xi} is the flow of traffic entity group X_i in heterogeneous traffic (entities/hour) and u_{xi} is the space mean speed of traffic entity group X_i (km/h). W_{85Xi} is the 85th percentile distribution width (m) for traffic entity group Xi in heterogeneous traffic, and PCU_{Xi} is the passenger car unit for traffic entity group Xi. Most heterogeneous traffic does not use the delineated lanes marked on the pavement surface. Traffic entities of similar speeds and size pre-segregate into a natural distribution across the pavement width. One determines these distribution widths by entity group from observations noted on the Roadway Width Utilization and Occupancy Forms. From distributions, one calculates the 85th percentile distribution widths that each entity group uses, as shown in Table 1. These percentile distribution widths depend on the distribution of the front tire or left front tire lateral pavement placement of traffic entity. In summary, one derives W_{85Xi} from observation notes on the Roadway Width Utilization and Occupancy Form and derives average traffic group widths from other measurements. One calculates the k_{Xi} values using data recorded from observations on the Traffic Count Form and Speed Form.

TABLE 1 Road Width Used by Traffic Entity Group

		HV[2]	LV	TRAC	CAR	M3W	M2W	NM2W	ONME
Width of vehicle		2.50	2.15	1.80	1.50	1.35	0.78	0.65	1.00
Single lane	W85%[1]	7.50	6.15	3.80	5.50	4.35	4.28	6.15	1.00
Intermediate lane	W85%	5.00	5.65	1.80	4.50	5.35	3.78	5.65	1.00
Two lane without shoulders	W85%	9.50	9.15	8.80	7.50	7.35	6.28	8.65	9.50
Two lane with 1.5 m shoulders	W85%	6.50	6.15	5.80	6.50	6.35	4.28	3.15	5.50
Two lane with 2.5 m shoulders	W85%	5.50	5.15	5.30	6.00	5.85	1.78	5.15	2.50
Four-lane divided highway	W85%	8.50	9.15	7.80	5.50	5.35	5.78	4.15	7.00

[1]W85% is the width utilized by 85% of the entities on the road.
[2]HV, heavy vehicles; LV, light vehicles, TRAC, tractor; CAR, cars, jeeps; M3W, motorized three wheeler; M2W, motorized two wheeler; NM2W, nonmotorized two wheeler (bicycle); ONME, other nonmotorized entities, e.g., animal carts.

2. METHODOLOGY

For estimating PCUs using adjusted density method, all traffic entities that comprised the heterogeneous traffic at 34 Indian highway sites were segregated into eight groups along with the traffic entity types in each group, which are as follows:

1. Heavy vehicle (HV): Bus, single-unit truck and trailer truck
2. Light vehicle (LV): Minitruck, light pick-up truck and minitruck

3. Tractor (TRAC):	Tractor, farm equipment vehicle and construction equipment vehicle
4. Car (CAR):	Car, jeep and van.
5. Motorized two-wheeler (M2W):	Scooter, motorcycle and moped
6. Motorized three-wheeler (M3W):	Auto rickshaw and tempo
7. Non-motorized two-wheeler (NM2W):	Bicycle
8. Other non-motorized entities (ONME):	Pedestrian, human powered cart, animal, animal cart and pedal rickshaw.

A camcorder recorded traffic on videotape during peak periods along with a time stand. Classifying the site by Indian highway type and roadside development produced a two-dimensional design of experiment matrix. Sites, which had roadside shops, parking, etc., were suburban sites. Sites which did not have any activity causing side friction to traffic stream were rural sites. The matrix had six highway types and two roadside development characteristics :

1. Single lane (3 rural, 1 suburban)
2. Intermediate lane (3 rural, 3 suburban)
3. Two lane without paved shoulders (3 rural, 3 suburban)
4. Two lane with 1.5 m paved shoulders (2 rural, 3 suburban)
5. Two lane with 2.5 m paved shoulders (2 rural, 1 suburban)
6. Four-lane divided (5 rural, 5 suburban).

From the videotapes one obtained traffic characteristics like volume, speed and density for each entity type on the six different highway types. Table 2 gives vehicle speed. The densities of various vehicle types during peak hour are listed in Table 3.

The modified density method requires comparison of density of various traffic entity types at the same speed. Therefore Table 4 gives estimated car density at speeds of other vehicle types present on the site. This is estimated by plotting car density vs. car speed graph and interpolating the density at the corresponding average speed of other vehicle type. The density of other non-motorized entities is found to be very small primarily because these entities do not use the paved shoulders or pavement. For some of the highway types, the density value for other non-motorized vehicles could not be calculated due to insufficient sample size. Table 5 shows density adjustment to unit width of road entities/km/m.

TABLE 2 Average Speed (km/h) on Six Highway Types

Highway Type	HV	LV	TRAC	CAR	M2W	M3W	NM2W	ONME
Single lane	33.6	33.1	28	43.4	35.2	29.3	10.9	NA
Intermediate lane	37.5	31.2	23.6	37.2	27.3	27.9	13.9	NA
Two lane without shoulders	46.8	39.6	20.2	53.8	43	29.9	13.5	NA
Two lane with 1.5 m shoulders	41.4	21.9	25.9	52.2	36.7	29.7	12.6	NA
Two lane with 2.5 m shoulders	52.2	43.5	15.9	55.5	38.4	34.2	14.3	6.8
Four-lane divided	51.5	50.8	22.4	62.5	38.5	31.1	13.9	9

TABLE 3 Density in Peak Hour (entities/km) on Six Highway Types

Highway Type	HV	LV	TRAC	CAR	M2W	M3W	NM2W	ONME
Single lane	0.36	0.14	0.05	0.12	0.81	0.11	0.31	0
Intermediate lane	0.71	0.13	0.5	0.49	1.03	0.32	1.26	0
Two lane without paved shoulders	1.51	0.37	1.24	1.07	1.5	0.19	2.59	0
Two lane with 1.5 m paved shoulders	3.62	0.91	0.25	2.56	1.48	2.23	3.31	0.4
Two lane with 2.5 m paved shoulders	2.22	0.7	0.42	4.05	3.68	0.45	3	0.93
Four-lane divided	2.05	0.67	0.72	2.33	2.13	0.44	1.89	0.43

TABLE 4 Density Forecast for Car (car/km)

Highway Type	HV	LV	TRAC	CAR	M3W	M2W	NM2W	ONME
Single lane	0.2	0.2	0.24	0.12	0.23	0.19	0.38	NA
Intermediate lane	0.49	0.49	0.49	0.49	0.49	0.49	0.48	NA
Two lane without shoulder	1.3	1.55	2.2	1.07	1.87	1.43	2.42	NA
Two lane with 1.5 m shoulder	4.41	7.1	6.54	2.94	6.02	5.06	8.37	4.89
Two lane with 2.5 m shoulder	4.62	6.19	11.12	4.05	7.85	7.1	11.4	12.74
Four-lane divided	2.91	2.95	4.61	2.27	4.1	3.67	5.11	5.4

It is important to note that one ensures that the unit width densities in the equations are determined from approximately equal speeds. One calculates density of cars for homogeneous conditions from the ratio of the average passenger car flow for the highway type to speed of cars. Division of this value of density by the standard lane width of cars, i.e., 3.7 m (12 ft) produces the density-lane width ratio (k_{car}/W_L) for cars as shown in Table 6. Table 7 shows unit width density using 85th percentile of other traffic entities. Table 8 gives unit width density forecast for car. For the determination of the PCU values of the various traffic entity groups, one uses the unit width densities, k_{car}/W_L. Table 9 shows these PCU values.

TABLE 5 Density Adjustment to Unit Width (entities/km/m)

Highway Type		Traffic Entity Group							
		HV	LV	TRAC	CAR	M3W	M2W	NM2W	ONME
Single lane	Density	0.36	0.14	0.05	0.12	0.11	0.81	0.31	0
	W_{85xi}	7.50	6.15	3.80	5.50	4.35	4.28	6.15	1.00
	k_{Xi} / W_{85xi}	0.05	0.02	0.01	0.02	0.03	0.19	0.05	0.00
Intermediate lane	Density	0.71	0.13	0.5	0.49	0.32	1.03	1.26	0
	W_{85xi}	5.00	5.65	1.80	4.50	5.35	3.78	5.65	1.00
	k_{Xi} / W_{85xi}	0.14	0.02	0.27	0.10	0.05	0.27	0.22	0
Two lane without paved shoulder	Density	1.51	0.37	1.24	1.07	0.19	1.5	2.59	0
	W_{85xi}	9.50	9.15	8.80	7.50	7.35	6.28	8.65	9.50
	k_{Xi} / W_{85xi}	0.15	0.04	0.14	0.14	0.02	0.23	0.29	0
Two lane with 1.5 m paved shoulder	Density	3.62	0.91	0.25	2.56	2.23	1.48	3.31	0.4
	W_{85xi}	6.15	5.80	6.50	6.35	4.28	3.15	5.50	5.50
	k_{Xi} / W_{85xi}	0.58	0.15	0.03	0.40	0.52	0.46	0.60	0.07
Two lane with 2.5 m paved shoulder	Density	2.22	0.7	0.42	4.05	0.45	3.68	3	0.93
	W_{85xi}	5.50	5.15	5.30	6.00	5.85	1.78	5.15	2.50
	k_{Xi} / W_{85xi}	0.40	0.13	0.07	0.67	0.07	2.06	0.58	0.37
Four-lane divided	Density	2.05	0.67	0.72	2.33	0.44	2.13	1.89	0.43
	W_{85xi}	8.50	9.15	7.80	5.50	5.35	5.78	4.15	7.00
	k_{Xi} / W_{85xi}	0.24	0.07	0.09	0.42	0.08	0.36	0.45	0.06

TABLE 6 Unit Width Density Using Homogenous Traffic Lane Width

Highway Type	k_{car}	k_{car}/W_L (3.7 m)
Single lane	0.12	0.03
Intermediate lane	0.49	0.13
Two lane without shoulders	1.07	0.29
Two lane with 1.5 m shoulders	2.56	0.69
Two lane with 2.5 m shoulders	4.05	1.09
Four-lane divided	2.33	0.63

TABLE 7 Unit Width Density Using 85th Percentile Road Width (entity/km/m)

Highway Type		Traffic Entity Group							
		HV	LV	TRAC	CAR	M3W	M2W	NM2W	ONME
Single lane	k_{Xi} / W_{85xi}	0.05	0.02	0.01	0.02	0.03	0.19	0.05	0.00
Intermediate lane	k_{Xi} / W_{85xi}	0.14	0.02	0.28	0.11	0.06	0.27	0.22	0.00
Two lane without shoulders	k_{Xi} / W_{85xi}	0.16	0.04	0.14	0.14	0.03	0.24	0.30	0.00
Two lane with 1.5 m shoulders	k_{Xi} / W_{85xi}	0.59	0.16	0.04	0.40	0.52	0.47	0.60	0.07
Two lane with 2.5 m paved shoulders	k_{Xi} / W_{85xi}	0.40	0.14	0.08	0.68	0.08	2.07	0.58	0.37
Four-lane divided	k_{Xi} / W_{85xi}	0.24	0.07	0.09	0.42	0.08	0.37	0.46	0.06

TABLE 8 Unit Width Density Forecast for Car (car/km/m)

Highway Type	Traffic Entity							
	HV	LV	TRAC	CAR	M2W	M3W	NM2W	ONME
Single lane	0.06	0.06	0.07	0.04	0.05	0.07	0.11	NA
Intermediate lane	0.14	0.14	0.14	0.14	0.14	0.14	0.14	NA
Two lane without shoulders	0.37	0.44	0.63	0.19	0.41	0.54	0.69	NA
Two lane w/1.5 m shoulders	1.26	2.03	1.87	0.65	1.45	1.72	2.39	1.4
Two lane w/2.5 m shoulders	1.32	1.77	3.18	0.9	2.03	2.24	3.26	3.64
Four-lane divided	0.83	0.84	1.32	0.6	1.05	1.17	1.46	1.45

TABLE 9 Passenger Car Units for Different Highway Type

Highway type	Traffic Entity Group							
	HV	LV	TRAC	CAR	M2W	M3W	NM2W	ONME
Single lane	0.9	2.0	7.0	0.8	0.1	1.4	1.6	—
Intermediate lane	0.7	4.7	1.2	1.0	0.4	1.8	0.3	—
Two lane without shoulders	1.9	8.8	3.5	1.0	0.8	10.8	1.2	—
Two lane w/1.5 m shoulders	1.6	11.3	31.2	1.1	2.7	2.6	1.9	15.6
Two lane w/2.5 m shoulders	2.4	11.8	35.3	1.0	2.4	28.0	1.8	7.9
Four-lane divided	2.4	10.5	12.0	1.0	1.4	11.7	2.8	24.2

3. RESULTS

Table 9 shows the PCU values for different entity types approximated to one decimal, of all the eight traffic entity types found on six highway types at the 34 rural and suburban highway sites. Table 10 gives the passenger car unit along with share of traffic entity present on the road. Table 11 gives adjustment facto f_{PCU}, to allow conversion between heterogeneous traffic and homogeneous traffic.

TABLE 10 Passenger Car Units for Different Highway Type vs. Share of Different Traffic Entity

	Traffic Entity Group							
Highway Type	HV (%)	LV (%)	TRAC (%)	CAR (%)	M2W (%)	M3W (%)	NM2W (%)	ONME (%)
Single lane	0.7 (19)	1.8 (7)	4.4 (3)	1.1 (6)	0.2 (43)	1.4 (6)	1.4 (16)	
Intermediate lane	0.8 (16)	5.4 (3)	0.4 (11)	1.0 (11)	0.4 (23)	1.8 (7)	0.5 (28)	
Two lane without shoulders	1.1 (18)	5.2 (4)	2.1 (15)	1.0 (13)	0.8 (18)	8.3 (2)	1.1 (31)	
Two lane with 1.5 m shoulders	1.2 (25)	6.8 (6)	25.2 (2)	1.1 (17)	1.7 (10)	1.8 (15)	2.1 (22)	11 (3)
Two lane with 2.5 m shoulders	1.9 (14)	7.4 (5)	23.2 (3)	1.0 (26)	0.6 (24)	16.3 (3)	3.3 (19)	6 (6)
Four-lane divided highway	2.2 (19)	7.7 (6)	9.3 (7)	1.0 (22)	1.8 (20)	9.3 (4)	2.0 (18)	16 (4)

TABLE 11 Conversion Factor from Heterogeneous to Homogeneous Traffic

Highway Type	f_{PCU}
Single lane	2
Intermediate lane	1
Two lane without shoulders	2
Two lane with 1.5 m shoulders	2
Two lane with 2.5 m shoulders	2
Four lane	1

4. CONCLUSIONS

The results in Table 9 show that as highway types vary in width and on-coming traffic friction, there are significant differences among the Indian highways types. Cars tend to occupy more space on highways that have greater widths. Lesser width forces cars to form tighter 85th percentile widths and hence occupy less space. Not only do the cars occupy more area on wider highways, but even other vehicle types do so as is evident from the higher PCU value on wider highways as compared to single-lane highways. Variation in PCU values for different vehicle type is explained by share of vehicle type present on the road.

Table 10 shows very high PCU value for tractors when the share of tractor is below 3% of the total traffic. Similarly PCU value of motorized three wheeler is also very high when the density share of three wheeler is low (<3%). This shows that vehicles with varying static and dynamic characteristics affect the capacity of the road even at low densities. A slow moving tractor has high PCU value when overtaking oppurtunities are less (undivided roads). The PCU value for the tractor group on the two lane with 2.5 m paved shoulders is the highest. One expected this as tractor density in Table 3 shows that the density of the tractor group on this highway is very low and the spread of the 85th percentile width distribution is high. Table 11 shows that a single Indian passenger car in heterogeneous conditions is equivalent to more than one passenger car in homogeneous conditions (1.2–1.5 PCU) on two lanes without shoulders. However on single-lane highway it is 0.6 of homogenous car and intermediate lane and four-lane highway it is same as homogenous car. For all 34 sites, one observed almost no break down in traffic during the peak periods of videotaping, 1.5 hours to 3 hours in duration. Free flow conditions generally prevailed at the rural and suburban sites, even the single-lane and intermediate-lane highway type sites.

By using f_{pcu} in Table 11, one can convert heterogeneous traffic based PCUs into their homogeneous counterparts. One can calculate the conversion values by multiplying f_{pcu} by the PCU value mentioned in Table 8 for a particular heterogeneous traffic group. For homogeneous traffic, on can calculate PCUs assuming a standard lane width of 3.7 m. However, based on data collected at four-lane divided sites throughout India the 85th percentile distribution width of passenger car group for four-lane divided highway was 5.5 m (18 feet). Stated another way, 85 percent of the passenger cars used a pavement width of 5.5 m out of a total pavement width of 12 m (39 feet). The resulting PCU and f_{pcu} values are applicable to those Indian highway types in rural and suburban areas. The values do not apply to urban facilities. The f_{pcu} values in Table 9 also show how traffic dynamics change for each Indian highway type. The closer the values are to one, the more the Indian heterogeneous traffic behaves like homogeneous traffic.

Multiply f_{pcu} by the Indian PCU in Table 11 to convert heterogeneous traffic to its homogeneous equivalent. For example 120 Indian passenger cars, 50 Indian heavy vehicles and 25 Indian motorized two-wheelers in one direction on a four-lane divided highway are equivalent to 275 cars in homogeneous traffic, as shown in the equation below:

$(120 + 50*2.2 + 25*1.8)*1 = 275$ cars in homogeneous traffic.

Same traffic on a two-lane road without shoulders is $(120 + 50*1.1 + 25*0.8)*2 = 390$ cars in homogenous traffic. For the same width of roadway and equal average speeds, heterogeneous traffic in rural and suburban facilities have more traffic entity throughput than homogeneous facilities, i.e., higher capacity.

The traffic engineer can use this equivalent into transportation software applications and models that are calibrated using homogeneous traffic.

Large PCUs of slow moving vehicles even at low density explains that these vehicles. consume a disproportionately high capacity of the road on highways where traffic stream includes a variety of modes. This is true in a large number of low income Asian and African countries. A homogenized behavior of vehicles and their drivers could contribute to increased capacities. Findings of the present study make a strong case for including service lanes for slow moving vehicles for improving the capacity of highways. If the service lane design is successful in attracting all slow moving traffic, e.g., bicycles, animal carts, and tractors away from the main carriageway, large capacity would be released on the main highway for motorized vehicles. The speed variation of traffic on the main carriageway would be reduced leading to fewer conflicts and improved speeds of the traffic stream. Provision of a service lane which can serve slow and local traffic, as a capacity enhancement strategy would have higher benefit cost ratio as compared to adding an extra lane on the main carriageway without a service lane. For example, a four-lane divided highway with service lanes will be a better option than six-lane divided highway without service lanes.

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