Impact of vehicular lateral placement on speed under non-lane discipline traffic stream

Dibyendu Pal¹, S. Sreenivasa²

¹Assistant Professor, Department of Civil Engineering, NERIST, Nirjuli, Arunachal Pradesh, India.
²Executive Director, Eclat Engineering Consultants, Hyderabad, India

¹Corresponding Author’s Email: pal_here00@yahoo.co.in

Abstract. The vehicles plying on the roads of developing nations such as India are mixed in nature and do not follow any lane markings. The vehicles can easily take place laterally on any free space across the road section anticipating better maneuverability on the next time step. The vehicles usually maintain different speed for faster and safer forward movement on the next time step. Therefore, this study aims to find the relationship between vehicular speed and lateral placement. For this purpose, two hrs traffic video data were collected from VIP Road, Kolkata, India. From the traffic video film, vehicle trajectories were extracted using image processing software TRAZER after applying appropriate corrections. From the lateral placement distribution of each category of vehicles, it is observed that LMV prefers median lane, whereas MTW and MThW prefer shoulder lane. Speed-placement models were developed for all vehicles clustered and each category of the vehicle using the first hour data. It was observed that the relationship between average speed and lateral placement is linear up to a certain distance from the median edge and quadratic for the remaining portion of the road width. The speed-placement models’ validation using second-hour data indicate that the developed models are highly accurate in terms of MAPE. The results obtained in this study may be used as an input parameter while assigning vehicular speed based on lateral placement for analyzing non-lane discipline traffic stream using the simulation model.

1. Introduction

The traffic stream plying on the roads of developing nations such as India are mixed in nature. The vehicles plying on the road sections do not follow any lane markings. This type of stream is generally termed as non-lane discipline traffic stream. Since on Indian highways no dedicated lane is available for a specific type of vehicle, hence the usage of road space is generally mixed in nature. The same road space is shared by different kinds of vehicles such as 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, lateral maneuverability) characteristics of these vehicles are not unique. The mixed vehicle interacts with each other and produces a complicated situation which affects the stream speed, capacity, safety, and level of service. The dissimilarity between the characteristics of various types of vehicles and ability of few vehicles to maneuver at live situation enforce the driver to look for the opportunities to overtake or pass the leading vehicle. A driver of the subject vehicle may change its current lateral position if he/she is not happy with the current speed in the present lateral position because of the presence of a leading vehicle [1]. Smaller size vehicles, such as MTW and MThW can easily pass
through the lateral gap between other vehicles or other vehicle and road edges. However, sometimes the available lateral gap in the forward direction of the subject vehicle is not adequate to pass through the current corridor of the subject vehicle. In such cases, the driver shifts the vehicles in the lateral direction to adjust its position for a comfortable movement on the next step. Vehicles occupy any place across the road section depending on its suitability and accessibility for faster progress on the next step. In real traffic stream movement, the driver simultaneously drives the vehicle in the lateral direction as well as in the longitudinal direction by maintaining a certain speed. Analyzing these traffic stream to mitigate the various operational glitches is a complex task. One cannot study these stream behavior just by standing beside the road section or implementing a solution without understanding its effect on traffic stream.

Traffic simulation model plays a vital role to analyze the complex interactions of non-lane discipline traffic streams. Simulation models are widely used to recommend alternative solutions. These models are used to understand the impact of substitute measures on traffic stream behavior and finally recommend to implement the most feasible and acceptable alternatives. Nevertheless, only a realistic and appropriate traffic simulation model would produce the best solution to the existing problems. However, the development of a non-lane discipline traffic simulation model requires enormous information on existing traffic stream. Among several parameters, vehicular lateral placement distribution is one of the crucial parameters for developing the non-lane discipline traffic simulation model. Hence, this study is concentrated on finding the lateral placement distribution for different types of vehicles using vehicular trajectory data collected from non-lane disciplined traffic streams and its impact on vehicular speed.

The lateral placement of a vehicle on the road section is the lateral position of the center line of the vehicle measured from the median edge. [2] estimated the lateral distribution of HMVs. They also tried to find the impact of lateral placement on the design of road pavements. They used “shift factor (SF)” to explain the relationship between speed and rutting. [3] studied the lateral placement data of Delhi-Gurgaon expressway collected during the daytime. They observed that vehicles speed reduces from median-side lane to shoulder-side lane. [4] studied the lateral placement and speed of vehicles on the two-lane bi-directional road section. They found that the speed of MThW, HMV and slow-moving vehicle increases from road edge to the center line. However, due to the effect of the vehicles coming from the opposite direction, the speed of car and MTW initially increase but later decreases toward the center line. The speed of MThWs, HMVs, and slow-moving vehicles have a linear relation with lateral placement, whereas, cars and two-wheelers have a non-linear relationship with lateral placement. [5] studied lateral positions of cars and HMVs at a two-lane, two-way road in the Port of Brisbane. They observed that opposing traffic and length of opposing vehicle effect the lateral positions of cars, utility vehicles, and semitrailer.

[6] analyzed the lateral distribution of mixed traffic on two-lane roads. They concluded that the lateral distributions of mixed traffic of two-lane roads consist of a unimodal or bimodal distribution. From their study with 19 sections of Indian highways, they found that lateral placement follows a unimodal curve if the “placement factor (PF)” and “skewness range (SR)” are less than 1.30 and 0.54, respectively. [7] conducted the study for placement distribution of U turning vehicles collected from 13 different median openings of six lanes divided roads. The placement data of five sections followed the normal distribution, i.e., unimodal when “placement factor (PF)” was less than 0.86.

The reviews of the above literature suggest that lateral placement has a significant effect on traffic flow analysis. Mostly the impact of this parameter was analyzed for the two-lane road section, eight lanes expressways and six-lanes U-turn on median openings. However, for urban arterial roads, the effect of lateral placement on the speed of different types of vehicles is not being explored in the literature specifically for the case of three-lane roads. Hence, this study has attempted to analyze the vehicular lateral placement distribution on non-lane discipline traffic stream plying on urban arterials. It is also planned to check the impact of lateral placement of vehicles on the speed of the traffic stream.

The remainder of this article is organized as follows. The next section described the brief description of data collected for this study and its relevant information. Section three illustrates the analysis of collected data for finding the relationship between speed and lateral placement. Validation
of the developed speed-placement models is given in section four. The final section summarizes the important conclusions drawn from the present study, its application and future works.

2. Data collection
In this study, traffic video films were captured from VIP Road, Kolkata, India. The video camera was mounted on foot over bridge located across the road section. The video camera was installed in such a way that it can focus toward the front of the traffic stream. The video camera was adjusted to focus on a stretch of about 50 m in the longitudinal direction of the arterials while filming the traffic flow. The road stretch was marked using cello tape for a length of 30 m in the longitudinal direction. The road width of the section was 10.80 m. The vehicles plying on this section were mixed and not following lane markings, i.e., lateral movements were not restricted. The mixed traffic contains various types of vehicles such as cars, buses, trucks, two-wheelers, three-wheelers, and light commercial vehicles. The traffic video films were collected between 9:30 hrs and 11:30 hrs on a working day with clear weather.

The collected video films were processed to extract the vehicle trajectories automatically using image processing software, TRAZER. Manual intervention is not required in TRAZER to track the vehicle trajectories. However, it also allows manual involvement and, this permits the user to augment unidentified vehicle trajectories or wrongly detected vehicle trajectories. TRAZER can collect about 20 to 40 m long trajectories. 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 tracked separately over 0.04 sec interval. The accuracy of vehicle detection by TRAZER is about 85-90% [8]. TRAZER classifies the vehicles in four different categories such as MTW(two-wheelers), LMV (cars, light commercial vehicles), MThW (three-wheelers, Auto) 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.

Trajectory data collection using image processing methods, specifically under non-lane discipline traffic streams consists of several errors. The reason may be due to the occlusions, illumination changes, and perspective angle changes of the camera [9]. The extracted trajectories were corrected to overcome the anticipated errors in position data of the vehicle trajectories. The method used to correct the trajectories is called complete ensemble empirical mode decomposition with adaptive noise (CEEMDAN). The corrected trajectories were used to find the hourly flows and compositions of the vehicles. These data were also used to obtain the lateral placements of the vehicles across the road width. The hourly flows for both hours traffic data were found to be 5170 and 4727 vehicles, respectively. The compositions of the traffic stream and descriptive statistics (mean and standard deviation (S.D.)) of lateral positions of the vehicles are shown in Table 1. The corrected 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 [9]. The descriptive statistics of the vehicular speeds are given in Table 1.

### Table 1. Traffic compositions and descriptive statistics of lateral positions and speeds

| SL. No | Data collection time | Vehicle type | Flow (Veh/hr) | Vehicle Composition (%) | Lateral Placement (m) | Speed (km/hr) |
|--------|----------------------|--------------|--------------|-------------------------|-----------------------|--------------|
| 1      | 9:30 hrs to 10:30 hrs | ALL          | 5170         | 100                     | 4.57                  | 2.27         | 40.13        | 7.65        |
|        |                      | LMV          | 2955         | 57.16                   | 3.65                  | 1.75         | 41.59        | 7.66        |
|        |                      | HMV          | 290          | 5.61                    | 4.68                  | 1.86         | 37.81        | 7.15        |
|        |                      | MTW          | 1478         | 28.59                   | 5.73                  | 2.47         | 39.04        | 7.39        |
|        |                      | MThW         | 447          | 8.65                    | 6.79                  | 1.46         | 35.55        | 5.77        |
| 2      | 10:30 hrs to 11:30 hrs | ALL          | 4727         | 100                     | 4.45                  | 2.26         | 42.53        | 12.81       |
|        |                      | LMV          | 2820         | 59.66                   | 3.51                  | 1.61         | 45.04        | 14.33       |
|        |                      | HMV          | 278          | 5.88                    | 4.74                  | 1.87         | 37.87        | 9.59        |
|        |                      | MTW          | 1332         | 28.18                   | 5.88                  | 2.52         | 39.11        | 8.65        |
|        |                      | MThW         | 296          | 6.26                    | 6.72                  | 1.49         | 38.39        | 9.41        |
3. Analysis of vehicular lateral placement and speed

After obtaining the corrected lateral position data, the frequency of all vehicles and each vehicle category for lateral placement is plotted over each meter of lateral positions of vehicles. Figure 1 shows the frequency plot of lateral placement for both the hours. It can be seen from the figure that around 25% to 28% LMVs are plying through the lane close to the median. This may be due to the reason that because of left hand side driving in the Indian traffic stream, overtaking/passing through right side is more convenient. Hence, to overtake/pass the vehicles, LMVs are trying to pursue through the median lane. The MTW and MThW are plying close to the shoulder lane. Since MTW and MThW are smaller in size; hence, they have the flexibility to pass through any small spaces ahead of them. Even these two vehicles may utilize the shoulder partially to overtake/pass the other vehicles. This may be due to the fact that majority of the MTWs and MThWs are utilizing shoulder lanes. In the case of HMV, due to its size, the maneuverability is very less. Hence, they mostly allow the other vehicles to overtake/pass them. After obtaining the lateral placement, and the average speed of all vehicles the analysis have been carried out to obtain the relationship between speed and lateral placement.

![Figure 1](image1.png)

**Figure 1.** Lateral placement distribution of vehicles during (a) 9:30 to 10:30; and (b) 10:30 to 11:30

![Figure 2](image2.png)

**Figure 2.** Variation of speed over each meter interval of lateral placement for (a) ALL vehicles; (b) LMV; (c) MTW; and (d) HMV for the traffic stream data collected between 9:30 and 10:30 hrs.
Figure 2 shows the variation of average speed over each meter interval of lateral placement for all vehicles clustered and each category of vehicles for the traffic data collected between 9:30 hrs and 10:30 hrs. The figure also shows the error bars of standard deviation. It can be seen from figure 2(a) that there are three distinct zones of trends of average speed. Up to 3 m, the average speed is increasing as the vehicle is placing away from the median edge. The reason may be due to the fact that vehicles feel less safety while situated close to the edge. Hence, they maintain less speed as close to the median. Similar is the case for shoulder lanes (above 7 m). At the middle of the road section (3 m to 7 m), the speed is more or less flat. Keeping this in mind and from the visual observation, the lateral placement is divided into three groups. Up to 3 m from the median edge (0 to 3 m) the average speed is linearly related with lateral placement. Between 3 to 7 m, the average speed has quadratic relation with lateral placement. The last distinct zone, i.e., above 7 m, the average speed also has a quadratic relationship with lateral placement. The speed-placement model developed for three distinct zones are given in Table 3. The R-square values obtained for these three relationships are 0.9975, 0.9986 and 0.9705, respectively. Similar analysis has been carried out for LMV, MTW, HMV, and MThW. The average speed and lateral placement relationship for LMV, MTW and HMV are shown in Figure 2(b), 2(c) and 2(d), respectively. The speed-placement models for the different distinct zone for each category of vehicles and their R-square values are presented in Table 2.

| Vehicle type | Models \[y = \text{average speed}(\text{km/hr}), \quad x = \text{lateral placement (m)}\] | The range of lateral placement (m) | $R^2$ |
|--------------|--------------------------------------------------------------------------------|-----------------------------------|------|
| ALL          | $y = 2.4855x + 33.911$; \quad $y = -0.5094x^2 + 4.528x + 32.32$; \quad $y = -1.1197x^2 + 17.133x - 26.406$ | $0 \leq x \leq 3$ \quad $3 \leq x \leq 7$ \quad $10.8 \geq x \geq 7$ | 0.9975 \quad 0.9986 \quad 0.9705 |
| LMV          | $y = 3.501x + 31.476$; \quad $y = -0.309x^2 + 3.474x + 33.974$; \quad $y = -4.197x^2 + 69.604x - 246.1$ | $0 \leq x \leq 3$ \quad $3 \leq x \leq 8$ \quad $10.8 \geq x \geq 8$ | 0.9748 \quad 0.5151 \quad 1 |
| MTW          | $y = 1.6332x + 35.174$; \quad $y = -0.347x^2 + 3.475x + 32.608$; \quad $y = -1.312x^2 + 20.181x - 37.768$ | $0 \leq x \leq 3$ \quad $0 \leq x \leq 7$ \quad $10.8 \geq x \geq 7$ | 0.9719 \quad 0.5888 \quad 0.9501 |
| HMV          | $y = 3.188x^2 - 19.379x + 67.527$; \quad $y = -2.461x + 51.809$; | $1 \leq x \leq 4$ \quad $9 \geq x \geq 4$ | 1 \quad 0.8865 |
| MThW         | $y = 2.037x + 29.993$; \quad $y = 0.251x^2 - 4.876x + 57.386$; | $1 \leq x \leq 5$ \quad $10 \geq x \geq 5$ | 0.9677 \quad 0.7246 |

4. Validation
Traffic stream data collected between 10:30 hrs and 11:30 hrs from VIP Road, Kolkata, India is used to validate the models developed for average speed and lateral placement of all category of vehicles. Figure 3 shows the average speed over each meter lateral placement of all vehicles clustered for the observed data and the estimated average speed using the developed models (as shown in Figure 2(a) and presented in Table 3). It can be seen from the figure 3 that both observed and estimated average speed are reasonably matching. Similar exercises have been carried out for each category of vehicles and found that the observed and estimated average speeds are fairly matching.
The per
cformance of the estimated models was carried out using the mean absolute percentage error (MAPE) value as given in equation (1)

\[
MAPE = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{O_i - E_i}{O_i} \right| \times 100\% \tag{1}
\]

Where \( N \) = number of observations, \( O_i \) = observed average speed (km/hr), \( E_i \) = estimated average speed (km/hr) using the developed model. The MAPE values for all vehicles clustered, LMV, MTW, HMV and MThW were found to be 6.74%, 9.69%, 4.04%, 5.47% and 9.16%, respectively. From the Lewis scale of interpretation of estimation accuracy [10] a prediction with a MAPE value less than 10% is considered to be highly accurate, 11%–20% as good, 21%–50% as reasonable, and 51% or more as inaccurate. The MAPE values for average speed and lateral placement were found in the range of 0%–10%. Hence, it can be inferred that the developed models are found to be in highly accurate range and can be used as a good estimator for average speed (km/hr) based on lateral placement (m).

5. Summary and conclusions

Non-lane discipline traffic stream data collected from VIP Road, Kolkata, India were used to analyze the impact of vehicular lateral placement on average speed. For this purpose, the vehicle trajectories were extracted from traffic video film using image processing software TRAZER. The raw trajectories were corrected using CEEMDAN techniques. The corrected speed from smoothed trajectories was obtained using WT. Lateral placement distribution of all vehicles and each vehicle category of first hour data indicates that at wider road (10.80 m) vehicles are placed across the road width. LMVs prefer to ply close to the median lane, whereas, MThW and MTW prefer shoulder lane. The impact of lateral placement on average speed shows that vehicles don’t maintain constant speed across the road width. It depends on the lateral placement of vehicles. In case of all vehicles clustered, LMV and MTW three different distinct zones across the road width were observed. Close to the median (up to 3 m from the median edge), the average vehicular speed is linearly related with lateral placement. For the other two zones (3 m to 7 m, and above 7 m), the relationship is quadratic. For HMV and MThW two distinct zones were observed. The second-hour data collected from the same road stretch was used to validate the developed speed-placement models using the MAPE between observed and estimated average speed over each meter interval of lateral placement. The MAPE were found to be 6.74%, 9.69%, 4.04%, 5.47% and 9.16% for all vehicles clustered, LMV, MTW, HMV, and MThW, respectively. According to the Lewis scale of interpretation of estimation accuracy [10] a prediction with a MAPE value less than 10% is considered to be highly accurate. Hence, it can be said that the developed models are found to be in highly accurate range and can be used as a good estimator of average speed (km/hr) based on lateral placement (m). The results of this study may be used as an input parameter for assigning vehicular speed based on lateral placement for analyzing non-lane discipline traffic stream using the simulation model of three lanes road. To further verify the results, more data covering different road width from various arterials consisting non-lane discipline traffic stream may be analyzed.
6. References

[1] Asaithambi G, and Joseph J 2018 *Journal of Transportation Engineering Part A: Systems* DOI: 10.1061/JTEPBS.0000170.

[2] Blab R, and Litzka J 1995 *Proc. of the Int. Symp. on Heavy Vehicle Weights and Dimensions* (Road Transport Technology University of Michigan) *Ann Arbor MI* 389–395.

[3] Bharadwaj N, Kumar P, Arkatkar S, Maurya A, and Joshi G 2016 *Current Science* **110** 808-822.

[4] Balaji K, Bharadwaj M R K, and Dey P P 2013 *Indian Highways* **41** 49-53.

[5] Bunker J M, and Parajuli A 2006 *Transport Engineering in Australia* **10** 129–139.

[6] Dey P P, Chandra S, and Gangopadhyay S 2006 *Journal of Transportation Engineering* **132** 597-600.

[7] Mohapatra S S, and Dey P P 2015 *Transportation Letters* **7** 252-263.

[8] Mallikarjuna C, Phanindra A, and Ramachandra R K 2009 *Journal of Transportation Engineering* **135** 174-182.

[9] Pal D, and Chunchu M 2018 *Canadian Journal of Civil Engineering* **45** 435-445.

[10] Kenneth D L, and Ronald K K 1982 *Advanced in Business and Management Forecasting* Emerald Book Bingley UK.