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Modeling to traffic flow on Indian expressway and urban mid-block section using simulation technique

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Abstract: - *The work aims to model the traffic flow on Indian expressways, by evaluating passenger car unit or passenger car equivalents of different categories if vehicles at different volume levels, using Micro simulation model VISSIM. Hence adopting single PCU for a given vehicle is not accurate but rather a dynamic or stochastic PCU that accounts for all the factors should be adopted. This work also aims to evaluate capacity of expressways and to study the vehicle composition. From the study, it has been found that PCU decreases with increase in volume capacity ratio irrespective of vehicle category. For this study tumkur flyover is selected as study stretch. The objective of this study is to estimate and study the possible variation of Passenger Car Unit (PCU) values of different categories of vehicles at various traffic volume levels under heterogeneous traffic conditions prevailing on basic expressway sections of India in level terrain. VISSIM is used to model the heterogeneous traffic-flow. Field data collected on traffic flow characteristics such as free speed, acceleration, lateral clearance between vehicles, etc. are used for calibration and validation of the simulation modeling VISSIM. The validated simulation model is then used to derive Passenger Car Unit (PCU) values for different types of vehicles.*

Key words: *heterogeneous traffic flow, expressways, urban mid-block section, simulation, pcu, roadway capacity*

1. INTRODUCTION

In Indian road, network highways are the standard grade of roads. At the location of intersection usually provided with grade, separators and they are 6-8 lane Controlled access highways. In India approximately 1455.4 km of expressways operational currently. In India, an expressway is an arterial highway for motorized traffic, with divided carriageways for high-speed travel, with full control of access and provided with grade separators is the definition. In India expressways is different from other roads in the country which traffic consists of only cars and trucks where bicycle, three wheelers and two-wheelers are not allowed to play. By the year 2022, the government of India aims to expand the highway network and plans to add additional 18,637 kms of expressways. In measuring the growth of a country, a well-developed network of roadways is a key factor. The fact that India ranks 3rd in the list of the countries by road networks next to United States and China, so this improving position of India globally.

To determine the traffic volume the non-uniform speed and vehicle dimensions also present a challenge. By standardizing the vehicle volume as Passenger Car Unit (PCU) by converting vehicles with non-uniform dimensions to passenger car equivalents, the hurdle of determining heterogeneous traffic volume can overcome. In traffic it is complicated of studying how non-uniform interact and effect each other. The interaction among the vehicles can be shown by the quantum of traffic flow impeded by a particular vehicle type. To measure Relative Impedance Passenger Car Unit (PCU) is used. For measuring traffic capacity or traffic volume PCU is the standard unit.For both homogeneous and heterogeneous traffic flows Vissim software is commonly used for simulation.

1.2 Objectives of the Study

- For the estimation of road capacity and PCU values base models to be prepared.
- In Vissim the calibrating and validating, the models for simulation the collected data's are used for the traffic are acceleration, lateral clearance, speed, etc.
- Influence of cars length and speed value, sedan and hatchbacks cars considering as standard passengers cars.
- The vehicles of all types to drive passenger car unit (PCU) the validated simulated model is used.

2. LITERATURE REVIEW

Various researches to estimate the PCU have adopted different methodologies. Large proportion of studies utilized simulation for traffic is to infer the PCU values of geometrical and for traffic conditions. The process base used for estimation is delay, speed, density, headway, queue discharge. Therefore, in this paper a short discussion of the previous literature has been made.

2.1 Bang (1995)

In Indonesia using the VTI (Vehicle Truck Interaction) microscopic simulation model determined PCU's for township roads. The PCU values are produced through successive simulations base the impact of speed of the light vehicle, because of addition of other types of vehicles in traffic. Speed-flow relationships for two-way, two-lane, undivided rural roads were obtained using the VTI microscopic simulation model. The observed data were used for validation and calibration the models process and for studying the effects of cross-section and environmental conditions on speed and capacity.

2.2 Eric, L.Keller and James.G. (1984)

Author used TRANSYT/ 7N microscopic traffic simulation tool PCE estimation by considering traffic volume, signal timing and vehicle size and as a function. As per this procedure, PCU was estimated by considering the amount of delay caused by different vehicle types. The PCE values obtained here were compared with that obtained by the report of PRC Voorhees for determining PCE value in intersections at city applying NETSIM model.

2.3 Marwah. B.R. (1976)

In India he was the pioneer of traffic simulation studied. The function of traffic volume and composition is the Passenger Car Unit value for a vehicle type assumed in his approach.

2.4 Sumner. R. et al. (1984)

To compute Passenger Car Equivalent (PCE) value described a simulation method in their paper. Using NETSIM the traffic flow was simulated, an enhanced version of traffic simulation model.

2.5 St.John.A.D. (1976)

He developed a microscopic simulation model to derive nonlinear truck factor for two-lane highways including all-important factors those can affect the flows. As a result indicates that the simulation model of the truck factor should be nonlinear. This paper presented a brief description of the simulation, the evidence for a nonlinear truck factor, and the derivation and testing of the nonlinear factor.

2.6 Araasan.V.T and Khoshy.R (2004)

They deals with the development and application of simulation model to standardize service volume and capacity standards for heterogeneous traffic movement on city roads.

2.7 Balaji Ponnu,Maanraj Singh Bains & S.S. Arkathkar,

Used micro-simulation model VISSIM. They evaluated the Passenger car unit values of various types of vehicles at different levels of traffic volumes by preparing a model of traffic flow on Indian expressways. They also evaluated the capacity of highways and studied the impact on PCU values by vehicle composition.

2.8 Methodology

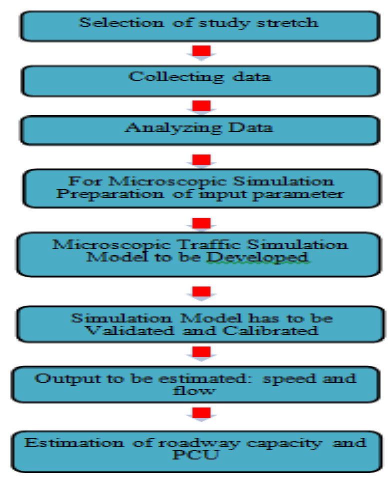

Fig-1: Methodology followed

3. DATA COLLECTION

3.1 Study Area

The following conditions are to satisfy the selected stretch after conducting reconnaissance survey in the study area.

a) Study area must be straight.
b) Study stretch must have uniform width.
c) Study stretch from adjoining areas should not contain direct access.

In this project there are two area of both expressway and urban mid-block section. Bangalore to Tumkur expressway and rastrothana area is the selected areas for the study. The road width of 1.0m is a two-divided road with median in the study stretch.

Fig-2: Study Area

3.2 Traffic Survey

In order to generate base model the input data should be collected from the study stretch.

- The whole duration for one hour, the field traffic flow data should be collected using digital video camera in the selected stretch.
- The recorded video id then analyzed by reducing the speed to 1/8th of the actual speed and from the recorded video the traffic obtained in expressway is 1581 vehicles and in urban mid block section is 1436 vehicles per hour.
- By noting down the time took to travel 30.0m length, all types of vehicles speed were observed. Under free flow conditions, free speed of all types of vehicles was observed.
- Any vehicles moving on road traffic stream must have sufficient lateral clearances should be maintained between those vehicles.
- The obtained maximum, minimum and mean speeds of different vehicles types which is standard deviations are shown below.

Table-1: Free Speed Parameters of various vehicle categories of expressway

Types of vehicle	Free speed parameter in km/hr.		
	Minimum	Maximum	Mean
Car	50	80	65
Motor bike	60	80	70
LCV	40	60	50
HCV	35	60	48

Table-2: Dimensions of different types of vehicles

Vehicle type	Length (m)	Width (m)
Car	4.7	2.06
Motor bike	2.0	0.84
LCV	4.96	2.07
HCV	11.54	2.69

Table -3: Minimum and Maximum Lateral Clearance for expressway

Types of vehicle	Lateral Clearance share (m)	
	At 0 speed	At 50kmph speed
Motor bike	0.1	0.3
4-wheeler	0.3	0.5
3-wheeler	0.2	0.4
LCV	0.3	0.5
Bus	0.3	0.6

Table-4: Free Speed Parameter of various vehicle categories of urban street

Types of vehicle	Free speed parameter in km/hr.		
	Minimum	Maximum	Mean
Car	25	55	40
Motor bike	30	80	44
LCV	10	30	20
HCV	20	50	35.46
Auto rickshaw	15	25	20

Table-5: Dimension of different categories of vehicles

Vehicle type	Length (m)	Width (m)
Car	4	1.6
Motor bike	1.8	0.6
Auto rickshaw	2.6	1.4
LCV	6.67	2.6
HCV	10.3	2.5

Table-6: Minimum and Maximum Lateral Clearance of urban street

Types of vehicle	Lateral Clearance share (m)	
	At 0 speed	At 50kmph speed
Motor bike	0.1	0.3
4-wheeler	0.3	0.5
3-wheeler	0.2	0.4
LCV	0.3	0.5
Bus	0.3	0.6

4. ANALYSIS AND RESULTS

4.1 Validation of the simulation model

From the calibrated model from the collected results the process of checking is known as validation. In the simulated values of the parameters in field are traffic volume and average speed. The obtained volume of traffic & composition was given as input for simulation process. After preparing the model the simulation is carried out for a period of 3600 seconds and the validation is done by comparing simulated volume and the observed volume in order to make the simulated volume equal to observed volume the desired speed distribution is adjusted and the model is validated.

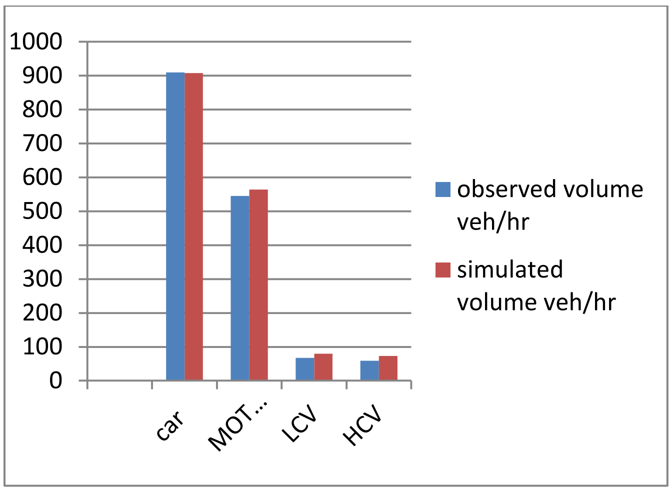

chart-1: Validation results of Tumkur Flyover

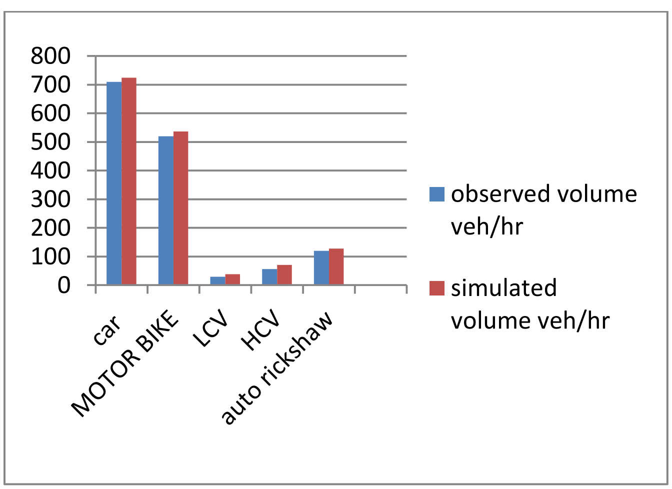

chart -2: Validation Results of rastrothana area

Table-7: Evaluation of simulated volume and observed volume on Athematic basis

Vehicle type	Observed volume Veh/hr	Simulated volume Veh/hr	Difference	Squared deviation
Car	910	908	2	81
Motor bike	545	564	-19	900
HCV	59	73	-14	625
LCV	67	80	-13	576

d_{mean} = Mean of the observed difference =44/4=11

t statistic,t_0=d_{mean} ($S_d/\sqrt{K}$)

Where S_d = Standard Deviation, K = number of data sets = 4

$S_d{}^2$ = 2182 / (K-1), S_d = 26.96

$t_0 = 11 / (26.96/\sqrt{4}) = 0.815$

From standard t-distribution table the critical value for t-statistic of 5.0% significance level and for 5.0^o of freedom is 2.36. By the above table the value of t-statistic (t_0) for Tumkur flyover is 0.815 and similarly for rastrothana area is 0.989. Therefore the calculated value for t-statistic (t_0) from the obtained results is lesser than the table value. This represents that the simulated volume considerably represent the observed volume.

4.2 Model application

The various traffic conditions for differentiating traffic and roadway condition in the study the VISSIM model can be applied. As shown in the fig in this study model application refers to the relationship between volume of traffic and speed on our expressway with four types of vehicles. It has also been used to quantify the relative impact of each vehicle on traffic flow by estimating their PCU values at different volume levels under heterogeneous traffic conditions prevailing on Indian expressways.

4.3 Capacity & Speed-flow relationships

To find the relationship between volume of traffic and speed is the basics of the study. By using these relationships the capacity of the traffic & roadway conditions can be calculated. In this study as same as that observed in the field, the relationship was prepared from the simulated model which is validated and roadway conditions. the avg speed of the stream was conducted for different simulation volume, begins from 400.0 vehicle per hour for the road capacity. Addition of volume-speed relation considered with 100.0 % simulated flow of traffic composition for different vehicle types.

The capacity is estimated from the speed flow graph

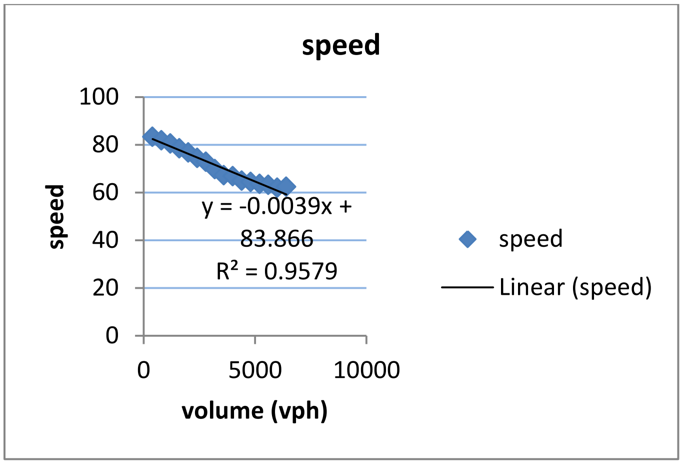

Chart-3: Speed flow graph for the observed heterogeneous traffic of expressway

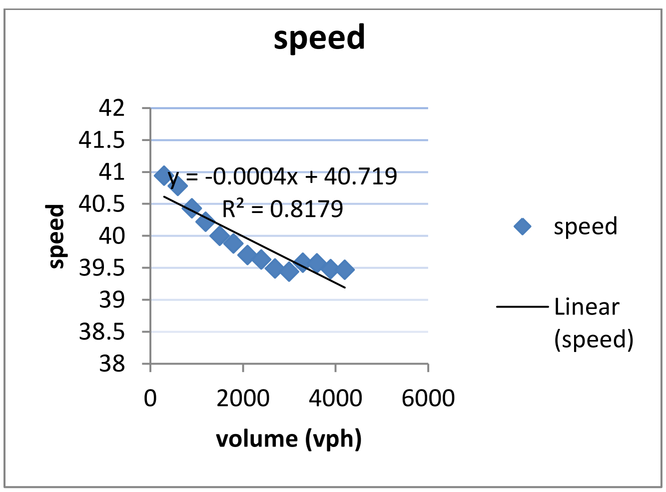

Chart-4: Speed flow graph for the observed heterogeneous traffic of rastrothana area

It can be observed that the capacity of the two lane expressway and urban mid-block section under heterogeneous traffic condition and observed traffic composition is 5253 and 2603 vehicles per hour as from the fig.

The estimated capacity of 100% cars under homogeneous traffic.

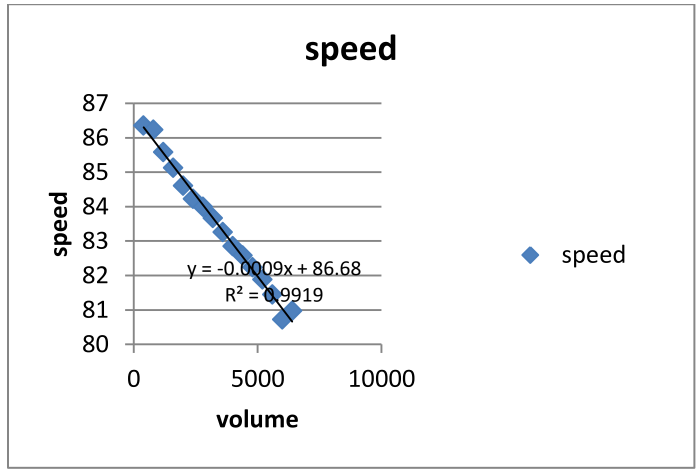

Chart-5: Speed flow graph for homogeneous traffic condition of expressway

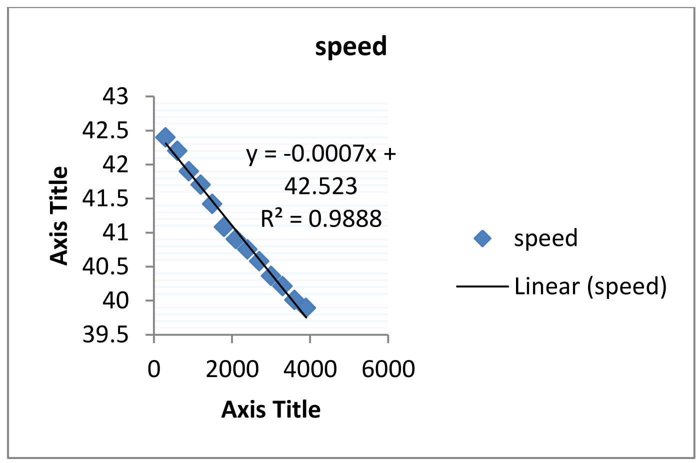

Chart-6: Speed flow graph for homogeneous traffic condition of urban street

The capacity of expressway and urban mid block section under homogeneous traffic condition is found to 5410 and 2856 cars per hour.

4.4 Estimation of PCU values

To expressed in terms of PCU as explained in the introduction, in India the traffic is seem to be heterogeneous traffic flow of vehicles with different driving behavior of drivers with the commonly fluctuating dynamic and static characteristic. In terms of equivalent Passenger Car Unit different vehicle categories such as LCV, HCV etc., can be expressed. This necessitates an accurate estimation of Passenger Car Unit which varies dynamically with various traffic flow parameters such as steam speed, vehicle composition and volume capacity ratio.

The PCU of the vehicle was calculated from the equation

$$PCU_i = \frac{Vc/_{Vi}}{Ac/_{Ai}} \ldots\ldots$$

Where, Passenger car unit of vehicle type i = PCU_i.

Speed of a 4-wheeler and vehicles type i, respectively = Vc, Vi;

Projected rectangular area of a 4-wheeler and vehicles type I = Ac, Ai.

To emphasize their dynamic nature, Passenger Car Unit value of various types of vehicles can be estimated using 8.0 various V/C ratios are .1250, .2500, .3750, .5000, .6250, .7500, .8750 and 1.00 were calculated using simulation. The capacity values are required for the estimation of this volume capacity ratios were collected from the speed flow graph. For the purpose of simulation, eight traffic volume levels corresponding to these V/C ratios with same compositions as observed in the field were considered.

Example: At V/C ratio = 0.125,

V/5253 = 0.125,

V= 657 vehicles/ hour similarly for all V/C ratios the simulation runs are carried for one hour duration and the below two fig explains the volume entered into the software and the output speed is taken for the entered volume. The results obtained are tabulated in the table below.

Table-8: Passenger Car Unit value of various vehicle classes at different V/C ratios of expressway

V/C ratio	Motor bike	Car	HCV	LCV
0.125	0.198	1	4.974	1.560
0.250	0.197	1	4.933	1.550
0.275	0.197	1	4.903	1.539
0.5	0.196	1	4.889	1.533
0.625	0.195	1	4.870	1.525
0.75	0.195	1	4.854	1.515
0.875	0.194	1	4.842	1.510
1.00	0.194	1	4.826	1.502

Table-9: Passenger Car Unit values of various vehicle classes at various V/C ratios of urban street

V/C ratio	Motor bike	Car	Auto	LCV	HCV
0.125	0.170	1	0.4073	1.362	4.132
0.250	0.171	1	0.4050	1.366	4.121
0.275	0.170	1	0.4071	1.369	4.137
0.5	0.170	1	0.4089	1.372	4.118
0.625	0.173	1	0.4135	1.373	4.108
0.75	0.176	1	0.4153	1.381	4.099
0.875	0.175	1	0.4167	1.370	4.083
1.00	0.175	1	0.4166	1.377	4.085

From the above table it can be seen that for the vehicles larger than car like bus and LCV the PCU increases at less volume level and reduces the growth in traffic volume. The reason for this is at lower volume levels. The subject vehicles like buses move slowly even under free flow condition. Hence there is a larger space headway between the vehicles as a result 4-wheelers can overtake the buses without much reduction in speed resulting in higher PCU values and at higher volume levels space headway decrease vehicles come very closer and there is an opposition to the movement of cars. As a result the speed of the cars decreases resulting in decrease in magnitude of PCU value because of this, the difference in percentage speed change between cars and buses is lesser at higher V/C ratios, resulting in lesser PCU values.

4.5 Influence of traffic composition on PCU values

The effect of composition of different categories of vehicles should be studied in the following manner. Firstly, the car composition are simulated, the capacity of the facility was found and then by adding various proportions (10.0%, 20.0%, 30.0%, 40.0%, 50.0%) of HCV were added to this 4-wheeler and then simulation is taken for one hour duration and estimate the capacity. The results show that the capacity of the stretch is decreases as the volume increases.

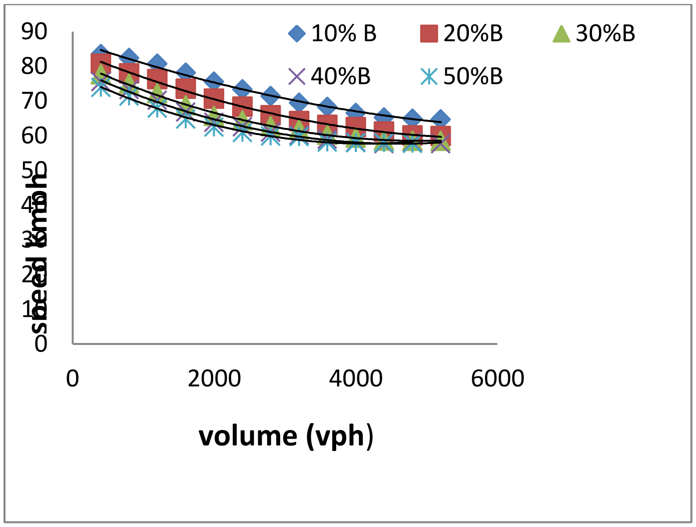

Chart-7: Speed flow relationship for cars and truck traffic steam

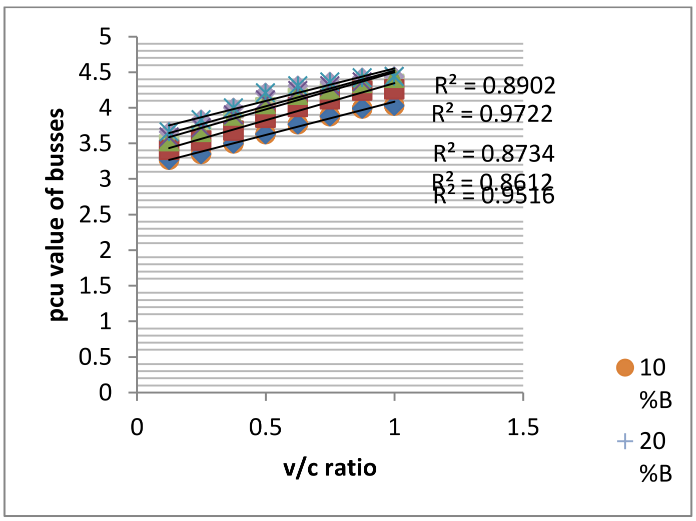

Chart-8: Variations of PCU values due to percentage variation of buses at different V/C ratio

The capacity calculated with the above speed-flow relationship for various composition were used to evaluate the Volume / Capacity ratios and then Passenger Car Unit value for every Volume / Capacity ratios were found by using the above formula. This Passenger Car Unit has been adopted in the form of graph as shown above. The Passenger Car Unit value of HCV decreases as Volume / Capacity ratios increases because of obtained speed difference between cars & HCV. Passenger Car Unit value of HCV decreases as proportion of HCV increases in the traffic stream, which is due to "platooning effect".

4.6 Accuracy Check for the estimated PCU values

Accuracy Check for the estimated PCU values was done by adopting the following procedure. Initially only heterogeneous traffic flow was simulated for the detected traffic configurations and for the designated V/C ratios before the no of vehicles exited out at end of the simulation area is noted down and each vehicle category is multiplied by the respective Passenger Car Unit values obtained and the products are added to change the traffic flow to PCU per hour. Then Cars only traffic is simulated for the same volume capacity ratios and the number of cars coming out from the simulation stretch is noted. In order to estimate the accuracy the statistical analysis is done by performing the paired T-test on simulated cars/hour and Simulated traffic/hour. The details of the paired t-test are shown in the table below.

Table-10: Details of the paired t-test

V/C ratio	Cars/hour	Traffic flow/hour	Difference	Deviation from the mean difference	Square of the deviation from mean difference
0.125	676	700	-24	-58.125	3378.51
0.250	1352	1338	-14	-48.125	2316.01
0.375	2029	2032	-3	-37.125	1378.26
0.5	2705	2681	24	-10.125	102.51
0.625	3381	3343	38	3.875	15.015
0.75	4057	4010	47	12.875	165.76
0.875	4734	4655	79	44.875	2013.76
1	5410	5284	126	91.875	8441.01
			∑=273		17810.835

d_{mean}= Mean of the observed difference=34.125,

t statistic,$t_0 = d_{mean}/(S_d/\sqrt{K})$

Where S_d= standard deviation,

K= number of data sets=8,

S_d^2=17810.835/(K-1),S_d=50.442,

t_0= 34.125/ (50.442/√8) =1.9134

From standard t-distribution table the critical value of t-statistic at 0.5% significance level and for 7degrees of freedom is 4.79. From the above table the value of t-statistic (t_0) for Tumkur flyover is 1.9134 and similarly for rastrothana area is 2.026. Therefore, the calculated value of t-statistic (t_0) for the observed data is less than the corresponding table value. This indicates that the difference of the measured volume in terms of Passenger Car Unit/hr and cars/hr signifying the projected the values of Passenger Car Unit are accurate for various vehicles.

5. CONCLUSION

1. VISSIM software is found to be satisfactory in simulating the heterogeneous traffic form by the practical observation and from the validation results of the model.

2. For the further validation of the model to determine the capacity of the urban mid-block section the speed volume relationship established.
3. By simulating the heterogeneous traffic condition in VISSIM the capacity of two lane urban mid-block section is found to be 2120PCU/hour.
4. A PCU value of different vehicle classes obtained by simulating the traffic at different flow levels varies in the volume was discovered.
5. There is a decrease in the PCU values of the vehicle class with the growth in volume because to reduction in difference in speed as increase in volume from free flow to capacity is concluded from simulation results.
6. There is a reduction in values of Passenger Car Unit of all classes' vehicles when there is increase in its proportion was found from the study.
7. It can also be able to say that the vehicle PCU value is treated as a dynamic measure rather than taking it as a stable value for the considered traffic condition.
8. When compared to that of the sedan car the length and speed of the car inversely depends on PCU values and by considering hatchbacks as standard passenger cars the PCU values are found to be higher was found from the study

5.1Future Scope and Study

The extension of the study can be done to find the extent of heterogeneity by studying the lane behavior and lane discipline between the vehicles, which the vehicles follows and which does not follow the lane discipline.

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