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Analysis of traffic characteristics of intercity highway

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ABSTRACT

Majority of Indian National Highways and State Highways are two-lane roads. Due to heterogeneous traffic and increase in the number of vehicles every year, the speed, capacity and Percentile speed of these roads is very less. Nowadays these two-lane roads are upgraded into multilane highways. In this project, an attempt is made to study the changes in traffic characteristics of the road after its up gradation. Four traffic characteristics namely Spot Speed, Volume, Percentile Speed and Capacity are studied in this project. Data were collected from National Highway No. 361 which was two-lane road and is now upgraded into a four-lane road. The data on two-lane road and four-lane road was compared and analysed. Spot Speed is used to derive the distribution of traffic stream at a particular location. Flow or volume denotes the number of vehicles travelling on the road with respect to time. 15th, 50th, 85th percentile speed was calculated to study the traffic behaviour on road. Capacity was calculated by using Greenshield's model.

Keywords— *Heterogeneous, Speed, Flow, Capacity, Percentile speed, Density.*

1. INTRODUCTION

For the economic development of any region, transportation is vital as it is required for carrying raw materials and finished goods from one region to another region. There are four major modes of transportation that are Roadways, Railways, Airways and Waterways. Of all the above modes the only mode which gives maximum service is the roadways. There has been substantial development in the field of road construction from its material use, modern road construction methods, use of modern equipment to the increase in carriageway width. India has one of the largest road networks in the world. Based on the carriageway width they are also classified as single-lane, two-lane or multilane roads. Intercity roads mostly consist of National highways and State highways which are used to connect two or more major cities. One-third of National Highways and more than half of the State Highways in India are still two-lane roads. Due to the increase in traffic in India, the two-lane roads are inefficient to handle the traffic. The frequent interaction among vehicles from both directions affects the performance of such roads. Nowadays large up gradation projects are taken by the government to convert the two-lane road into multilane roads. The purpose of this project is to study the changes in traffic characteristics of intercity highways after its up-gradation from the two-lane road into a four-lane road. The data for speed and volume from National Highway No. 361 which was two-lane road and is up graded into the four-lane divided carriageway. After the calculation of speed and volume, the data was further analysed to calculate Percentile speed and Capacity of both the road sections. Four traffic characteristics namely Spot Speed, Volume, Percentile Speed and Capacity are studied in this project. Speed is an important factor in terms of safety, comfort, time and economics. It is used to record speed characteristics at a traffic location under prevailing traffic conditions. Flow or volume denotes the number of vehicles travelling on the road with respect to time. The capacity and Percentile Speed of the road changes correspondingly with the change in carriageway width. An attempt has been made to study the changes in traffic characteristics after the up gradation of road.

2. LITERATURE REVIEW

Speed is one of the important characteristics of the traffic. Many Indian researchers have given various methods to calculate the speed of the traffic on Indian roads. M. Mardani, S. Chandra and I. Ghosh (2015) calculated Passenger car unit of vehicles on undivided intercity roads in India. For the data collection, 10 road section all over India were taken of which four were two-lane roads, another four were intermediate-lane roads and two were single-lane roads. For estimation of Passenger Car Unit, Chandra's formula was used. Then the PCU values of different types of roads were compared and studied. Ashish Dhamaniya and Satish Chandra (2013) calculated percentile Speeds in their paper namely "Speed characteristics of mixed traffic flow on urban arterials". Speed and volume data was collected by video graphics technique. Then the speed data was converted into a frequency distribution table. Then using this frequency table 15th, 50th, 85th speed percentile was calculated. In this paper, a new term called Speed Spread Ratio (SSR) is introduced which is given by,

$$SSR = \frac{V_{85} - V_{50}}{V_{50} - V_{15}}$$

Speed data are truly normally distributed if SSR is unity. Speed data follows a normal distribution only when SSR is in the range of 0.86 – 1.11. Javid Ahmad Khan and Shahid Rasool Tarry (2018) compared time mean speed and space mean speed for the speed spot study. Spot speed was calculated on a major road in western India. A sample size of 50 vehicles which included 10 samples of trucks, buses, 4 wheelers, 3 wheelers, 2 wheelers were taken on the site. Normal distribution and cumulative frequency distribution were carried out to find speed percentiles from spot speed data. It was found that Time means speed is always greater than Space mean speed. Chandra and Kumar calculated capacity on 10 different highways of Northern and Eastern India. The carriageway width of the roads varied from 5.5m to 8.8m. Spot speed data was calculated by using videography technique. The recording was done for 4 to 5 hrs on typical weekdays. PCU was calculated by using the previous equation given by Chandra and Kumar. For speed-volume relationship and capacity, calculation means stream speed was calculated. It is given by,

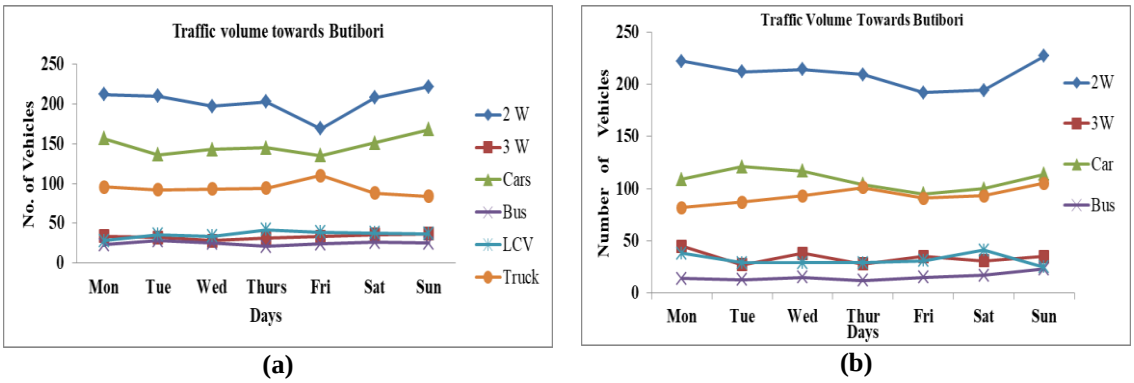
$$Vm = \frac{\sum_{i=1}^{k} ni * vi}{\sum_{i=1}^{k} ni}$$

Using this equation mean stream speed was calculated. It was further used to calculate Capacity graphs of all the sections. A relationship was derived for adjustment factor of lane width. Arpit Sharma and N. G. Raval (2018) calculated Level of Service for the road sections in Ahmedabad city in their research work. In this study, a six-lane divided sub-arterial road of 2km length was selected in Ahmadabad city. The traffic survey was conducted for morning and evening peak and non-peak hours to calculate speed and Volume. Then Space mean speed was calculated and using it Capacity graphs were plotted. Then by using V/C ratio and space mean speed a graph is plotted for different types of Level of Service. LOS A to LOS F has been defined using the graph. Nabanita Roy, Rupali Roy, Talukdar and Saha (2017) studied the capacity and Speed percentile on Indian Highways. The traffic data was collected on typical weekdays during the daytime. Video graphic Survey was used to calculate Speed and Volume. Speed-flow equations were developed on the basis of Green shields model for calculation of Capacity.

3. STUDY AREA AND DATA COLLECTION

For the study purpose, National Highway No. 361 connecting cities of Butibori (Nagpur) and Wardha was selected. It was a two-lane road of 60km which is upgraded into a four-lane road. A section of 200m of the road was selected for collecting data after the survey of the road. The 200m section was so selected that it was free from any villages, bus stops, petrol pumps. The pavement on the section was in good condition so as to get the ideal traffic data. The site was so selected that the directional split of traffic was 50 to 55%. For two-lane road, the earthen shoulders were in good conditions with 1.2m width on either side. The carriageway width of the two-lane road varied from 6.7m to 7.1m. The carriageway width of the four-lane road is 20m with 9m on each side and 2m Divider. For four-lane road 1.5m paved shoulder is provided with a lane width of 3.75m.

A video camera was used to collect the speed and volume data. A trap of 40m was made at the middle of the 200m stretch for the measurement of spot speed. The video camera was fixed on a tripod and placed at a sufficient distance from the road so as to cover the 40m length and some margin on either side. The camera was placed at such a location that it will not cause disturbance to the ongoing traffic. The recording on the camera was done for one hour during daytime off-peak hours for seven days of the week. The recorded film was played on a Computer screen to extract volume and speed data. The vehicles were divided into six categories mainly 2 Wheeler, 3 Wheeler, Car, Bus, Light Commercial Vehicle (LCV) and Truck. The traffic data was split according to the direction that is, traffic flow towards Butibori and traffic flow towards Wardha. The one-hour recording was divided into fifteen 5 minute count for each type of vehicles. The 1-minute count is done for capacity calculations. The time taken by each vehicle to travel the trap length was calculated with an accuracy of 0.01sec by using a stopwatch.



(a) **(b)**

Fig. 1: Traffic flow from Wardha to Butibori on (a) two-lane and (b) four-lane road

The total traffic count data for one hour on all seven days of the week is shown in figure 1(a) and 1(b) for both two-lane road and four-lane road. The maximum flow on both roads is observed on Sunday. From figure 1 the major proportion of vehicle on National Highway No. 361 is 2 wheelers and cars.

The spot speed data is extracted from a video recording. The speed of each and every vehicle is calculated individually. The average spot speed of each of the vehicle category for seven days is calculated and represented in Table1. It represents the average spot speed of the vehicle from Wardha to Butibori. Such type of data extraction was done for all days and for both sides separately. For the calculation of speed percentile, the numbers of vehicles were distributed into speed ranges as shown in table 2. For cumulative distribution, it is necessary to calculate the number of vehicles in each of the speed range.

Table 1: Average Speed from Wardha to Butibori

Speed Parameter (km/hr)						
Days	**2 Wheelers**	**3 Wheelers**	**Cars**	**Bus**	**LCV**	**Truck**
Monday	40.62	31.78	51.56	42.81	40.63	35.23
Tuesday	40.64	33.42	51.58	42.44	40.53	35.38
Wednesday	42.07	35.60	53.65	46.32	41.29	34.51
Thursday	42.48	34.81	53.31	39.21	41.08	33.72
Friday	42.59	30.89	55.81	38.83	44.30	35.01
Saturday	41.50	31.61	54.76	41.20	39.87	30.96
Sunday	40.64	32.03	51.23	37.73	42.89	35.74

Table 2: Speed distribution on Sunday

Speed Range		**2 Wheeler**		**3 Wheeler**		**Car**		**Bus**		**LCV**		**Truck**	
From	**To**	**North**	**South**	**North**	**South**	**North**	**South**	**North**	**South**	**North**	**South**	**North**	**South**
20	**25**	1	0	0	0	0	0	0	0	0	0	9	24
25	**30**	7	2	10	5	0	0	1	0	0	0	15	36
30	**35**	35	32	18	12	2	4	6	6	1	2	31	20
35	**40**	71	70	7	9	12	12	5	5	4	6	32	12
40	**45**	60	55	0	1	22	23	3	4	12	7	13	3
45	**50**	30	36	0	0	24	12	2	3	7	6	5	2
50	**55**	16	26	0	0	21	39	0	0	1	2	0	0
55	**60**	7	13	0	0	13	16	0	0	0	0	0	0
60	**65**	0	1	0	0	7	4	0	0	0	0	0	0
65	**70**	0	0	0	0	7	10	0	0	0	0	0	0
70	**75**	0	0	0	0	1	2	0	0	0	0	0	0
75	**80**	0	0	0	0	4	2	0	0	0	0	0	0
80	**85**	0	0	0	0	0	0	0	0	0	0	0	0
85	**90**	0	0	0	0	0	0	0	0	0	0	0	0
90	**95**	0	0	0	0	0	1	0	0	0	0	0	0
95	**100**	0	0	0	0	0	0	0	0	0	0	0	0
100	**105**	0	0	0	0	1	0	0	0	0	0	0	0
105	**110**	0	0	0	0	0	0	0	0	0	0	0	0
Total		**227**	**235**	**35**	**27**	**114**	**125**	**17**	**18**	**25**	**23**	**105**	**97**

For the plotting of graph of speed percentile, we need to do the statistical analysis of the cumulative percentage of vehicles on two-lane road and speed data. The cumulative percentage table is prepared for each individual vehicle category. Table 3 represents the cumulative percentage of 2 wheelers only. The class frequency according to the speed range is obtained from above table 2. The class frequency of two-wheelers is combined for both the directions. Percentage of observation in class, mentioned in column no.4 is obtained by dividing each class frequency with the total number of vehicles (462) calculated at the bottom.

Table 3: Cumulative percentage of 2 Wheeler on a two-lane road

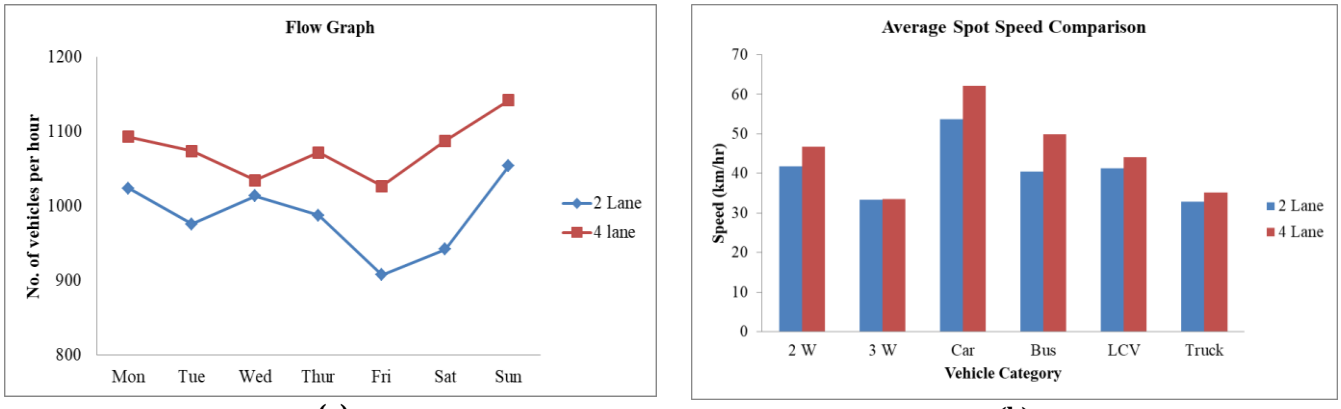
Speed Class (km/hr)	**Class Mid value Vi**	**Class Frequency fi**	**Percentage of observation in class**	**Cumulative percentage of all observation**	**Speed**
20 - 24.99	22.5	1	0.22	0.22	20
25 - 29.99	27.5	9	1.95	2.16	25
30 - 34.99	32.5	67	14.50	16.67	30
35 - 39.99	37.5	141	30.52	47.19	35
40 - 44.99	42.5	115	24.89	72.08	40
45 - 49.99	47.5	66	14.29	86.36	45
50 - 54.99	52.5	42	9.09	95.45	50
55 - 59.99	57.5	20	4.33	99.78	55
60 - 64.99	62.5	1	0.22	100	60
65 - 69.99	67.5	0	0	100	65
70 - 74.99	72.5	0	0	100	70
75 - 79.99	77.5	0	0	100	75
80 - 84.99	82.5	0	0	100	80
85 - 89.99	87.5	0	0	100	85
Total		**462**			

4. RESULTS AND DISCUSSIONS

4.1 Speed and Flow

The spot speed of two-lane and four-lane highways are compared in the figure 2(a). From figure 2(a) we can derive that the spot speed on a two-lane road is less than the four-lane road. There is an increase in the speed of the entire vehicle category except for the 3 Wheelers. The speed of three wheelers on two-lane and the four-lane road is the same. This shows that the vehicles

responsible for the blockage of the flow of traffic on two-lane roads are 3 Wheelers and trucks. The average percentage increase in the speed of the vehicles is about 11.7%. The Flow of the traffic has increased on the four-lane road as compared to the two-lane road as shown in figure 2(b). Due to more carriageway width and an extra lane provided to the users, the speed and flow have somewhat increased on the four-lane road. Users prefer this road more as compared to the old two-lane road. As compared to other parameters volume increase is the only nominal that is only 8% volume has increased.

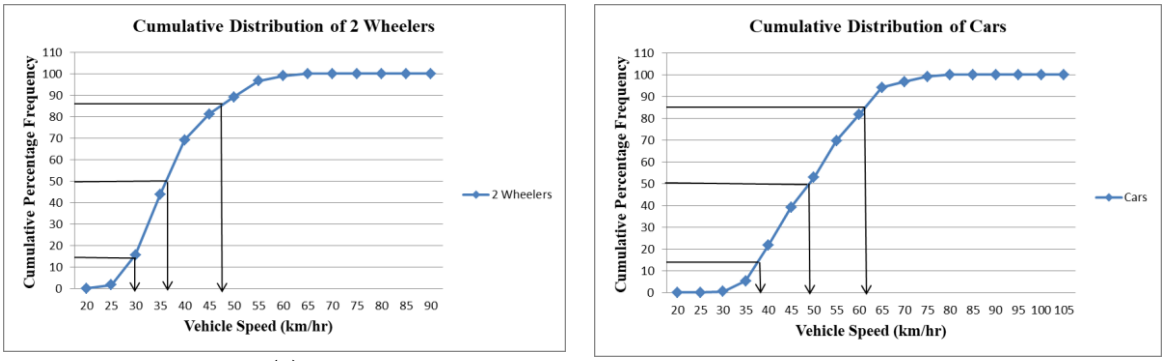


(a) **(b)**

Fig. 2: Comparison of two-lane and four-lane road (a) Spot Speed and (b) volume

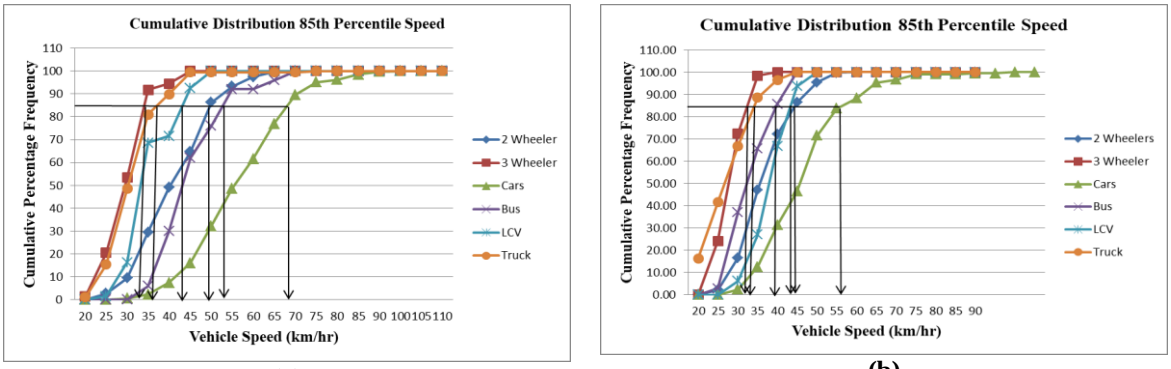
4.2 Speed Percentile

The Speed Percentile is used to calculate the effective and adequate speed limits. The three most important speed percentiles are 15th, 50th and 85th percentile speed. The 50th percentile speed denotes the median speed while 85th-speed percentile denotes that 85% of the vehicle is travelling below this speed. This percentile speed is used for the maximum speed limit. In this study, the speed percentile of individual vehicles are shown in figure 3 (a) and (b) for a two-lane road. From figure 3 (a) we can say that the 85th percentile speed of 2 Wheelers on two-lane roads is 48km/hr and 50th percentile speed is 36km/hr. For cars, the 85th percentile speed is 65km/hr on two-lane roads as shown in figure 3 (b)



(a) **(b)**

Fig. 3: Cumulative Distribution of (a) Cars and (b) 2 Wheelers

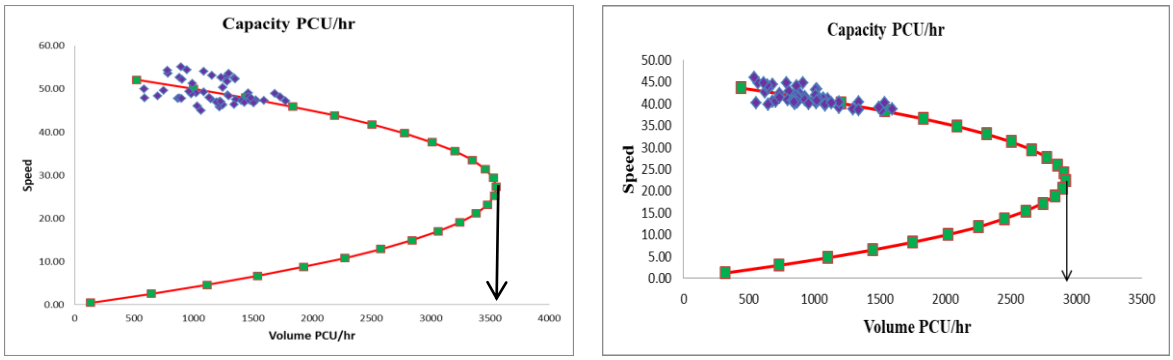


(a) **(b)**

Fig. 4: 85th Percentile Speed of (a) Two-lane road and (b) Four-lane road

The 85th speed percentile of all the vehicles is plotted in the figure 4 (a) for Sunday on a two-lane road. The 85th percentile speed of cars is 56km/hr as shown in figure 4 (a). While that of LCV and 2 Wheeler is 44km/hr. For buses, 85th-speed percentile is 40km/hr. It is lowest for 3 Wheelers and truck which is33km/hr and 34km/hr respectively on a two-lane road. The 85th speed percentile of all the vehicles is plotted in the figure 4 (b) for Sunday on a four-lane road. The 85th percentile speed of cars is 68km/hr as shown in figure 4 (b). For 2 Wheelers it is 50km/hr and buses it is 53km/hr. The 85th speed percentile of LCV is 44km/hr from figure 4 (b). It is lowest for 3 Wheelers that is 33km/hr and truck which is 36km/hr on a four-lane road.

4.3 Capacity



(a) **(b)**

Fig. 5: Capacity graph

Capacity graph is derived from speed density relationship. Greenshields model is used to derive Capacity from the speed density relationship. To draw the capacity graph we need a k-v relationship. It is a graph plotted between Density (k) and Speed (v). The capacity graph is drawn by using the k-v graph and its equations. A parabolic curve is obtained after plotting the speed and volume values for Capacity. Figure 5. the capacity of Wardha-Butibori lane in PCU/hr (a) two-lane road and (b) Four-lane road. The mean stream speed was plotted against the traffic volume. The curve in figure 5 (a) and (b) shows the speed-volume relationship. The maximum point on the graph denotes the capacity of the road. From figure 5 (a) Capacity of a two-lane road in PCU/hr is about 2900. From figure 5 (b) Capacity of a four-lane road in PCU/hr is about 3600. So there is an increase in the Capacity of the road after its up gradation.

5. CONCLUSION

Traffic Engineering is a vast field in which the traffic characteristics are studied to improve the facilities provided to users. The traffic characteristics play an important role in traffic engineering. So, it is necessary to collect traffic stream characteristics from the field. The lane width of these highways varies from 3m to 4m. These narrow width lanes decrease the speed of the vehicles due to lack of margin of error for drivers. Under heterogeneous traffic conditions, the effect of Carriageway width is more protruding. On two-lane roads, the interaction between vehicles from the opposite direction is more prominent thus leading to accidents. This also affects the traffic Characteristics of the road. The speed of fast moving vehicles gets decreased. The density of the vehicles increases at a point if a slow-moving vehicle blocks the road. The speed percentile of the vehicles decreases thus increasing the time of travel. This also affects the capacity of the road substantially. The present study thus made an attempt to study the changes in traffic Characteristics of the two-lane road and four-lane road after its up gradation.

The spot speed of the vehicles on the four-lane road is more than the two-lane road because of increase in carriageway width. This provides the driver with the easy manuvering capability and increases the speed of the vehicle. There is a slight increase in the speed of trucks and no increase in the speed of the 3 Wheelers. This shows that these are the vehicles which obstruct the speed and flow of the traffic on a two-lane road and increase congestion. There is a slight increase in the volume of the traffic after its up gradation from the two-lane road into a four-lane road. This increase in volume is not as per the design volume. But in coming years, by looking into traffic growth there will be a substantial increase in the flow of traffic. The speed percentile for the four-lane road has increased as compared to two-lane roads. Due to the increase in carriageway width and use of rigid pavements the speed percentile of Cars, 2 Wheelers, Bus and LCV have increased. The 85th percentile speed has increased to 70km/hr from 55km/hr on the previous road. The result also shows that the PCU values vary according to the carriage way width. The PCU values for the four-lane road is more in some vehicle categories as compared to two-lane roads. This shows that assuming the only a single type of PCU values for all lane roads is not feasible as provided in American HCM and Indo HCM. The capacity of the four-lane road is more than the two-lane road by about 28%. The capacity of the two-lane road is found out to be 2900pcu/hr which is less than the 3200 PCU/hr capacity mentioned in HCM (2000).

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