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Analysis of the Lateral Gap Maintaining Behavior of Vehicles in Heterogeneous Traffic Stream

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Abstract

In India, vehicular traffic is heterogeneous and vehicles do not follow lane discipline and can move anywhere on the available free space of the road. Lateral gaps maintained by the vehicles play major role in the passing/overtaking behavior of the following vehicles. For a detailed understanding of the lateral gap maintaining behavior huge data, covering various traffic scenarios, are required. In this study a detailed methodology for collecting the microscopic traffic data has been presented. It has been observed that the lateral clearance between two adjacent vehicles significantly vary depending on several traffic conditions. Speed of the subject vehicle, speed and type of the adjacent vehicle, and road width, were found to be significantly influencing the lateral gap. It has been found that the lateral gap maintained by vehicles, moving with similar speeds, can be modeled with normal distribution. Similarly, lognormal distribution can be used in modeling the gaps maintained by a vehicle moving with certain speed with respect to any speed of the adjacent vehicle.

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Keywords: Heterogeneous Traffic; Lateral gap; Microscopic Model.

1. Introduction

Tremendous growth in personal vehicles of different sizes, prevalent on the Indian urban roads, results in a peculiar traffic scenario where the driver utilizes any free space available on the road, without following any lane discipline, termed as heterogeneous traffic. Analysis and modeling of such traffic stream requires huge data. A comparison of traffic flow in Indian conditions, and that of the developed countries, where drivers follow lane discipline, gets clearly conveyed from the photographs shown in fig. 1.

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Fig. 1. Comparison of traffic flow (a) with lane discipline (left); (b) without lane discipline (right)

From fig. 1(b) it can be clearly seen that in heterogeneous traffic stream, vehicles look for free space to move forward depending on their physical dimension, speed, availability of gaps in their vicinity, etc. When different types of vehicles share the same road space, without any physical segregation, the extent of vehicular interactions varies widely with variation in traffic mix and other traffic characteristics. In heterogeneous traffic conditions, even when the traffic volumes are higher, a large proportion of motorized two-wheelers and bicycles utilize the small gaps in the stream and move with speeds closer to their free speeds. Hence, lateral gap maintaining behavior between the two similar or different types of adjacent vehicles moving with the same or different speed needs to be analyzed and to be incorporated in the microscopic traffic flow models.

Vehicles moving in the heterogeneous traffic stream interacts both in longitudinal and lateral directions and both these interactions are strongly correlated. Analysis and modeling of these correlated interactions is a complex task and some researchers (Chakroborty, et al, 2004 and Gunay, 2007) have attempted to model this behavior. Nagaraj et al. (1990) have investigated the linear and lateral placement of vehicles in heterogeneous traffic stream, to develop microscopic traffic flow models. They have found the minimum lateral clearance at zero speed and at 60 kmph speed. Singh (1999) developed empirical relations between lateral space and speeds of the interacting vehicles. For this, different types of vehicles were considered and according to this study, each vehicle maintains a certain minimum clearance to avoid lateral collision.

Koshy and Arasan(2005) found out that the transverse clearances between vehicles depend upon the speed of the vehicle being considered, speed of the adjacent vehicle in the transverse direction, and their respective vehicle types. According to their study, the transverse clearance maintained by two adjacent vehicles, during passing, can be approximated as the sum of the two independent clearances, each contributed by the type and speed of the vehicles involved. The studies related to this aspect have indicated linear relationship between speeds and transverse clearances. In this study, they have not presented any field data analysis in support of their hypothesis. Gunay (2007) analyzed the car following theory with lateral discomfort and from the collected field data he has observed that with the increase in the frictional clearance, speeds of passing vehicles have increased. He has also observed that the increase in the centre line separation reduces the time headway between leader and follower. Mallikarjuna (2007), in developing a CA based heterogeneous traffic flow model, has shown the variation of average gap (m) with respect to the area occupancy (%). The fraction of majority vehicle type present in the traffic stream has shown significant influence on the gap maintaining behavior of vehicles.

Dey et al. (2008) have developed a simulation model for mixed traffic moving on two-lane roads and they have used the data such as lateral placement, arrival pattern, acceleration, and overtaking characteristics of different types of vehicles. They have found that any vehicle was able to pass the lead vehicle when the lateral clearance was one and half times the width of the passing vehicle. But they didn't mention anything about the variation of lateral clearance with respect to road and traffic conditions. Pal and Mallikarjuna (2010) have analyzed the lateral gap maintaining behavior and its affect on the traffic flow modeling under heterogeneous traffic conditions. From the collected data on the gap maintaining behavior they have observed that the vehicles were maintaining different gaps when travelling under different traffic conditions and this was also influenced by lateral position of the vehicle.

From the literature review it can be observed that the researchers have proposed various methodologies in modeling vehicular movement under heterogeneous traffic conditions. It can also be seen that very little data have been collected and analyzed to model this behavior. Due to the difficulties in modeling the combined movement and the relevant field data collection many researchers have modeled the lateral and longitudinal movements separately, in a sequential manner. Even for doing this not many field studies have been carried, may be due to the difficulties in data collection. A single lateral gap value for a particular vehicle type, given for a particular speed, as proposed in the previous studies, cannot be used for modeling purposes.

In this study, an attempt has been made to collect and analyze the lateral gap data from various types of roads, with varying traffic compositions and traffic conditions. Lateral gap data have been analyzed with respect to the speeds of both the side-by-side moving vehicles, and road widths, for various vehicle combinations. An attempt has also been made to analyze the probabilistic nature of the lateral gap data when both the vehicles are travelling with similar speeds. Similar exercise has been carried out for the gap data when one of the vehicles (of the considered vehicle pair) traveling at a particular speed and the other vehicle is traveling at any other speed. The scope of this study is limited to the lateral gap data analysis for divided urban roads widths varying from 6.6 meter to 12.5 meters.

2. Data Collection on Microscopic Characteristics

2.1. Field data collection

Collecting microscopic data is difficult under heterogeneous traffic conditions. Microscopic data are essential when modeling the heterogeneous traffic at microscopic level. In this study, data have been collected using video image processing software, TRAZER. Video films have been collected using the cameras focused over the mid block sections of divided multilane roads, with uninterrupted flow, at different urban locations in New Delhi, Bangalore, Hyderabad, and Kolkata. Video films have been collected for twenty one hours. Traffic flow data were collected in peak and off peak hours, so as to observe the lateral gap maintaining behavior in congested as well as in free flow conditions. Data were also collected on roads with different widths ranging from 6.60m to 12.50m so as to study the change in lateral gap maintaining behavior with respect to the change in road width.

The locations were selected based on the following conditions.

- The road stretch under consideration should be straight for at least 50-100m.
- The road stretch under consideration should not have any potholes or other defects which would affect the driving pattern of the driver.

After successfully collecting the video data, the relevant traffic data have been extracted using TRAZER and the methodology adopted in this process is discussed in the following sections.

2.2. Data extraction using TRAZER

In this study, an offline image processing software, named TRAZER, was used to extract the traffic data from the video film. TRAZER is capable of tracking vehicles, even under highly congested traffic conditions. The specific advantage of this software is its ability to capture lateral movements, which is a typical feature of no-lane disciplined traffic. It is also able to track small sized vehicles such as two wheelers and three wheelers, under dense traffic conditions. From the trajectory data, several microscopic and macroscopic traffic features can be extracted. Among the macroscopic characteristics, classified traffic volume, average occupancy, and average speed data can be collected. Mallikarjuna et al. (2009) established that TRAZER gives high detection accuracies if the video camera is aligned with the centre lane of the road and at a certain altitude.

2.3. Details of the video data

A total of twenty one hours data have been collected and processed. Details, such as the road width and time of data collection, variation of hourly flow and vehicle compositions are given in table 1. It was observed that the majority number of vehicles were TWs (Two Wheelers) and LMVs (Light Motor Vehicles). Keeping this in view lateral gap data have been analyzed mainly for LMV-LMV, LMV-TW, and TW-TW. Wherever sufficient data were available lateral gaps have been analyzed for other vehicle combinations also.

Table 1. Details of the data collected for extracting lateral gap and their compositions

Location	Width (m)	Duration (hrs)	Time of data collection	Variation of hourly flow (vehicles/hr)	Vehicle compositions (%)			
					LMV	TW	THW	HMV
VIP Road, Kolkata	10.8	7	9:25 am to 4:44 pm	5228 to 2913	59	23	10	8
Salt lake, Kolkata	6.6	4	9:40 am to 3:40 pm	3019 to 2799	63	20	13	4
Maharanibagh, Delhi	12.5	4	1:00 pm to 5:30 pm	7897 to 6396	48	29	10	13
Indiranagar, Bangalore	12.0	2	10:50 am to 12:50 pm	3771 to 3726	41	47	8	4
Kodially, Bangalore	8.3	2	11:0 am to 2:00 pm	4186 to 3952	34	49	13	4
Jubilee hills, Hyderabad	10	2	2:42 pm to 4:42 pm	4550 to 3621	46	43	10	1

2.4. Lateral gap and speed data extraction

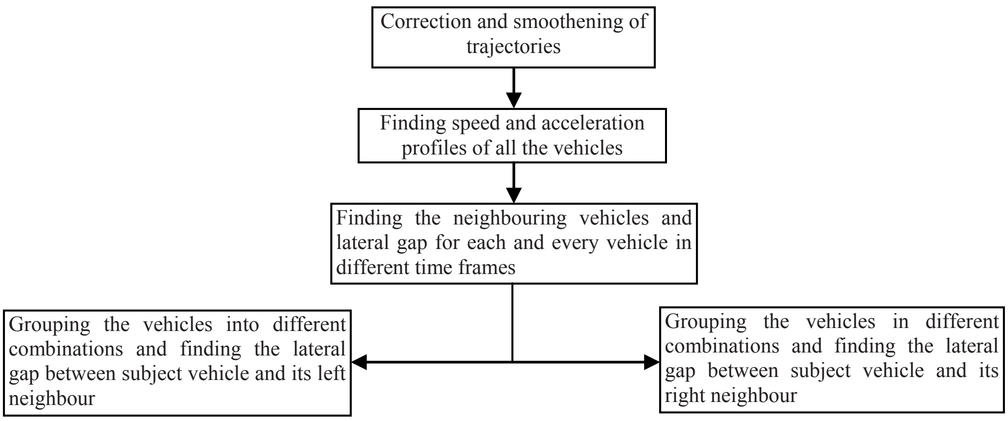

Fig. 2. Flow chart representing the extraction of speed and gap data using MATLAB.

Trajectory data collected from TRAZER were further processed to get the lateral gap and speed related data. Procedure used to find out the lateral gap between two adjacent vehicles is shown in fig. 2.

3. Analysis of Lateral Gap Data

Lateral gap collected from various types of roads, for different conditions have been analyzed in this section. In case of all the roads enough data were available for LMV-LMV, LMV-TW, TW-TW, and LMV-THW vehicle combinations. Gap data have been averaged over a specified speed range of 5 km/hr, except in case of the data collected from Kolkata where the data were averaged over the speed range of 10 km/hr. Lateral gap data, corresponding to 0-5 km/h and 25-30 km/h, for all the four vehicle combinations have been analyzed. Role of driver behavior in maintaining the lateral gap has been analyzed when both the subject and the adjacent vehicles traveling with similar speed. Variation of the mean and standard deviation of the lateral gap with respect to the road width and the average speed has been also analyzed. Lateral gap variation with respect to the variation of the adjacent vehicle speed was also analyzed.

3.1. Analysis of data

Four hours of data, collected from Maharanibagh, Delhi, were analyzed and the variation of average lateral gap with respect to the speed of the adjacent vehicle, for different vehicle combinations is shown in fig. 3.

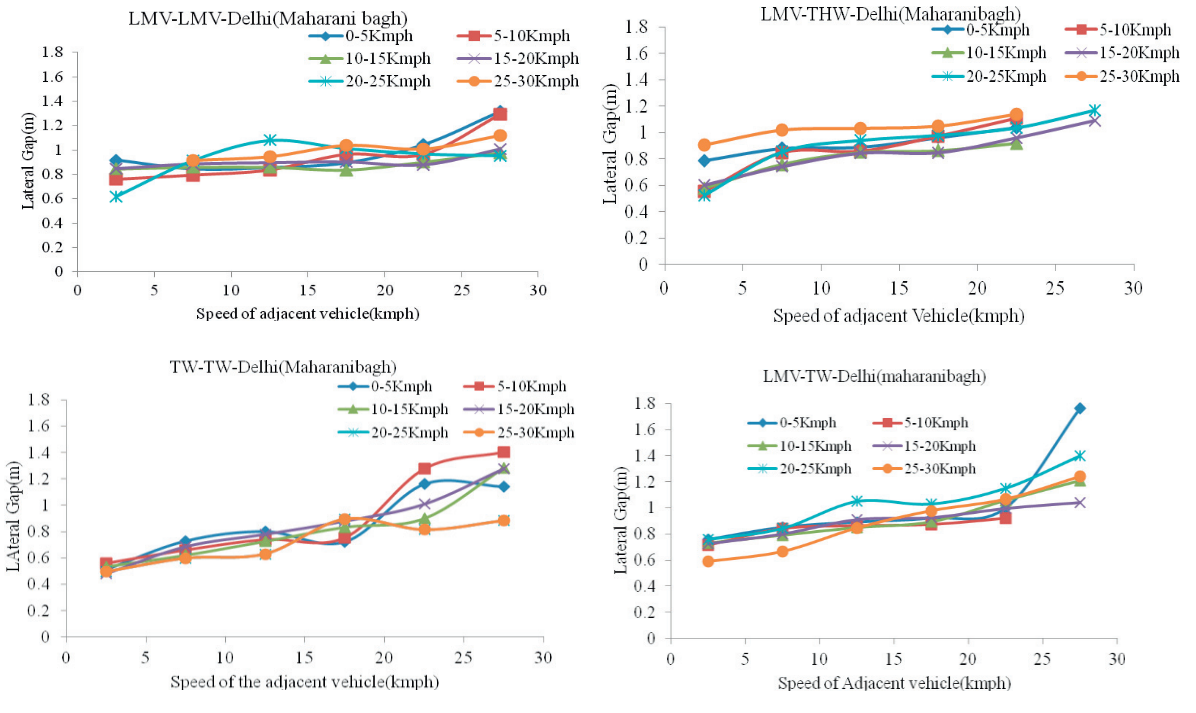

Fig. 3. Variation of lateral gap, maintained by the subject vehicle when travelling at different speeds with varying speeds of adjacent vehicle for (a) LMV-LMV(Top left); (b) LMV-THW(Top right);(c)TW-TW(Bottom left);(d)LMV-TW(Bottom right)

From fig. 3, it can be observed that with the increase in the speed of the adjacent vehicle, when the subject vehicle travelling with speeds falling in certain speed range, lateral gap between the two vehicles is increasing. In case of TW-TW, and LMV-TW there is a significant variation in the lateral gaps and the variation was found to be non-linear. Similar analysis for lateral gap variation with speed of adjacent vehicles, for different vehicle combinations, was carried out and similar trends were observed in the remaining cases also. Lateral gaps between vehicles when traveling at 0-5 kmph and 25-30 kmph, for different vehicle combinations, were found out and given in table 2.

Table 2. Lateral gap for various vehicle combinations

Location	Speed range(km/hr)	LMV-LMV Gap(m)	LMV-THW Gap(m)	LMV-TW Gap(m)	TW-TW Gap(m)
Bangalore(Indiranagar)	0-5	0.37-0.89	0.21-0.3	0.36-0.82	0.37-0.43
	25-30	1.05-1.75	1.18-1.45	0.82-1.0	0.86-1.7
Delhi(Maharani Bagh)	0-5	0.62-0.91	0.52-0.78	0.58-0.76	0.48-0.75
	25-30	0.95-1.32	1.09-1.17	1.04-1.76	0.88-1.40
Hyderabad(Jubliee Hills)	0-5	0.34-0.9	-	0.64-0.68	0.22
	25-30	1.31-1.56	-	0.83-1.3	0.67-1.22
Kolkata(VIP Road)	0-10	0.60-0.79	0.64-0.93	0.75-0.81	0.68-0.77
	40-50	0.93-1.02	1.38-1.72	1.11-1.26	1.43-1.75
Bangalore(Kodially)	0-5	0.46-0.89	-	0.89-0.33	0.46-0.89
	25-30	1.10-1.41	-	1.09-1.32	1.10-1.41
Kolkata(Salt lake)	0-10	0.18-0.97	-	0.63-0.7	0.23-0.77
	30-40	0.86-0.97	-	0.7-1.40	1.18-1.45

3.2. Analysis of the driver behavior in the presence of side vehicle

In the previous sections it has been observed that even when the adjacent vehicles travelling at similar speeds due to the differences in the driver behavior there was a significant variation in the lateral gaps. For some of the vehicle combinations, with enough data on the lateral gaps at similar speeds of side-by-side moving vehicles, an attempt has been made to analyze the lateral gap data. From the observed relative frequency data it has been found that the gap data were normally distributed. Same hypothesis has been tested at 1% significance level. Results obtained from the hypotheses testing are listed in table 3. In hypotheses testing 'data follow normal distribution' was taken as the null hypothesis. Except for combinations, LMV-TW (Bangalore), TW-TW (Hyderabad), TW-TW (New Delhi) and LMV-THW (New Delhi) all the other combinations, the assumed normality was proven correct.

3.3. Variation of lateral gap with road width

For a particular vehicle combination and for a particular speed range, variation of the mean of the normal distribution with road width has been plotted to see whether there is any significant change in the lateral gaps as a function of the road width (Fig. 4). From the figure it can be seen that no consistent conclusion can be made about this relationship.

Table 3. Results obtained from the hypotheses testing on the normality of lateral gap

Location	Vehicle combination	Mean	Standard Deviation	α	Reject null hypothesis
Indiranagar, Bangalore	TW-TW(20-25kmph)	0.86	0.41	0.01	NO
	TW-TW	0.89	0.50	0.01	NO
	LMV-TW(20-25kmph)	0.943	0.50	0.01	NO
Indiranagar, Bangalore	LMV-TW	0.92	0.52	0.02	YES
	LMV-THW(2025kmph)	1.054	0.56	0.01	NO
	LMV-THW	0.954	0.51	0.01	NO
	LMV-LMV(20-25kmph)	0.82	0.54	0.01	NO
	LMV-LMV	0.98	0.54	0.01	NO
Jublee Hills, Hyderabad	TW-TW(20-25kmph)	0.67	0.45	0.01	NO
	TW-TW	0.80	0.54	0.2	YES
	LMV-TW(20-25kmph)	0.92	0.42	0.01	NO
	LMV-TW	0.87	0.44	0.01	NO
	LMV-THW(20 25kmph)	0.98	0.53	0.01	NO
	LMV-THW	0.93	0.51	0.01	NO
	LMV-LMV(20-25kmph)	0.97	0.51	0.01	NO
	LMV-LMV	1.01	0.48	0.01	NO
Maharanibagh, New Delhi	TW-TW(20-25kmph)	1.02	0.51	0.01	NO
	TW-TW	0.78	0.57	0.2	YES
	LMV-TW(20-25kmph)	1.048	0.46	0.01	NO
	LMV-TW	1.29	0.473	0.01	NO
	LMV-THW(20 25kmph)	1.03	0.44	0.01	NO
	LMV-THW	1.15	0.84	0.2	YES
	LMV-LMV(20-25kmph)	0.97	0.44	0.01	NO
	LMV-LMV	0.86	0.42	0.01	NO
VIP Road, Kolkata	TW-TW(20-25kmph)	0.97	0.47	0.01	NO
	TW-TW	1.03	0.51	0.01	NO
	LMV-TW(20-25kmph)	0.89	0.47	0.01	NO
	LMV-TW	1.04	0.51	0.01	NO
	LMV-THW(20 25kmph)	0.97	0.44	0.01	NO
	LMV-THW	0.86	0.42	0.01	NO
	LMV-LMV(20-25kmph)	0.88	0.42	0.01	NO
	LMV-LMV	0.96	0.46	0.01	NO
Saltlake, Kolkata	TW-TW(20-25kmph)	0.71	0.339	0.01	NO
	TW-TW	0.88	0.41	0.01	NO
	LMV-TW(20-25kmph)	1.12	0.501	0.01	NO
	LMV-TW	0.98	0.49	0.01	NO
	LMV-LMV(20-25kmph)	0.934	0.55	0.01	NO
	LMV-LMV	.88	0.42	0.01	NO
Kodially, Bangalore	TW-TW(20-25kmph)	0.633	0.33	0.01	NO
	TW-TW	0.788	0.31	0.01	NO
	LMV-TW(20-25kmph)	0.87	0.43	0.01	NO
	LMV-TW	0.91	0.44	0.01	NO
	LMV-THW(20 25kmph)	1.02	0.50	0.01	NO
	LMV-THW	0.98	0.396	0.01	NO
	LMV-LMV(20-25kmph)	0.93	0.488	0.01	NO
	LMV-LMV	0.96	0.439	0.01	NO

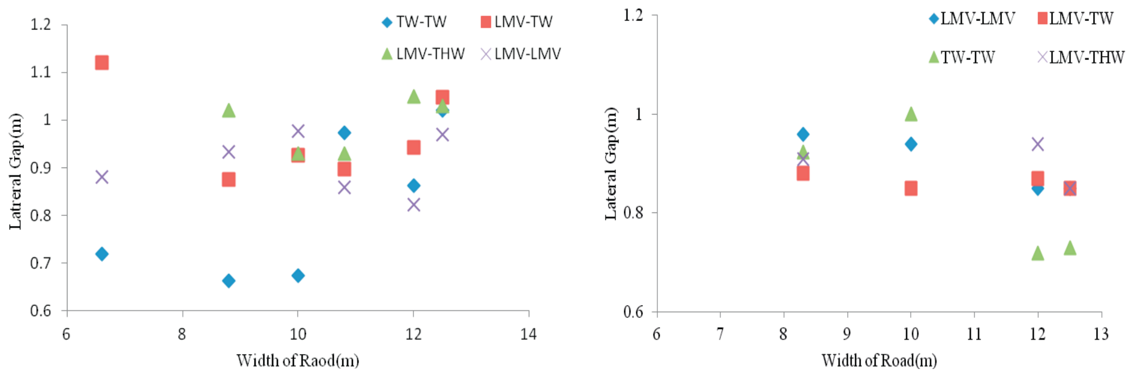

Fig. 4. Mean lateral gap when the speeds of subject and adjacent vehicle are between (a) 20-25 Kmph for various road widths(left); (b) 10-15 Kmph for various road widths(right)

3.4. Variation of mean lateral gap with speed when subject and adjacent vehicles moving with same speed

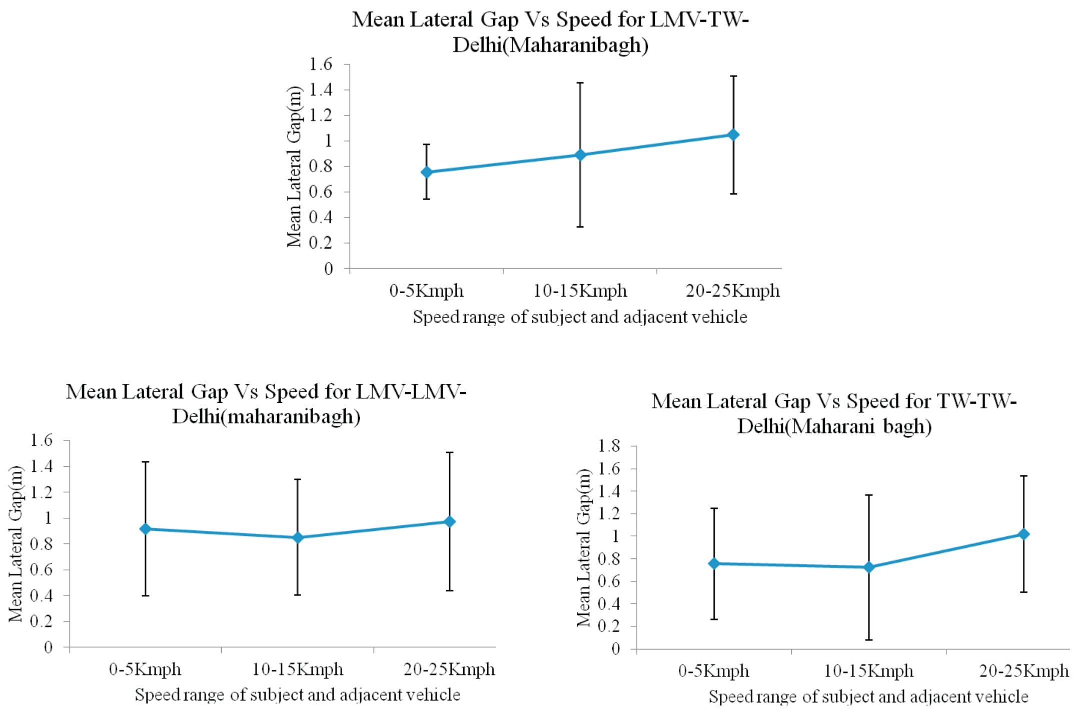

Fig. 5. Mean lateral gap vs speed with standard deviation, when both subject and adjacent vehicle are moving in same speed range for (a) LMV-TW(Top); (b) LMV-LMV(Bottom left); (c) TW-TW(Bottom right)

Mean lateral gap data have been plotted against the speed maintained by both the subject and the adjacent vehicles (both the vehicles were moving with similar speed). For some of the vehicle combinations these relations are shown in fig. 5. From the figures it can be seen that in all the cases there is a significant change in the mean lateral gap and from the standard deviations shown for each mean indicates a significant variation within a speed range.

3.5. Distribution of lateral gap when one of the vehicles is travelling with specific speed and the other vehicle is travelling at any speed

An attempt has also been made to model the gaps maintained by the drivers of a subject vehicle, moving with certain speed, with respect to the adjacent vehicles moving with any speed. For specific vehicle combinations (for which adequate field data were available) these models are shown in fig. 6. In all the cases log normal distribution was able to model these gaps.

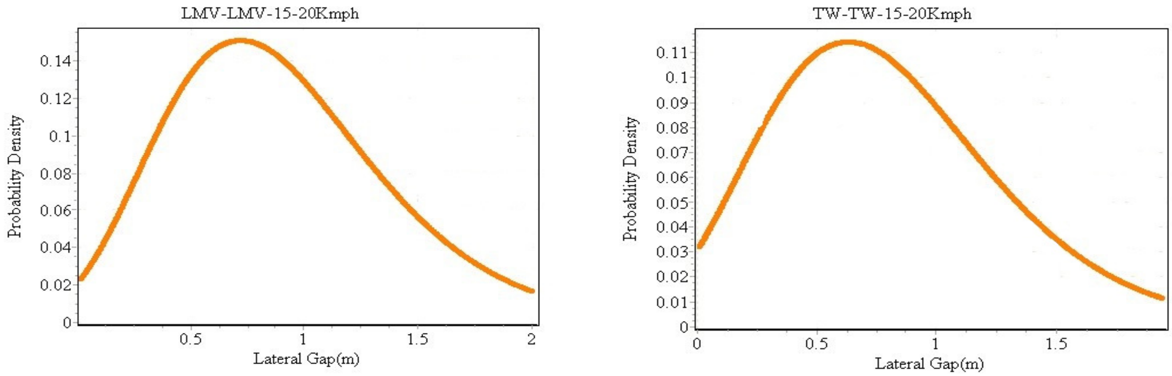

Fig. 6. Lateral gap vs Probability density plot for Delhi data, when the speed of subject vehicle is between 15-20 Kmph and adjacent vehicle is travelling at any speed for (a) LMV-LMV combination; (b) TW-TW combination

4. Summary and Conclusions

Lateral gaps maintained by different types of vehicles, when moving under different traffic conditions, and on different types of roads have been analyzed in this study. The microscopic traffic parameter, lateral gap, has been explained in terms of macroscopic variable speed. It has been found that lateral gaps maintained by vehicles vary with respect to their own speed, type of the adjacent vehicle, and the speed of the adjacent vehicle.

From the analysis of the lateral gap data the following important conclusions have been drawn;

- It has been found that the lateral gap maintained by a particular vehicle varies significantly with the speed of the adjacent vehicle; hence a single value for the lateral gap cannot be used.
- Lateral gaps maintained by vehicles, moving with more or less similar speed, can be approximated with the normal distribution, irrespective of the type of the vehicle and the speed range.
- Lateral gaps maintained by vehicles, where one vehicle maintains certain speed and the other vehicle maintains any speed, can be approximated with the lognormal distribution.

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