

Estimation of Traffic Capacity in a 4-lane Divided National Highway (NH-275) & Analysis of Traffic Volume

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Abstract - The traffic is increased enormously due to rapid growth of vehicle ownership and increase of population in the urban area of India. Traffic capacity is a key parameter for planning, design and operation of any type of urban roads. In the present study, Traffic flow data is collected on a section of four-lane divided national highway (NH-275) at kumbalgodu in Bangalore. The traffic composition and classified volume of traffic on the study stretch is found. The same set of field data is used in VISSIM and simulated speed-flow curve is developed for the heterogeneous traffic flow. Capacity of 4-lane divided national highway is estimated using the speed flow relationship and it is found to be 5334 PCU/hr/dir. Additionally, speed-volume relationships considering simulated traffic flow with 100% composition for different categories of vehicles are plotted for volume levels starting from near-zero until capacity of the facility. Further, Passenger Car Unit (PCU) of different vehicle categories at different volume levels was found. It has been found that PCU decreases with increase in volume-capacity ratio irrespective of vehicle category.

Key Words: Heterogeneous traffic flow, VISSIM, simulation, PCU, traffic capacity

1. INTRODUCTION

The vehicular traffic on highways and urban streets has increased substantially due to rapid growth in industrial and economic activities and this scenario has spread through the developed and developing countries both. Increased traffic demand is requiring an efficient traffic flow operations on highway facilities. India has a large road network of about 4.32 million kilometers, and acquired a density of 1.31 km of roads per square kilometer of land, which is quite high when compared with countries like US, Australia, Korea and Sweden where density is around 0.67, 0.11, 1.05 and 1.29 respectively. Traffic volume in India is further likely to increase in future due to substantial growth rate and it may cause severe congestion on all important highways in the country. Many developing nations are facing different levels of difficulties for providing efficient vehicular traffic operations due to mixed nature of traffic. There are several types of vehicles sharing and operating on same carriageway width without any physical segregation between motorized and non-motorized vehicles, and without proper lane discipline.

The operating characteristics of these vehicles vary from location to location with varying traffic composition. Several two lane rural highways in India have been widened to four

lanes and many new multilane highway projects are in progress so as to meet the requirements of higher traffic with increasing number of commercial vehicles on these highways. Multilane highways need more attention with respect to traffic flow state and capacity analysis due to different lane-changing and overtaking maneuvers as compared to two-lane roads.



Fig: 1 Traffic congestion in Bangalore

1.1 ABOUT PTV VISSIM

PTV VISSIM is a microscopic multi-modal traffic flow simulation software package developed by PTV Planning Transport Verkehr AG in Karlsruhe, Germany. The name is derived from "Verkehr In Städten – Simulations model" (German for "Traffic in cities - simulation model"). PTV Vissim was first developed in 1992 and is today a global market leader. "Microscopic simulation", sometimes called micro simulation, means each entity (car, train, and person) of reality is simulated individually, i.e. it is represented by a corresponding entity in the simulation, thereby considering all relevant properties. The same holds for the interactions between the entities. The scope of application ranges from various issues of traffic engineering (transport engineering, transportation planning, signal timing), public transport, urban planning over fire protection (evacuation simulation) to 3D visualization (computer animation, architectural animation) for illustrative purpose and communication to the general public. PTV Vissim is part of the PTV Vision Traffic Suite which also includes PTV Visum (traffic analysis and forecasting) and PTV Vistro (signal optimization and traffic impact).

1.2 OBJECTIVE

- To estimate the traffic capacity of Bangalore –Mysore highway (NH-275) under the mixed traffic conditions and study of its flow characteristics.
- To generate the microscopic traffic simulation model VISSIM by inputting the field data and study of mixed traffic condition on the selected highway.
- To estimate the dynamic PCU values of different vehicles at different V/C ratios and study the effect of vehicle composition on PCU values.

2. METHODOLOGY

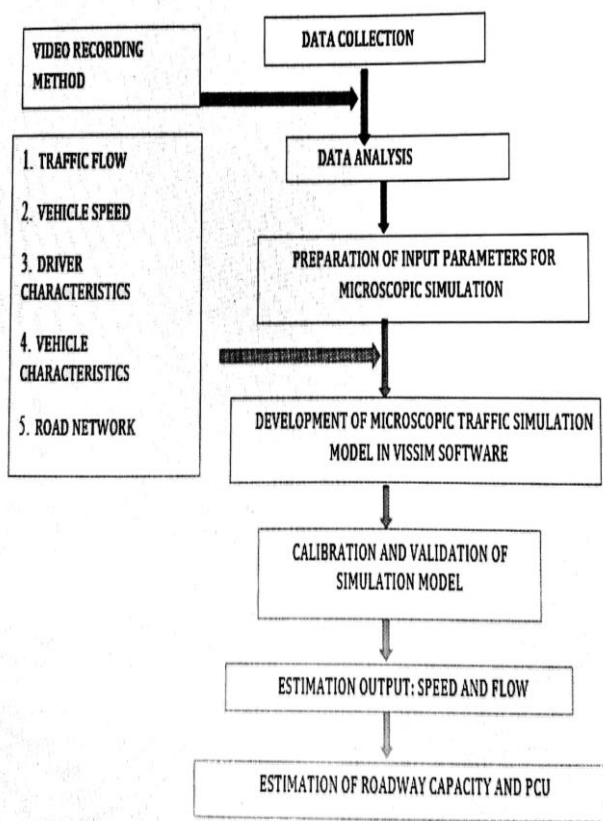


Fig- 2: SIMULATION MODEL

Table -1: Recommended design service volume (PCU per hour) as per IRC-106:1990

Types of carriage way	Total design service volume for different categories of urban roads		
	Arterial *	Sub-arterial **	Collector ***
2- lane (one way)	2400	1900	1400
2- lane (two way)	1500	1200	900
3- lane (one way)	3600	2900	2200
4- lane undivided (two way)	3000	2400	1800
4- lane divided (two way)	3600	2900	-
6- lane undivided (two way)	4800	3800	-
6- lane divided (two way)	5400	4300	-
8- lane divided (two way)	7200	-	-

Where,

*: Roads with no frontal access, no standing vehicles, and very little cross traffic

** : Roads with no frontal access but no standing vehicles and very little cross Traffic high capacity intersection.

***: Roads with free frontage access, parked vehicles and heavy cross traffic.

Table-2: PCU values of vehicles as per IRC 106:1994

vehicle type	Equivalent PCU factors	
	percentage composition of vehicle type in traffic stream	
	5%	10% or over
Two wheelers	0.5	0.75
Car	1	1
Auto rickshaw	1.2	2
Light commercial vehicle	1.4	2
Truck or bus	2.2	3.7
Tractor trailer	4	5

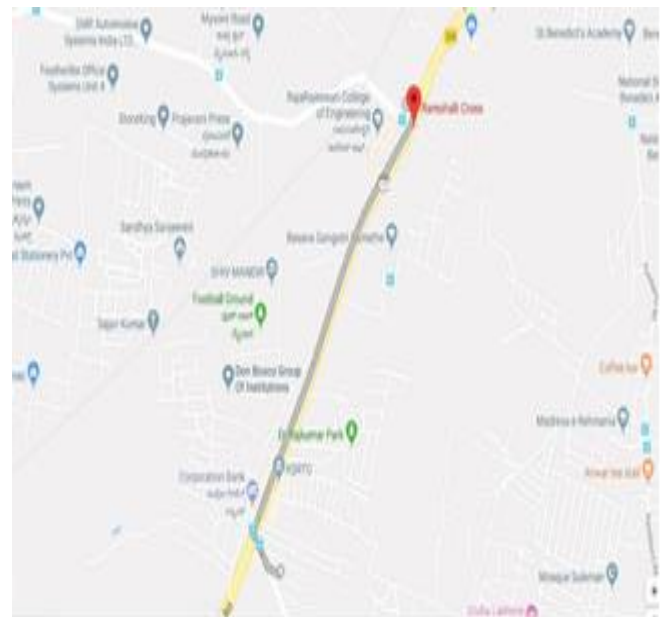


Fig-3: study area

2.1 STUDY STRETCH

The road stretch selected for the study is NH-275 highway in Bangalore. The study stretch was selected after conducting a reconnaissance survey such that it satisfies the following conditions:

1. The stretch should be fairly straight,
2. Width of roadway should be uniform and
3. There should not be any direct access from the adjoining areas.

The study stretch is a four lane divided road. The width of main carriageway in one direction of traffic flow is 7.5m and the unpaved shoulder width is 1.2 m.

Table-3: Details of the selected study stretch

Type of section	Location	Carriageway width in one direction of travel (m)	Trap length (m)	Remarks
Four lane divided	Kumbal godu, Bangalore-Mysore highway (NH-275)	7.5	30	Unpaved earthen shoulder of width 1.2 m

2.2 DATA COLLECTION

The field data input required for the model was collected at the above location with the help of a digital video camera for capturing the traffic flow movement for morning and evening peak hours. The study stretch of 30 meter was marked on the highway with the help of measuring tape in both the direction of traffic flow (i.e. towards Bangalore as well as towards Mysore).

The videography is carried out from morning 8 am to 9 am for the morning peak hour and from 5pm to 6pm for evening peak hours at the selected stretches. The time taken by the vehicles from start point to end point is measured. The spot speed is determined considering distance travelled by vehicles to cross the start point and end point, divided by the time taken. The traffic flow passing from start point and end points are measured for every 5 minute interval. The video recorded was later replayed and data on classified volume count was decoded and collected. All vehicles were divided into 7 categories like car, bus, two-wheeler (2W), three-wheeler (3W), light commercial vehicle (LCV), and heavy commercial vehicle (HCV) And tractor tailor.



Fig-4: width of pavement for selected stretch

Table-4: Morning peak hour traffic from Bangalore to Mysore

Vehicle Type	No. of vehicles	Speed parameters (km/h)			% of vehicles	Equivalent PCU factor	PCU/hr.
		Max.	Min.	Avg.			
CAR	1016	83	60	70.43	51.08	1	1016
BUS	196	60	33	52.72	9.85	3.5	686
2W	540	63.5	31	50.71	27.15	0.75	405
3W	44	51	35	44	2.21	1.2	52.8
LCV	116	72	54	60.88	5.83	2	232
HCV	68	51.4	38.6	45	3.42	3.7	251.6
TRACTOR	9	32.5	21.6	27.05	0.45	4	36
TOTAL	1989				100		2679.4

Table 6: Evening peak hour traffic from Bangalore to Mysore

Vehicle Type	No. of vehicles	Speed parameters (km/h)			% of vehicles	Equivalent PCU factor	PCU/hr.
		Max.	Min.	Avg.			
CAR	704	71.6	51.4	61.5	37.37	1	704
BUS	152	57.38	39.3	48.34	8.07	3.5	532
2W	748	60.2	49	54.6	39.70	0.75	561
3W	80	50.32	41.5	45.91	4.25	1.2	96
LCV	88	67.5	50.2	58.85	4.67	2	176
HCV	104	46.93	35.63	41.28	5.52	3.7	384.8
TRACTOR	8	30.23	22.6	52.83	0.42	4	32
TOTAL	1884				100		2485.8

Table -5: Morning peak hour traffic from Mysore to Bangalore

Vehicle type	No. of Vehicles	Speed parameters (km/h)			% of vehicles	Equivalent PCU factor	PCU/hr.
		Max.	Min.	Avg.			
CAR	408	85	60	72.5	26.49	1	408
BUS	180	62	34	48	11.69	3.5	630
2W	688	65	35.6	50.3	44.68	0.75	516
3W	84	52	35	43.5	5.45	1.2	100.8
LCV	88	76.3	52.8	64.55	5.71	2	176
HCV	88	53.4	38.6	46	5.71	3.7	325.6
TRACTOR	4	33.4	21.6	27.5	0.26	4	16
TOTAL	1540				100		2172.4

Table -7: Evening peak hour traffic from Mysore to Bangalore

Vehicle Type	No. of vehicles	Speed parameters (km/h)			% of vehicles	Equivalent PCU factor	PCU/hr.
		Max.	Min.	Avg.			
CAR	1036	72	51.4	64.14	42.42	1	1036
BUS	168	56.84	37.24	49.25	6.88	3.5	588
2W	684	56.84	49	52.21	28.01	0.75	513
3W	164	49	41.5	45.5	6.72	1.2	196.8
LCV	200	67.5	49	55.36	8.19	2	400
HCV	184	41.53	31.7	36.95	7.53	3.7	680.8
TRACTOR	6	29.3	22.6	25.93	0.25	4	24
TOTAL	2442				100		3438.6

The overall dimensions of all categories of vehicles are shown in Table 8 below. Any vehicle moving in a traffic stream has to maintain sufficient lateral clearance on the left and right sides with respect to other vehicles/ curb/ median to avoid side friction. These lateral clearances depend upon the speed of the vehicle being considered, speed of the adjacent vehicle in the transverse direction, and their respective vehicle categories. The minimum and maximum values of lateral-clearance share are also mentioned in the below table. The minimum and the maximum clearance-share values correspond to zero speed and free speed conditions of respective vehicles are considered.

Table-8: Vehicle types and their dimensions

vehicle type	vehicle length (m)	vehicle width (m)	projected area (m ²)	lateral clearance share	
				minimum	maximum
CAR	3.5	1.5	5.5	0.4	1
BUS	11.4	2.5	28.5	0.4	1
2W	1.8	0.6	1.2	0.4	1
3W	3.2	1.4	4.4	0.4	1
LCV	6	1.9	11.4	0.4	1
HCV	10.21	2.5	25.52	0.4	1
TRACTOR	7.3	1.88	16.28	0.5	1

The acceleration values of the different categories of vehicles over different speed ranges used for simulation are shown in Table 9 below.

Vehicle Type	acceleration(m/sec ²)		deceleration(m/sec ²)	
	maximum	desired	maximum	desired
CAR	2.7	1.3	1.8	1.2
BUS	2.3	1.7	1.6	1
2W	2.5	1.5	1.7	1.2
3W	1.1	0.9	1.1	0.8
LCV	2.4	1.2	1.6	0.9
HCV	2.2	1.6	1.5	0.5
TRACTOR	1.7	1.5	1.5	0.4

The total traffic observed in morning and evening peak hours is represented in the following tables.

Table-10: Morning peak hour traffic

vehicle type	Avg. spot speed (Km/hr.)	Traffic flow towards Mysore	Traffic flow towards Bangalore	total traffic flow	Equivalent PCU factors	PCU/hr
CAR	71.47	1016	408	1424	1	1424
BUS	50.36	196	180	376	3.5	1316
2W	50.51	540	688	1228	0.75	921
3W	43.75	44	84	128	1.2	153.6
LCV	62.72	116	88	204	2	408
HCV	45.50	68	88	156	3.7	577.2
TRACTOR	27.28	9	4	13	4	52
TOTAL				3529		4851.8

Table-11: Evening peak hour traffic

Vehicle type	Avg. spot speed (Km/hr)	Traffic flow towards Mysore	Traffic flow towards Bangalore	total traffic flow	Equivalent PUC factor	PCU/hr
CAR	62.82	704	1036	1740	1	1740
BUS	48.80	152	168	320	3.5	1120
2W	53.41	748	684	1432	0.75	1074
3W	45.71	80	164	244	1.2	292.8
LCV	57.11	88	200	288	2	576
HCV	39.12	104	184	288	3.7	1065.6
TRACTOR	26.18	8	6	14	4	56
TOTAL				4326		5924.4

3. RESULTS AND DISCUSSIONS

3.1 ANALYSIS OF FIELD DATA

After collecting traffic data from the selected stretch, the composition of traffic volume is analyzed. The proportion of vehicles in a traffic stream is very important parameter for geometric and structural design of any pavement. Analysis of traffic composition gives the idea of proportion of wide variety of vehicles. So, it is crucial to know the traffic composition of various sections. Vehicle class percentages of the study area is represented by using pie chart. For the evening peak hour traffic, 2w have highest percentage of traffic composition towards Mysore and cars have highest percentage of traffic towards Bangalore as shown in figures 5 and 6 below.

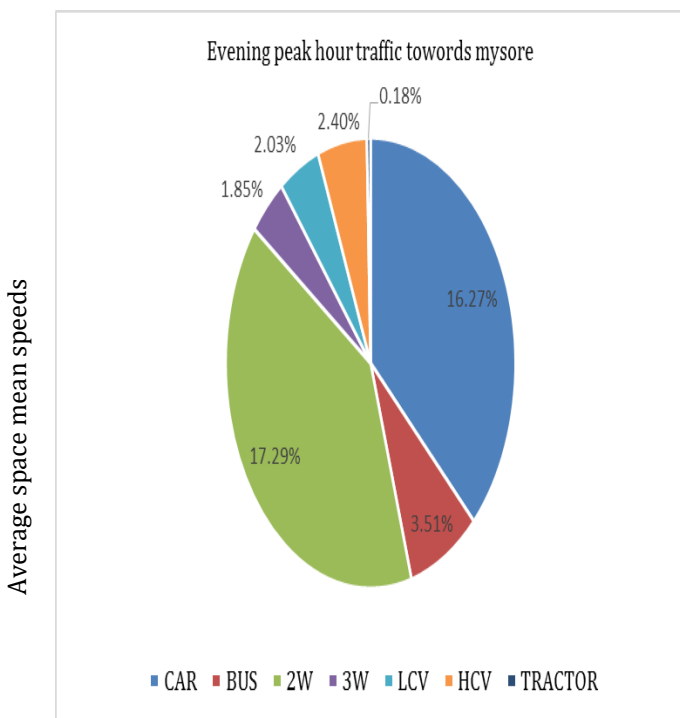


Fig: 5 Evening peak hour traffic composition towards Mysore

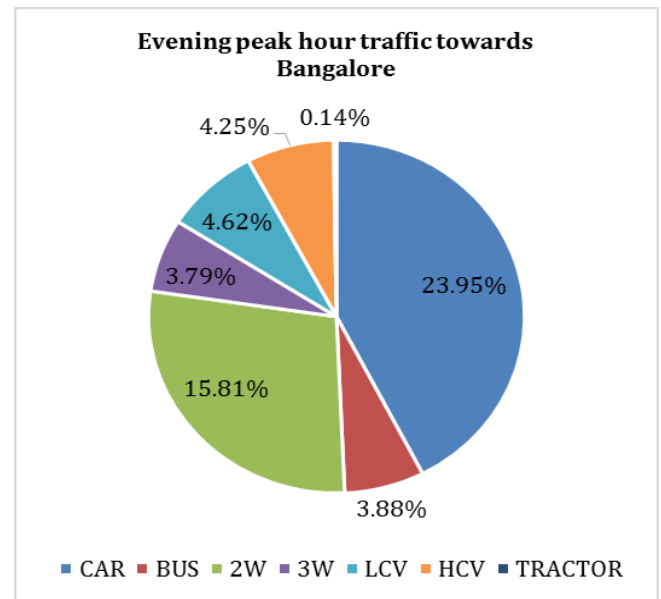


Fig-6: Evening peak hour traffic composition towards Bangalore

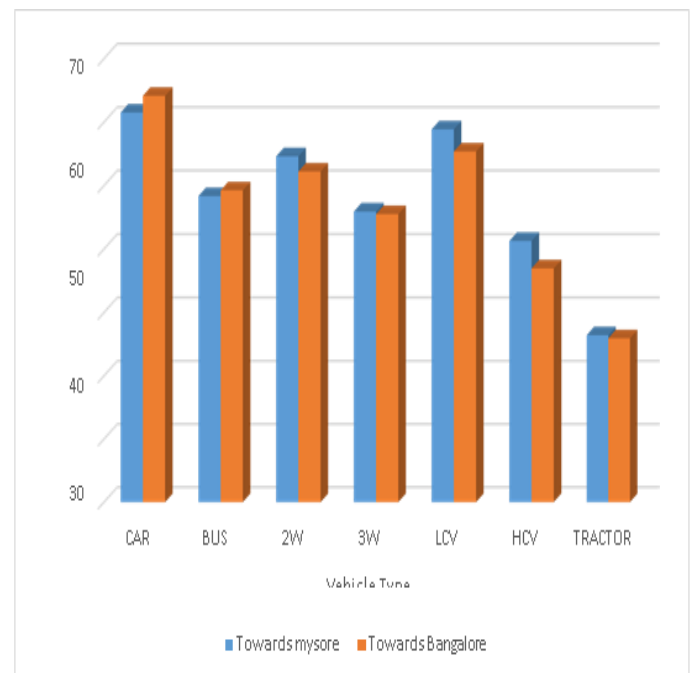


Fig: 7 Variation of average speed for different vehicle type

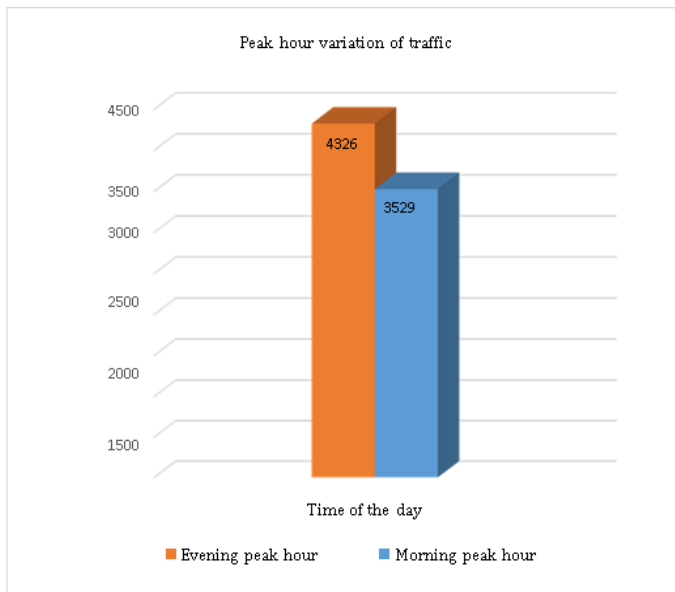


Fig: 8 Peak hour variation of traffic in the study stretch

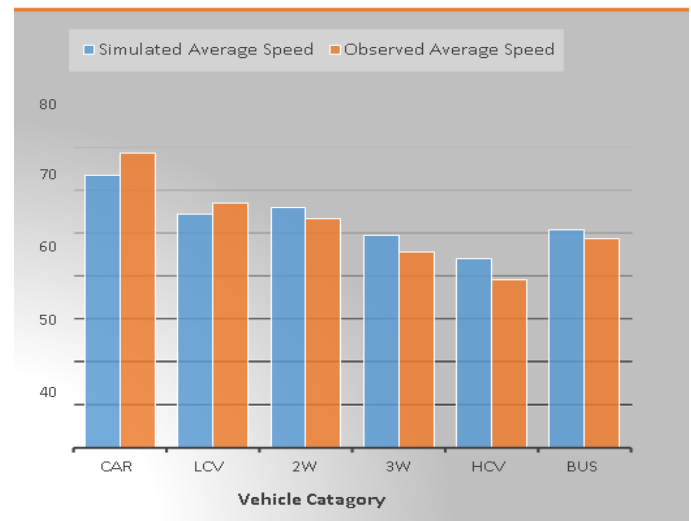


Fig: 9 Comparison of observed and simulated speeds

3.2 SPEED-FLOW RELATIONSHIPS AND CAPACITY

One of the basic studies in traffic flow research is to examine the relationship between speed and volume of traffic. The capacity of the facility under different roadway and traffic conditions can be estimated using these relationships. In this study, speed-flow relationship was developed using the validated simulation model for a heterogeneous flow with vehicle composition and roadway conditions same as that observed in the field. The average speed of the stream was plotted for different simulated volumes, starting from 200 vph to the capacity of the road. Additionally, speed-volume relationships considering simulated traffic flow with 100% composition for different categories of vehicles were plotted for volume levels starting from near-zero until capacity of the facility.

The comparison of the observed and simulated speeds, for an observed traffic volume of 2163 vehicles per hour is as shown in figure 9 below.

The following procedure was adopted for finding the capacity of the facility when developing the above speed-flow relationships. During successive simulation runs with increments in traffic volume from near-zero volume level, there will be a commensurate increase in the exit volume at the end of simulation stretch. After a specific number of runs, the increments in the input traffic volumes will not result in the same increase in the exit volume. Such a decrease in exit volume (in spite of increase in the input) in successive runs indicates that the facility has reached its capacity. It is clear from the figures that the curves follow the established trend and the capacity in terms of vehicles per hour decreases as we proceed from car, light commercial vehicle and buses in that order, which is quite intuitive. The values of capacity obtained from the simulation for the observed flow and simulated one vehicle type flows are given in Table 11.

Table 12: Estimated roadway capacity of four lane National highway

Flow Type	Traffic Composition	Estimated Capacity (veh/hr./dir)
Observed	Heterogeneous	4110
Simulated	100% Car	5000
Simulated	100% Bus	1800
Simulated	100% LCV	2950
Simulated	100% 2W	6200

The derived simulated capacity is compared with the design capacity values recommended by IRC106:1990 for urban roads. The obtained simulated capacity is found to be higher than the design capacity recommended by IRC106:1990 and is tabulated as follows.

Table: 13 Comparison of observed capacity & capacity recommended by IRC106-1990

Name of the urban road	Type of road	Width of road in meter	Derived capacity (PCU/hr)	Capacity recommended by IRC106:1990 (PCU/hr.)
NH-275, kumbalگو section	Four lane divided (2-way)	14 m	5334	3600

To emphasize their dynamic nature, PCU values for different categories of vehicles under heterogeneous traffic conditions at eight different volume-capacity (V/C) ratios viz. 0.125, 0.250, 0.375, 0.500, 0.625, 0.750, 0.875 and 1.000 were estimated using simulation. The capacity values for the calculation of these V/C ratios were obtained from the speed flow graphs. For the purpose of simulation, eight traffic volume levels corresponding to these V/C ratios with same composition as observed in the field were considered. Outputs obtained from simulation runs served as inputs for Equation 1 for calculating the PCU values of different types of vehicles at different volume levels. The computed values are shown in Table 14

Table 14: PCU Estimates of different vehicles at different V/C ratios

V/C Ratio	TRUCK	BUS	LCV	3W	2W
0.125	7.36	6.73	2.40	1.05	0.24
0.250	6.53	6.38	2.36	1.00	0.24
0.375	6.49	6.22	2.34	0.94	0.24
0.500	6.44	5.97	2.32	0.92	0.23
0.625	5.84	5.92	2.30	0.90	0.22
0.750	5.75	5.41	2.28	0.90	0.21
0.875	5.66	5.36	2.26	0.88	0.21
1.000	5.38	5.30	2.24	0.85	0.20

4. FUTURE RESEARCH SCOPE

This study can be further extended to study the following aspects:

1. Developing the concept of stochastic capacity estimates under heterogeneous traffic conditions

prevailing on expressways in India. Such estimates would account for vehicle composition in the traffic stream.

2. Studying lane utilization and lane discipline in Indian Expressways to determine the degree of heterogeneity in these facilities with clear demarcation between vehicles following a lane discipline and those who do not.

3. The terrain of selected stretch is plain, so the present study does not include impact of gradient on capacity.

5. CONCLUSIONS

The estimation of capacity of urban roads is an important parameter for proper planning of the transportation system. The accurate determination of capacity is also important for reduction of congestion and delay on urban roads. The study yielded out many interesting conclusions. The micro-simulation model VISSIM is suitable to simulating and hence studying heterogeneous traffic flow in a national highway to a satisfactory extent. For all categories of vehicles, the PCU of a given vehicle category decreases with increase in volume capacity ratio. This is due to the decreasing speed difference as volume increases from free flow to that at capacity. The PCU value of all categories of vehicles decreases when their proportion increases in the traffic stream. This is due to the platooning effect of trucks. The capacity of the four-lane national highway facility is found to be approximately 5334 PCU/hour/direction as simulated under heterogeneous traffic conditions in VISSIM. It is found that due to the complex nature of interaction between vehicles under the heterogeneous traffic condition, the PCU estimates made through simulation for different types of vehicles of heterogeneous traffic, significantly changes with change in traffic volume level. The speed – flow relationships are developed for the selected stretches. It is also observed that derived capacity is higher than the value recommended by IRC: 106-1990.

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