TRANSPORT
2010
25(3): 262–268

ANALYSIS OF MICROSCOPIC DATA UNDER HETEROGENEOUS TRAFFIC CONDITIONS

Mallikarjuna Chunchu[1], **Ramachandra Rao Kalaga**[2], **Naga Venkata Satish Kumar Seethepalli**[3]

[1]Civil Engineering Dept, Indian Institute of Technology Guwahati, Assam, India
[2, 3]Civil Engineering Dept, Indian Institute of Technology Delhi, New Delhi, India
E-mails: [1]c.mallikarjuna@iitg.ernet.in; [2]rrkalaga@civil.iitd.ac.in; [3]satishsnv@gmail.com

Received 7 July 2009; accepted 19 July 2010

Abstract. Collecting microscopic data is difficult under heterogeneous traffic conditions. This data is essential when modelling heterogeneous traffic at a microscopic level. In this paper, microscopic data collected under heterogeneous traffic conditions using a video image processing technique is presented. Data related to heterogeneous traffic such as vehicle composition in the traffic stream, a lateral distribution of vehicles, lateral gaps and longitudinal gaps have been collected. The lateral distribution of vehicles on a ten-meter wide road has been analyzed with a specific emphasis on motorized two-wheeler movement. Using trajectory data, an attempt to examine the gap maintaining the behaviour of vehicles under different traffic conditions has been made. Empirical relationships between the lateral gap and area occupancy have been proposed for various vehicle combinations. The influence of difference in the lateral positions of leading and following vehicles on the longitudinal gap has been analyzed.

Keywords: microscopic data, heterogeneous traffic, image processing.

1. Introduction

Traffic data collected either at microscopic or macroscopic levels is important for understanding traffic behaviour. Such understanding is necessary for developing traffic flow models. In most of developing countries, traffic is heterogeneous and in many ways differs from homogeneous traffic seen in developed countries. The absence of lane discipline and the presence of several vehicle types including motorized two-wheelers (TW) and three-wheelers (AUTO) are the typical features that characterize heterogeneous traffic. In the streams of heterogeneous traffic, vehicle movement is influenced by all surrounding stationary and moving objects (vehicles, median etc.). Under these conditions, the driver can utilize any space available on the road without any lane discipline. In order to model this traffic, it is essential to collect data related to interactions between moving vehicles and their surrounding objects. Many researchers are working on modelling heterogeneous traffic but with limited understanding on the relations between traffic variables that characterize heterogeneous traffic.

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 traffic conditions. It also generates a significant level of friction between adjacent moving vehicles in the traffic stream. Under heterogeneous traffic conditions, at higher traffic volumes, a large proportion of motorized two-wheelers and bicycles are able to move with speeds closer to their free speeds because of their ability to utilize smaller gaps in the traffic stream. This observed feature of heterogeneous traffic is too complex to model without analyzing field data on vehicular interactions.

For example, it is supposed that under homogeneous traffic conditions, vehicles maintain low speeds at smaller space headways. Similarly, vehicles maintain high speeds at larger space headways. This feature is well understood by supporting field data which has been utilized in many traffic flow models dealing with homogeneous traffic. As explained in the previous paragraph, under heterogeneous traffic conditions vehicular speeds are influenced by several other factors besides space headways. Vehicle type, lateral position of vehicles, lateral separation in the centrelines of the vehicles following one another, and traffic densities in the lateral and longitudinal direction are only a few factors to name. Unless data is available on most of these factors, it is difficult to analyze and understand how drivers vary the gaps with respect to different traffic conditions.

In this paper, a microscopic analysis of traffic data useful for studying heterogeneous traffic is presented.

ISSN 1648-4142 print / ISSN 1648-3480 online
www.transport.vgtu.lt
doi: 10.3846/transport.2010.32

Data analysis is carried out to understand relationships between vehicle characteristics and longitudinal and lateral gap maintaining behaviour. The classified data on vehicle trajectory collected using video image processing software called TRAZER have been utilized for this purpose. Trajectory data have been used to extract microscopic data for studying vehicular interactions. Lateral and longitudinal gap maintaining behaviour and the lateral distribution of vehicles under different traffic conditions have been studied. It has been found that the gap maintaining behaviour in both lateral and longitudinal directions is influenced by several factors. When the influence of each of these factors is studied separately, no single factor is found to have substantial correlation with the gaps. Area occupancy (Mallikarjuna and Rao 2006), which is a function of vehicle area and speed, is found to be a better variable in representing lateral gap maintaining behaviour. Both vehicle speed and difference in the lateral position of the leading and following vehicles are found to be influencing longitudinal gaps.

This paper is organized into four sections. In the first section, literature review on data collection under heterogeneous traffic conditions is presented. Field setup of collecting video and methodology used in extracting traffic data from TRAZER is discussed in the second section. In the third section, different microscopic data extracted from trajectories and the analysis of the gap maintaining behaviour of vehicles is analyzed. In the final section, summary and important conclusions drawn out of the study are presented.

2. Literature Review

Manual data collection, i. e. collecting data using man power on the road side was usual practice used under heterogeneous traffic conditions (Kumar 1994). Time-lapse photography was widely employed in the 80's and early 90's to collect traffic data. Chari and Badarinath (1983) used the time-lapse photographic technique to measure aerial density defined as the sum of the total vehicle area projected on the ground per unit road area. A time-lapse camera with a 1-sec interval between successive exposures of the film was applied for data collection. The identified vehicles are traced for a minimum period of five seconds. Using this information, space-mean speeds of different vehicle groups were obtained. Gupta and Khanna (1986) also used time-lapse photography to establish speed-flow relationships for different types of vehicles under heterogeneous traffic conditions. Though this technique is useful for collecting data since it involves manual observations, researchers started using video camera based techniques. Tuladhar (1987) studied lateral and longitudinal spacing maintained by different types of vehicles using a video camera based technique. Using this technique, Nagaraj *et al.* (1990) carried out extensive data collection studies. Data was collected on a two-lane two-way road, covering 30 m road stretch. In this study, data regarding longitudinal and lateral spacing maintained by various vehicles moving at different speeds was collected. Lateral and longitudinal gap data has been collected with the help of a grid placed on a television monitor while playing back the video film. In another study, Nazer and Nagaraj (2002) used fixed and moving camera methods to study the overtaking behaviour of different vehicle groups. In this study, they have collected data regarding gaps maintained by different vehicle combinations during overtaking operations. Kumar (1994) employed a different technique to collect traffic data on National Highways in India. Four persons were employed on each end of one km road stretch to collect data such as the time of entry, registration number and the type of a vehicle. Using this data, average flow, average space-mean speed and density observed over the road stretch as well as headway data have been obtained. Singh (1999) used a video recording technique to collect microscopic traffic data under heterogeneous traffic conditions. Using calibrated image size and distance relationship speeds, time headways and lateral spacing data were obtained. Chandra (2004) used a similar technique to obtain data necessary for developing a simulation model for heterogeneous traffic.

Gunay (2007) used a video recording technique to collect data on lateral position, centre line separation of vehicles in car-following scenario, and frictional clearances between vehicles. He then employed this data to develop a car-following model with lateral discomfort. Applying a video image processing technique, Wei *et al.* (2005) extract vehicle trajectories which then were used for getting speeds, accelerations and longitudinal gaps of the targeted vehicles. Hoogendoorn *et al.* (2003) used a sequence of aerial images to collect trajectory data along with vehicle dimensions which were then put to extract the longitudinal and lateral positions of the vehicles.

There were some attempts to use customized induction loops and image processing based software to collect traffic data under heterogeneous traffic conditions. Chari *et al.* (1997) used induction loops and dynamic axle sensors (DYNAX) to collect traffic data under heterogeneous traffic conditions. Dual loop detectors were installed on two-lane undivided National Highways to collect classified flow and speed data. All the highways considered in this study cater bi-directional traffic. This technique was successful in counting heavy vehicles but a failure in counting motorized two-wheelers and three-wheelers. Success in counting heavy vehicles was attributed to narrow road widths (about 3.75 m per direction). Recently, Central Road Research Institute (CRRI) has utilized image processing based vehicle detection software called CITILOG. This system was employed on the major urban roads to obtain flow and speed data. One of the drawbacks of this system was its limitation in classifying vehicles.

The above review discloses that there were attempts to collect microscopic data under heterogeneous traffic conditions. Notable studies are those by Nagaraj *et al.* (1990) and Singh (1999) who used a video graphic technique to observe a certain road area to collect different microscopic and macroscopic traffic data. Since manual intervention is necessary, this process of collecting gap related data takes much time and the resulting data may also be error prone.

3. Data Collection Methodology

TRAZER is video image processing software developed by KritiKal Solutions Pvt. Ltd., Noida, India, in collaboration with the Indian Institute of Technology Delhi. The classification and tracking of vehicles over certain road length has been the major objective in developing this software. A detailed methodology adopted in TRAZER is available in Mallikarjuna *et al*. (2009). Some of the major steps involved in this methodology such as collecting a video film and correcting trajectory data are described in the following sections.

3.1. Collecting a Video Film

Data has been collected from the mid-block section of the Dabri road near Delhi–Noida–Delhi (DND) flyway connecting Delhi and Noida. This section is a three lane road with a lane width of 3.4 m. It has been observed that lane markings are not followed by vehicles and effective road width used by vehicles is limited to 8 m (Figs 1 and 2). The road section under consideration is free of curves and gradients. A video film has been collected from DND flyover that passes over the Dabri road. A section of 70 m road length was covered from the flyover using a video camera. Traffic data was collected on Wednesday (working day) for a period of six hours from 9:00 to 15:00. The majority of the vehicles present in the traffic stream are cars, motorized two-wheelers and three-wheelers. During the study period, traffic volumes are varying in between 2000 to 4000 vehicles/hour. In this paper, data collected during the intervals from 8:45 to 9:45, from 10:15 to 11:15 and from 12:15 to 13:15 have been used for extracting microscopic data.

3.2. Trajectory Data, Comparison and Correction of Trajectories

The classified trajectory data is the basic input for extracting useful microscopic data. The video film has been processed using TRAZER to obtain the classified trajectory data. Using MATLAB microscopic data such as acceleration, space-headways, lateral-gaps, difference in lateral positions and macroscopic data including speed, flow, occupancy and area occupancy have been collected. TRAZER has the capability to classify vehicles into different vehicle groups based on physical features. TRAZER is also capable of capturing lateral movements of vehicles even under partial occlusion conditions. TRAZER classifies vehicles into four types. Vehicles such as cars, vans, jeeps and mini buses are classified as Light Motor Vehicles (LMV). Cycles, motor bikes, scooters and cycle-rickshaws are classified as Two Wheelers (TW). All trucks and buses are classified as Heavy Motor Vehicles (HMV). All motorized three wheelers known as auto rickshaws are classified as AUTOs.

Using the frame by frame analysis of the video, trajectory data on a few vehicles in each category have also been collected manually. This trajectory data was compared with the one collected using TRAZER. It has been found that some corrections are required and the error was found to be varying with the lateral positions occupied by vehicles. From a comparison of the trajectories, a systematic error was observed in the lateral positions of LMVs and AUTOs. When LMVs are travelling in the centre of the road (4 to 6 m), i.e. when they are directly in line with the video camera, the trajectories obtained from TRAZER are matching with the manually obtained ones. When vehicles are travelling on the lanes adjacent to the middle lane, it is found that there is some discrepancy in TRAZER data. It is also observed that this discrepancy seems to be similar to a vehicle type (e. g. LMV) when they are travelling over a particular portion of the road. This is found to be resulting due to the sideward movement of the box placed on the vehicle once it is identified by TRAZER. A detailed methodology adopted for correcting the trajectories can be found in Mallikarjuna (2007). Different corrections applied to LMV trajectories are shown in Table 1.

Table 1. Corrections applied to LMVs' trajectories

Lateral position, m	Correction required, m
0–2	–0.35
2–4	–0.15
4–6	0
6–8	0.15
8–10	0.35

For AUTOs, error is not varying with the lateral position they occupy and a uniform correction of 0.27 m is applied irrespective of the lateral position. Error is negligible in case of HMVs and TWs. This analysis is specific to a three lane road and the video film has to be collected with the specification discussed in the previous section.

3.3. Microscopic Data from the Trajectories

Speed, acceleration, lateral position and gaps maintained by vehicles under different traffic conditions are the key data extracted from the corrected trajectories. Data on the lateral distribution of vehicles and gaps are presented and analyzed in the following sections.

3.3.1. Lateral Distribution of Vehicles

Under heterogeneous traffic conditions, vehicles assume any lateral position over the available road width irrespective of their physical and mechanical characteristics. If lane discipline is not strictly enforced, to avoid the discomfort of travelling on the shoulder lanes (lane immediately beside shoulder), vehicles tend to travel away from the shoulder lane. Besides this reason, vehicles tend to travel in the middle of the road due to various other reasons. The presence of small vehicles such as TWs and AUTOs in the traffic stream is one of the major factors contributing to this behaviour. When traffic volumes are high, there is a tendency to segregation where two wheelers and slow moving vehicles tend to travel on the left side of the road (for traffic conditions observed in India). This characteristic of heterogeneous traffic is crucial for studying and modelling the traffic behaviour. Due to this tendency, slow moving vehicles frequently obstruct the movement of fast vehicles even at low traffic levels. A two-lane road can have three columns of traffic moving side by side under certain traffic and road conditions. Hence, when simulating traffic under these conditions, a two-lane road can be treated as a three lane road or an intermediate one between two-lane and three-lane road. In this scenario, the analysis of the lateral distribution of vehicles is helpful in modelling vehicle movement behaviour. The lateral distribution of vehicles found near the studied location is presented in Figs 1 and 2.

Hourly traffic volumes observed in the three-hour study period is ranging from 2000 to 4000 vehicles per hour. The volumes observed in the consecutive three hours are 4000, 2700 and 2000 vehicles per hour respectively. The first hour is falling in the morning peak period. The lateral distribution of four vehicle categories has been analyzed in two ways: total vehicles together and each vehicle type separately. In Fig. 1a, the lateral distribution of TWs, LMVs and all vehicles combined are shown. This figure also indicates that the majority of vehicles are utilizing the available road space as if the road

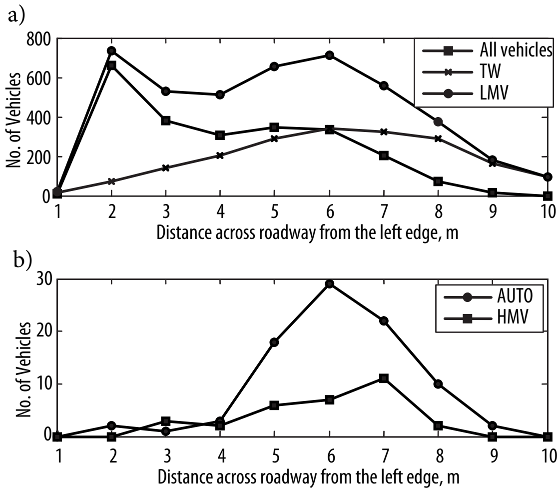

Fig. 1. Lateral distribution of various vehicles observed over 10 m wide road at the traffic volume of 4000 vehicles/hr

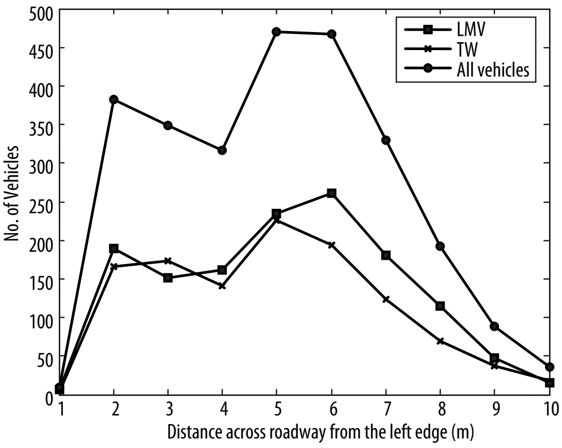

Fig. 2. Lateral distribution of various vehicles observed over 10 m wide road at the traffic volume of 2700 vehicles/hr

is a two lane one. Two distinct peaks at around 2 m and 6 m can be observed. It can also be noticed that most of LMVs are travelling on the right side (with respect to flow direction) and TWs are travelling on the left side of the road. Three-wheelers and HMVs are travelling on the left side of the road as shown in Fig. 1b. The obtained information discloses that when traffic volumes are high, LMVs utilize the right part and other types of vehicles utilize the left part of the road. From the second one-hour traffic data, as shown in Fig. 2, a different pattern of the lateral distribution of vehicles can be witnessed. Significant numbers of TWs are moving on the right part of the road and LMVs are found to be moving on left part of the road. The third-hour data displays more or less same trend as that of the second-hour data.

The performed analysis shows that the volume and composition of traffic are important factors influencing the lateral distribution of vehicles. It has been observed that the three-lane road is being utilized as a two-lane one irrespective of traffic volumes. When traffic volumes are relatively high, a clear segregation of TWs and LMVs can be noticed (Fig. 1). At low traffic volumes this kind of segregation has not been found (Fig. 2). At relatively low traffic volumes, as can be seen in the second and third-hour data, road space utilization is more uniform.

3.3.2. Lateral Gaps

Lateral gaps maintained by vehicles are crucial for studying traffic behaviour and useful for developing traffic flow models. It is necessary to know how vehicles maintain gaps when moving under different traffic conditions. Under heterogeneous traffic conditions, lateral gap maintaining behaviour is influenced by several factors. The gaps maintained by different vehicles also vary depending on the type of the side vehicles. Though this gap maintaining behaviour is a function of several factors, the effect of each of these factors is analyzed separately. The influence of flow, speed, occupancy, area occupancy and the fraction of the major vehicle types observed in the traffic stream is analyzed in this study. Among several possible vehicle combinations, four vehicle combinations have been analyzed. The gap maintaining behaviour of LMV–LMV, LMV–AUTO, LMV–TW and TW–TW are analyzed in the present study.

The effect of flow, the fraction of LMVs, occupancy, speed, and area occupancy on the lateral gap maintaining the behaviour of LMV–LMV vehicle combination is presented is Fig. 3 showing that the average lateral gap for this vehicle combination is decreasing with increasing flow, occupancy and area occupancy. The gap is increasing with increasing speed and fraction of LMVs present in the traffic stream. A similar analysis of TW–TW vehicle combination is presented in Fig. 4. In this case, with respect to all variables except speed, the gap maintained between TW–TW is decreasing. Literature suggests that speed is the major factor influencing the lateral gap maintaining behaviour of the vehicles (Nagaraj *et al.* 1990). However, the results obtained in this study indicate that the influence of other factors such as the fraction of the major vehicle type is more significant

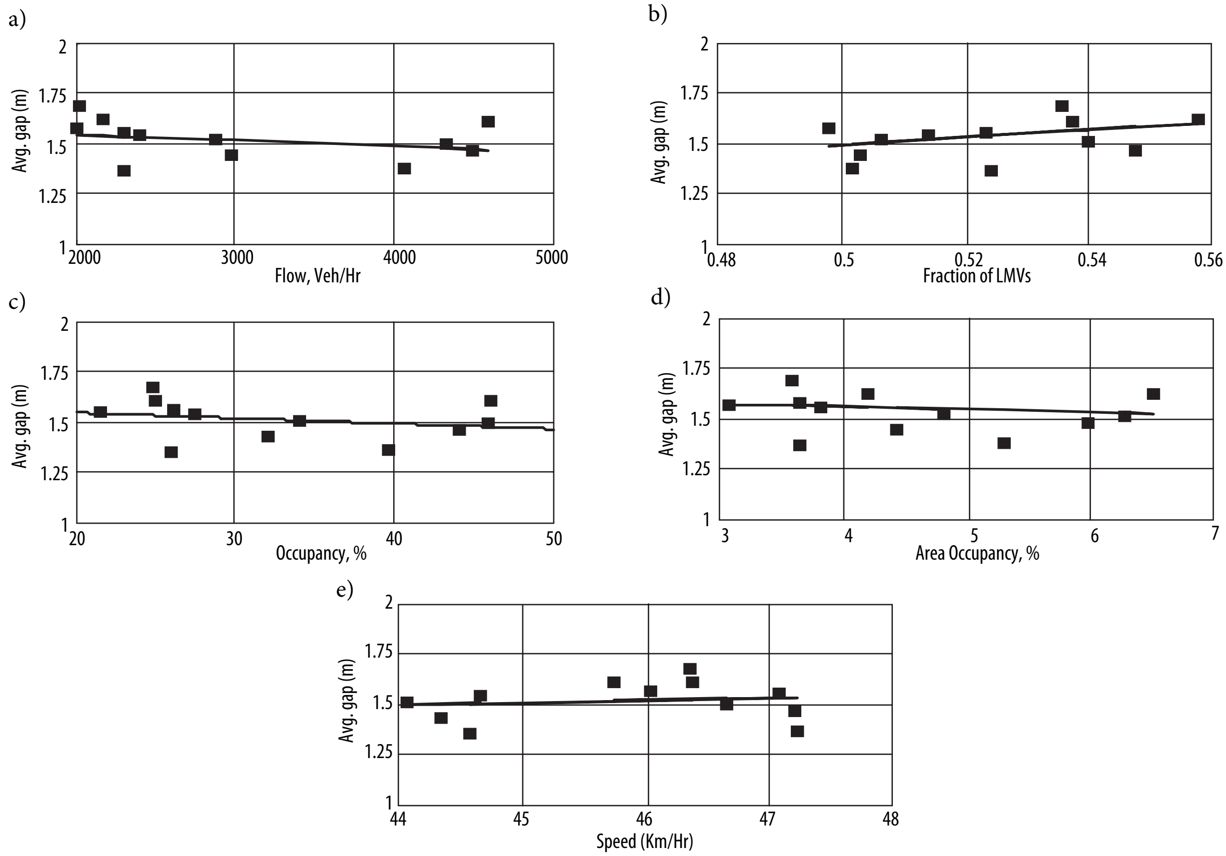

Fig. 3. The influence of various traffic characteristics on the average lateral gap observed for LMV–LMV vehicle combination

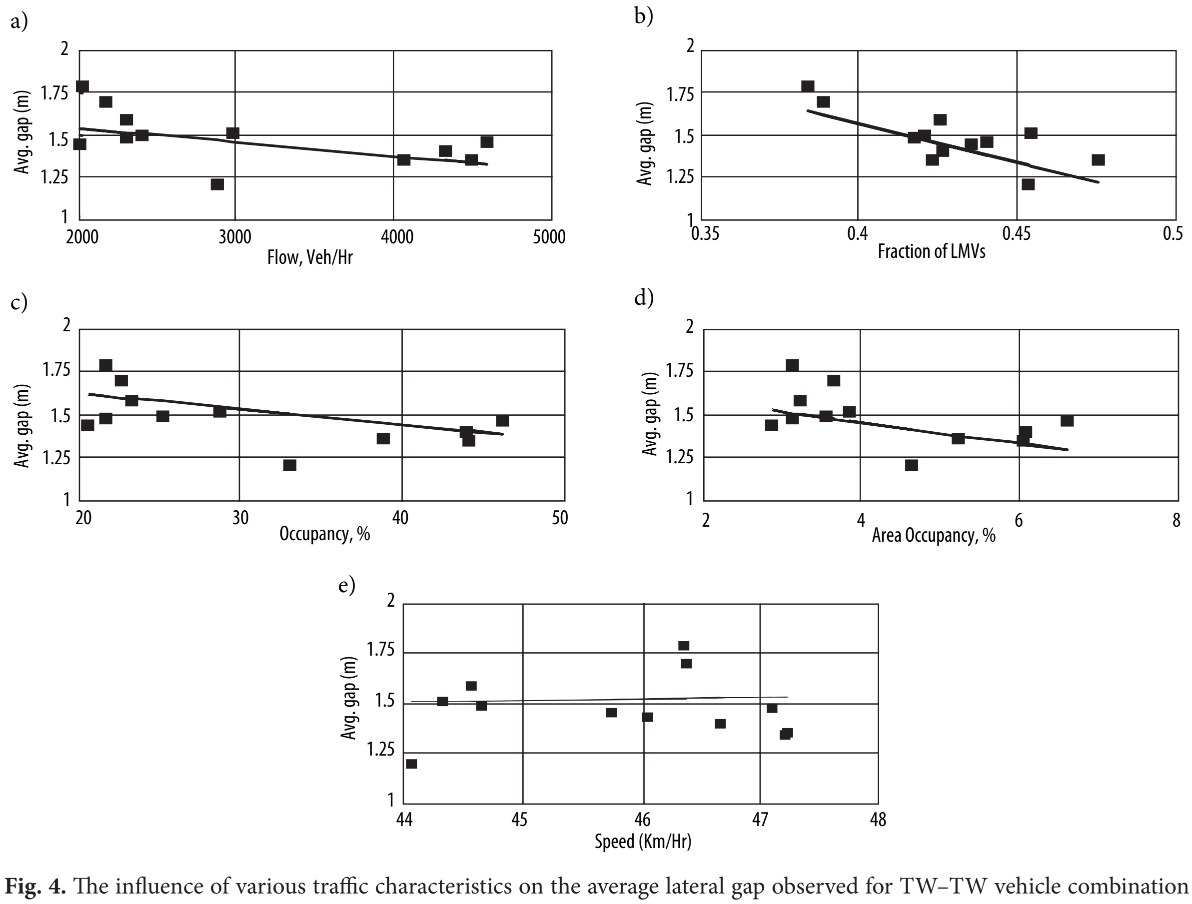

Fig. 4. The influence of various traffic characteristics on the average lateral gap observed for TW–TW vehicle combination

Table 2. Correlation between the average lateral gap and various traffic characteristics

Vehicle combination	Flow	Speed	Fraction*	Occupancy	Area occupancy
LMV–LMV	–0.31	0.17	0.59	–0.25	–0.15
LMV–Three Wheeler	0.24	–0.095	–0.42	0.22	–0.33
LMV–TW	–0.45	–0.23	–0.47	–0.36	–0.30
TW–TW	–0.50	0.18	–0.54	–0.55	–0.50

* for LMV–LMV and LMV–three wheeler combination, fraction denotes the fraction of LMVs and in remaining two cases it is the fraction of TWs

(Table 2). Table 2 discloses that area occupancy consistently correlates with the lateral gap maintaining behaviour of different vehicle combinations. Area occupancy is a function of speed as well as a physical size of the vehicle. Relationships between the lateral gap and area occupancy are shown below:

Avg. lateral gap for LMV–LMV, in meters= –0.013 × *Area occupancy* + 1.58;

Avg. lateral gap for LMV–Three wheeler, in meters = –0.039 × *Area occupancy* + 1.44;

Avg. lateral gap for LMV–TW, in meters = –0.025 × *Area occupancy* + 1.63;

Avg. lateral gap for TW–TW, in meters = –0.059 × *Area occupancy* + 1.74.

Area occupancy values obtained in this study are falling in the range from 2 to 6.5%. These equations are useful to dynamically updating the gaps maintained by various vehicles under varying traffic conditions.

3.3.3. Longitudinal Gaps

As described earlier, under heterogeneous traffic conditions, longitudinal gaps maintained by vehicles are influenced by several factors. The relationship between the speed of the following vehicle and the longitudinal gap for LMV–LMV vehicle combination is shown in Fig. 5. Wide scatter seen in this figure suggests that in addition to the speed of the following vehicle, some other factors are influencing the longitudinal gap. As suggested by Gunay (2007), this behaviour is significantly influenced by lateral separation between the longitudinal axes of vehicles. When vehicles are following one another and lateral separation in the centrelines is high, the following vehicle tends to follow the leading vehicle more closely. Under similar traffic conditions, when lateral difference is less, following vehicles maintain a more longitudinal gap. Fig. 6 shows that with increasing difference between the centre lines of vehicles, the longitudinal gap maintained by the following vehicles is decreasing.

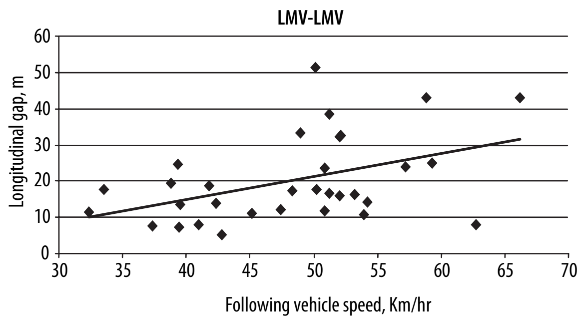

Fig. 5. The influence of the following vehicle speed on the longitudinal gap in case of LMVs following LMVs

In addition to the factors discussed above, there may be other variables which may affect the lateral and longitudinal gap maintaining behaviour of vehicles. Several other variables such as speed differentials were tried and found to be less significant in influencing the lateral and longitudinal gap maintaining behaviour of vehicles. More data collected under varying traffic conditions from different road sections is required for substantiating these results.

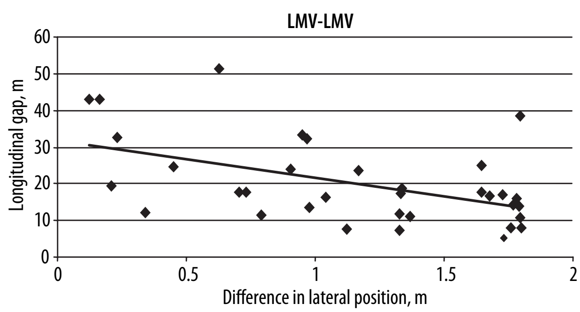

Fig. 6. The influence of difference in the lateral position on the longitudinal gap in case of LMVs following LMVs

4. Conclusions

Microscopic data such as lateral and longitudinal gaps and the lateral distribution of vehicles is crucial for studying and modelling heterogeneous traffic. The classified vehicle trajectories have been utilized to extract microscopic traffic data such as lateral and longitudinal gaps and the lateral distribution of vehicles under different traffic conditions. The lateral distribution of vehicles has been found to be influenced by traffic composition and traffic volume. Road width utilization is found to be significantly different under heterogeneous traffic conditions compared to that of lane-based homogeneous traffic. An attempt has been made to relate the gap maintaining behaviour and macroscopic traffic variables. The observations have revealed that there are several factors influencing the lateral gap maintaining behaviour. The fraction of the majority vehicle type present in the traffic stream is found to be influencing the gap mainteining behaviour. A macroscopic variable termed as area occupancy, which is a function of speed and vehicle area, is found to be having consistent correlation with lateral gaps. Relationships between the lateral gap and area occupancy are presented for different vehicle combinations. In addition to speed and vehicle type, difference in lateral positions (staggering) has been found to be influencing longitudinal gaps maintained by vehicles. Further studies, with more data, are necessary to substantiate the above findings. This would also help in understanding the microscopic behaviour of various combinations of vehicles from the traffic modelling perspective.

References

Chandra, S. 2004. Effect of road roughness on capacity of two-lane roads, *Journal of Transportation Engineering–ASCE* 130(3): 360–364. doi:10.1061/(ASCE)0733-947X(2004)130:3(360)

Chari, S. R.; Badarinath, K. M. 1983. Study of mixed traffic stream parameters through time lapse photography, *Highway Research Bulletin, Indian Road Congress* 20: 57–83.

Chari, S. R.; Chandrasekhar, B. P.; Rao, V. R.; Singh, S. P. 1997. Experiences in the installation and operation of permanent traffic counting stations in Andhra Pradesh, *Highway Research Bulletin: Journal of Indian Road Congress* 57: 55–83.

Gunay, B. 2007. Car following theory with lateral discomfort, *Transportation Research Part B: Methodological* 41(7): 722–735. doi:10.1016/j.trb.2007.02.002

Gupta, A. K.; Khanna, S. K. 1986. Mixed traffic flow analysis for developing countries w. s. t. to India, in *Research for Tomorrow's Transport Requirements. Proceedings of the Fourth World Conference on Transport Research*, Vancouver British Columbia, Canada, 2: 1521–1534.

Kumar, V. M. 1994. *A study of some traffic characteristics and simulation modelling of traffic operations on two lane highways*. PhD Thesis, Indian Institute of Technology, Kharagpur, India.

Mallikarjuna, C. 2007. *Analysis and modeling of heterogeneous traffic*. PhD Thesis, Indian Institute of Technology Delhi, New Delhi, India.

Mallikarjuna, C.; Rao, K. R. 2006. Area occupancy characteristics of heterogeneous traffic, *Transportmetrica* 2(3): 223–236. doi:10.1080/18128600608685661

Mallikarjuna, C.; Phanindra, A.; Rao, K. R. 2009. Traffic data collection under mixed traffic conditions using video image processing, *Journal of Transportation Engineering–ASCE* 135(4): 174–182. doi:10.1061/(ASCE)0733-947X(2009)135:4(174)

Nagaraj, B. N.; George, K. J.; John, P. K. 1990. A study of linear and lateral placement of vehicles in mixed traffic environment through video-recording, *Highway Research Bulletin: Journal of Indian Road Congress* 42: 105–136.

Nazer, P. A.; Nagaraj, B. N. 2002. A study on overtaking behaviour of vehicles in two way mixed traffic flow environment at highway mid blocks, *Highway Research Bulletin: Journal of Indian Road Congress* 66: 131–148.

Singh, B. 1999. *Simulation and animation of heterogeneous traffic on urban roads*: PhD Thesis, Indian Institute of Technology, Kanpur, India.

Tuladhar, S. B. S. 1987. *Mixed traffic flow characteristics on urban roads*: PhD Thesis, Bangalore University, Bangalore, India.

Hoogendoorn, S. P.; Van Zuylen, H. J.; Schreuder, M.; Gorte, B.; Vosselman, G. 2003. Microscopic traffic data collection by remote sensing, *Transportation Research Record* 1855: 121–128. doi:10.3141/1855-15

Wei, H.; Feng, C.; Meyer, E.; Lee, J. 2005. Video-capture-based approach trajectory data for to extract multiple vehicular traffic modeling, *Journal of Transportation Engineering–ASCE* 131(7): 496–505. doi:10.1061/(ASCE)0733-947X(2005)131:7(496)