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DEVELOPMENT OF LANE CHANGE MODELS THROUGH MICROSCOPIC SIMULATION UNDER MIXED TRAFFIC

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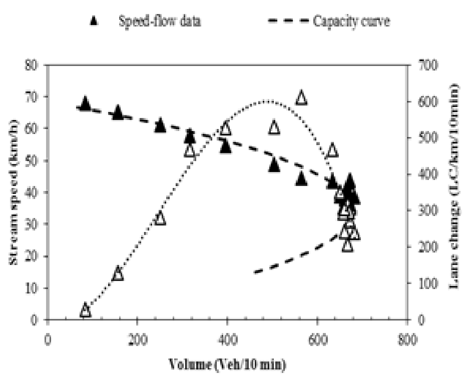
Graphical abstract



Abstract

The number of motor vehicles and traffic demand is growing in tandem with society's rapid economic development and the quickening process of urbanization. In India, traffic congestion has become the most serious issue. Vehicle's poor lane-changing behaviors have a significant impact on the speed of the traffic system. The lane change behavior was observed in the study with the traffic flow simulation model VISSIM. The purpose of this investigation is to estimate the number of lane changes by simulating them at different volume levels. The study also shows the capacity estimate and its relationship with the lane change. The maximum traffic flow and lane changes were calculated based on the proportions of each vehicle type in the standard car traffic flow. The maximum number of lane change models for known traffic compositions on 4-lane, 6-lane, and 8-lane divided highways has been developed. According to the results, the number of observed lane changes depends on the volume of traffic and the number of lanes provided for a particular direction of travel. The composition and vehicle types also have a significant influence on lane changes and highway capacity, which involves uncertainties in the analysis of traffic flow properties.

Keywords: Highway traffic flow, capacity, mixed traffic, lane changes, VISSIM

1.0 INTRODUCTION

Traffic flows are formed by merging and diverging vehicles, which slow down the flow of traffic. Vehicle's poor lane-changing behavior have a significant impact on the speed of the traffic system. The number of motor vehicles and traffic demand is growing in tandem with society's rapid economic development and the quickening process of urbanization. In India, traffic congestion has become the most serious issue. The reduced speed will be propagated upstream in the form of waves, causing the road capacity to decrease. Multi-lane highways need serious consideration in terms of traffic flow and capacity. The way vehicles change lanes has a significant impact on their driving behavior on the highway. It is sometimes necessary to change lanes to overtake and cross a weaving segment on a roadway. Vehicle lane changes create voids or spaces within traffic streams that tend to increase stream speed and capacity.

Various lane changing and overtaking maneuvers, take place on such highways, which sometimes lead to serious accidents [1,2].

Traffic flow phenomena are highly complex in mixed traffic due to unpredictable interactions of vehicles over road space. In addition, vehicles interact not only by obeying laws but also by the behavior of human drivers in impending or un-impending situations. However, the conventional approaches to assessing traffic flow behavior have some limitations, especially when it comes to complex situations with a significant amount of stochastic driver behavior and attributes. An empirical approach is based on extensive field data that is neither available nor easily collected. The analytical approach has the limitation of the underlying homogeneity assumptions, which are far removed from the high variations in driver-vehicle properties in heterogeneous traffic conditions. Against this background, the present article concentrated on a suitable modeling technique and the modeling approach using VISSIM simulation, which turned out to be the most powerful, flexible, and acceptable tool. Microscopic simulation models are increasingly being used to evaluate safety performance and predict crashes. These models must first be calibrated using real-world traffic conditions before they can be used. The primary goal of calibration is to ensure that the simulation model's parameter inputs produce the best estimates of safety performance. The VISSIM model can be used to investigate various traffic scenarios under various road and traffic conditions. The VISSIM model is used to simulate traffic flow at various levels, from low to high, and to evaluate the number of lane changes on multilane roadways.

Micro simulation research has used a heuristic set of rules to resolve the parameter combination to obtain the parameter calibration. The set of rules can't calibrate all parameters, specifically the physical traffic characteristics. Various studies observed the sensitivity of various driving behavior parameters of the VISSIM model with respect to capacity under mixed traffic conditions [3-9]. Various authors determined the capacity of highways using field data [10-14]. Authors estimated capacity with and without lane changing behavior on multi-lane divided highways using VISSIM [15]. Authors used the examined calibrated values for logical, conscious driving in VISSIM to examine the influence of important traffic features that can influence traffic safety on the frequency of lane changes [16]. Authors examined the relationship between the target vehicle and the surrounding vehicles on the target lane, taking into account influencing parameters such as longitudinal distance, lateral distance, and speed of vehicles in the target lane [17]. Based on the vehicle speed, [18] presented a lane change algorithm for driverless cars. This strategy has significantly improved fuel consumption, saved around 7.63 percent in fuel, and reduced fuel consumption by 12.5 percent. After all, self-driving cars will change lanes when necessary to improve efficiency and safety when changing lanes while reducing fuel consumption. The fuzzy logic lane change models were developed and the models were tested with simulation tests. The test results showed that the models warn better when changing lanes [19]. These models can provide the theoretical basis for safety warnings when changing lanes and for the long-term further development of transport safety.

The present study aims to use the VISSIM simulation model to explore the impact of lane change behavior on homogeneous and heterogeneous traffic. To fulfill the study's goal, field data is used to calibrate and validate VISSIM model parameters, and then the calibrated VISSIM model is used to analyze vehicle lane change behavior.

2.0 METHODOLOGY

The study sections are devoid of any influence of bus stops, parking, vicinity of intersections, pedestrians or other side frictions, and curvature or gradients. For the present work, field data was collected at mid-block sections of NH 163, near Bibinagar and madikonda, telangana, and details are given in Table 1. The video-graphic technique was used to collect the required field data. The data was collected for 4 hours from 8:00 a.m. to 12:00 p.m. on a weekday.

Table 1 Study area details

Sections	Highway No.	Location	Properties	Posted speed limit (Kmph)
I	NH 163	Near Madikonda (Telangana)	Carriage way width: 7.0 m Shoulder width: 1.5 m	80
II	NH 163	Near Bibinagar (Telangana)	Carriage way width: 7.0 m Shoulder width: 1.5 m	80

The different vehicle types are consider for this study includes motorized two wheelers (TW), big cars (CB), small cars (CS), autos (3W) and heavy vehicles (HV). Two thick white lines were marked across the road width to act as reference lines for measuring the speed of vehicle types. Speed of the vehicle was calculated from the entry and exit times of the vehicles required for crossing the reference lines. Speed-related parameters such as 15th, 50th, and 85th percentile speed were also estimated and are given in Table 2. The traffic volume count was made based on one of the reference lines. The traffic composition of the study section was measured from observed volume data and shown in Figure 1. The calculated field data was used for calibration and validation of the VISSIM model.

Table 2 Field speed parameters of study section-I

Speed parameters (km/hr)	CS	CB	2W	3W	HV
Mean	68.1	70.2	51.3	42.7	46.9
15th	58	59.3	41.2	36.5	37.7
85th	80.5	81.7	61.3	47.7	56.9
Standard deviation	11.1	11.3	10.7	7.6	9.2

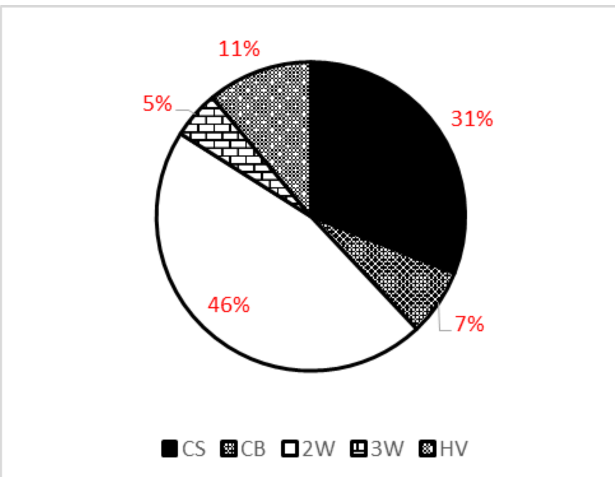


Figure 1 Traffic composition of study section-I

2.1 VISSIM Model

VISSIM microscopic traffic simulation model as calibrated for mixed traffic conditions is used for observing the lane change behavior. The Calibration methodology proposed by [20] was used in the present study. Field data collected in study section-I were used as inputs to the base model as prepared in VISSIM. The base model created in VISSIM has the following characteristic: link length 1.4 km (200 m used as buffer length on both the ends); four-lane divided section with 1.5 m of the paved shoulder on both the sides of travel directions.

Driver behavior parameter values have been calculated using the trial and error method and found that each parameter is sensitive to the other. For any fixed value of CC2, variation in CC0 and CC1 is plotted for different CC2 values. Similarly, for the fixed value of CC0, variation in CC1 and CC2 is plotted. All the obtained plots are then merged to get the optimal point; the plot has been made on the 3-axis graph. The plotted graphs are shown in Figure 2. The X-axis represents CC0 (Standstill distance), Y-axis represents CC1 (headway time), and the X-secondary axis represents CC2 (following distance variation). Data has been plotted considering 2-axis at a time by keeping 3rd one as a constant, and the intersection points of the lines have been identified as optimal points. Calibrated values of driver behavior model parameters such as CC0, CC1, and CC2 are assigned as 1.8 m, 0.53 sec. and 6 m respectively. Driver behavior model as modified for mixed traffic conditions are used and simulation run was performed for 2 hrs. After completion of the simulation run, simulated output was extracted at 10 min intervals to observe the lane change behavior.

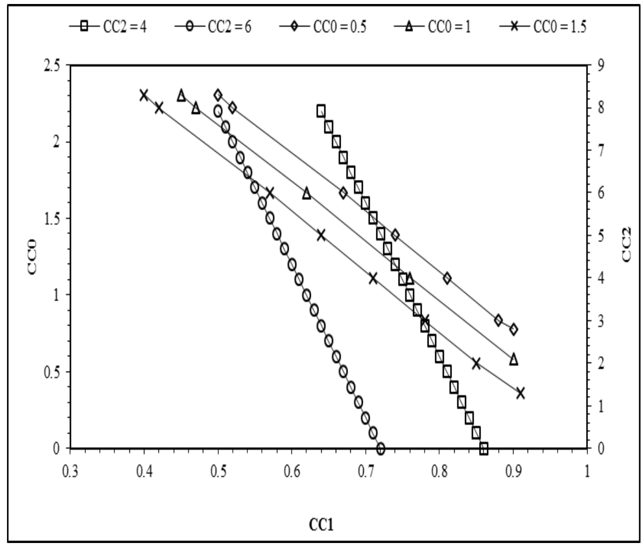


Figure 2 Variation of parameters for the equal capacity line

3.0 RESULTS AND DISCUSSION

3.1 Lane Changing Behavior Under Homogeneous Traffic Conditions

A simulation experiment was performed out under homogeneous traffic scenarios with a four-lane divided road to demonstrate general lane change behavior. VISSIM was used to model the whole CS traffic flow. At 10-minute intervals, traffic volume and lane change data were extracted from the simulated output. The lane change profile was used to calculate the maximum number of lane changes in one direction in a time interval. The maximum number of lane changes was determined from the trend line, which was adopted in each case to multi-lane road sections. Table 2 shows the maximum lane change values measured on 4-lane, 6-lane, and 8-lane highways. At 10-minute intervals, the speed-flow curve was developed by using simulated speed and volume data as shown in Figure 3. The speed flow curves for 6-lane and 8-lane highways were created similarly. The simulated capacity along with a number of lane changes of different highway sections are given in Table 3. It can be observed that the number of lane changes decreases at the capacity level of the volume. The phenomenon occurs because it is extremely difficult for drivers to find an empty lane when the volume reaches capacity.

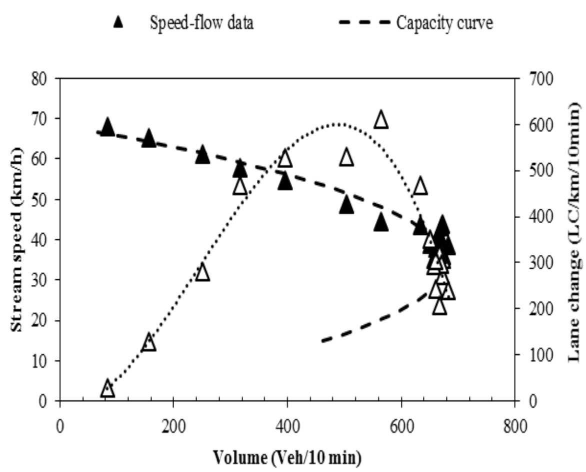


Figure 3 Lane change and Speed-Flow Curve on Four-lane Highway

Table 3 Numbers of Lane change on Multilane Highways

Highway type	Capacity (Veh/10 min)	Lane change at capacity (LC/km/10 min)	Maximum lane change (LC/km/10 min)
4 lane	800	310	600
6 lane	1007	1000	1480
8 lane	1253	2160	2526

3.2 Lane Changing Behavior Under Heterogeneous Traffic Conditions

This section deals with the analysis of lane changing behavior under mixed traffic conditions. It is believed that the size of vehicle type affects the lane change behavior of the overall traffic stream. Therefore, this analysis was performed to examine whether the proportion of one vehicle type affects the overall lane change behavior when two types of vehicles are simulated in the traffic stream.

The effect of two-wheelers on lane changes on multilane highway sections was examined through VISSIM. To study the effect on lane changes, the proportions of two-wheelers were added to the 'All cars' traffic flow stream by 10%, 20%, 30%, 40%, 50%, and 100%. This incremental proportion of two-wheelers was simulated in VISSIM under varying traffic volume conditions. Traffic volume was also varied and simulation runs were performed for at least 2 hours. Simulated lane changes and traffic volume were extracted from the output at 10 minutes intervals. A similar exercise is done for 6 lane and 8 lane simulated sections and the lane change behavior of two vehicles was examined. Further, maximum lane change frequency under each incremental proportion of two wheeler mixed with "All car" traffic stream was determined for different multilane divided highway sections. Figure 4 shows the variation of the maximum number of lane changes with different proportions of two wheelers mixed in the traffic stream when simulated on multilane-divided highway sections.

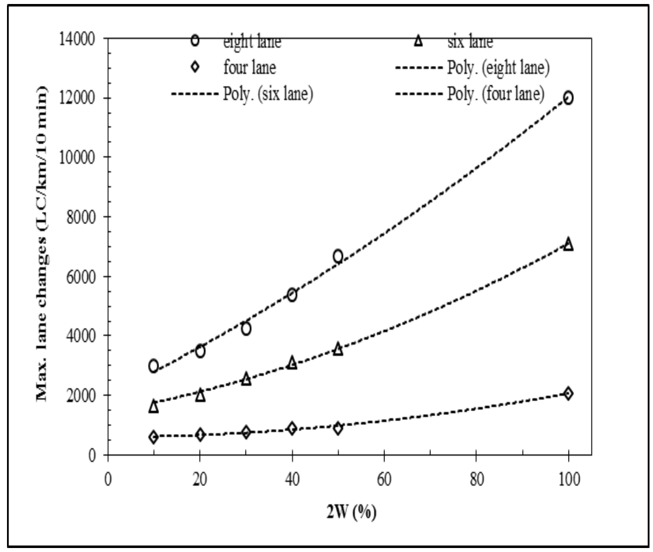


Figure 4 Variation of maximum lane changes with varying proportions of 2W

The increase in proportion share of 2W in the traffic stream will increase the total number of lane changes proportionally. The maximum lane change with different proportional share was obtained and their percentage increase was estimated. Table 4 gives the percentage increase in the maximum number of lane changes with different proportions of two-wheelers on different multilane-divided highways respectively. From Table 4, it can be inferred that the maximum number of lane changes observed per kilometer per 10 minutes increases in the same amount with an increase in the proportion of two-wheelers in the traffic stream, and the addition of a lane further increases the lane changes frequency linearly.

Table 4 Maximum lane changes on four lane divided section for varying 2W proportion

Proportion of 2W (%)	Maximum No. of lane changes (LC/km/10 min)			Percent decrease in Max lane changes		
	4 lane	6 lane	8 lane	4 lane	6 lane	8 lane
0	600	1450	2500	0	0	0
10	621	1636	3000	4	13	20
20	700	2020	3500	17	39	40

Proportion of 2W (%)	Maximum No. of lane changes (LC/km/10 min)			Percent decrease in Max lane changes		
	4 lane	6 lane	8 lane	4 lane	6 lane	8 lane
30	780	2578	4245	30	78	70
40	891	3100	5400	49	114	116
50	913	3585	6700	52	147	168
100	2085	7095	12000	248	389	380

A similar exercise was also performed with varying proportions of HVs in the "All car" traffic stream by 10%, 20%, 30%, 40% 50%, and 100%, and is shown in Figure 5. It is observed that as the proportion of HVs increases the frequency of lane changes also increases. However, the lane change frequency starts to decrease after attaining a maximum number of lane change levels. The values of the maximum number of lane changes were obtained with an increase in the proportion of HVs obtained by simulating traffic streams on multilane-divided highway sections. It is found to be interesting that the maximum number of lane changes are reduced significantly as the percentage of the heavy vehicle are added proportionately in a stream of "All cars" which is contrary to the results obtained in the case of 2Ws.

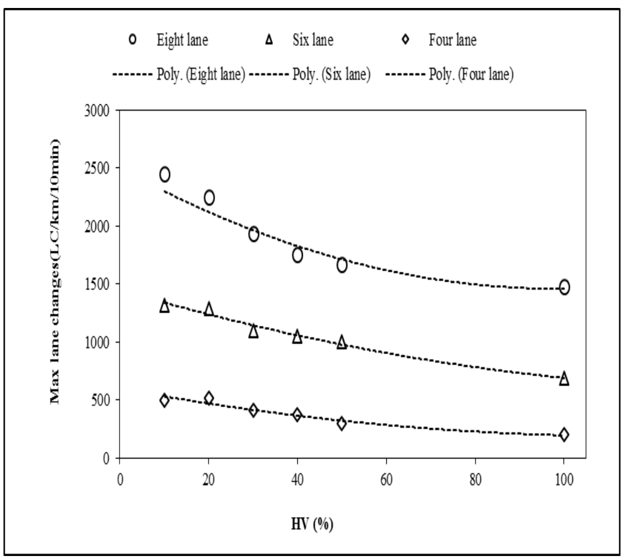


Figure 5 Maximum number of lane changes at varying proportions of HV

Table 5, gives the percentage decrease in the maximum number of lane changes at different proportions of HVs on simulated multi-lane divided highway sections. It can be inferred that the maximum number of lane changes decreases with an increase in the proportion of heavy vehicles in 'All CS' traffic stream with the addition of an extra lane in direction of travel.

Table 5 Maximum lane changes on simulated four lane divided section under varying HVs proportion

Proportion of HV (%)	Maximum No. of lane changes (LC/km/10 min)			Percent decrease in Max lane changes		
	4 lane	6 lane	8 lane	4 lane	6 lane	8 lane
0	600	1450	2500	0	0	0
10	500	1320	2448	17	9	2
20	516	1290	2251	14	11	10
30	410	1100	1936	32	24	23
40	380	1050	1757	37	28	30
50	300	1000	1668	50	31	33
100	200	690	1479	67	52	41

3.2 Maximum Lane Change Models

Maximum lane change behavior with respect to four different vehicle types was analyzed independently through simulation. Traffic flow stream was simulated with only homogeneous vehicle traffic stream such as 'All 2W', 'All Car', 'All 3W', and 'All HV', and maximum lane changes were obtained through simulation. It is believed that the composition of vehicle types affects lane change behavior. Therefore, linear models were proposed for 4 lane, 6 lane, and 8 lane divided highway sections to estimate maximum lane change for the condition when all the above types of vehicles are present in the traffic stream. The expressions to estimate the maximum number of lane changes for the known traffic composition on simulated highway sections are as shown in equations 1, 2, and 3.

For four lane divided highway

$$\frac{100}{LC_{max}} = \frac{P_{car}}{600} + \frac{P_{2W}}{2085} + \frac{P_{HV}}{200} + \frac{P_{3W}}{489} \tag{1}$$

For six lane divided highway

$$\frac{100}{LC_{max}} = \frac{P_{car}}{1480} + \frac{P_{2W}}{7095} + \frac{P_{HV}}{690} \tag{2}$$

For six lane divided highway

$$\frac{100}{LC_{max}} = \frac{P_{car}}{2526} + \frac{P_{2W}}{12000} + \frac{P_{HV}}{1479} \tag{3}$$

Where, LCmax is the maximum number of lane changes (LC/km/10min) and Pcar, PHV, P3W and P2W are the percentage of car, HV, 3W and 2W percentage. The numerical values in denominators are the maximum lane changes/km/10min under homogeneous type of traffic.

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4.0 CONCLUSION

Driver behavior model as modified for mixed traffic conditions are used and simulation run was performed. After completion of the simulation run, simulated output was extracted at 10 min intervals to observe the lane change behavior on 4 lane, 6 lane, and 8 lane sections of multilane divided highways. In 10-minute intervals, lane change behavior was measured and compared with traffic volume. The number of lane changes is increased with traffic volume to a certain extent, but as further traffic volume increased, the number of lane changes are decreased. When traffic volume reaches capacity, the number of lane changes are stagnated. This is because of not enough free space available for the movement of vehicles. The frequency of lane changes increases as the number of lanes added to the lane increases, yet the capacity of one lane per lane reduces as the number of lanes increases. Because extending a lane allows vehicles to change lanes more easily, it also causes more disturbance to traffic flow among non-lane disciples, resulting in a drop in lane capacity. With an increasing proportion of two-wheelers in the traffic flow and the addition of extra lanes in the direction of travel, the maximum number of lane changes are increased. It is observed that as a percentage of heavy vehicles are added; the maximum number of lane changes is significantly reduced. Maximum lane change models were proposed for multilane divided highway sections under mixed traffic by considering traffic composition. The proposed models are important for better understanding of mixed traffic particularly in the application field of capacity and safety analysis. Further research, validation of maximum lane change models with field data will be performed.

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