ASSESSMENT OF ROADWAY CAPACITY FOR A FOUR- LANE DIVIDED ROAD UNDER HETEROGENEOUS TRAFFIC

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Abstract— The economic growth of any country depends on transportation for its overall development. The highways in India follow heterogeneous traffic conditions in contrast to highways in other countries. Hence, the models developed for capacity estimation of highways by other countries cannot be adapted in India. In this paper, the assessment of roadway capacity for a 4-lane divided National highway-44 with two sections each of 60 meter stretch is identified and considered for the study. The sections were selected taking into account the effect of varying road geometry, pavement surface conditions and possible variations in traffic conditions only on normal weekday traffic. Traffic data consisting of classified traffic volumes, space mean speeds and free speeds of vehicles were obtained using videography technique in blocks of four hours each for 10 to 12 hours in a day to capture the effects of morning and evening peak hours as well as the heavy traffic plying primarily in the night-time. The methodologies involved in this study are 1) free flow speed 2) Dynamic passenger car unit and 3) speed flow study. Speed-flow relationships on the study sections were then developed for the study sections and capacity flow was taken to be the traffic flow at half of the free flow speed at a section microscopic simulation of the traffic on the study sections was attempted using VISSIM 7.0. The simulation model was calibrated and validated using the observed volumes, space mean speeds. Subsequently the capacity was estimated using the speeds and flows obtained using the simulation model. The capacity with respect to four lane divided National highway is estimated to be around 4100 PCU/hr/lane/direction. Assessment of lane change behaviour for four-lane through field observations and model refinement can be done. Study can be extended to the estimation of Capacity for eight-lane and six-lane divided highways.

Key words: Indian Highway Capacity Manual, PCU, microscopic simulation, Highway Capacity.

I. INTRODUCTION

India had the one of the biggest street arranges on the planet, traversing over an aggregate of 5.6 million kms. More than 64.5 for every penny of all products in the nation are transported through streets, while, 90 for each penny of the aggregate traveller activity utilizes street system to drive. More noteworthy availability between various urban areas, towns and towns has prompted expanded street activity throughout the years. Development in autos and cargo development orders a superior street arrange in India. Ascend in the quantity of 2 and 4 wheelers, expanding activity bolsters the development. The administration has given a gigantic push to foundation by apportioning US$ 61.8 billion for framework in the Union Budget 2017-18. Developing interest of the private division through Public-Private Partnership (PPP) is being embraced. The Government of India intends to contribute Rs 1.45 lakh crore (US$ 22.40 billion) towards street framework in North-East locale between 2018-2020. The Central Government has optimized no less than 24 streets and interstates ventures. Government is intending to offer a reward of 10 for each penny of the aggregate venture cost to firms that develop and convey interstate undertakings previously due date. Street foundation has been key government need; part got solid budgetary help throughout the years. Budgetary establishments got government endorsement to fund-raise through tax-exempt securities 100 for every penny. FDI is permitted under programmed course subject to material laws and controls. The aggregate length of street in India is 5.6 million Kms. State Highways: Total length: 176,166 kms Share: 3 for every penny of the aggregate streets in India, National Highways: Total length: 115,530 kms Share: 2 for every penny of the aggregate streets in India and District and Rural streets: Total length: 5,326,166 kms Share: 95 for every penny of the aggregate streets in India. Expanding mechanical action, expanding number of 2 and 4 wheelers would bolster the development in the street transport framework ventures. In January 2017, the administration proposed to set down cycle tracks on all thruways and significant streets skillet India, to advance the utilization of electric autos and open transport. Twofold path expressways constitute the biggest offer of interstates in India (40658 kms).

Twofold path parkways are trailed by single/middle path (19330 kms) and 4/6/8-path (19128 kms) interstates. The Government has proposed to update 2 path national interstates into 4 path national expressways for which US\$ 65 billion has been allotted. This progression is required to diminish the traveller auto units (PCU) to 10000 every day In the province of Telangana, the aggregate gathered length of National Highways including those endorsed after arrangement of the state and before bifurcation remains at 5,512-km as on April 2017. India's national expressway arranges is relied upon to cover 50,000 kilometres by 2019. The aggregate length of national roadways is relied upon to achieve 100,000 kilometres before the finish of the12th Five-Year Plan In September 2015; government set an objective of building national expressways of 30 km for each day. By February 2017, government developed 6,604 kms of national thruways. An aggregate of 50,000 kms of state thruways is to be taken up for up-degree as National Highways.

II. LITERATURE REVIEW

This area centres around the applicable past examinations from around the world for limit estimation of multilane partitioned National parkways. Some past hypotheses and experimental explores concentrated on the interrelationships among the impact of limit, activity highlights, geometric components, ecological conditions and worldly climate factors on intruded on multi-path roadways. Numerous long stretches of research has prompted the improvement of speculations and philosophies in roadway limit examination in the created nations. For instance, the parkway limit manual (HCM) created in the United States of America portrays roadway limit under perfect conditions and after that assessments pragmatic limits under winning conditions in the field.

In the end, the main real research exertion in India toward this path was done as a major aspect of the RUCS-1982 (CRRI, 1982) and this was trailed by URUCS-1992 (Kadiyali and Associates, 1992) and URUCS-2001 (CRRI, 2001). IRC-64 (1990) proposed the conditional outline benefit volume (DSV) of 40,000 PCUs for the four-path separated carriageway in plain territory which is essentially lesser than the qualities advanced in the vast majority of the created and creating nations and along these lines the need was felt for returning to the DSV esteems developed under IRC-64. Thus, many research thinks about (Kadiyali et al., 1991; Tiwari et al., 2000; Velmurugan et al., 2002, 2004, 2009, 2010; Chandra and Kumar, 2003; Reddy et al., 2003; Chandra, 2004; Errampalli et al., 2004, 2009; Dey, 2007) went for surveying the roadway limit with respect to fluctuating carriageway widths including single path, halfway path, two-path bi-directional and four-path separated carriageway widths covering diverse territories have been done amid the most recent two decades. URUCS-2001 (CRRI, 2001) prescribed conditional roadway limit of 70,000 to 90,000 PCU's/day for a four-path partitioned carriageway in plain terrain. Hadi et al (2007) contemplated the decrease in roadway limit because of episodes. They used CORSIM, VISSIM and AIMSUN to mimic movement conduct of road section. They tuned the adjustment parameters to accomplish their objective of assessing join limit under ordinary and occurrence conditions and they characterized connect limit as the vehicle throughput every hour that can cross the connection, gave there is sufficient request to achieve limit. For the model created in VISSIM, they distinguished model parameter CC1 as the most grounded parameter impacting the turnpike limit. Their examination likewise presumed that the changing rate closely resembles changing the auto following parameters as far as modifying the limit esteems. Shukla (2008) examined the blended activity stream conduct on four-path separated thruway for differing states of movement volume and bear and built up a reproduction display for the watched activity stream to evaluate roadway limit under these conditions. To comprehend the movement stream conduct on four-path isolated thruways under blended activity condition, the entry example of vehicles, speed qualities, sidelong position of vehicles and surpassing conduct was examined. Velmurugan et al. (2011) investigated free-stream paces of various vehicles compose for evaluating limit on rapid multilane thruways in India.The measured speeds of different vehicles were further incorporated in simulation model for the estimation of highway capacity. Mehar et al. (2013) estimated multilane highway capacity through VISSIM calibrated for mixed traffic conditions. He has developed five different driver behaviors for different categories of vehicles based on their static and operating characteristics. Literature review reveals that little work has been done towards the effect of heterogeneity of traffic on saturation flow and performance and capacity analysis of multi-lane highways. Highway Capacity Manual (HCM) provides basis for the capacity analysis based on estimation of speed and flow. This approach is being widely used in most of the developed countries as it represents their traffic conditions. Arpan Mehar et.al, (2013) determine the capacity of Indian highway in diverse traffic flow operating situations by the use of microscopic simulation software (VISSIM) and compared the simulated traffic data with field traffic data and modify certain parameters(driver behavior) which disturb the simulation result. Chandra et.al, (2003) studied effect on the capacity by means of lane width of roads in varied traffic conditions, work on diverse roads is carried and study analysis express that PCU values for a different vehicle classes suddenly upsurge with width of lane.

Based on the review of mentioned studies in both developed and developing countries, it is obvious that the roadway design and traffic control practices are mostly country or region specific and hence cannot be simply transferred to any country for direct applications. In this context, it is to be noted that the roadway capacity and the conditions for adjustment are vastly different on Indian roadways as the local roadway design (that is, lane width, curves and grades), vehicle size and more importantly, traffic mix and behaviour of a driver especially lane changing and lane discipline phenomenon are entirely different. Further, since there is no systematic approach to this problem, coupled by a lack of fundamental data, the adjustment factors from say, the US HCM 2000 (TRB, 2000) cannot be easily revised and applied to Indian highways. This is because adherence to lane discipline characterizes homogeneous traffic in the developed nations whereas very loose lane discipline describes heterogeneous traffic which is very much an integral part of all roadways in India including multi-lane highways. This is due to fast moving vehicle cars, goods vehicles, motorized two wheelers sharing the same road space with bicycles, farm tractors, tractor trailers and other types of slow moving vehicles (like cycle rickshaw, animal drawn vehicles, etc.) on the Indian traffic scene accounting for varying proportion on multi-lane highways depending on its geographical location.

III. MODELS AND METHODS

Bimodal Distribution Method: When the observed traffic stream includes some intensity at about the point of capacity of the road a bimodal distribution may be observed (Cohen, 1983). The special character of the intensity distribution can be explained by the existence of two different traffic states, one representing the traffic demand and one representing the stochastic maximum flow level (both collected during the observation period). Two separated distributions are assumed to represent the compound distribution of the observed flow rates. The definition of capacity according to this bimodal distribution method could be stated as: The capacity of the road is the expectation (or some other /location characteristic) of the probability density function representing the (stochastic) maximum flow variable, in case a bimodal distribution of intensities is observed during the observation period. For this method, only traffic volumes have to be counted at a cross-section of a road. The Bimodal Distribution method can be used when the conditions concerning the location choice and survey aspects have been satisfied.

The Selected Maxima Method: Methods based on the Selected Maxima principle use the maximum flow rates measured over the observation period. The road capacity is assumed to be equal to the traffic flow maxima (distributions') observed during the total observation period. An example of a very easy application of the Selected Maxima Method is taking the average of observed maximum day intensities. The observation of flow rates should take place over several days until sufficient data is collected for analysis purposes. Road capacity may be defined here as: The average maximum flow based on selected observations over the observation period (or some other location characteristic of the observed distribution of maximum flows).The data to be used with the Selected Maxima Methods consist of hourly traffic volumes or flow rates observed in an averaging interval less than an hour.

Direct Probability Method: What are the characteristics of the extreme flow rate values which occur occasionally in everyday traffic condition? If maxima are recorded over a suitable period of time, can any useful information be deduced from them? These questions were the starting point for the development of the Direct Probability method which can be found in Hyde & Wright (1986). With this expected extreme value method, a prediction of the largest possible value can be made on the assumption that the traffic volumes conform to a theoretical model such as the Poisson process. The Direct Probability Method requires that the capacity level of a road has been reached during the observation period. Here, the approach to the capacity problem is to consider variations in volumes over time during 'normal' traffic conditions (no congestion at the measuring point or accidents). The capacity estimate resulting from the calculations can be considered as a certain exceptional value of the maximum flow. The capacity of a road is the expected maximum flow rate predicted from the distribution of traffic counts given an assumed traffic arrival process The Direct Probability method uses flow rates to calculate the expectation of the largest value, the assumed capacity of the road.

Asymptotic Method: The Asymptotic Method (Hyde & Wright, 1986) is another approach (instead of the Direct Probability Method, Section 3-3) to solve the extreme value estimation problem. The assumptions and capacity definition will be explained here. The method relies on the theory that the behaviour of the extreme values arising from any natural process can be described in terms of a simple statistical model. The model turns out to have two parameters, whose values can be estimated from observed maxima when analysed in the appropriate way. This estimation gives a direct indication of whether the variable has an absolute upper limit, and if so, its value. The upper limit will lie outside the range of the observed data, and in such cases the validity of the method depends on the extent to which the data satisfies the assumptions on which the method is based (Gumbel , 1958). Instead of trying to estimate the exceptional maximum flow rate what is done in Section 33, one is trying to estimate a (yet unobserved) limit, which can be referred to as the 'maximum' or 'limiting' capacity.

Here, also the assumption is made that the traffic volume observations for all averaging intervals are independently and identically distributed. The capacity of a road is defined as: The expected maximum flow rate predicted from the distribution of observed extremes in selected intervals (cycles). The Asymptotic method uses vehicular flow rates to calculate the expectation of the limit value, the assumed capacity of the road.

Empirical Distribution Method: The theory of the method is based on an explicit division of the flow observations that have been made over the observation period. The idea is that a capacity value can be derived from the distribution of capacity measurements. It can easily be understood that a flow rate measurement can be divided into one of the following categories if the traffic state is observed upstream the measuring point: Measurements representing the traffic demand (a free flow intensity measurement), Measurements representing the capacity-state of the road maximum congested flow intensity) indicated with observation elements of set {O} and {C} respectively. With this division, it is possible to estimate the Empirical Capacity Distribution function F(q). This categorisation of observations is also an important aspect of the Product Limit Method (Section 4-2). The definition of road capacity according to the Empirical Distribution Method is the following: A capacity distribution (and a capacity value at a certain location characteristic) may be derived using intensities observed at a bottle-neck during upstream congestion conditions. The Empirical Distribution Method is based on observations of traffic volumes at a weil chosen measuring point at a bottleneck,. Speed measurements upstream a bottleneck (Location a) are necessary to ascertain a traffic state with congestion. It is mostly assumed that speed measurements below a certain level (e.g. 70 km/h) imply this congestion state. In addition, this means that traffic in the bottle-neck (Location b) is at the capacity-state of the road. However, speed observations downstream the bottleneck, location c, are required to determine the traffic state and the possible occurrence of congestion. If congestion is measured at that point c, a bottle-neck further downstream the freeway affects the observed intensities at location b, so that roadway capacity at b is not yet reached. The bottle-neck observations are then no longer representative for a capacity situation, and therefore the observations are included in neither set {O} nor {C}.

Product Limit Method (PLM): The theory of the PLM method (Van Toorenburg, 1986) is based on an explicit division of the flow observations that have been made over the observation period. The categorisation already mentioned in Section 4-1-1 is an important aspect of the Product Limit Method. The idea is that we can use free flow intensity measurements to improve our capacity estimate based on capacity measurements only, since these measurements can give us a better indication about the real capacity value. There for, the Product Limit Method takes into account all free flow intensities which are equal or exceed the lowest capacity measurement made during the observation period. The road capacity definition according to the Product Limit Method is therefore: The capacity is a location characteristic (mean, median, percentile point) of the estimated distribution of capacity. This estimated distribution is derived from the empirical distribution of capacity observations using information contained in the free flow observations. The Product Limit Method is based on observations of traffic volumes at a well-chosen measuring point at a bottle-neck. Speed measurements upstream a bottleneck (location a) are necessary to ascertain a traffic state with congestion. It is mostly assumed that speed measurements below a certain level (e.g. 70 km/h) imply this congestion-state. In addition, this means that traffic in the bottle-neck (Location b) is at the capacity-state of the road. However, speed observations downstream the bottle-neck, location c, are required to determine the traffic state and the possible occurrence of congestion. When congestion is measured at that point c, a bottle-neck further downstream the freeway affects the observed intensities at location b, so that roadway capacity at b is not yet reached. The bottle-neck observations are then no longer representative for a capacity situation, and therefore the observations are included in neither set {Q} nor {c}.

Selection Method: The application of the Selection Method is a possibility in case there is insufficient capacity measurements collected for an appropriate use of the Product Limit Method, although until now no quantitative expression for this needed proportion is given. The Selection method will result in a single value instead of a capacity distribution. The basic procedure of the Selection Method, assigning observations to one of the two possible categories has already been explained. The observed maximum intensity can be an element of set {Q} or {C}, and that the proportion of the number of measurements in the sets can be different. The difference between the depicted situations A and B can be described as the difference of a complete (situation B) or incomplete (situation A) Capacity Distribution function. In other words: in situation A same of the free flow intensities observed are higher than the highest measured capacity value. Therefore, the Capacity Distribution will show no absolute maximum, while in the case of situation B a maximum value will be found. The same holds for A' and B'. The situations A' and S' differ from A and B because now only a few capacity measurements are collected. However, what is the implication of the differences between A, Band A' and B' for the capacity estimation result? First of all, we must remark that for bath situations A and B the Product Limit Method may be applied, since there are sufficient capacity observations in comparison with the number of intensity observations. As a result, reliable capacity distribution based on the PLM procedure can be determined. For situations such as A' and B' the Selection Method is a feasible alternative to the Product Limit Method.

The definition for this capacity value is: A single capacity value is derived from the empirical distribution of capacity observations using information contained in the free flow observations in case the proportion capacity to free f tow observations is insufficient to an appropriate PLM capacity estimation. The Selection Method uses the same traffic data as the Empirical Distribution Method described in Section 4-1 and Section 4-2 (the Product Limit Method.

Micro-Simulation method: Micro-simulation models track individual vehicle movements on a second or sub second basis. Micro-simulation relies on random numbers to generate vehicles, select routing decisions, and determine behaviour. Because of this variation, it is necessary to run the model several times with different random number seeds to obtain the desired accuracy. There will be a 'warm-up' period before the system reaches a steady state, and this period should be excluded from the results. Micro-simulation models usually produce two types of results: animated displays, and numerical output in text files. It is important to understand how the software has accumulated and summarized the numerical results to prevent incorrect interpretation. Animation can allow the analyst to quickly assess the performance; however it is limited to qualitative comparisons. The main indication of a problem that can be seen in an animation is the forming of persistent queues. 'Measures of Effectiveness' (MOEs) may be calculated or defined in a manner which is unique to each simulation program. MOEs are the system performance statistics that categorize the degree to which a particular alternative meets the project objectives. The following MOEs are most common when analysing simulation models:

IV. RESEARCH METHODOLOGY

The primary objective of the study is to assess the free flow speeds of different vehicle types and determine the Dynamic PCU factor on multi-lane National Highways so that the estimated roadway capacity will yield the real picture of ground condition and thus help to develop a realistic speed - flow equations for estimating the roadway capacity. In order to achieve the above envisaged objectives, separate methodologies are adopted. To accomplish the above stated objectives, the following case study is conducted to estimate Free Flow Speed study, Dynamic PCU study, Speed - Flow study, etc.
Case Study: In this case study, MEDCHAL-NIZAMBAD highway is selected for test section as shown in Figure 1. It is a multi-lane highway which comes under NH-44. The distance between Medchal to Nizambad is about 144 kilometres.
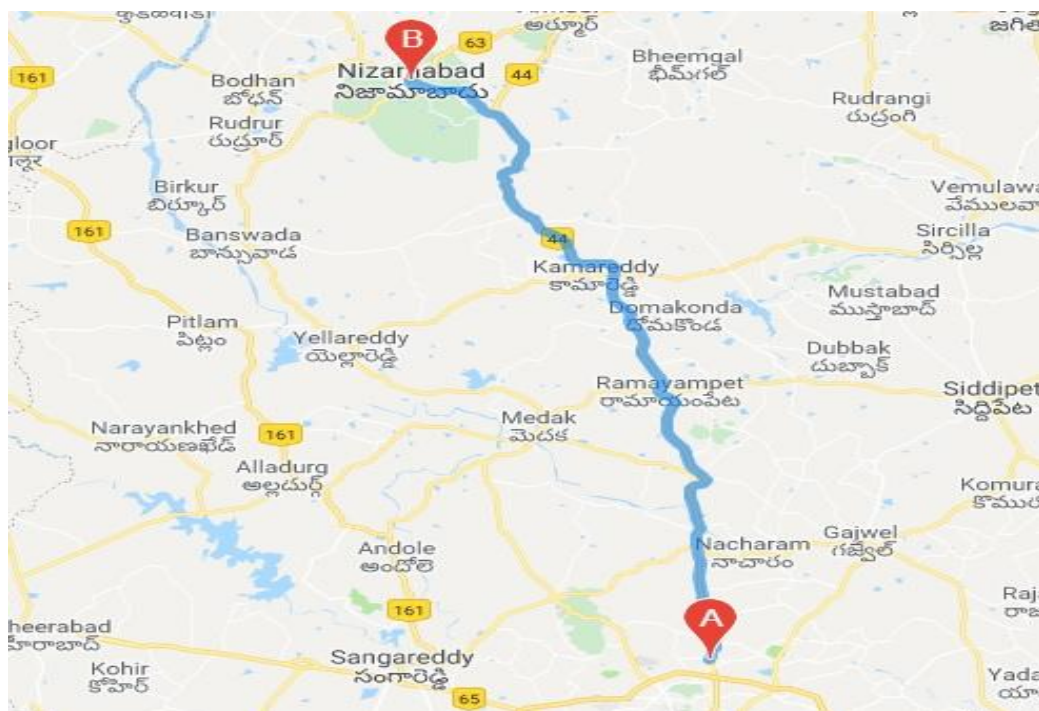

Figure 1 Study Area

Data Collection: The data for this study were collected at two sections of multi-lane divided national highway roads spread over 12 hour period with the help on videography technique in order to determine the effect of lane width, directional split and shoulder condition on the capacity of four-lane and divided Carriageways. The sections were selected in a manner that the effect of each parameter could be studied individually. The details of these sections are presented in Table 1.

Table 1 Selected Test Sections

Section No.	Type of section	Location	Carriage way width in one direction of travel (m)	Trap length (m)	Remarks
1.	Four lane divided	Medchal in the state of Telangana. NH44	7.5	60	Unpaved earthen shoulder of 1.2m

Research Process: The recorded video data was replayed on the screen and the required data for speed and traffic were decoded. The vehicles were divided into fifteen categories and the data extracted from video recording were volume, space mean speed, headway and lateral clearance by individual vehicles during every five minute of time interval. The data collected through videography technique survey was finally used for further analysis. The speed - flow studies were conducted along with free flow speed studies at the test sections mentioned in Table 1. In the case of speed - flow studies, videography technique was used for the determination of journey speeds and simultaneously Classified Traffic Volume Counts were conducted to estimate flow by synchronizing start time of the traffic Volume Counts were conducted to estimate flow by synchronizing start time of the traffic trap length was determined and thereby the travel speed was derived. Based on the collected speed and flow data, speed - flow relationships have been developed for different vehicle types for four-lane divided Carriageways separately. The methodology followed for the simulation is shown in the form of flow chart in Figure 2. From the Figure 2, it can be observed that the data collection is the first and foremost requirement for understanding speed-flow characteristics on multilane highways videography method was adopted for data collection. The recorded film was replayed on screen and the required data were decoded through manual method. The vehicles were divided into fifteen categories and the data extracted from video recording were traffic Volume, Space Mean Speed (SMS) of vehicles during every five minute time interval. The video data on classified traffic volume counts and space mean speed were decoded in a synchronized fashion. Using this data, a model has been developed in VISSIM 7.0, microscopic simulation software. Then the model is appropriately calibrated and validated using the observed data considering traffic volume and speed.
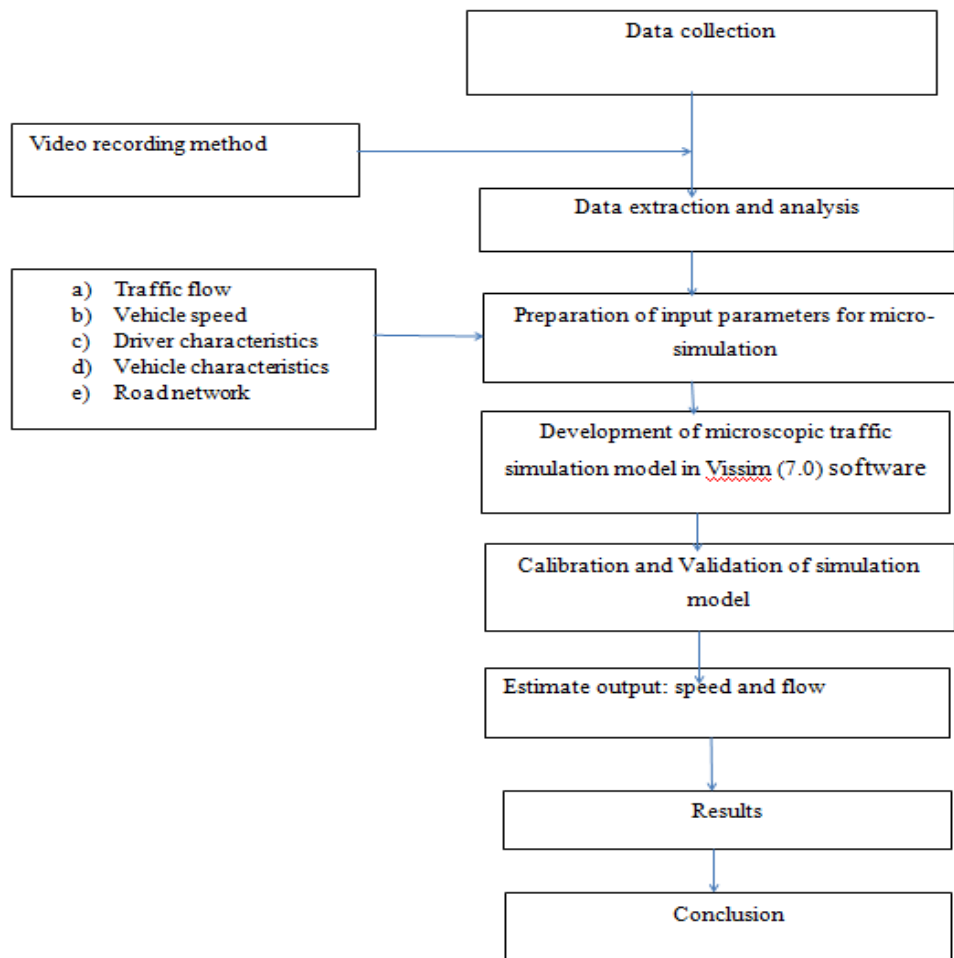

Figure 2 Research Process

Free Flow Speed Analysis: The analysis of collected free speed data was carried out as per the methodology. The data collected for the two test sections covering both directions of travel In the above given equation, the first variable of speed ratio will be function of composition of traffic stream as the speed of any vehicle type depends on its own proportion, type and proportion of other vehicles. Hence the speed of any vehicle type will be true representation of overall interaction of vehicle type due to presence of other vehicles. The second variable space ratio indicates influence area of vehicle with respect to car. The observed free speed data was fitted through normal distribution and relevant parameters namely average speed, standard deviation, percentile speeds and SR were estimated. From the normal distribution curves, free speeds of vehicles on various selected sections of the multi-lane high speed corridors are estimated and presented in Table 4.2 for four-lane divided Carriageways. These tables also present the various percentile speeds and the spread ratio of different vehicle types. Since the free speed analysis mainly focuses on free-flow conditions, the vehicles travelling with higher speeds are considered while arriving at the average free speeds. From Table 4.2 it can be observed that the normal distribution curve described the speed distributions satisfactorily in most of the vehicle types since the SR value is ranging around 1.0 (from 0.994 to 1.001) demonstrating that SR is well within the limits. A critical evaluation of the free speed studies on four-lane divided carriage way reveals the following: The free speed of both small and big cars is much higher when compared with other vehicle types demonstrating the rapid advancements in car manufacturing technologies and superiority of these engines. The mean free speed of Mini Bus and Light Commercial Vehicle (LCVs) are more or less same. The mean free speed of Two Wheeler is marginally higher than that of LCVs and Heavy Commercial Vehicle.

Vehicle Type	Sample Size	Avg. Speed *	V_{15}^{*}	V_{50}^{*}	V_{85}^{*}	Max. Speed*	SD*	SR
Two Wheeler	267	62	48.29	62.22	76.16	100	13.45	1.000718
Auto	42	42	34.89	41.6	48.32	64	6.78	1.00149
Motorized Four Wheeler	42	57	45.7	55.77	65.84	77	9.71	1
Small Car	445	73	57.23	72.68	88.12	120	14.9	0.999353
Big Car	408	76	58.9	76.3	93.7	125	16.81	1
Bus	147	65	53.46	64.84	76.22	91	10.98	1
Mini Bus	54	62	46.9	62.26	77.61	93	14.82	0.999349
Light Commercial Vehicle	173	58	47.91	57.95	67.98	82	9.68	0.999004
Heavy Commercial Vehicle	138	53	41.08	52.86	64.64	80	11.37	1
Multi Axle Vehicle	76	64	46.17	54.52	62.86	97	8.05	0.998802

Table 2 Free Flow Speed Data

Analysis of Dynamic PCU: The analysis of collected data for headway and lateral clearance was carried out as per the methodology explained above. The data collected for all the 2 test sections have been utilized, Eqn. 1 is used to analyse the data collected on four lane divided Carriageways independently. $PCU_i = (V_C / V_i) / (V_C / V_i)$ ....Equation (1). Where, PCU_i = equivalent passenger car unit of vehicle i, V_C = clearing speed of car (km/hr), V_i = clearing speed of vehicle i (km/hr), A_i = projected rectangular plan area of car (m2), A_i = projected rectangular plan area of vehicle i (m2). The values of PCU factor obtained using Eqn. 1 is presented in Table 3.

Dynamic PCU for different categories of vehicles																						
Motorized 2-W		Motorized 3-W		Motorized 4-W		Small Car		Big Car		Bus		Mini Bus		LCV		HCV		Multi-Axle Vehicle		Bicycle		Cycle Rickshaw		Tractor	
Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4-Lane Divided NH-44																									
0.3	0.2	1.5	1.3	1.9	1.5	1.0	1.0	1.4	1.2	5.6	5.0	3.3	2.7	2.8	2.1	4.1	3.5	8.7	7.4	0.5	0.5	1.6	1.5	2.7	2.0

Table 3 PCU Data

Speed-Flow Analysis: Using the validated simulation model, speed - flow relationships have been developed. The roadway capacity has been estimated using Static and Dynamic PCU in this study. In microscopic simulation, a model which accurately represents the existing situation is known as the 'Base Model'. The base model is constructed by representing the network area that was defined in the model and using actual, observed traffic flow data. The validated base model is used to develop a 'future year base model' against the various scenarios and design options to be compared. The base model development can be summarized in the following steps: (1) Developing base network. (2) Defining model parameters. (3) Calibrating the network. (4) Validating the model. Development of a network that accurately determines the constraints of a road network is an important stage in the modelling process. The basic key network building components are: Links and Connectors. In the present simulation model, links are created spanning for 60m representing the test section near Medchal on NH-44 for both directions. However, a buffer link is provided for buffering process of the network which is taken 200m. Both test section link and buffer links are appropriately connected by connectors. As mentioned earlier, the test section selected on NH-44 is a four-lane divided carriage way with approximately 2.0m paved shoulder and 0.5m earthen shoulders. Accordingly, the links are created in VISSIM 7.0 with total of four lanes on each link including two lanes of main carriage way.

Calibration of Microscopic Simulation Model: Calibration is a process of adjusting the model parameters, network and vehicle demand to reflect and represent observed data and/or observed site conditions to a sufficient level to satisfy the model objectives. The calibration process adopted in this study is explained in the form of flow chart as in Figure 3.
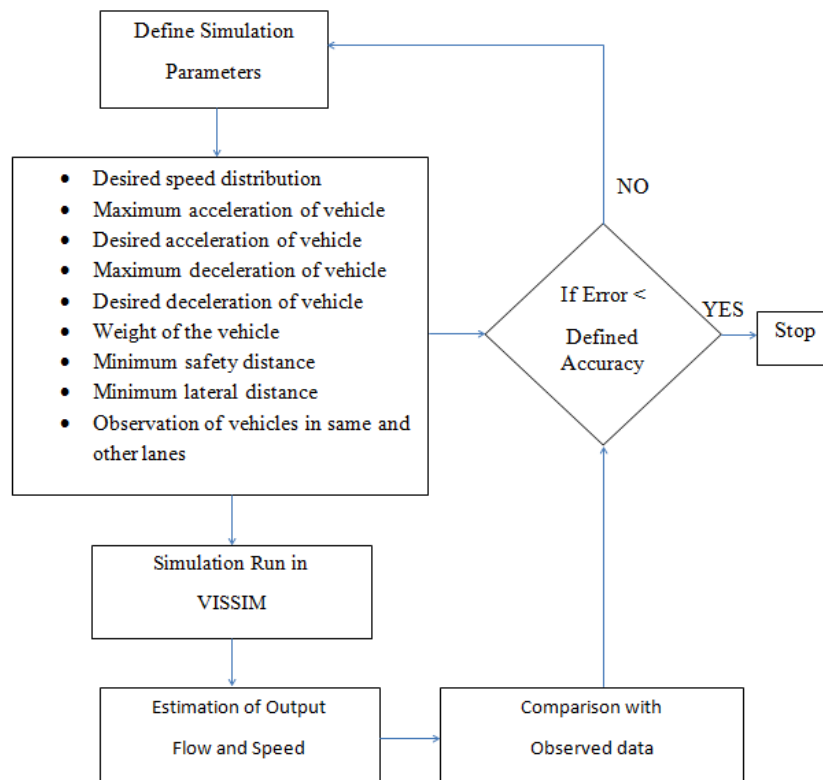

Figure 3 Simulation Model

By giving the parameters listed in Figure 3 as an input to simulation model, simulation runs were carried out in order to estimate the output. In this simulation model, the outputs obtained are volume and speed of vehicles. The observed data on these parameters were collected in the field for validation of the developed simulation model. The comparison of estimated values with observed values is carried out and error is estimated. This iterative process of simulation model calibration was carried out through the modification of the various model parameters and simulation runs were performed till the error is within the satisfactory level of 1-5%.

V. RESULTS AND DISCUSSION

Results: The estimated roadway capacities based on simulation models proved to be realistic as the estimated error with respect to estimated and observed speed and traffic volume is very small. The evolved capacity for multilane divided National Highway is 4100 PCU/hr/lane/dir for four lane divided carriage way respectively. The equation for speed-flow relationship, based upon this evolved capacity is validated using SPSS software. Approval is the way toward checking the created re-enactment demonstrates regarding anticipated activity execution for street framework against field estimations of movement execution, for example, activity volumes, travel times and normal paces. In the present study, the calibration and validation process was carried out by trial and error method. After carrying out many trials, the prediction error in volume and speed is reduced to satisfactory level. The final validation results for traffic volume and speed are estimated for Medchal to Nizambad as well as from Nizambad to Medchal directions separately. It has been observed from the comparison that the error in estimation of traffic volumes is less than 5 per cent across different vehicle types whereas the overall error in the estimation of traffic volume is almost zero which represents the accuracy of the developed simulation model. The comparison of observed and estimated data of different vehicle speeds shows that the error in vehicular speeds is ranging from 1 per cent to 5 per cent for different vehicle types which represent, the developed simulation model is reasonably accurate and showing the actual ground conditions. It can be inferred that the developed simulation models are able to predict the vehicular movements (i.e. flow and speed) with reasonable degree of accuracy under heterogeneous traffic conditions for four-lane divided Carriageways. Based on the developed simulation models, the evolution of speed - flow relationships is attempted. Using the same, the roadway capacity is estimated. Figures 4 to 13 presents the developed speed flow relationship from the calibrated simulation models. By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested two wheelers are obtained. The speed-flow equation is deployed two wheelers is: $Y = -0.00509x + 90.57377$, $R^2 = 0.83122$. By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested LCV are obtained. The speed-flow equation is deployed LCV is $Y = -0.005x + 86.86$, $R^2 = 0.8286$, Where, Y= speed (mph), X = flow (PCU/hr/dir)
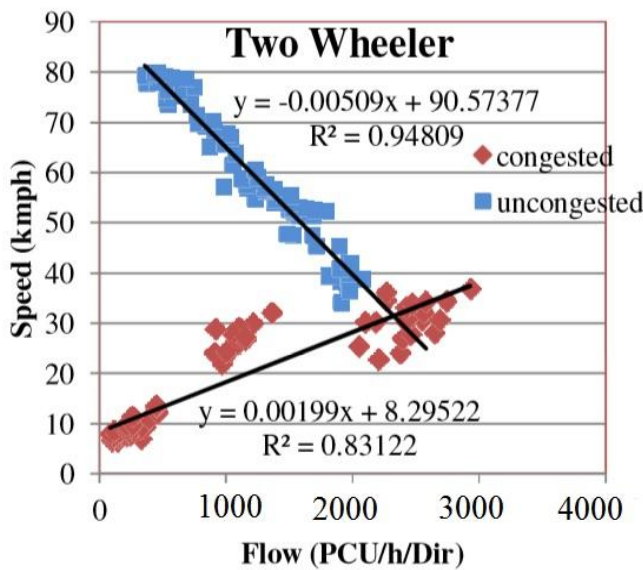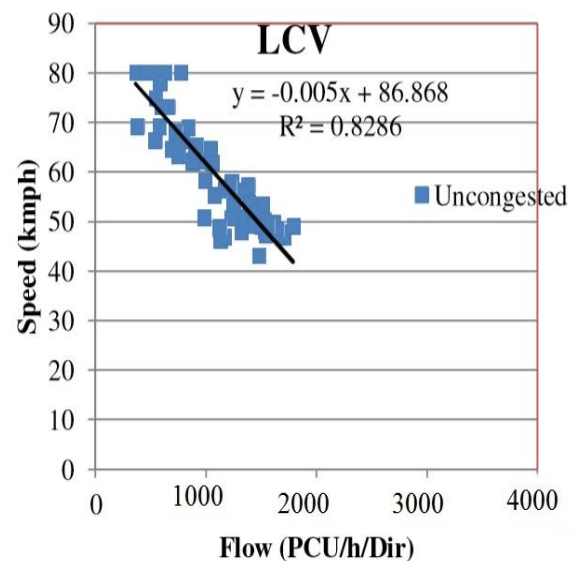

Figure 4 Two wheelers   Figure 5 LCV

By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested auto are obtained. The speed-flow equation is deployed Auto is $Y = -0.003x + 70.00$, $R^2 = 0.412$. By taking the values from table 4.2 speed flow relationship is drawn for congested and uncongested small cars are obtained. The speed-flow equation is deployed small cars is: $Y = -0.00609x + 103.39505$, $R^2 = 0.96412$, Where, Y= speed (mph), X = flow (PCU/hr/dir)
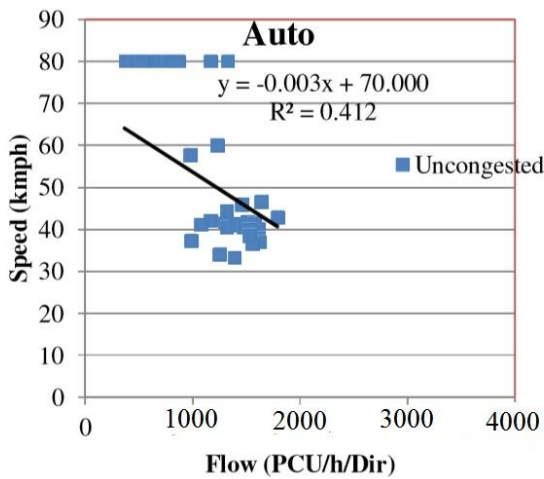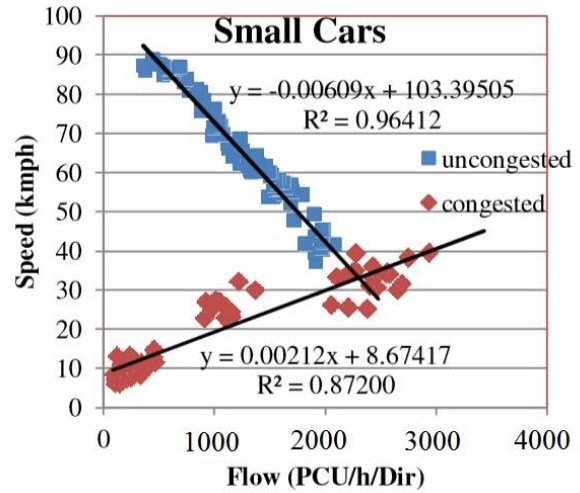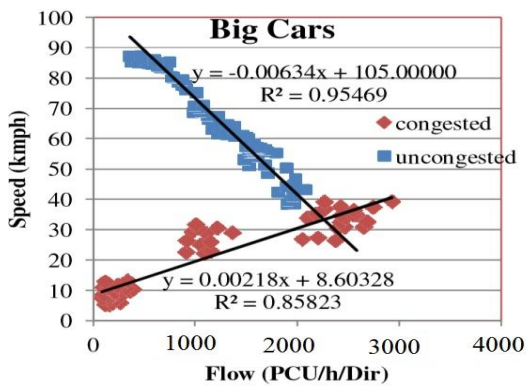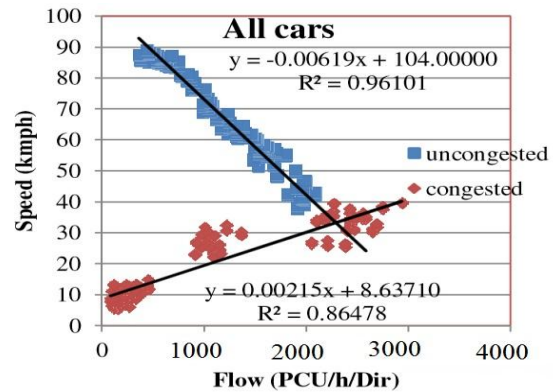
Figure 6 Auto

Figure 7 Cars

By taking the values from table 4.2 speed flow relationship is drawn for congested and uncongested Big cars are obtained. The speed-flow equation is deployed Big cars is: $Y = -0.00634x + 105.00$ $R^2 = 0.95469$. By taking the values from table 4.2 speed flow relationship is drawn for congested and uncongested all cars are obtained. The speed-flow equation is deployed all cars is: $Y = -0.00619x + 104.00$, $R^2 = 0.96101$, Where, $Y =$ speed (mph), $X =$ flow (PCU/hr/dir)

Figure 8 Big Cars

Figure 9 All Cars

By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested HCV are obtained. The speed-flow equation is deployed HCV is: $Y = -0.0049x + 80.94$, $R^2 = 0.5478$. By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested bus are obtained. The speed-flow equation is deployed bus is: $Y = -0.0045x + 84.006$, $R^2 = 0.7816$. Where, $Y =$ speed (kmph), $X =$ flow (PCU/hr/dir).
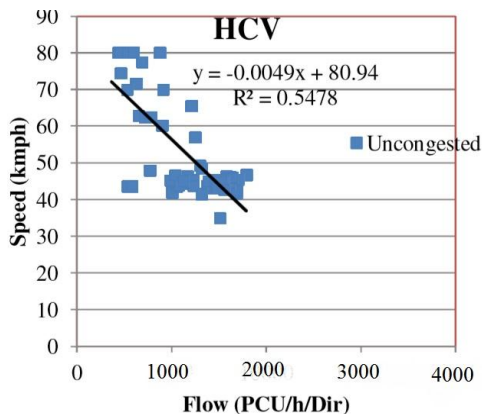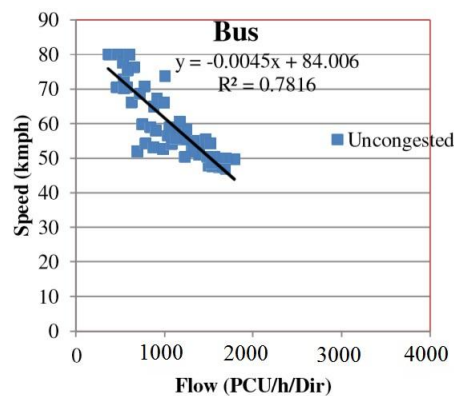

Figure 10 HCV

Figure 11 Bus

By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested MCV are obtained. The speed-flow equation is deployed MCV is shown below: $Y= -0.004x + 75.00$ $R^2= 0.418$. By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested all vehicles are obtained. The speed-flow equation is deployed All vehicles is: $Y= -0.00581x + 99.57722, R^2= 0.96205$ Where, Y= speed (kmph), X = flow (PCU/hr/dir).
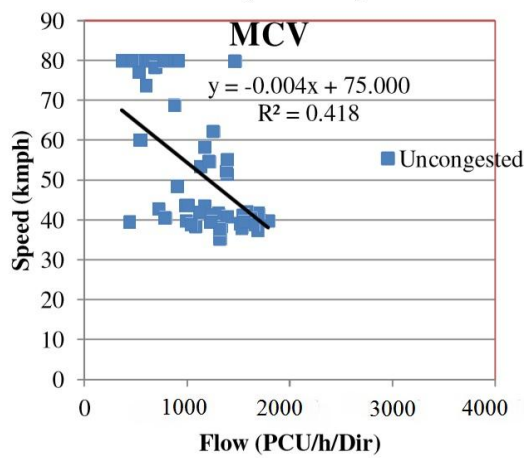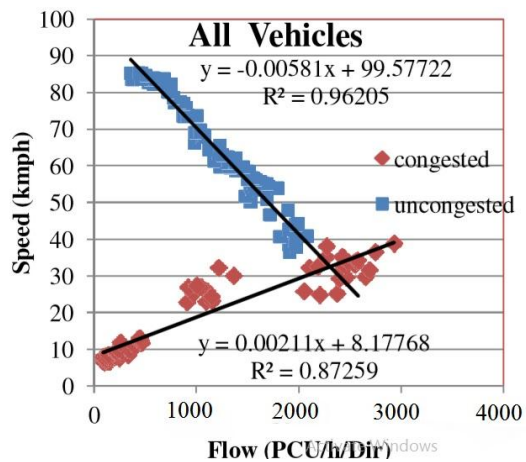

Figure 12 MCV	Figure 13 All Vehicles

By taking the values from Table 2 speed flow relationship is drawn for congested and uncongested four-lane divided National Highway are obtained. The speed-flow equation is deployed four-lane divided National Highway is shown below: $Y= -0.00619x + 104.00$, $R^2= 0.96101$, Estimated Capacity= 4100 PCU/hr/Dir.
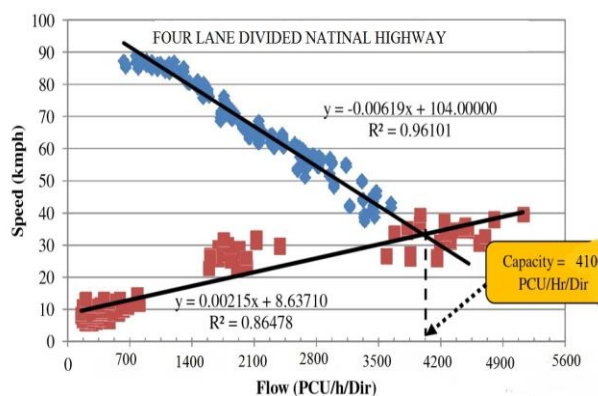

Figure 14 Roadway capacity of Four-lane divided National Highway

The level of service for multilane divided National Highway is calculated as shown in Table 3.

Table 3 Level of service

Level of service	Operating speed	Service volume per hour
A	100	650
B	90	1000
C	75	1300
D	60	1600
E	50	2000
F	<50	>2000

Development of Speed - Flow Equations and Roadway Capacity through Simulation: Using the developed simulation model, the speed data for different vehicle is estimated or different traffic volume conditions for four-lane divided carriage way. The simulation runs are carried for various scenarios of traffic volumes ranging from 2500 vph, 3000 vph and this process was considered up to 5500 vph. However, the driving behaviour is kept as four-lane divided carriage way assuming that it will not drastically change in spite of increase in the number of lanes. These aspects would be further investigated by observing real data on these Carriageways as the desired speed characteristics might be different on these Carriageways compared to four-lane divided Carriageways. This may be regarded as the limitation of the present model and it is worthwhile to study this aspect in future scope of the study. Considering the above traffic flow conditions, the simulation runs are made to estimate speeds of different vehicles on four-lane. The developed linear speed - flow equations present high goodness-of-fit as the R2 values are more than 0.7 for all the Carriageways, Further, the capacity of these Carriageways is calculated from these linear speed-flow equations by taking the intersect between uncongested and congested curve. From this exercise, the capacity is estimated as 4,100 PCU/hour/during the case of four lane divided Carriageways as shown in Figure 14. The fit of the speed-flow equation is very good as the estimated free speed and capacities are realistic with respect to four divided Carriageways. Speed flow Equation developed for the uncongested and congested flows are presented in the Table 4.

Table 4 Roadway Capacity of 4-Lane Divided Carriageway

Equation	4-LANE DIVIDED NATIONAL HIGHWAY	
	STREAM SPEED VS FLOW USING S PCU EQUATION	STREAM SPEED VS FLOW USING D PCU EQUATION
Upper Curve	$y = -0.0084x + 72.997$ $R^2 = 0.6609$	$y = -0.0084x + 75.434$ $R^2 = 0.6526$
Lower Curve	$y = 0.0084x + 2.323$ $R^2 = 0.7079$	$y = 0.0084x - 0.3655$ $R^2 = 0.6928$

VI. CONCLUSION

The present study is intended to estimate highway capacity and speed-flow curves and hence it is necessary to know the relative effect of different types of vehicles on traffic flow. Capacities from these speed-flow curves are estimated by fitting speed flow data to second degree equation. Based on the studies carried out in this study, an attempt has been made to evolve capacity of National highway for four lane divided carriage-way by deploying simulation model. The capacity with respect to four lane divided National highway is estimated to be around 4100 PCU/hr/lane/direction. The value obtained is similar to those obtained in US and Indonesia HCMs which are 4800 PCU/hr/dir and 4600 PCU/hr/dir. *Future Scope:* Assessment of lane change behavior for Four-lane through field observations and model refinement can be done. Study can be extended to the estimation of Capacity for eight-lane and six-lane divided highways. *Limitations*: Study is limited to two test sections only. PCU factors vary with traffic conditions, roadway conditions and environmental conditions. The effects of curvature, gradient were not taken into consideration.

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