Driving Behavior and Safety Analysis In Context Of Weak Lane Discipline At Urban Mid-Block Section

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Abstract
In this research work, the behavior of driver on urban mid-block section with heterogeneous traffic conditions is evaluated. The study of vehicle to vehicle interaction plays vital role to identify the microscopic characteristics in mixed traffic streams. In this background, an access controlled mid block road section was selected for video data collection. The main objectives of this study include developing vehicular trajectory data and analyzing the lane changing and vehicle following behavior of driver on the mid block section considering the relative velocities and relative spacing between various types of vehicles under heterogeneous traffic conditions. The videos were collected from urban roadway in the Kurnool district of Andhra Pradesh. The length of the stretch is 120m and the width is 7.0 m. Data was collected by dividing the stretch into four equal parts each of length 30m. The data was extracted to know the variations in terms of longitudinal and lateral speeds, vehicle following and lane changing behavior of the drivers. The data extracted was smoothened by moving average method to minimize the human errors. Lateral amplitude of the vehicles of various types was analyzed. The study revealed that vehicles in the mixed stream, in general and in particular, Bikes and Autos particularly move substantially in the lateral direction.

Key words: Driver behavior, Mixed traffic conditions, urban mid-block section

Introduction

Analyzing behavior of driver on no or little lane discipline under heterogeneous traffic conditions is more complex in urban mod-block sections. Extraction of vehicle trajectories plays an important role to analyse the longitudinal and lateral gaps maintained by the drivers in mixed traffic stream. As all types of vehicles with different static and dynamic characteristics occupies the same lane in heterogeneous traffic conditions, that leads to no lane discipline which allows drivers to simultaneously look for possible lateral movements while progressing longitudinally. This is predominant on Indian highways under mixed traffic conditions. The subject vehicle will have impact of the vehicle moving ahead, behind and its surroundings. From several decades, the behavioral models for vehicle following and lane changing have been studied for various traffic situations.

Microscopic analysis is widely used to envisage longitudinal and lateral movement of vehicles in traffic stream including acceleration, deceleration, relative distances and relative velocities by bearing in mind the immediate neighboring vehicle characteristics and the traffic environment. Whereas macroscopic analysis describes the movement of vehicle in platoons or clusters or groups in a traffic stream. This analysis is used to determine the fundamental traffic characteristics such as speed, flow and density and their inter-relationship. The foremost methodologies apply to illustrate macroscopic analysis.

The basic behaviors behind this analysis are, it is assumed that all the drivers behaves similar under same traffic conditions. But, in reality, each driver's perception and reaction according to the traffic environment in a traffic stream is totally different. Especially this is not suitable for heterogeneous traffic conditions with no lane discipline. Hence researchers initiated to analyse individual driver characteristics by microscopic analysis.

Objectives

- Developing vehicular trajectory data at the mid-block study locations under mixed traffic conditions
- Analysing the Longitudinal and lateral behaviour of driver on the mid block sections in mixed traffic conditions
- To determine the time to collision in vehicle following and lane changing behavior of driver

The paper is divided into six sections, one of which is this one. Section two contains a review of the literature as well as an explanation of the gaps. Section 3 explains the data collection process, approach, and study area description. The fourth section discusses the driver's lane-changing behavior. The section is divided into subsections that characterize lane changing duration, vehicle lateral position, and lateral amplitude. Section five discusses the driver's car following behavior in terms of relative velocities, distances, and time to collision. The paper's summary and conclusions are reported in section six.

Literature Review

It is essential to know the vehicle trajectory data for investigating vehicle behavior in a mixed traffic conditions. Several methods have been used to know the vehicle trajectory data in the past works. Narayana raju et al., (2018) have studied vehicle behavior in mixed traffic environment. They analyzed the macroscopic and microscopic flow characteristics, including the relative velocity, relative spacing between the vehicles both in the longitudinal and lateral direction. They have concluded that the lateral behavior of a vehicle plays a vital role in the driving behavior and its patterns which is not predominant under homogenous traffic conditions on high-speed multilane highways. Pallav kumar et al.,(2017) extracted the trajectory data of the urban mid-block section and smoothened the extracted trajectory data to minimize human errors by moving average method, local weight regression method and Savitzky golay filtering method and performed SWOT analysis for smoothening techniques. They concluded that for smoothening vehicle trajectories, 'Moving Average Method' is the best technique.

Few researchers have addressed the need for lateral movement in different vehicles. The lane change acceptance and duration carried out by Minming Yang et al. (2019). They examined one of the time for collision for safety improvement. In this study the lane shift time of the naturalistic driving study was analysed using an automated extraction algorithm. The effect is also analysed on the following driver and found that the lane change varies between 0.7 second and 16.1 seconds for different type of vehicles. Danish Farooq(2019) investigated the impact of major traffic parameters on lane changing for a two-lane freeway road section. They used traffic simulation software with "cautious" driving logic calibration to estimate the impact of designated traffic parameters on lane change frequency. Two notable phenomena characterise traffic conditions in developed countries. The first is a mix of truck styles, and the second is a lack of lane discipline. Anuj Kishor Budhkar and Akhilesh Kumar Maurya (2017) conducted testing on various instrumented vehicles of various types that are designed using ultrasonic sensors mounted on both sides of the vehicle, which provide which provides inter-vehicular lateral distance and relative speed; and a GPS device equipped with cameras, which provides vehicle type and speed of interacting vehicles. They are driven on different highways in six Indian cities to measure the lateral gaps held by various interacting vehicles at different speeds. Which provides inter-vehicular lateral distance and relative speed; and a GPS device equipped with cameras, vehicle type and speed of interacting vehicles. They are driven on different highways in six Indian cities to measure the lateral gaps held by various interacting vehicles at different speeds.
In considering the available space gaps, speeds, the surrounding vehicles and the lateral lifting of the vehicle during medium traffic flow conditions, Gowri Asaitambi et al. (2018) have researched and constructed a model on vehicular lateral shift time. Study findings indicate that the time of the lane change varies from 0.15 to 15 seconds at an average of 2 seconds. For the right side move (2.5sec), was seen to be slightly greater than the left one (2.3 sec). The study was performed by Munigety et al.(2014) on the lane change movement of vehicles on the highway, under mixed traffic conditions found that 2W (3 sec), 3W lateral movement time (12 sec). MATLAB programming has extracted the results.

Venkatesan Kanagaraj and Gowri Asaithambi (2016), evaluated vehicle following behavior and concluded that vehicles in the mixed stream-in particular motorcycles moves unsubstantially in the lateral direction. Chakradhar Reddy et al., (2017), smoothened the extracted vehicular trajectory data for homogeneous traffic conditions to minimize the human errors while extracting the data and suggested that, the Moving Average method is the best suitable method. Bangarraju, and Ravi Shankar (2016) worked on the lateral distance keeping driver behavior in mixed traffic conditions with little lane discipline.

They have concluded that Lane changing frequency is influenced by the density, flow and mean speed of the traffic stream. Lane by lane vehicular arrivals is not very independent. Mohd Erwan Sanik et al,(2016) worked on drivers lane changing behavior at urban intersection by using gap acceptance approach and they concluded that the main factor which influences lane changing event, is the flow rate of vehicle movements. Mohd Erwan Sanik et al,(2016) have researched on driver lane changing behavior at urban intersections by using the Gap acceptance approach. They have concluded that the main factor which influences the lane changing event is the flow rate of vehicle movements. Geethi Mukta Mahapatra et al.,(2013) studied the vehicles lateral movements on non lane discipline traffic stream, on a straight road and concluded that lateral acceleration and heading angles are high, in the case of three-wheelers than in case of Cars. The variation of lateral acceleration and heading angles are high at lower speeds. Daniel (Jian) Sun, studied the driver behavior characteristics considering focus group studies and in-vehicle driving tests and developed a gap acceptance algorithm to model lane changing on urban arterials. CORSIM was used to develop the model. C. Mallikarjuna et al., have done research on lateral gaps maintained by different types of vehicles under different traffic conditions. The statistical analysis was done and the gaps maintained by the vehicles with more are less same speeds were normalized.

Time to collision for longitudinal behavior of driver was also carried out by some researchers and is varies from 0.5 sec to 90 sec depending on relative distance and velocity. In the case of opening the mid-range section, rear and side swipe collisions are more common. Simulated driving simulation tests have been conducted by Nengchao et al (2020). The analysis of variance test to assess driving characteristics including TTC was carried out in this study. They found that when shifting the lane from the opening section to the inner lane, drivers can usually control the distance and speed difference from the previous vehicle. Qiang Luo et al (2020) analysed various driver types and quantified the impact on road safety by setting the new car rear end collision model. They used fuzzy theory to develop the reasoning model, which took into account conventional safety factors like driver age and fatigue level and output the driver reaction time. They came to the conclusion that keeping a safe distance of 50 meters between the leading and following vehicles would prevent rear-end collisions. Chang Wang et al (2020) developed a lane shifting decision model with a 2-level safe threshold in mixed traffic situations that took into account rear vehicle deceleration behavior. The safe thresholds were determined to be 0.85 m/sec2 and 1.76 m/sec2, respectively, based on risk perception of different drivers. Quingwan xue et al. (2018) created a model of rear end collision avoidance behaviour that takes into account driver differences during the car following and collision avoidance process. A Mote Carlo approach was used in model simulation and found that the likelihood of rear-end collisions increased considerably with driving if the distance maintained by subsequent cars dropped under 15 m. TTC is one of the most relevant safety indicators based on time in road safety assessments for the detection of rear end conflicts. Mohmoud Safferzadeh et al (2015) suggested a generalised TTC formulation using motion equations which could be used according to availability of data and the necessary level of accuracy. They came to the conclusion that the TTC ranges between 0.5 and 10 seconds.

Gaps in the literature

The studies were carried out to analyse the safety and lane changing behavior of the driver and to extract the vehicle trajectories were done on national highways, multi lane roads and on bridges i.e., on control points. The focus group and invehicle data may not give accurate results as the group of selected people already knows about the test. Only a few studies were found in urban areas to describe the acceleration and deceleration, longitudinal and lateral behavior of vehicles. Most of the research works were carried out without considering the safety aspect i.e., the safe distance between the vehicles in longitudinal as well as in lateral direction. There is a need to study the behavior of drivers on urban mid blocks, considering the above mentioned characteristics.

Study Area

The road taken is the land mark and entrance way into the Kurnool city via Hyderabad National highway of India, which is a two lane road always having heavy traffic. The carriageway is of 7.0 m width with divided road markings at 3.5m from the median. The width of shoulder is of 1.5m. The length covered is 120m from the fly over and towards new Bus stand.

The Road approaching near Bellary cross roads, Kurnool, is taken as a study area. Kurnool, one of the most populous districts of the state Andhra Pradesh, has seen a considerable increase in traffic over the last few years. Bellary cross roads is a door way into Kurnool city which is always having heavy traffic. Road dividers had been provided that divides the four lane road into through and opposite traffic. Traffic flow videos were taken from provided CCTV camera on the fly-over located at a height of 6.0 m from the surface of the road. Traffic is recorded continuously for a time period of 5 hours from 8:00 AM to 1:00 to assess the volume, speeds, trajectories, and lane change behavior of drivers of different types of vehicles.

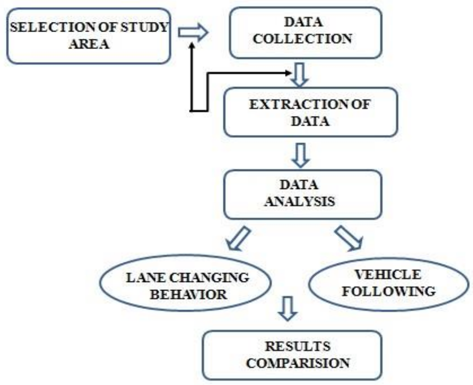


Fig.1: Methodology **Fig.2: Study Section**

For analyzing the traffic characteristics the peak 15 minutes data was considered. The total length of road stretch is divided into two parts, each part 60m in length. This was done to know the accurate values of vehicle trajectories, vehicle following and lane changing behavior of the driver. The vehicle trajectories, flow, speed were extracted using Traffic Data Extractor (TDE), for every 1.0-second resolution. To minimize the error of parallax the video is cropped through Free Crop video software and enlarged for every 60m and the lateral movements corresponding to the longitudinal distance of the vehicle were reported. The Methodology involved in the study is shown in fig.3

To perform the analysis of the data collected for our project, we have used Traffic Data Extractor (TDE) software. TDE package developed by IIT Bombay for the purpose of data extraction for the Development of Indian Highway Capacity Manual Project. The software package contains tools for vehicle trajectory extraction, speed extraction and vehicle counting from a Video based survey. By using Traffic Data Extractor, we can also extract the pedestrian data. The following numerical shows the extracted trajectory data for the area of 7x120m2.

Flow data was extracted by observing the number vehicles crossing the line through manual monitoring; whereas speeds and trajectories of various types of vehicles were extracted from TDE. The maximum flow rate was observed as 3487 vph and minimum as 2837 vph. Total 2350 vehicles of trajectories were extracted to determine the longitudinal and lateral traffic flow characteristics.

Table.1:Observed vehicles for Trajectories and traffic flow

Vehicle type	No.of vehicles (
Bike	1271
Auto	802
Car	194
Bus	34
LCV	49

Type of vehicle	**Flow(vph)**
Bike	3487
Auto	1660
Car	374
Bus	78
LCV	101
Average	952

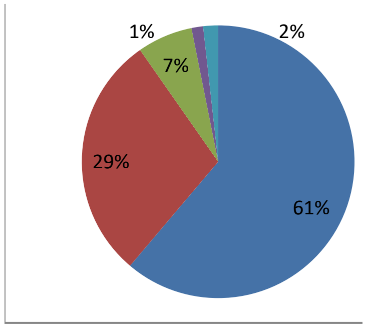


Table2: Instantaneous Speeds of vehicles

Type of veh	Min	Max	Mean	St.De
Bike	8.36	50.23	30.96	6.72
Auto	5.57	42.03	28.51	5.81
Car	7.30	41.73	27.95	6.75
Bus	7.00	40.52	27.73	6.72
LCV	7.51	36.48	26.90	5.96
Avg.	6.87	40.25	26.89	6.21

Fig.3: Percentage of vehicles on selected stretch

Longitudinal and Lateral Velocities

Speed is the rate at which a vehicle covers distance. Velocity is the rate at which the position of the vehicle changes. When going in the negative direction, the average speed is reflective and can be interpreted as a negative number. The average speed does not signify direction and may be either zero or positive. It's in the other direction that the velocity gets negative. A velocity value may be negative and it means that the vehicle is moving in the opposite direction. A lateral velocity with negative sign indicates the vehicles are moving in left side and that of right side are positive sign. Lateral velocities with negative value reveal vehicle on the left side and positive value on the right side. The instantaneous speeds of all the vehicles were premeditated and were observed precisely equal as there was a huge traffic. The vehicles are moving with an average speed of 26kmph. The mean lateral velocity is found as 0.063m/sec. It was observed that about 70 percent of the overall vehicles head to the left side and the remaining 30 percent to the right. This can be attributed to the median on the right hand side. The increase in lateral velocities examined higher on the left hand side and the velocities are more or less same for all types of vehicles. This may be because of more vehicular friction due to high traffic volume and congestion. Whereas, the average longitudinal velocity is found as 9.0m/sec. The major proportion of two wheelers followed by autos, cars, LCVs and busses were observed on the road section. Figure 4 shows the lateral and longitudinal velocities of vehicle types.

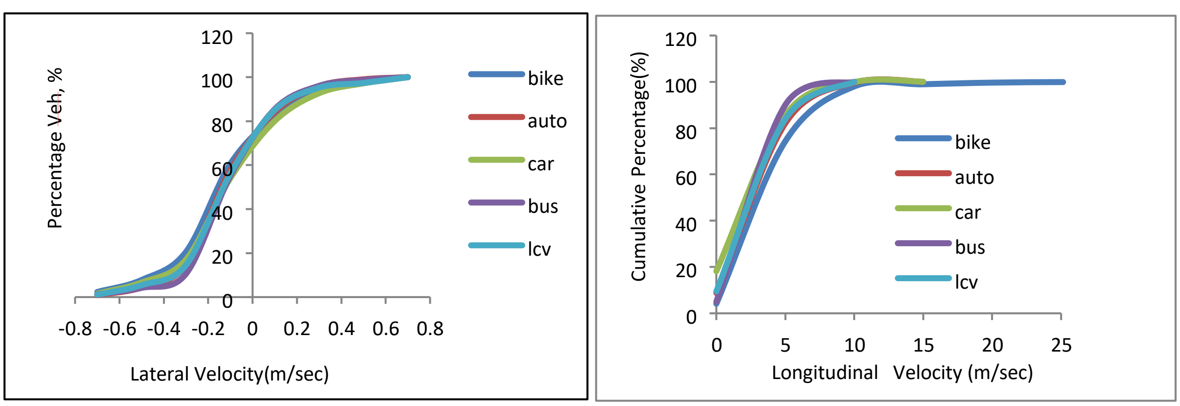
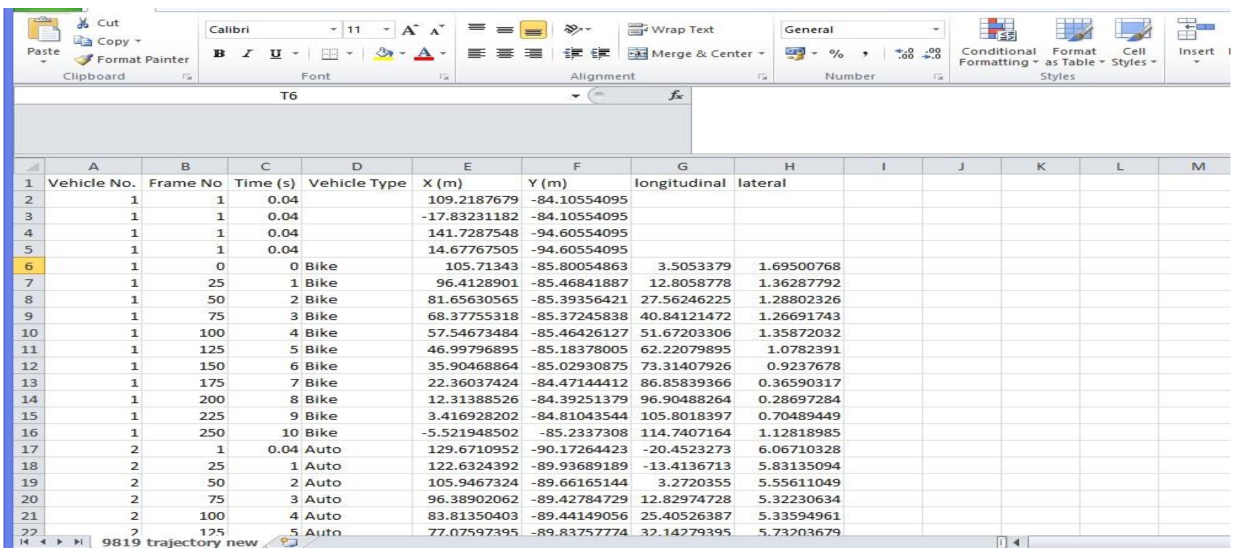


Fig.4: Lateral and Longitudinal velocities over the study section

Smoothening of data

While extracting the data, longitudinal and lateral velocities, higher speeds and accelerations of vehicles were observed. The functional conditions in the field resulting from data incoherence cannot be identical. This is due to human mistakes during vehicle tracking, as the data has been extracted manually. From the past studies, it was observed that the extracted data can be smoothened by using moving average, Savitzky–Golay filtering techniques and, local regression methods

(Narayana Raju), Local weighted regression method (Tomer Toledo) to obtain the continuous positions of the vehicles. Narayana Raju et al. suggested the moving average method as the best method to smoothen the data, as this method can remove errors and improve internal coherence by simple moving average dependent on the adjacent data points. Hence, in this study, to minimize the human errors while extracting the data, the extracted data was smoothened by Moving Average Method. Moving average is type of intricacy; the mean is normally taken from an equal number of data on either side of a central value. This ensures that variations in the mean are aligned with the variations in the data rather than being shifted in time. Hence a central moving average can be computed, using data equally spaced on either sides of the point in the series where the mean is calculated. In this graph orange colored curve shows the variation of original extracted data and the blue colored trend line depicts the moving average curve of 5 points. From the time space plots, it is observed that with increase of degree in moving average, the data has been smoothened in a much better way. However, smoothening should be kept to a minimum of 3,5 and a maximum of 7 points. The degree of smoothing is again determined by the quality of the video footage and the movement of the vehicles in the study segment. Figure 5 depicts the trajectory data obtained using TDE. Figure 6 depicts data that has been smoothed using the moving average process.



Vehicle No.	Frame No	Time (s)	Vehicle Type	X (m)	Y (m)	longitudinal	lateral
1	1	0.04		109.2187679	-84.10554095		
1	1	0.04		-17.83231182	-84.10554095		
1	1	0.04		141.7287548	-94.60554095		
1	1	0.04		14.67767505	-94.60554095		
1	0	0	Bike	105.71343	-85.80054863	3.5053379	1.69500768
1	25	1	Bike	96.4128901	-85.46841887	12.8058778	1.36287792
1	50	2	Bike	81.65630565	-85.39356421	27.56246225	1.28802326
1	75	3	Bike	68.37755318	-85.37245838	40.84121472	1.26691743
1	100	4	Bike	57.54673484	-85.46426127	51.67203306	1.35872032
1	125	5	Bike	46.99796895	-85.18378005	62.22079895	1.0782391
1	150	6	Bike	35.90468864	-85.02930875	73.31407926	0.9237678
1	175	7	Bike	22.36037424	-84.47144412	86.85839366	0.36590317
1	200	8	Bike	12.31388526	-84.39251379	96.90488264	0.28697284
1	225	9	Bike	3.416928202	-84.81043544	105.8018397	0.70489449
1	250	10	Bike	-5.521948502	-85.2337308	114.7407164	1.12818985
2	1	0.04	Auto	129.6710952	-90.17264423	-20.4523273	6.06710328
2	25	1	Auto	122.6324392	-89.93689189	-13.4136713	5.83135094
2	50	2	Auto	105.9467324	-89.66165144	3.2720355	5.55611049
2	75	3	Auto	96.38902062	-89.42784729	12.82974728	5.32230634
2	100	4	Auto	83.81350403	-89.44149056	25.40526387	5.33594961
2	125	5	Auto	77.07597395	-89.83757774	32.14279395	5.73203679

Fig.5: Trajectory Data Extraction in TDE

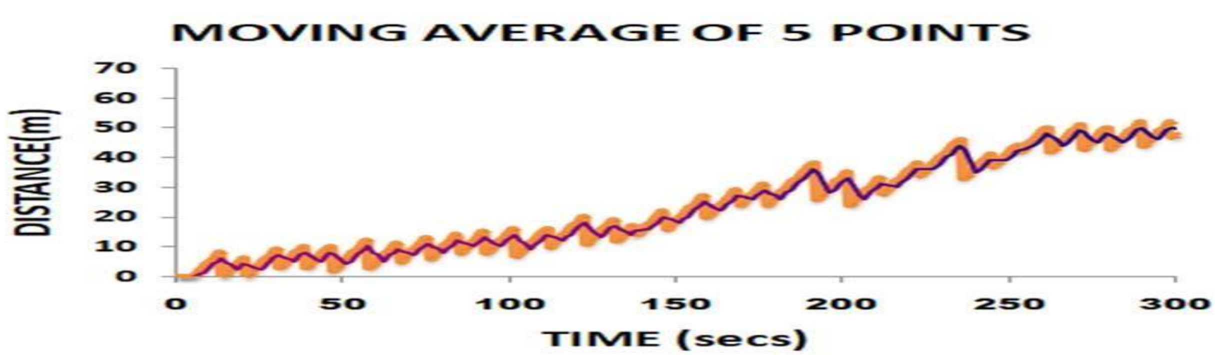


Fig. 6: Data Smoothening

Time space diagram is a pragmatic approach to vehicle travel interpretation. It depicts a two-dimensional trajectory plot of the vehicle. Time space diagrams can be traced for one specific vehicle and several vehicles. By taking one motor vehicle at a time, analysis processes on the location of the vehicle can be done in terms of time. The results of the analysis create a graph that describes the movement of the vehicle in one dimension in a common, simple and detailed manner. This analysis illustrates the position of the vehicle in relation to time on a road. The following activities, as well as the behavior between and inside the vehicles, can be easily visualised using these plots. This can then be summarized and the actions of the vehicle around the road can be measured. The Time-space diagram is useful in studying the relationship between the position of vehicles in the traffic stream and time. The diagram shows the movement of vehicle along the longitudinal distance with respect to time. The upper part of Fig.7 shows the Time Space diagram when all the vehicles are considered for obtaining the observations. In the contrast, the lower part shows the Time-Space diagram when only a few numbers of vehicles are considered for obtaining the observation. Overlie is a situation that occurs during the overcoming of the vehicles in adjacent lane. Two wheels, autos and cars were found to be more likely to take over the lead vehicles than others. Reduced speeds flatten the lines' slopes, while increased speeds result in steeper slopes. Acceleration allows the time-space curve of the accelerating vehicle to curve until the new speed is reached. Crossing curves mean that both vehicles were in the same place at the same time. Unless passage is permitted, crossed curves are an indicator of collisions.

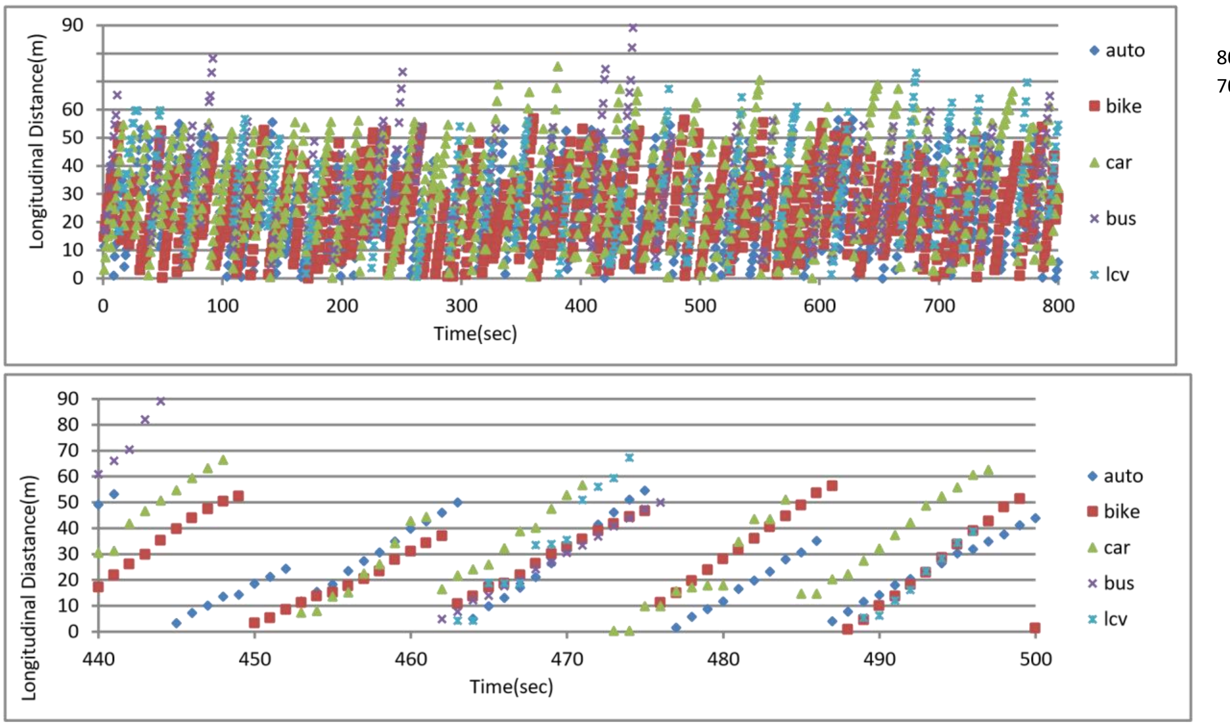


Fig.7: Time-Space diagram

Lane Changing Behavior

Lane changing phenomenon is considered as an act of driving maneuver that moves a vehicle from one lane to another when both lanes have the same direction of flow (Gowri.A). Lane changes can be classified into Mandatory (MLC) and Discretionary (DLC) lane changes. An analysis of lane changing behavior indicates the differences in lane changing characteristics of different types of vehicles. This phenomenon is quite common in heterogeneous traffic conditions with nolane discipline. Lane changing is a difficult task due to its natural randomness and the amount of things drivers look at. We can't see the beginning of a driver's hesitation to change lanes, but there is a point at which they are able to predict the moment at which the driver changes lanes for sure.

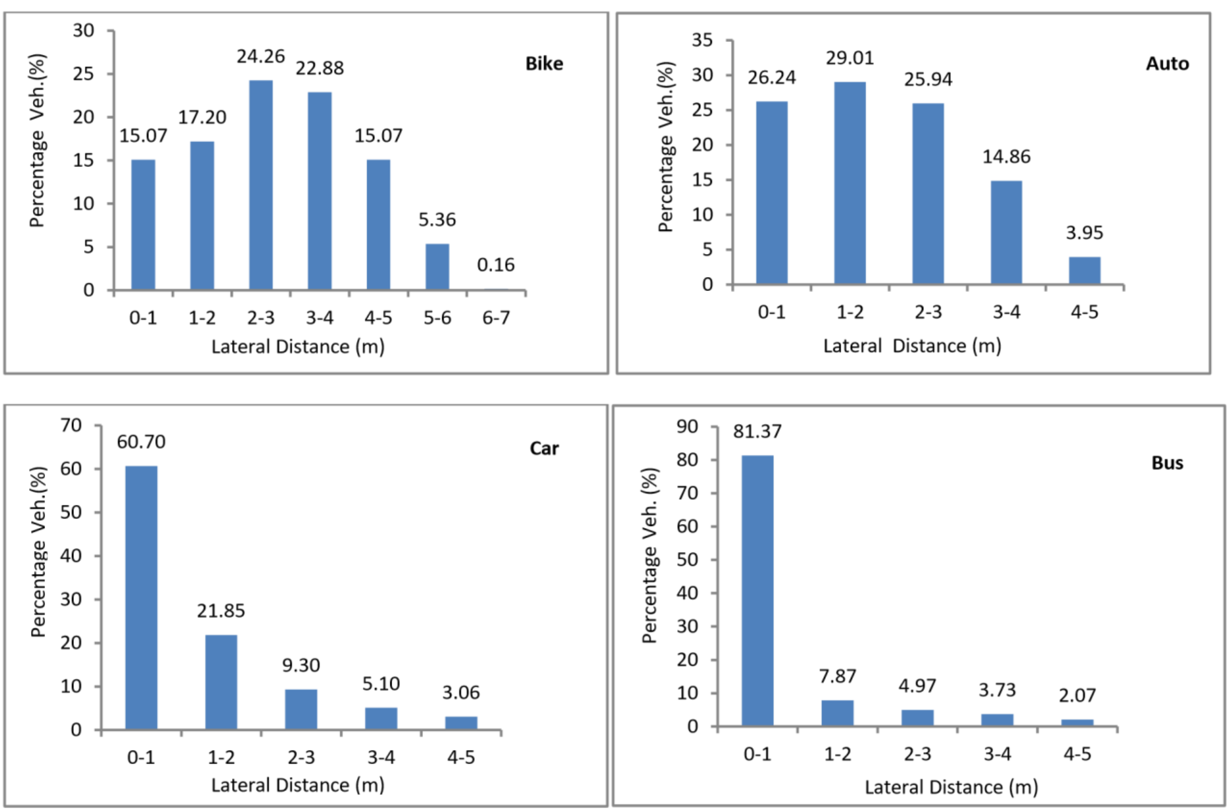
Lane Changing Duration

Lane Changing Duration may be defined as the passing of vehicle from present lane to the preceding lane and is the process that occurs between the initiation time and completion time during lane changing. There are numerous factors which influence lane change duration such as flow conditions, traffic density, lead, front , lag and surrounding vehicles in the traffic lane in which the subject vehicle is been changed. A total of 2350 effective lane changes were observed. Of that, 54 % of bikes, 34%

of autos, 8.25% of passenger cars, 1.5% of busses and 2.08% of LCVs were identified. For each lane change starting and end points in time were collected which are defined as the time instances when the lateral movement of subject vehicle begins and ends respectively. The lane change duration is the time lapse between its initiation and completion and the value of lane change duration is always positive. The mean values are found as 4.0, 4.7 and 5.3 seconds for bikes, autos and cars. The value ranges from 3.5 sec to 9.3 sec for different types of vehicles. Due to the heavy traffic friction busses and LCVs are not changing the lane and are moving on mid lane with a shy gap of 0.25m from the median. Linear regression analysis of lane change duration in seconds verses the lateral distance shows the maximum R2 value of 0.98 for autos, 0.91 for bikes and 0.68 for cars.

Lateral position of vehicles

The trajectory data was extracted, both in longitudinal and lateral directions using the TDE. In the traffic data extractor user interface, the surveyed video files were loaded. The trap length and width of road sections were given as length and width of the marked rectangle portion, which acts as calibration of the road section on the software screen. Further, the vehicle class of a given vehicle was entered in the software interface by observation. Then, that particular vehicle will be tracked employing clicking on the vehicle with the help of the mouse pointer. On a similar basis, every vehicle present in the traffic stream was tracked for the selected time duration. The tracked data were exported to MS Excel files in the form of image coordinates, and it was further converted to real-world coordinates along with vehicle trajectories. Vehicle trajectories were extracted with a time resolution of 0.5 sec. The tracked vehicles will be shown with a green color mark. The lateral position of vehicles across the width of the road are shown in figure 8.



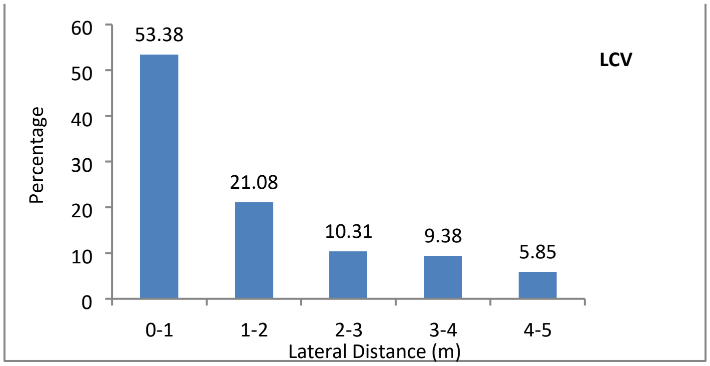


Fig.8: Lateral displacements of vehicles from median side

The lateral position of various types of vehicles was studied by extracting the video footages using TDE. For this, the median side was taken as the origin with lane -1 followed by lane-2. Pedestrian volume, pedestrian crossings and parking of vehicles adjacent to shoulder lane were not considered in the study as the main aim of this research article is to analyse the driver behavior on selected stretch. It is observed that a minimum gap from the median for bikes 0.2m, autos 0.33m, cars, busses and LCVs 0.25m. These charts reveal that most of the autos are moving in lane-1, buses, cars and LCVs are moving close to the median and bikes are moving almost all the width of the lane. For cars, buses, and LCVs, effective use of lane-2 was not noted, indicating that most large-vehicle drivers prefer to drive close to the median and choose lane-1 even though space is available on the adjacent lane. These cars move in a logical lane-by-lane manner through the road section. All smaller vehicles, on the other hand, operate with non-lane based sagacity and act as small particles through the porous medium created by bigger vehicles. From these results, it can be deduced that mixed traffic conditions with high traffic flow plays a critical role in reducing compliance with lane-visibility.

Lateral Amplitude

Nonetheless, little research has been conducted to date on vehicles' lateral action (the most essential criteria for the Indian state). Due to the lack of lane control and mixed traffic, vehicle laterality is extremely high in comparison to countries with lane discipline. Due to the absence of lane behaviour, a driver develops associations with vehicles not only longitudinally, but also on the surrounding vehicles.

To study the lateral behavior of vehicles lateral amplitude was computed for each vehicle category over the study stretch. Lateral amplitude is the lateral weaving of vehicles, which is the difference in maximum and minimum lateral positions over the study section (Narayana raju), as shown in Figure 9. Regard to this, the descriptive statistics were determined for each category of vehicle, and were shown in fig.9. From keen observations, it is thought full to be as the volume levels steps up, the lateral weaving goes on increases for all the vehicles over the section. Since, bikes and autos are magnified in size compared to other vehicles static characteristics, are capable in order to pass through other vehicles with meager space between them. The study on lateral amplitude depicts that, the magnified vehicles are mostly liable for non lane base movement of other vehicles on road section. Bikes posses' greater value of lateral spin varies from 0.5m to 7.0m, followed by autos 2.2m to 7.0m across the road.

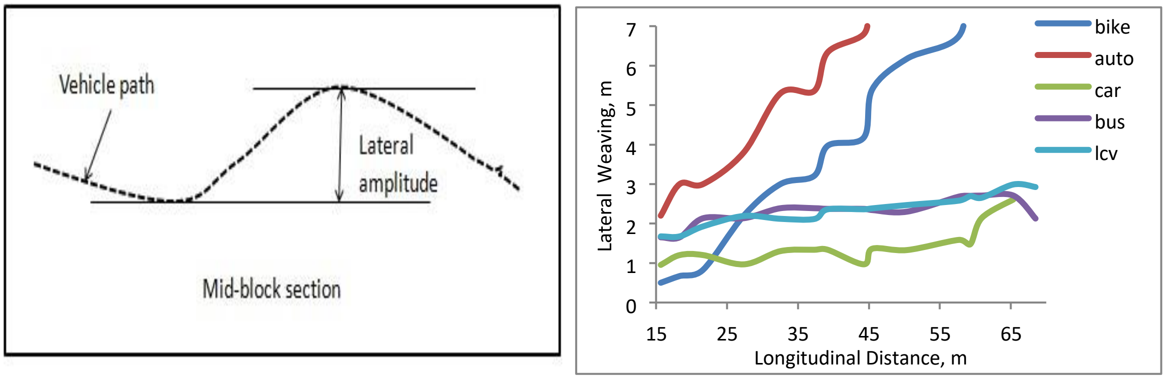


Fig.9: Lateral Amplitude of various types of vehicles

Lateral Clearance between vehicles

Lateral clearance is the lateral distance between the vehicles. With no lane control, vehicles travelling in a heterogeneous traffic stream maintain some lateral gaps with adjacent vehicles/objects. It is important to consider both the stochastic and deterministic aspects of driver behavior when describing traffic gap lengths. The majority of the studies agree that lateral differences either differ continuously or can be constant over time (Dibyendu Pal). The lack of sufficient field data makes it difficult to understand lateral gap behavior and its effect on overall traffic flow behavior. At the macro level, lateral gaps affect individual vehicle movement and as a result, traffic flow behavior. If the available lateral gaps restrict the speeds of individual vehicles, the average stream speed and ability of the traffic stream would be impacted. As a result, one of the most important aspects of assessing the traffic stream with no-lane-discipline is vehicle lateral gap maintenance behavior. One of the crucial aspects that influence the no lane-discipline traffic stream behavior is the lateral gaps held with adjacent vehicles or with the Median, or Curb. The lateral gap is a feature of several other factors besides the passing/overtaking vehicle's pace, according to studies. The current study's findings clearly show that the lateral gap analysis between vehicle groups has a major impact on the fluctuations in traffic flow. Autos have a narrower distance than any other vehicle type, followed by bikes, cars, and light commercial vehicles (LCVs). This may be due to auto drivers behaving more aggressively with neighboring vehicles. With other vehicles, the buses maintain a clear gap of almost one meter. Almost all of the bikes and cars are travelling with a protected lateral distance between them and the buses. **Table.3: Lateral clearance (m) of vehicles**

Type of vehicle	**Bike**		**Auto**		**Car**		**Bus**		**LCV**	
	Mean	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**
Bike	0.60	0.36	0.71	0.48	0.68	0.40	1.07	0.34	0.62	0.41
Auto	0.36	0.26	0.70	0.46	0.67	0.53	0.75	0.64	0.51	0.33
Car	0.59	0.38	0.84	0.37	0.91	0.49	1.14	0.57	0.92	0.24
Bus	0.98	0.60	0.90	0.63	1.19	0.39	1.29	0.39	1.06	0.27
LCV	0.70	0.46	1.10	0.74	0.96	0.52	1.60	0.40	1.01	0.40

Car Following Behavior

Car or vehicle following behavior is one of the complicated perceptions from several years. In mixed traffic conditions, with no or little lane discipline, the following vehicle is associated with leading vehicle ahead and the lag vehicle. There were innumerable researches upon car-following behavior of driver. From this study, the relative distances and relative velocities of the lead and following vehicles were examined. Relative distance is defined as the longitudinal distance between lead and following vehicles in similar direction and within the same line. Whereas the relative velocity refers the difference between following vehicle velocity with respect to lead vehicle velocity. The value of positive velocity indicates the higher value of following vehicle velocity and vice-versa.

Table.3: Relative velocities (m/sec) of vehicles based on following driver

Type of veh	Min	Max	Mean	St.de	Range
Bike	-12.25	11.86	0.32	2.79	24.11
Auto	-12.85	13.83	-0.07	3.00	26.68
Car	-8.52	7.56	-0.18	2.53	16.08
Bus	-11.96	4.71	-0.64	3.44	16.66
LCV	-4.10	3.72	0.02	1.97	7.82

To better understand the behavior of following drivers in relation to the leading vehicle, descriptive statistics such as minimum, maximum, mean, standard deviation, and range were computed for each following vehicle group. The findings show that the vehicles are operating at a congested level of service. In this state, the vehicles are unable to travel laterally freely, and as a result, they simply follow the vehicles ahead. As a result, a significant amount of following behavior was observed among the vehicles. The close proximity of the vehicles can result in a rear-end collision. The observed mean relative speeds of bikes and LCVs of 0.32 m/sec and 0.02 m/sec, respectively, indicate that following vehicles travel marginally faster than leading vehicles, which is negligible.

Whereas autos, cars and buses accompany their leading vehicles at a slower rate than the vehicles ahead. The distance between bikes with any other vehicle is less when compared with other vehicles. On the other hand, the velocity of autos is higher as noticed. Even if the following vehicle's speed increases significantly, smaller relative distances between vehicles will result in a rear-end collision. Since all vehicles' instantaneous speeds range from 26 to 31 kmph, the chances of an accident are reduced on this stretch. The obtained values of relative distance and velocities of various types of vehicles are tabulated in Table 3 and Table 4.

Table.4: Relative distance (m) of vehicles based on following driver

Vehicle Type	Bike		Auto		Car		Bus		Lcv	
	Mean	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**	**Mean**	**St.de**
Bike	1.97	0.85	2.68	1.16	2.40	1.03	2.98	1.22	3.02	1.40
Auto	2.43	1.14	2.78	1.89	2.33	1.26	2.71	1.32	3.20	1.15
Car	2.93	1.27	2.66	1.76	2.82	1.18	3.39	1.40	3.91	1.05

Time to Collision

A new physical quantity was calculated on the basis relative distance and relative velocity which is said to be time to collision (TTC). TTC is greater illustrious safety factor and is utilized in various car following models for assessing risk in rear-end collision. Rear –end collisions occur in car following processes. TTC value is commonly known as time for two vehicles to collide if they go on in their current speed and on the similar path. Hence greater the TTC value infer a much protected situation. Based on relative distance and velocities the time to collision values are obtained. TTC depends on acceleration characteristics of following vehicle. The TTC thresholds were attained from k-means clustering analysis using PYTHON tool. The TTC risk level is divided into three categories which are high, medium and low. The risk level is high with a lower value of 0.105 sec to a higher value of 11.5 sec with an average of 4.34 sec. 77.6% of the vehicles are observed to be in high risk level. The medium risk level ranges from 11.8 sec to 37.2 sec with a mid range of 19.16 sec simultaneously 18.18% of the vehicles are recorded to be at medium risk level. Lastly the least risk level begins at 46.8 sec to 92.4 sec with a mean of 66.2 sec and only 4.41% of the vehicles' presence is noticed in the low risk level. The TTC values acquired are shown in Table5. As maximum number of vehicles is maintaining less relative distances and more relative velocities based on following type vehicle, there is a chance of rear end collision between lead and following vehicle.

Table.5: Time to collision thresholds

Risk Level (sec)	Min	Max	Mean	St.De	Risk %
High	0.105	11.50	4.34	2.96	77.6
Medium	11.80	37.22	19.16	6.92	18.18
Low	46.82	92.44	66.24	14.21	4.41

Conclusions

The aim of this paper is to investigate the traffic characteristics of mixed traffic. To estimate longitudinal and lateral characteristics, a comprehensive collection of vehicle trajectory data was collected in an urban midblock road section in Kurnool, Andhra Pradesh. The lack of lane control is a common feature of mixed traffic. Vehicles in the mixed traffic stream, in general, and Bikes and Autos in particular, travel significantly in the lateral direction, according to the analysis. The following general conclusions have been reached based on the research and interpretation of data observed.

- The longitudinal flow characteristics show that the speeds and accelerations are high in the case of bikes, cars and buses comparative to the LCV's. This may be due to poor dynamic operations of LCV's
- All most all the buses and LCV's are moving very close to the median and choosing the first lane. As the majority of autos and bikes are choosing both first and second lanes
- Due to high traffic friction along the study stretch, relative distances between successive vehicles are found to be very small, and relative velocities of following vehicles are also small, with the exception of bikes and LCVs, whose velocities may be ignored.
- The lateral amplitude of vehicles shows that the lateral weaving of bikes and autos were more as these vehicles tend to have more weaving nature due to their smaller size compared to other vehicles
- The TTC values acquired are shown that the maximum number of vehicles is maintaining less relative distances and more relative velocities based on following type vehicle, there is a chance of rear end collision between lead and following vehicle.

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