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Highway Capacity Through Vissim Calibrated for Mixed Traffic Conditions

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Abstract

The present study demonstrates applicability of VISSIM software to determine capacity of multilane highways under mixed traffic flow conditions. Traffic flow data collected on a section of four-lane divided highway are used to develop the speed-flow curve. The same set of field data is used in VISSIM and simulated speed-flow curve is compared with field curve. It was found that VISSIM in its original form overestimates both speed and capacity of the highway. Driver behaviour parameters *CC0* and *CC1* are first determined for homogeneous traffic conditions having only one of the four types of vehicles in the stream and then results are aggregated to get the values of these parameters for a mixed traffic stream. Further analysis of field data with calibrated values of *CC0* and *CC1* indicated a good match between field and simulated capacity. The procedure is shown to work on another section of four-lane divided highway with paved shoulders, where simulated capacity was 5329 pcu/hr against the field capacity of 5277 pcu/hr.

Keywords: *simulation, capacity, speed, VISSIM, mixed traffic*

1. Introduction

The vehicular trafficonhighways and urban streets has increased substantially due to rapid growth in industrialand economic activities and this scenario has spread through the developed and developing countries both.Increased traffic demandis requiring an efficienttraffic flow operationson highway facilities. India has a large road network of about 4.32 million kilometres, and acquired a density of 1.31 km of roads per square kilometre 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 nationsare facing different levels of difficulties for providingefficient 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 varyingtraffic 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 manoeuvres as compared to two-lane roads.

Rapid increase intraffic volume, mixed nature of traffic and poor lane discipline prevailing on roads in developing nations need a good understanding of traffic flow analysis and data interpretation. The roadway system and operational analysis greatly depends on availability of reliable, relevant and recent traffic flow data from field. The period of time over which a traffic count data is recorded is an important consideration in assessing the load borne by the facility in terms of traffic flow rate. Estimation of roadway capacity poses different levels of difficulties under mixed traffic and poor lane discipline of drivers. Vehicles of different types are allowed to mix and they share the same road space along the length of a roadway. Unrestricted mixing of various classes of vehicles makes the capacity analysis more complex as compared to homogeneous traffic condition. Field data in such situation are generally not suitable to study the effect of individual vehicle type on stream speed and capacity. Simulation of traffic flow has been a very effective tool for such problems. Various traffic simulation programmes have been developed in different countries based on homogeneous traffic conditions. One such microscopic traffic simulation model is VISSIM which was developed in Germany based on the continuous work of Wiedemann (1999) on car-following behaviour. It has default values of certain parameters

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evaluated for the type of traffic prevailing in the Europe and other developed countries. Although traffic conditions are heterogeneous in the Europe and the US also, but the degree of heterogeneity is different in developing and developed nations. The roads in developed countries have dominating traffic of cars with very low (5-10 percent) proportions of light/heavy commercial vehicles. The traffic stream in developing countries like India has variety of vehicles like cars, light commercial vehicles, heavy commercial vehicles, motorised two-wheelers, three wheelers, non-motorised vehicles etc. The applicability of VISSIM in mixed traffic conditions of the type prevailing on Indian roads has been examined in the present study and some of the driver behaviour model parameters are calibrated to truly reflect these traffic conditions.

2. Study Objective and Scope

The objective of present research is to examine the applicability of VISSIM to mixed traffic condition and thereby to calibrate two major parameters of the model to suit mixed traffic condition. The study analyses mixed traffic flow data on a four lane divided road to establish the speed-flow relationship and to estimate the capacity. The same traffic flow data are used as input to the microscopic traffic simulation model VISSIM and simulated speed flow curve is compared with that obtained from field data. Driver related parameters used in the VISSIM (*CC0* and *CC1*) are examined and their influence on simulated highway capacity is described. *CC0* is the standstill distance in meters and *CC1* is the time headway in seconds between two vehicles at any speed V (m/s). The parameters are determined for homogeneous type of stream containing only one of the four categories of vehicles, and then a method is suggested to estimate value of these parameters for mixed traffic stream. It is shown that appropriate values of these parameters can truly reflect mixed traffic conditions as prevalent on Indian roads.

3. Background Literature

Extensive research on traffic flow theories and models for analysis of roadway capacity has been carried out through many years in developed and developing countries. Studies on traffic flow analysis started with the classical work of Greenshields *et al.* (1934) and have achieved several advancements in terms of understanding and technology. Many empirical studies on speed-flow models are summarized by Hall and Montgomery (1993) who proposed a generalized shape of speed-flow curve. Yang and Zhang (2005) established speed-flow relations based on their extensive field survey of traffic flow on multilane highways in Beijing. They estimated the capacity for four-lane, six-lane and eight-lane divided carriageways as 2104, 1973 and 1848 pcu/hr/lane respectively. Different speed-flow curves for multilane highways are described in HCM (2010) where the speed almost remains unaffected by the flow and at capacity small decrease in speed is reported. The guidelines in most of the literature are for traffic conditions as prevalent in the US and other developed countries. Vehicular traffic in developing countries is completely different due to its heterogeneous nature.

Various traffic simulation models have been investigated by the researchers in different real world conditions and parameters of the model have been calibrated using actual field data. Arasan and Arkartkar (2011) derived the capacity standards for multilane intercity roads in India through simulation of heterogeneous traffic and suggested a capacity value of 4600 pcu/hr for four-lane and 7200 pcu/hr for six-lane divided road. Shukla and Chandra (2011) studied the behaviour of traffic flow on four-lane divided highways and developed a simulation model for traffic with non-lane discipline. They reported the capacity of four-lane divided road with earthen shoulders as 4770 pcu/hr in each direction and in the case of paved shoulders the capacity increased to 5290 pcu/hr in each direction. Fellendorf and Vortisch (2001) performed analysis through microscopic simulation model VISSIM for validation of car-following model on German and US roads. They calibrated the model by setting the distribution of desired speeds from a study conducted on the German highways. The capacityfound for two-lane freeway is around 3500 vehicle/hr. For the US roads, capacity up to 2700 vehicles/hr was reached through the simulation model. Lownes and Machemehl (2006) performed the manual calibration of VISSIM and investigated the impact of driver behaviour parameters on freeway capacity. Menneniet *et al.* (2007) also performed the parameter calibration of VISSIM using optimization algorithm and developed a new methodology for assessing the capacity based on matching speed-flow graphs from field as well as from simulation. Chitturi and Benekohal (2008) described a procedure for calibration of VISSIM for freeways to obtain the desired capacity and queue length. The effects of *CC0* and *CC1* on capacity were quantified and their relationship with average headway was established. Authors found that for good capacity results, the parameter should be kept greater than 0.8 s.Gomes *et al.* (2004) proposed a methodology for construction and calibration of a simulation model for unidirectional freeway with on-ramp control. FREQ was used for generating origin-destination matrices and VISSIM as a microscopic simulation approach. The developed model was tested in field and the VISSIM simulation approach was found suitable for modelling freeway traffic with complex interactions.

Mathew and Radhakrishnan (2010) also calibrated VISSIM model for mixed traffic flow at urban intersections. Several other studies in literatures have described the performance of VISSIM software in comparison to other software. Moen *et al.* (2000) performed a comparative study between two simulation software VISSIM and CORSIM and described the efficacy of VISSIM software over CORSIM. Choa *et al.* (2002) conducted a comparative analysis of the three major traffic simulation models (CORSIM, PARAMICS, and VISSIM) and validated them by considering travel time, queue length and level-of-service as validation parameters. Park and Won (2006) suggested a calibration procedure to set parameters into microscopic model VISSIM as per field data. The minimum time headway ranged from 0.1 to 0.9 s with *CC0* parameters value ranging from 1 to 2 m. The safety distance reduction factor defined for the links was also found to be important factor indicating the aggressiveness of drivers. Statistical test results were used to identify key calibration parameters such as time headway and car-following distance and plotted the correlation curves between simulation resolution and travel time. Park and Kwak (2011) further evaluated the results of calibration and validation procedure by comparing the distribution of simulation output with field data. Raka and Gao (2011) also performed parameters calibration based on steady-state car-following models being incorporated in traffic simulation software namely CORSIM, AIMSUN2, PARAMICS, INTEGRATION and VISSIM. VISSIM was found to be better as it contains multiple parameters that add flexibility in fine tuning of parameters to replicate traffic operations as observed in field.

4. Field Data

Field data for the present study was collected at a section of four lane divided inter-urban highway with earthen shoulders in India. The section for field data was selected sufficiently away from any intersection or access point to have uninterrupted flow condition. A longitudinal section of 65 m length was made on the highway (in one direction of traffic movement) using white self adhesive cloth tape and video recording of the section was done for 4 hours on a typical weekday. The video film was later replayed on a wide screen monitor in laboratory and data on classified volume count was decoded and collected. All vehicles were divided into 4 categories like car, motorised two-wheeler (*2W*), motorised three-wheeler (*3W*) and heavy vehicle (*HV*). Dimensions and proportions of these vehicles in traffic stream are given in Table 1.

The speed of a vehicle was determined by noting the time taken by the vehicle to cross the longitudinal trap of 65 m using a stop watch of 0.01 s accuracy. Speeds of individual categories of vehicles were analysed and the distribution profiles were created. The parameters such as mean, standard deviation and percentile limits as estimated from the field data are given in Table 2.

Table 1. Vehicles Dimensions and Their Proportion in Traffic Stream

Vehicle type	Length (m)	Width (m)	Projected area (m^2)	Proportion in traffic (%)
Car	3.5	1.5	5.5	40
2W	1.8	0.6	1.2	17
3W	3.2	1.4	4.4	05
HV	10.2	2.5	25.5	38

Table 2. Speed Parameters from Field Data

Vehicle Type	Speed Parameters (km/h)				Percentile Speeds (km/h)	
	Maximum	Minimum	Average	Standard Deviation	15^{th}	85^{th}
Car	98.8	30.3	63.5	12.0	45.2	82.1
2W	103.3	34.9	59.0	15.0	36.6	81.5
3W	61.4	26.7	43.2	9.7	28.6	57.8
HV	87.4	23.4	47.2	13.0	27.6	66.8

5. Speed-Flow Relation from Field Data

Classified volume and speed data were extracted for 5 min interval from the recorded film. Flow and capacity are generally expressed in terms of passenger cars per hour and therefore, Passenger Car Unit (PCU) are used to convert heterogeneous traffic stream into a homogenous equivalent. The PCU is a measure of relative interaction caused by a vehicle to the traffic steam compared to passenger car and this interaction will depend on traffic and roadway conditions. There are several methods available in literature to estimate PCU for a vehicle type. All these methods do not consider the dynamic nature of PCU and invariably provide a single set of PCU factors (Chandra *et al.*, 1997). In a highly heterogeneous traffic condition like in India, the PCU for a vehicle type will depend upon traffic composition, total volume of the road and physical size of the vehicle. Any change in the traffic volume or composition of traffic stream would be reflected in speed of individual type of vehicle. Chandra and Kumar (2003) proposed the following equation to determine the PCU for a vehicle and the same is used in the present study as well.

$$PCU_i = \frac{v_c/V_i}{A_c/A_i} \tag{1}$$

where, PCU_i = Passenger car unit of i^{th} vehicle
V_c/V_i = Speed ratio of car to i^{th} type of vehicle
A_c/A_i = Physical area ratio of car to the i^{th} type of vehicle

The stream speed for a time interval was determined by taking the average of speeds of all vehicles counted during that interval. The speed-flow curve for the field data is plotted in Fig. 1 and it yields the capacity value of 4980 pcu/hr/dir or 2490 pcu/hr/lane.

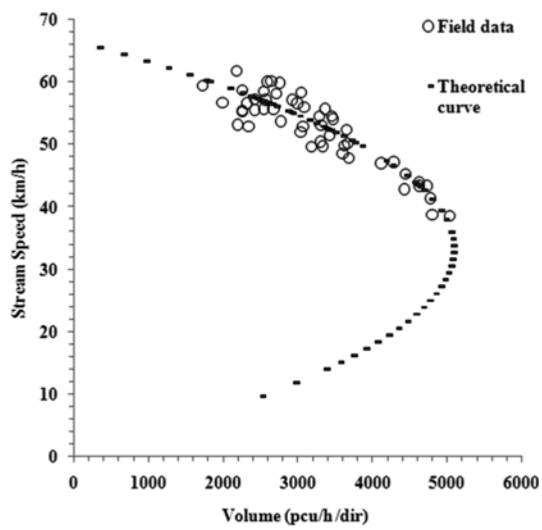

Fig. 1. Speed-flow Curve from Field Data

6. Simulation of Field Data using VISSIM

VISSIM is a microscopic, time step and behaviour based simulation model developed to model freeways, urban traffic and public transit operations (PTV, 2011). It performs trajectory based analysis that utilizes psycho-physical driver behaviour developed by Wiedemann (1999). The car-following behaviour contains ten different driver related parameters ranging from *CC0* to *CC9* with their default values. The values of these parameters have been investigated in different scenarios by researchers and checked the sensitivity of these parameters on simulated results.The literature suggests that simulated results are highly sensitive to parameters namely,*CC0* and *CC1*. *CC0* is the standstill distance in meters and *CC1* is the time headway in secondsbetween two vehicles at any speed *V*(m/s). Other parameters *CC2* to *CC9* do not have much influence on capacity of simulated section (Gomes et al., 2004). Therefore, the present research focuses on calibration of these two parameters for the mixed traffic conditions. As a first step, the speed flow diagram is estimated through VISSIM with default values of all ten parameters.

Basic input data in VISSIM require some specific details about roadway geometry, vehicle types and composition and desired speed. The minimum, maximum and desired acceleration or deceleration varies with the speed of a vehicle type in VISSIM. Vehicle composition was kept same as observed in field. The acceleration characteristics of different vehicles were recently estimated on Indian highway by Shukla and Chandra (2011) and the same were adopted in the present study. These are given in the Table 3.

One km of link stretch was created in VISSIM and the attributes were assigned to the selected link as observed in field. Travel time section of 65 m was selected on this link at 600 m from the point of vehicle input. Vehicular lateral and overtaking behaviour was modified to allow the vehicles to overtake from the left as well as from right under the left sided rule. Speed distribution curves as observed in the field for each vehicle type were given asinput to the simulation model and speed-flow curve was plotted. The simulation curve has been developed using the default values for *CC0* (1.5 m) and*CC1* (0.9 s) provided in VISSIM and presented in Fig. 2. Simulated capacity is 5256 pcu/hr/dir against the field capacity of 4980 pcu/hr/dir. As may be seen, the simulated data points are consistently above the field data points indicating that VISSIM overestimates the capacity and speed under mixed traffic condition.

Table 3. Accelerations and Decelerations Rates of Vehicles Assigned to VISSIM

Vehicle Type	Acceleration (m/s^2)		Deceleration (m/s^2)	
	Maximum	Desired	Maximum	Desired
Car	2.7	1.3	1.8	1.2
2W	2.5	1.5	1.7	1.2
3W	1.1	0.9	1.1	0.8
HV	2.2	1.6	1.5	0.5

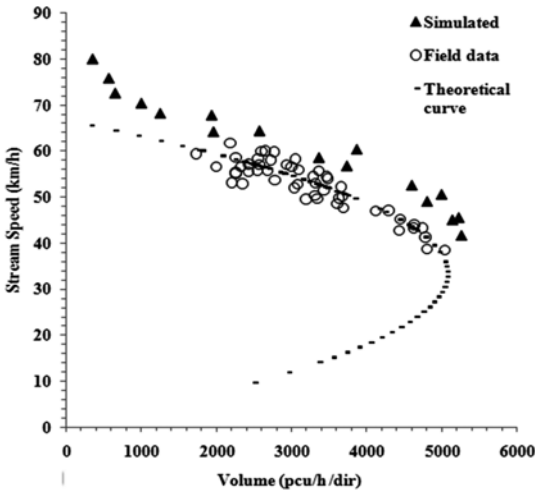

Fig. 2. Simulated and Field Speed-flow Curves with Default Parameter Values

7. Calibration of VISSIM Parameters

As mentioned earlier, *CC0* and *CC1* are the major parameters in VISSIM influencing the capacity of a section of highway. The default values of these parameters are the average values considered for the traffic stream. The model calculates the safe distance between a following and leading vehicle using Eq. (2).

$$Safe\ distance = CC0 + CC1 \times V \quad (2)$$

In a mixed traffic situation, the parameters *CC0* and *CC1* will be the function of a vehicle type and its share in the stream. To determine a generalized solution, a traffic stream consisting of only one type of vehicle at a time is considered first and then results are aggregated to estimate the parameters *CC0* and *CC1* for mixed traffic stream.

Shukla and Chandra (2011) developed a simulation model for 4-lane divided highways in India incorporating overtaking and lane changing behaviour of vehicles as observed in field. They validated the program statistically, using the data on speed, arrival of vehicles, traffic volume and composition of traffic stream collected in field. The simulation program was run for these input values and speed and arrival of vehicles obtained from the simulation program were compared with observed data. The maximum difference in observed and simulated speed was 7.7 percent, while the curve for simulated arrivals (number of arrivals in 10 s interval) closely followed the curve for actual arrivals. These results indicate that the developed simulation program replicate the actual traffic flow satisfactorily.

The above simulation program was run to determine the capacity of four-lane divided highway with earthen shoulders for homogeneous type of traffic with only one type of vehicle in the traffic stream, either car, heavy vehicle (*HV*), two-wheeler (*TW*) or three-wheelers (*3W*). It resulted in capacity of 4770 veh/hr in

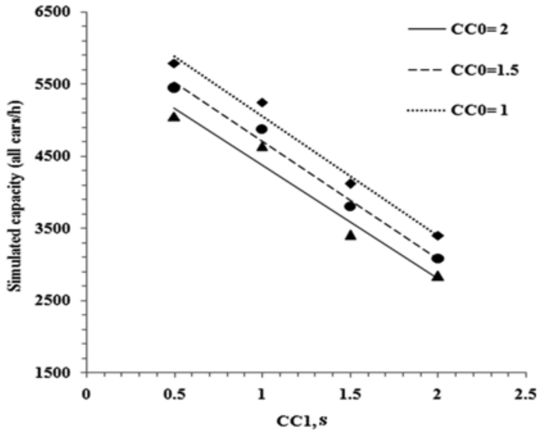

Fig. 3. Effect of CC0 and CC1 Parameters on Simulated Capacity

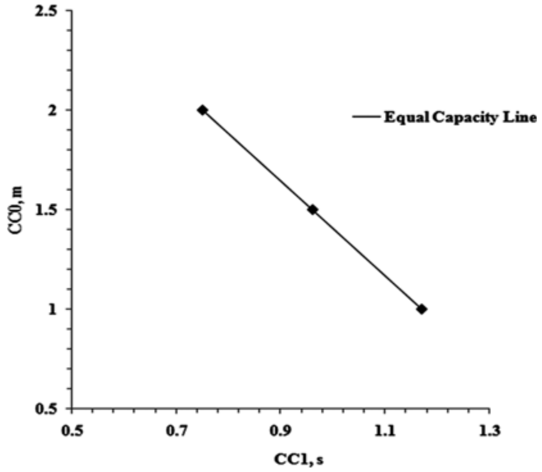

Fig. 4. Relation between CC0 and CC1 for All Car Situation

each direction for 'all cars' condition. It changed to 1300 veh/hr for 'all *HV*', 2970 veh/hr for 'all *3W*' and 13520 veh/hr for 'all *2W*'. These results are used in the present study to determine the value of VISSIM parameters for homogeneous traffic conditions. VISSIM was run for 'all cars' situation with varying values of these parameters and capacity of the section was evaluated. The results are shown in Fig. 3. As may be seen, capacity is sensitive to both *CC1* and *CC0*. The threshold capacity for this situation is 4770 veh/hr and it can be obtained with different combinations of *CC0* and *CC1* parameters. Fig. 4 shows relation between *CC0* and *CC1* for a threshold capacity of 4770 veh/hr for 'all cars' situation. Any combination of these two parameters satisfying the relation shown in Fig. 3 would produce a capacity of 4770 veh/hr. The default value of parameter *CC1* in the model is 0.9 s. Dey *et al*. (2008) have reported that drivers in India are more aggressive than their counter parts in Germany or US. Therefore, a slightly higher value of *CC1* will better reflect mixed traffic behaviour. Therefore, a value of 1.10 s is taken for *CC1* and corresponding value of *CC0* is 1.17 m.

Similar exercise was done of scenarios of all *HV*, all *2W* and all *3W* traffic streams and also optimum values of *CC0* and *CC1*

Table 4. VISSIM Parameters for Homogeneous Traffic Stream

Homogeneous vehicle type	Simulated capacity (veh/hr)	Driving behaviour parameters	
		CC0	CC1
Car	4740	1.17	1.1
2W	13500	0.3	0.3
3W	2950	1.5	0.9
HV	1300	2.4	1.7

were determined at capacity close to the one estimated through simulation programme developed by Shukla and Chandra (2011). Simulated capacity for each homogeneous traffic stream and corresponding value of *CC0* and *CC1*parameters are given in Table 4. Standstill distance (*CC0*) and time headway maintained by a vehicle depend upon the size of the vehicle and its operational efficiency. Small sized vehicles like 2-wheelers have better manoeuvrability and therefore *CC0* and *CC1* parameters for 2W are quite low. These are the maximum for heavy vehicles due to large size and poor manoeuvrability.

The values of parameters *CC0* and *CC1* as given in Table 4 are for homogeneous type of traffic stream. In a mixed flow situation, all the four categories of vehicles are present in different proportions. *CC0* and *CC1* for a mixed traffic flow calculated by Eqs. (3) and (4), respectively.

$$CC0_{mixed} = CC0_{car} \times P_{car} + CC0_{TW} \times P_{TW} + CC0_{3W} \times P_{3W} + CC0_{HV} \times P_{HV} \tag{3}$$

$$CC1_{mixed} = CC1_{car} \times P_{car} + CC1_{TW} \times P_{TW} + CC1_{3W} \times P_{3W} + CC1_{HV} \times P_{HV} \tag{4}$$

where, $CC0_{car}$ and $CC1_{car}$ are the *CC0* and *CC1* valuesfor 'all cars' situation and P_{car} is the proportional share (in fraction) of car in traffic stream.

For example, for field data reported in Table 1, the values of these parameters would be calculated as below.

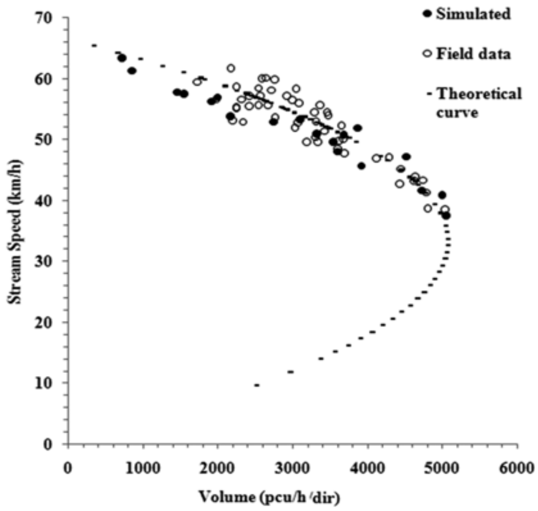

Fig. 5. Comparison of Speed-flow Curves between Simulated and Field Data

$$CC0_{mixed} = 1.17 \times 0.40 + 0.30 \times 0.17 + 1.50 \times 0.05 + 2.40 \times 0.38 = 1.50$$
$$CC0_{mixed} = 1.10 \times 0.40 + 0.30 \times 0.17 + 0.90 \times 0.05 + 1.70 \times 0.38 = 1.18$$

VISSIM was run with these parameter values and speed-flow curve was developed and compared with the field data as shown in Fig. 5. It gives the capacity value of 5052 pcu/hr, which is almost same as the field capacity of 4980 pcu/hr. The percent difference in simulated and field values is less than 2 %.

8. Model Validation

Validation of the above procedure was performed using another set of field data collected ona four-lane divided inter-urban highway with paved shoulders. The traffic composition on this section was nearly the same as observed on the first section with earthen shoulders (Table 1). Speed data collected in field were analysed for each type of vehicle and the speed parameters required as basic input to VISSIM were evaluated as shown in Table 5. The acceleration and deceleration characteristics of different types of vehicles were taken as observed on sections with earthen shoulders and given in Table 3. Simulation parameters *CC0* and *CC1* for mixed traffic stream were calculated for observed composition of traffic stream using Eqs. 3 and 4, and their values were obtained as 1.50 m and 1.15 s respectively.

Simulation runs were made with these values of *CC0* and *CC1*parameters for full range of traffic volume. The simulated data were analysed to draw the speed-flow curve and thereby to estimate capacity of the highway. The simulated data and the field data are plotted in Fig. 6. The simulated capacity is 5329 pcu/hr/dir(2665 pcu/hr/lane) against the field capacity of 5277 pcu/hr/dir (2638 pcu/hr/lane). The difference in simulated capacity and the field capacity is less than one percent. It shows that calibrated parameters are suitable for simulating mixed traffic conditions on four-lane divided roads with paved shoulders also.

Table 5. Input Parameters for Highway with Paved Shoulders

Vehicle Type	Speed Parameters (km/h)				Percentile Speeds (km/h)	
	Maximum	Minimum	Average	Standard Deviation	15th	85th
Car	103.0	29.4	57.7	11.7	40.1	75.2
2W	102.2	34.4	55.6	11.5	38.3	72.9
3W	70.3	26.8	48.7	7.8	37.0	60.3
HV	80.1	18.5	50.4	8.6	37.6	63.3

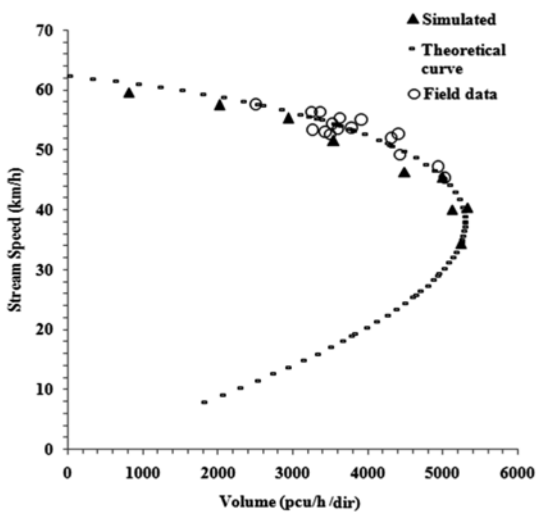

Fig. 6. Comparison of Simulated and Field Speed-flow Data for Validation

9. Conclusions

Traffic flow data calibrated at a section of four-lane divided highway under mixed traffic conditions are analysed using microscopic traffic simulation model VISSIM. It was found that the VISSIM in its current form is not able to simulate mixed traffic flow of the type prevalent on Indian highways. The driver behaviour parameters *CC0* and *CC1* are determined for homogeneous type of traffic stream consisting of only one of four vehicle type at a time. Threshold capacity value used for homogeneous traffic streams were estimated through another simulation programme developed for Indian conditions. Base values of *CC0* and *CC1* determined for homogeneous stream are used to estimate *CC0* and *CC1* for mixed traffic conditions. It is illustrated from this study that the method of weighted average suggested in this paper for calibrating *CC0* and *CC1* for field observed traffic composition worked well and produced the simulated capacity with 2% error when compared with capacity obtained from the field data.

The present study considered calibration of two major parameters (*CC0* and *CC1*) of VISSIM software for mixed traffic conditions. These parameters were chosen based on earlier studies reported in literature. Further analysis may be carried out to observe the influence of remaining parameters (*CC2*-*CC9*) on capacity of a roadway and these parameters may also be calibrated for mixed traffic, if needed.

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