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Characteristics of Vehicular Lateral Shifts in Non-lane-disciplined Traffic Stream

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Abstract

Following vehicles moving in non-lane-disciplined traffic stream continuously looks for the opportunities to overtake or pass the leading vehicle(s) without negotiating the safety. The accomplishment of this aspiration forces the driver of the following vehicle for a nonstop shift in the lateral direction in addition to the longitudinal direction. The contineous lateral shifts by different vehicle types are not the same. Therefore, this study aims in quantifying the amount of vehicular lateral shifts in the non-lane-disciplined traffic stream. For this purpose, one hr traffic video data were collected from Hyderabad city, India. From the video film, vehicle trajectories were extracted using image processing software TRAZER after applying relevant corrections. The lateral shifts of each vehicle at every time frame (0.04 sec) were extracted from the corrected trajectories. The cumulative lateral shifts of the vehicle over the longitudinal shift were calculated from the lateral shift data. The extracted data were averaged for all vehicles and each type of vehicles over a longitudinal shift of one meter. The results indicate that lateral shifts for different types of vehicles are not the same. Motorized two-wheeler (MTW) shows maximum lateral shift. Further, lateral shifts distributions of different types of vehicles were carried out. It was found that he lognormal distribution can fit lateral shifts of different types of vehicles except for MTW (weibull). The results obtained in this study will give an idea to the researchers on modeling lateral shift performance of non-lane-disciplined traffic simulation model.

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Keywords: Lateral shift; lateral movement; non-lane-disciplined; mixed traffic; lognormal distribution

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1. Introduction

The enormous increase in urban populations, the growth of individual household income and growing lifestyle encourages the urban dwellers to own a vehicle even if not a luxurious. As a result, the vehicle populations in every urban area are increasing rapidly. However, the growths of required transport infrastructures are not in line with the growth of the vehicle. This situation leads to various transport related issues such as congestion on roads, reduction in stream speed, delays, road accidents, increase in air and noise pollution, shortage of parking space, etc. In addition to these, the sharing of same road space by different types of vehicles is dominant in developing Nations. Various types of vehicles that share the same road space are Motorized two-wheelers (MTWs), Light motor vehicles (LMVs) such as Car, Motorized three-wheelers (MThWs), and Heavy motor vehicles (HMVs) such as Bus, Truck. The static (dimensions) and dynamic (speed, acceleration, deceleration, the ability of lateral maneuver) characteristics of these vehicles are different. Due to the irregular characteristics of different types of vehicles and ability to maneuver at the diverse situation, these vehicles always look for the opportunities to overtake or pass the leading vehicle. A driver of the subject vehicle may shift laterally if he/she is not pleased with the current speed in the existing lateral position owing to the presence of a leader (Asaithambi and Joseph, 2018). Smaller size vehicles such as MTW and MThW can easily wave through the available lateral gap between other vehicles or other vehicle and road edges. Even LMV also wave through the available lateral gap ahead or adjacent to it. However, many cases the available lateral gap ahead of the subject vehicle is not enough to wave through the current passageway of the subject vehicles. In such cases, the driver maneuvers the vehicles laterally to adjust the available lateral gap ahead of it. Once the driver finds a safe lateral gap and interprets a safer and faster movement in the intended pathway, the driver maneuvers the vehicle laterally while driving longitudinally.

Nonetheless, the driver may further shift laterally or may come back to the original path or may further shift in the opposite direction provided the intended lateral position is not suitable for a safe and faster longitudinal movement. This type of traffic scenario is multifarious and termed as non-lane-disciplined traffic stream. Though driver looks for a better placement in the lateral direction, but can't shift as much as he/she desired. This depends on the surrounding objects (vehicles or road edges) and dynamic characteristics of vehicles such as lateral speed and lateral acceleration. Even for a similar type of vehicles with similar characteristics, the lateral shift is not the same because of the stochastic nature of drivers. Therefore, a thorough understanding is essential to know the amount of lateral shift a vehicle can take place for improved placement in the lateral direction.

Many researchers (Gunay, 2007; Koshy and Arasan, 2005; Mallikarjuna, 2007; Dey, et al., 2008; Minh, et al., 2006; Lenorzer, et al, 2015; Pal and Chunchu, 2017) stressed on the need of analyzing the non-lane-disciplined traffic stream. Few parameters of non-lane-disciplined traffic stream analyzed by various past studies are lateral gap model(Pal and Mallikarjuna, 2017; Luo, et al., 2013; Minh, et al., 2006; Nagraj, et al., 1990; Mathew et al., 2013; Munigeity, et al., 2013; Budhakar and Maurya, 2017), lateral gap maintaining behavior of vehicles (Mallikarjuna, et al., 2013), duration of lateral shifts in mixed traffic (Asaithambi and Joseph, 2018; Munigety, et al., 2014), lateral movement behavior (Munigety, et al., 2013), lateral acceleration (Mahapatra and Maurya, 2013; Mahapatra, et al., 2016), lateral position (Pal and Mallikarjuna, 2010; Kanagaraj, et al., 2015; Wong, et al., 2016), effect of adjacent vehicles (Gunay, 2007; Pal and Mallikarjuna, 2017), effect of mixed traffic proportion (Asaithambi, et al., 2012), and maximum steering angle (Chakraborty, et al., 2004). Lateral gap maintaining behavior of vehicles are important (Pal and Mallikarjuna, 2017; Mallikarjuna et al., 2013) to understand and model the non-lane-disciplined traffic stream. Some of the studies observed that the lateral gap depends on the subject vehicle's speed (Luo, et al., 2013; Minh, et al., 2006; Nagraj, et al., 1990) only. However, Dey, et al. (2008) considered a constant lateral gap. Lateral gap maintains by different types of vehicles also influenced by the speed of the adjacent vehicles (Mallikarjuna, et al., 2013). Gunay (2007) analyzed the heterogeneous traffic stream and observed that the speed of passing vehicle depends on frictional clearance. Pal and Mallikarjuna (2017) analyzed the total lateral gap (summation of both side lateral gaps) of the passing/overtaking vehicles. They concluded that the total lateral gap maintains by subject (passing/overtaking) vehicle is a function of subject vehicles own speed, and type and speed of either of the adjacent vehicles. Wong, et al. (2016) analyzed the mixed traffic flows of Taipei city, Taiwan. They analyzed the speed and lateral position distribution of cars and motorcycles thoroughly including different congestion levels. However, this study also does not speak about the lateral shift characteristics of vehicles.

Only a few studies (Mahapatra and Maurya, 2013; Mahapatra, et al., 2015; Asaithambi and Joseph, 2018; Munigety, et al., 2014) were conducted on lateral shift characteristics of vehicles under non-lane-disciplined traffic stream. Few parameters of lateral shift characteristics of vehicles under non-lane-disciplined traffic streams, such as lateral shift duration (Asaithambi and Joseph, 2018; Munigety, et al., 2014) and lateral acceleration (Mahapatra and Maurya, 2013; Mahapatra, et al., 2015) have got little attention by researchers. However, an important parameter, 'the amount of lateral shift per unit longitudinal shift' is overlooked in the literature. During actual vehicular movement on the road surface, the longitudinal shift and the lateral shift occurs simultaneously. Therefore, it is not clear from these studies that how much lateral shift a vehicle can take per unit longitudinal shift on non-lane-disciplined traffic stream to relocate on desired lateral position? Is it the same for different types of vehcles? The lack of this aspect may be due to the non-availability of vehicular trajectories of non-lane-disciplined traffic streams. Hence, the center of attention of this study is on finding the amount of lateral shift per unit longitudinal shift for different types of vehicles using vehicular trajectory data collected from non-lane-disciplined traffic streams.

The remainder of this paper is organized as follows. The next section provides a brief description on data collection method and its relevant information. Section three describes the methods used to estimate the lateral shifts. Section four deals with the analysis of the results obtained for lateral shifts. Lastly, the final section discussed the important conclusion drawn from the present study and future scope for further research in this direction.

2. Data Collection

In this study, traffic video films were collected from the arterials of Jubilee hills, Hyderabad, India. The video camera was mounted on foot over bridge situated across the road section. A strecth of about 50 m were focused by the video camera while fliming the traffic flow. A marking for a lenth of 30 m was done longitudinaly on road stretch. The road width of the section is 10 m. The vehicles plying on this section was mixed and not following lane markings, i.e., lateral shiftings were not restricted. The mixed traffic contains various types of vehicles such as cars, three-wheelers, buses, trucks, two-wheelers, and light commercial vehicles. The traffic video films were collected between 15:45 hrs and 16:45 hrs on a working day with clear weather. A snapshot of the traffic video film is shown in Fig. 1.

Fig. 1. Snapshot from traffic video film, collected at

Jubilee hills, Hyderabad, india

The video films were processed to extract the vehicle trajectories using image processing software, TRAZER. It is an automated image processing software, that is manual intervention is not required to track the vehicle trajectory. However, it also allows manual intervention and, this allows the user to add unidentified vehicle trajectories or wrongly detected vehicle trajectories. TRZER collects the trajectory data for a length of about 20 to 40 m. The frequency of the vehicle trajectory tracking is 25 Hz, i.e., vehicle's positions were detected by TRAZER at every 0.04 sec interval. Longitudinal and lateral positions of the vehicles were detected separately over 0.04 sec interval. The accuracy of vehicle detection by TRAZER is 85-90% (Mallikarjuna, et al., 2009). TRAZER classifies and track the vehicles in four categories such as MTW(two-wheelers), LMV (cars, light commercial vehicles), MThW (three-wheelers) and HMV (buses, trucks). Accordingly, the trajectories of four categories of vehicles such as MTW, LMV, MThW, and HMV were extracted from the traffic videos. The hourly flow was found to be 3094 vehicles/hr. The compositions of the traffic stream are shown in Table 1.

Table 1. Traffic compositions

Road stretch	Data collection time	Vehicle type	Flow (Veh/hr)	Vehicle Composition (%)	Total trajectory data points	Trajectory data points composition (%)
Jubilee hills, Hyderabad	15:45 hrs to 16:45 hrs	LMV	3094	51.13	218181	58.47
		HMV		1.97		0.87
		MTW		33.65		30.35
		MThW		13.25		10.32

Trajectory data collection using image processing techniques, specifically under non-lane-disciplined traffic conditions may contain series of errors. This may be due to occlusions, illumination changes, and perspective angle changes of the camera (Pal and Chunchu, 2018). To overcome the possible errors in position data of the vehicle trajectories, the extracted trajectories were smoothed using the techniques, called complete ensemble empirical mode decomposition with adaptive noise (CEEMDAN). The correctd trajectories were used to estimate the speed of the vehicles using the method of Wavelet Transforms (WT). The details of both the techniques are available in Pal and Chunchu (2018). The corrected trajectories were then used to extract the lateral shifts over longitudinal shifts. The following section describes the extraction of lateral shifts from vehicle trajectory data.

3. Lateral Shifts

A lateral shift on a straight road is the movement of the centre line of a vehicle along the road width at each time step. This lateral shift may be in either direction along the road width. The cumulative lateral shift is the cumulative summation of the lateral shift irrespective of the direction over the continuous longitudinal shift. The corrected vehicle trajectories extracted from traffic video film as discussed in the previous section is used to estimate the lateral shift and cumulative lateral shift of each vehicle using MATLAB programming language. Fig. 2 shows the lateral and longitudinal trajectories of two vehicles collected at the different period from Jubilee hills, Hyderabad. The length of the trajectories is also not the same. Since, TRAZER tracks the vehicle position automatically, hence, tracking length of different vehicles are different.

In the process of determining the lateral and longitudinal shifts for each vehicle, the lateral and longitudinal positions on a previous time frame (0.04 sec) are scanned. The difference between the centre line positions of the same vehicle in both the direction is extracted. This process continuous until the last frame of tracking, i.e., the last point of vehicle trajectory is scanned by the program. The continuous addition of the lateral shift and the longitudinal shift is also carried out. Finally, the lateral shift over the longitudinal shift is calculated by dividing the cumulative lateral shift by cumulative longitudinal shift. Fig. 3 and 4 show cumulative lateral shifts of MTW and LMV, respectively.

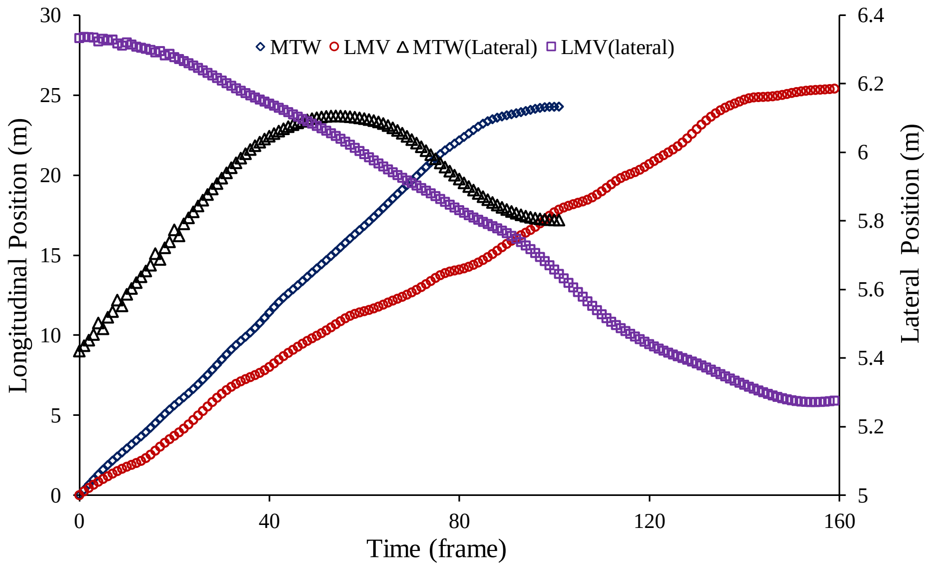

Fig. 2. Longitudinal and Lateral Trajectories

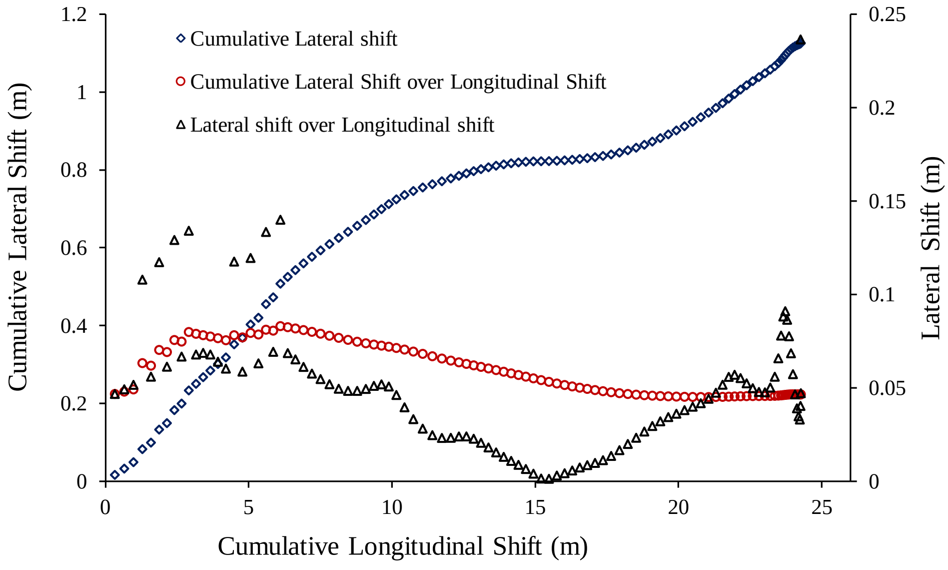

Fig. 3. Cumulative lateral shifts MTW

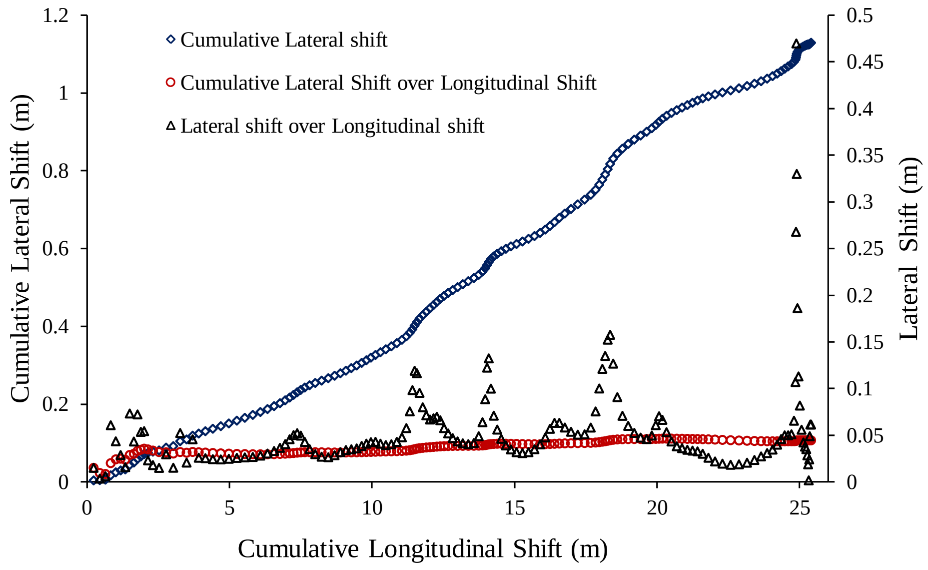

Fig. 4. Cumulative lateral shifts of an LMV

It can be seen from Fig. 3 and 4 that at every time step lateral shifts over longitudinal shifts are fluctuating. This may be due to the detection of vehicles over a high frequency rate. The same is rectified when the cumulative lateral shifts over cumulative longitudinal shifts are estimated. The reason may be the process of data collection. At each time interval, when the frequency of data extraction is high, fluctuation on image processing is dominant; however the same is nullified on cumulative data. At each time interval, a minimum of 0.003 m and 0.01 m longitudinal shifts are observed for MTW and LMV, respectively. Because of such a low level of longitudinal shifting, even a minor change in image detection may lead to large error. Therefore, considering any microscopic parameters, in such a minor level of longitudinal shifts, may not be suitable. Hence, in this case, a cumulative lateral shift is appropriate to consider for further analysis.

Due to the non-lane-disciplined behavior of the traffic stream, sometimes smaller size vehicles are fully or partially overlapped by larger size vehicles for a certain period. In such cases that vehicle may overlook by TRAZER or may detect for a shorter duration. A vehicle detected for the duration of fewerer than 10 frames (0.4 sec) and trajectory length less than 5 m is not considered in this study, pretending that this vehicle was partial or fully overlapped by other vehicles and overlooked by TRAZER while processing. A total of 3094 vehicles collected from Hyderabad, were considered to extract the data of lateral shifts over longitudinal shifts. Majority of the vehicles are LMV (49.51%) followed by MTW (38.80%). MThW and HMV proportions are 10.52% and 1.17%, respectively. Details of the lateral shifts data are given in Table 2. Comparative study of the average and maximum lateral shifts are shown in Fig. 5 and 6. It is clear from Fig. 5 that the average shift by MTW is higher. It is lower in the case of LMV. Though in Fig. 5, HMV is showing higher average shift, but this may not be true in reality. Since the number of samples is very less here, hence, this trend is showing the opposite. However, in case of maximum lateral shift per meter longitudinal shift, the smaller size vehicle MTW is showing higher followed by LMV. This is because of the flexible maneuverability of MTW. An MTW can always wave through the other vehicles. In case of LMV, lateral shift is better to compare to MThW and HMV. In this case, also maneuverability is comparatively better. However, in case MThW maneuverability is comparatively less. It may be due to safety reason as it has a lesser front wheel. HMV cannot shift laterally much due to its size.

Table 2. Summary of Lateral shifts data

Road stretch	Data collection time	Vehicle type	No. of Lateral shift	Vehicle Composition (%)	Average Lateral shift (m)	Maximum Lateral shift (m)
Jubilee hills, Hyderabad	15:45 hrs to 16:45 hrs	LMV	3094	49.51	0.039	0.2959
		HMV		1.17	0.0629	0.2694
		MTW		38.80	0.0521	0.5518
		MThW		10.52	0.0476	0.2849
		ALL		100	0.0452	0.5518

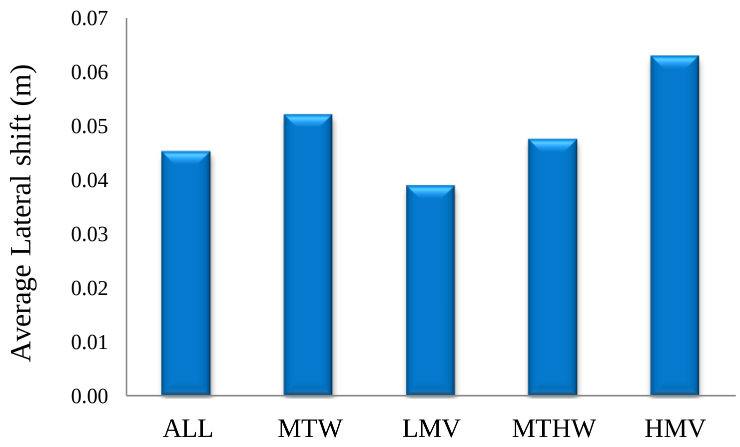

Fig. 5. Average Lateral Shift

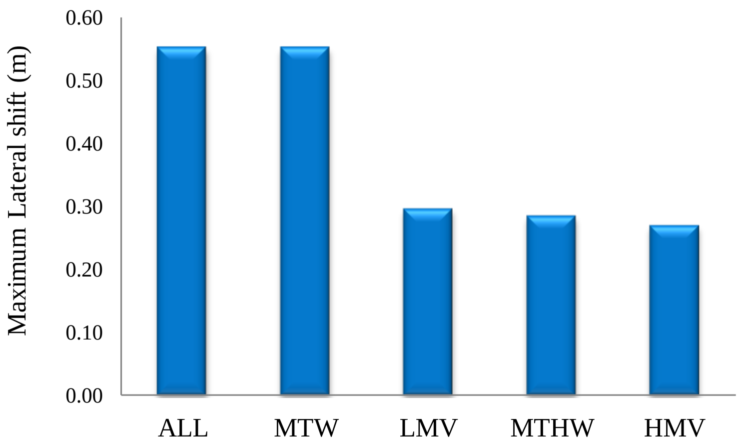

Fig. 6. Maximum Lateral Shift

4. Analysis of Lateral Shifts

The lateral shifts distribution of different types of vehicles and all vehicles together are shown in Fig. 7. A set of probability density functions (pdf) were evaluated for lateral shifts data using OriginPro statistical software which fits the frequency distribution based on K-S test results. In K-S test the null hypothesis is taken as the data follows a distribution among Normal, Lognormal, Weibull, and Gamma. Parameter estimation and the goodness of fit tests were conducted at 5 % significance level. In addition to the K-S value, p-values were also calculated by the software. If the p-value comes out to be more than 0.05, the null hypothesis is accepted. However, here only the best fitted distribution data is presented in Table 3, which is having p-values above the critical p-value.

Table 3. Summary of statistical parameters of the best fitted distribution

Vehicle type	Type of Distribution	Mean (log(X))	Standard deviation (log(X))	Alpha	p-value	K-S statistics
ALL	lognormal	-3.43655	0.86924	0.05	0.0648	0.02589
LMV	lognormal	-3.60767	0.87509	0.05	0.31543	0.02699
MTW	Weibull	scale: 0.05743	Shape: 1.40133	0.05	>0.1	0.03434
MThW	log-normal	-3.41726	0.93293	0.05	0.1902	0.06589
HMV	log-normal	-3.1077	0.87579	0.05	1	1

5. Summary and Conclusions

This paper discussed on lateral shift characteristics of vehicles plying in the non-lane-disciplined traffic stream. Vehicle trajectories extracted for one hr traffic video data is analyzed thoroughly. It was observed that considering lateral shift at every frame (0.04 sec) is not suitable to verify the lateral shift behavior of vehicles. It is always better to consider cumulative lateral shift over cumulative longitudinal shift to find the average lateral shift of a vehicle. The analysis shows that smaller size vehicle, MTW has better maneuverability. The maximum lateral shift was found in the case of MTW. HMV has the lowest maneuverability, so it has the lowest value of maximum lateral shift. Average lateral shift is also higher in the case of MTW, followed by LMV and MThW. In this study numbers of HMV were less, hence, the obtained average lateral shift for HMV may not be useful. The analysis of lateral shift distribution of different types of vehicles shows that lognormal distribution is the best-fitted distribution for all types of vehicles except MTW, which is weibull. The results obtained in this study will give an idea to the researchers to implement lateral shifts restriction while developing lateral shift model for non-lane-disciplined traffic simulation model. To further verify the results, more data covering various situations may be collected from non-lane-disciplined traffic stream. Various parameters that are affecting vehicular lateral shift over a longitudinal shift may further be checked.

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