TRAFFIC CHARACTERISTICS STUDY THROUGH PROCESSING OF VIDEO IMAGE FOR EXPRESSWAY IN INDIA

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ABSTRACT

India has the third-largest road network in the world. Expressways are the highest class of roads in the Indian Road Network. India's progress in the road sector measure 600 km of expressways approximately and is planning for achieving more than 15000km of expressway by 2021. Expressways are a controlled-access highway designed for fast traffic, with controlled entrance and exit. Expressways are vastly different from other roads of the country as vehicles such as bicycles, two-wheelers, three-wheelers and bullock carts are not allowed on these roads and additionally, there is no strict lane discipline. A number of research papers are available on studies on traffic stream characteristics for various roadway and traffic conditions. However, very limited studies are carried out on expressways in India

Video graphic data collection is widely used in traffic engineering, as video recordings can act as a more detailed, complete, accurate and reliable observational technique. To figure out the exact relationship between the traffic parameters, lots of research has been done over the past. Many attempts have been made earlier for data retrieval from videos. But, there have been very few attempts to discuss the methodology for data extraction and analysis from video for expressway data in India. This paper discusses about video graphic data collection, extraction and analysis of traffic stream characteristics for a duration of 8 hours by taking Ahmedabad -Vadodara expressway (four lane divided carriage way) as a case study. Data has been collected using video graphic survey by fixing high resolution cameras on road over bridge (ROB) such that traffic flow faces the camera.

Data on traffic volume, vehicle composition, speed of different vehicle categories, lane utilization etc. are manually extracted from the recorded video after converting it into frames. Data extraction and analysis has been done with the help of the softwares such as Ulead Video Studio, Irfan View and SPSS, MS Excel. The analysis on degree of lane discipline showed that, 97% of vehicles are following lanes. The results also showed that median side lane had high speed traffic as compared to other lane, which may be due to very high car composition (90%).

Key words: Expressway, Traffic Flow Characteristics, Videography, Mixed traffic flow.

1. INTRODUCTION

The Expressways, National Highways, State Highways and Rural roads together comprise the road network in India. Expressways are the highest class of roads in the Indian Road Network. Mahatma Gandhi expressway is one of them. Mahatma Gandhi Expressway is also known as National Expressway-1 and is having a length of 95 km (opened in 2004). This expressway was India's first four-lane expressway project, and includes minor bridges, canal crossings, cross-drainage works and interchanges at Nadiad and Anand.

Proper understanding and analysis of traffic stream characteristics are necessary for design, analysis, operation and management of roadway facilities. A number of research papers are available on traffic stream characteristics study for various roadway and traffic conditions. The traffic stream parameters are broadly classified as macroscopic, macroscopic or mesoscopic. Macroscopic parameters are the fundamental traffic stream parameters which characterizes the traffic as a whole. They are speed, density and flow. The microscopic parameters are related to the behavior of individual vehicle in the traffic stream with respect to each other include the headway, longitudinal gap and lateral gap between vehicles. Longitudinal spacing of vehicles are of particular importance from the point of view of safety, capacity and level of service. The longitudinal space occupied by a vehicle depend on the physical dimensions of the vehicles as well as the gaps between vehicles. It is difficult to find the microscopic parameters from field. Speed can be measured from field with help of radar gun. But practically it is impossible to take the speed of all vehicle from field and it will be difficult under a congested traffic condition. To execute the task of detailed data collection in easier way, video graphic method is generally adopted. The video, as an observational technique proves to be quite effective as compared to the observations made by the naked human eye and it appears more detailed, complete and accurate. Many attempts have been made but very few discussions are done regarding data retrieval from the traffic video data on expressways in India. This paper discusses about video graphic data collection method and the data extraction process in detail for finding speed, headway, lateral gap, longitudinal gap by taking Ahmedabad Vadodara expressway as a case study. Later, vehicle composition, speed, lane utilization and lane discipline are also analysed for the traffic flow on expressway.

2. LITERATURE REVIEW

Videography technique is widely used for traffic data collection. There are different methods, which have been used and are still in use for finding traffic parameters from traffic video. In 1987, Tuladhar 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. In his study, lateral and longitudinal gaps have been collected with the help of a grid placed on a television monitor, while playing back the video film. Conventional method employed is manual counting of vehicles from the video and speed by noting time taken by each vehicle to cover a particular known length. Later, Singh (1999) used a video recording technique to collect microscopic traffic data under heterogeneous traffic conditions. Hoogendoorn (2003) used a sequence of aerial images to collect trajectory data along with vehicle dimensions which were then put to extract the lateral positions of the vehicles. Naveen (2013) ploted grid lines using AutoCAD and created an image file, which suits to the road way section under consideration in the traffic video. The image file is then superimposed over the video using Ulead Video Studio Editor and converts this new video with grid file into frames using Irfan View Software. During analysis, different coordinates of the subject and surrounding vehicle are found from frames and finally the lateral position of each vehicle and there by lateral gap between vehicles are obtained.The above mentioned approaches need certain manual efforts, whereas there are few software available which can give traffic parameters directly as the outcome provided the video clip is inserted in the software. A video image processing software, namely, TRAZER has been utilized by Mallikarjuna in 2010 for collection of classified data on vehicle trajectory. He carried out analysis to understand relationships between vehicle characteristics and longitudinal and lateral gap maintaining behaviour. This software is specially developed for Indian traffic condition. TRAZER generates an output in excel consisting of classified count, classified speed, classified occupancy by simple running of video having frame rate -25fps, video size-640*480 vga in the software. For classified vehicle count, a software named MCME (Manual Count Made Easy) is introduced by Ramadurai. MCME is a powerful tool for data extraction, which works on the principle of speech recognition. Classified vehicle count can be obtained in an easier way with higher accuracy through the use of MCME.

There are various studies carried out in past for finding traffic parameters on expressway. Breman et. al. (1976) analyzed the statistical properties of freeway traffic on expressway situated in California using aerial photographs. Bains et al. (in 2012) modeled traffic flow on Indian expressways (Mumbai-

Pune Expressway) by considering different vehicle categories at different volume levels using VISSIM. Puvvala et al. (2013) developed a traffic flow model for Delhi–Gurgaon expressway and determined the capacity in terms of dynamic PCU. Ardekani et al. (2011) developed macroscopic speed-flow models for characterization of freeway and managed lanes (freeway site in Dallas, Texas). Wang et al. (2009) developed a stochastic fundamental diagram of traffic. He found that deterministic speed-density relationship models can explain physical phenomenon underlying fundamental diagrams and the stochastic model is more accurate and more suitable to describe traffic phenomenon. Roux and Bester (2002) studied speed-flow relationships on Cape Town freeways and presented a model to state the merit of representing the whole range of speed-density data with two separate curves (uncongested regime and congested regime). It was found that the curves may vary considerably from time to time owing to changes in factors like traffic composition, weather conditions, day-night conditions, etc. Arkatkar et al. (2011) developed a fundamental traffic flow relationships with a traffic flow model for Delhi-Gurgaon expressway (eight-lane divided urban expressway) and determined the capacity in terms of vehicles per hour using VISSIM.

3. DATA COLLECTION

3.1 Study Area

For the present study, traffic survey was carried out on Mahatma Gandhi Expressway during 18-19 October 2013 on road stretches near ROB-17 (Vadodara to Ahmedabad direction) between Vadodara and Nadiad, ROB-9 (Ahmedabad to Vadodara direction), ROB-12 (Vadodara to Ahmedabad direction) between Nadiad-Ahmedabad respectively .Video graphic data collection has been done for the selected three stretches as shown in figure 1 using high resolution cameras.

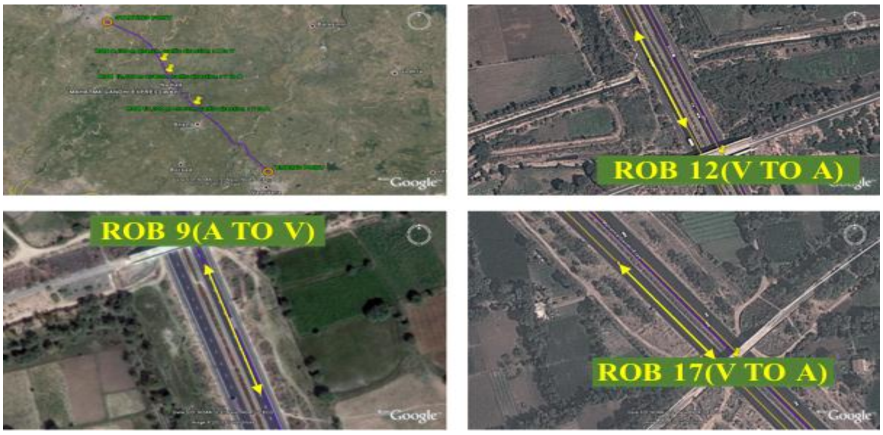

Figure 1: Typical snapshots of the study stretches from google earth

3.2 Methodology

<u>Step 1: Selection of study stretch</u>

Inventory survey has been carried out for the selected study stretch. Based on that basic freeway segments with flat straight stretches are selected for traffic flow analysis. This implies that, there is no influence of maneuvers such as merge, diverge and weaving on the selected sections. Later in each sections, lateral width (m) and longitudinal dimensions on the road way section are measured and marked such that it is clearly visible in video. The dimensions of lanes are same for all the selected stretches.

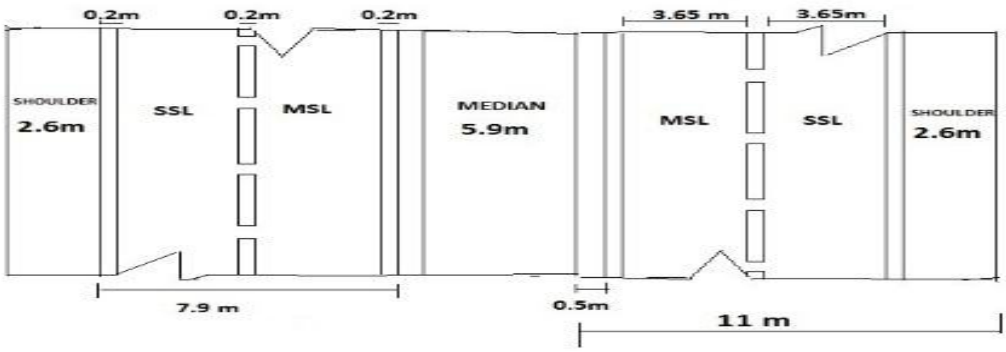

Figure 2: Plan of road showing dimensions across the road.

Step 2: Installation of video cameras

Traffic data collection through video recording has been widely applied due to its ability to collect data of all the traffic flow characteristics simultaneously and facilitate data extraction at both microscopic as well as macroscopic levels. Here, field surveys are carried out on the selected stretch using video graphic technique to collect the data regarding speed, classified volume count, vehicle composition, and lane utilization for the duration of 8 hours (7.30 A.M to 11.30 A.M and 2.30 P.M to 6:30 P.M) using high resolution camera. Video is recorded in such a way that it covers marked 100 m section on the expressway. Speed is also measured using radar gun for all category of vehicles. Entire survey data is compiled so as to get the traffic data in desired format. The data for 8 hours for 3 sections required storage space of 66.4 GB. Later, data is retrieved from video by converting them into frames followed by manual observation and counting.

Figure 3: a) Camera location. b) Video graphic view

Step 3: Data retrieval from video

Data extraction is the process of retrieving data from unstructured or poorly structured data sources for further data processing, storage and analysis. A number of microscopic and macroscopic level features can be extracted from a database like traffic video. In this study, data extraction is carried out manually from images developed from video. Images (frames) are extracted from video at a rate of 25 per second with the help of Irfan View. Xilisoft video converter and U Lead video studio are also used as supporting softwares. This study precisely attempts to explain the method to retrieve data like headway, lateral gap, longitudinal gap and speed from traffic video. Different stages of extraction of various data from recorded video are explained below in detail.

Stage 1: Conversion of video to avi. format

Xilisoft video converter software is used to change the video to .avi format. Various steps for conversion are shown in figure 4.

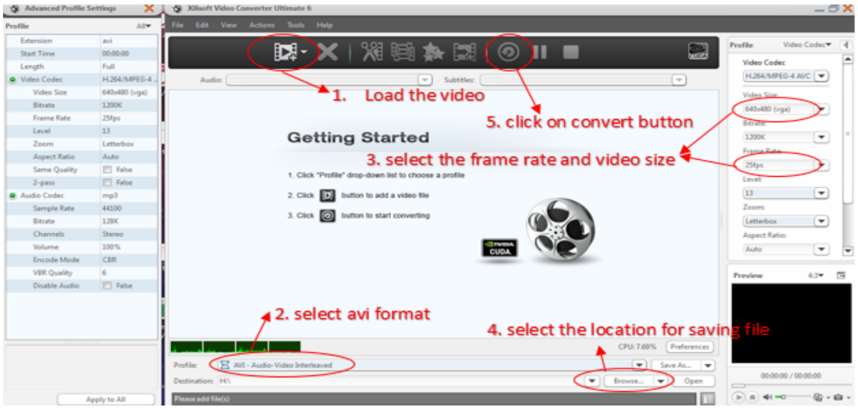

Figure 4: Conversion of video to .avi format using Xilisoft video converter software

Stage 2: Overlaying grid over video

Grid overlay is the best solution to extract microscopic data like lateral gap, longitudinal gap from video. It simplifies the data extraction process. Ulead Video Studio software is used in this study for overlaying grids on video. Grids are made on Auto CAD platform. For this purpose, points are marked on road laterally and longitudinally while taking video. This points are located in image and noted down the image coordinates (X, Y). Later, in Auto CAD, points are marked and connected them accordingly to develop a grid. From auto CAD, this grids are carried in .jpg format and overlayed on .avi format video using Ulead Video Studio software. Figure 5 represent the various steps of overlay and figure 6 shows Overlaying process. Grids are overlayed in transparent form with proper care for positioning the grid. The steps during overlay are shown in figure 7.

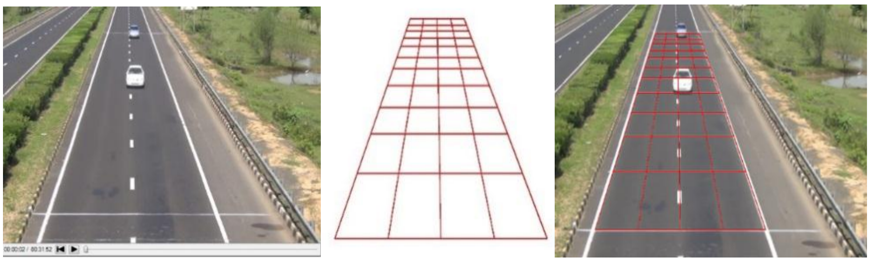

Figure 5: overlay of grid developed from auto CAD on video

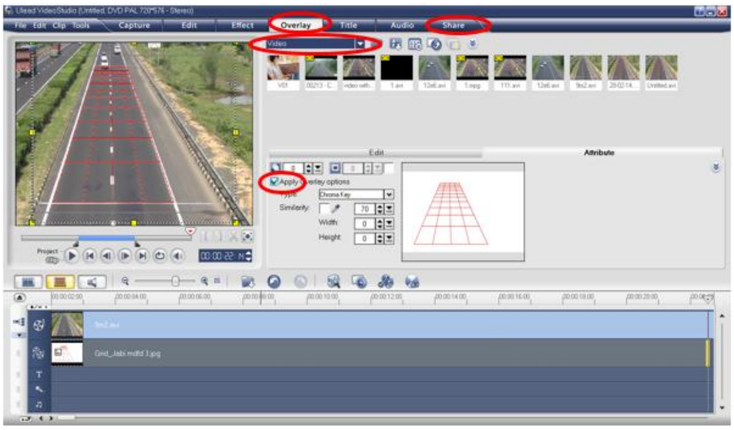

Figure 6: Overlaying the grid image into video file using Ulead Video Converter

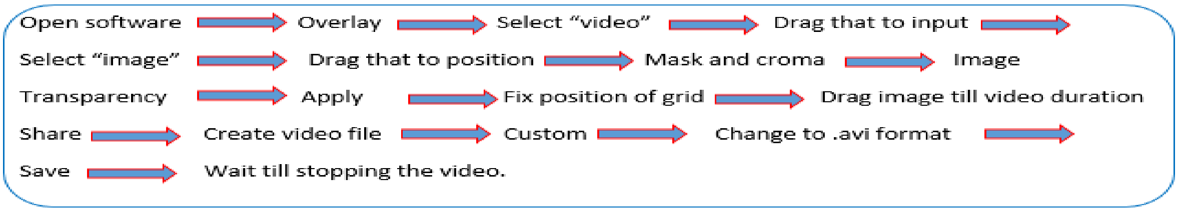

Figure 7: Overlay steps

Stage 3: extraction of frames from video

Irfan view software is used to convert video into images at particular interval of time for the entire duration. Frames are extracted at a rate of 25 frames per second.

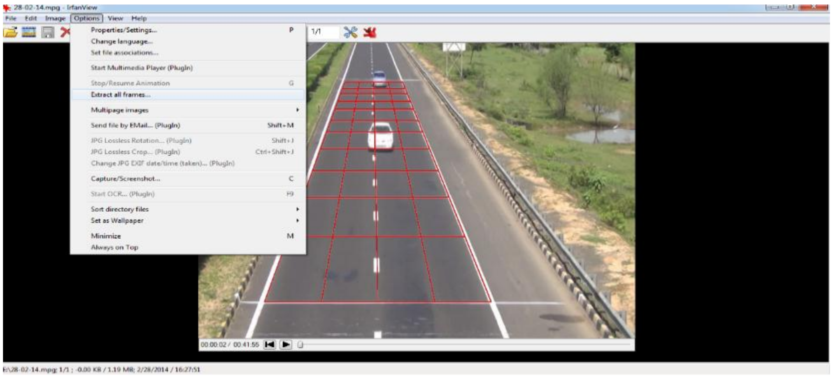

Figure 8: Extraction of frames using Irfan View

Stage 4: Data acquisition

All frames of a video are saved in one folder. For taking data from frames, this frames opened in Irfan View software. These images are run in forward and backward direction and while vehicle touches the marked entry and exit line, corresponding frame number is noted for all the vehicles. Vehicle category, lane number, entry and exit frame numbers are note down in excel sheet. Entry and exit frame numbers are used to find the headway and speed of vehicles. For computing lateral and longitudinal gaps the coordinates representing left and right tyre while subject vehicle is touching the central lateral grid line are noted. Same task is performed for surrounding vehicles located at adjacent, back and front side of the subject vehicle. By comparing the coordinates, it is possible to findout the lateral and longitudinal gaps between the subject vehicle and surrounding vehicles. The number of vehicles crossing first reference line of the detection zone in the direction of flow for every 5 minutes are observed. Using this 5 minute aggregate classified counts, hourly flow rate is estimated in vehicles per hour (VPH). Speed of individual vehicle (the rate of change of its position) is the measure of distance covered per unit time by the vehicle.

In this study, the trap length is 100 m and time is in terms of number of frames. Noted down the frame number for each vehicle when vehicle is at entry and exit of the stretch. As frames are generated at the rate of 25 frames per second, time taken in seconds to cover the stretch is the difference in entry and exit frame numbers divided by 25.

$$tme(s) = \frac{(exit\ frame\ no. - entry\ frame\ no.)}{(no.of\ frames\ per\ second)} \quad (I)$$

$$speed\left(\frac{m}{s}\right) = \frac{distance(m)}{time(s)} \quad (2)$$

(3)

$$speed\ (kmph) = \left(\frac{100 * 25}{difference\ in\ frame\ number}\right) * 3.6$$

Figure 9 illustrates extraction of speed from the processed video files

Figure 9: Extraction of speed from frames

Headway:
Headway (time headway) is the time difference between the front of a leading vehicle and the next vehicle arriving at the same point (in seconds).

$$headway(s) = \frac{(difference\ in\ frame\ number\ between\ 2\ successive\ vehicle\ at\ same\ point)}{(frame\ rate)} \quad (4)$$

$$headway(s) = \frac{(entry\ frame\ no.of\ 1st\ vehicle - entry\ frame\ no.of\ next\ vehicle)}{25} \quad (5)$$

Figure 10 illustrates the extraction of headway data.

Figure 10: Extraction of headway from frames

Lateral gap & longitudinal gap:
For getting gaps between vehicles, noted down the coordinate representing left and right tyre in image, while subject vehicle touching the central lateral grid line. At the same time, same task is performed for the surrounding vehicles.

Figure 11: Extraction of lateral and longitudinal gap between vehicles

Difference in X value of two vehicles nearer sides gives the lateral gap. The difference in Y value of leading and following vehicles minus length of front vehicle gives the longitudinal gap between those two vehicles. Here, the coordinates and gap are corresponds to the coordinates and gap in the image. But, in video the far end appears to have less distance compared to nearer end. Hence, correction factor is required to get the real ground distance (gap) between the vehicles. The correction factor for each lateral blocks as given in figure 12 are found and applied to get the gap on ground

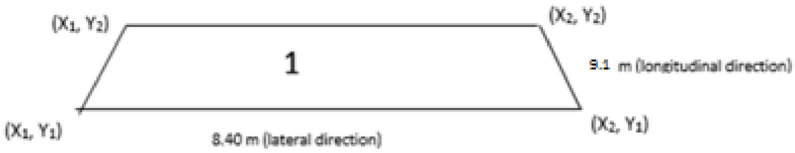

Figure 12: Lateral block of the grid overlay

Screen to Ground Mapping is expressed in the following equation:

$$D_{obs}\ (cm) = \sqrt{((X_2 - X_1)^2 + (Y_2 - Y_1)^2)}\ (pixel) \tag{6}$$

Where,

D_{obs} = Observed distance on road in m.

X_1, X_2 = X coordinates from frame for block 1

Y_1, Y_2 = Y coordinates from frame for block 1.

Correction factor have to be foundout for the two lateral sides of the block and average gives the lateral correction factor of the block. Similarly the longitudinal correction factor have to be foundout. This will gives the ground distance corresponding to 1 pixel of image in lateral and longitudinal direction. Repeated the same for all blocks. Application of the correction factor gives the real ground gaps between vehicles. In this study, on the selected stretch, the number of vehicles per hour was low (600 to 700 vehicles/hour). The traffic volume is found to be under free- flow conditions during the whole duration of traffic survey. Hence, extraction of micro-level longitudinal and lateral gap data was not considered. The acquired data of different type of vehicles is collected in MS Excel

4. TRAFFIC DATA ANALYSIS

4.1 Vehicle composition and traffic flow

The vehicle categories present on the expressway are small car (<1200cc), big car, light commercial vehicle (LCV), bus and trucks. For analysis, trucks are categorized into two types- single and tandem-axle trucks together forms one category and multi axle trucks constitutes the second. Contribution of small car and big car together is around 75% for all the three sections. In traffic composition, small car is the highest contributor (50%) followed by big car, small axle trucks, LCV, bus, and multi axle trucks. Multi axle trucks are always less than 2% of total traffic. The result also shows that truck and big car proportion is high during morning hours and less during evening hours. At the same time LCV and small car proportion is increasing from morning to evening. Figure 14 shows vehicle composition in each study location with time.in the figure, 'MP' represents morning hours and 'EP' represents evening hours.

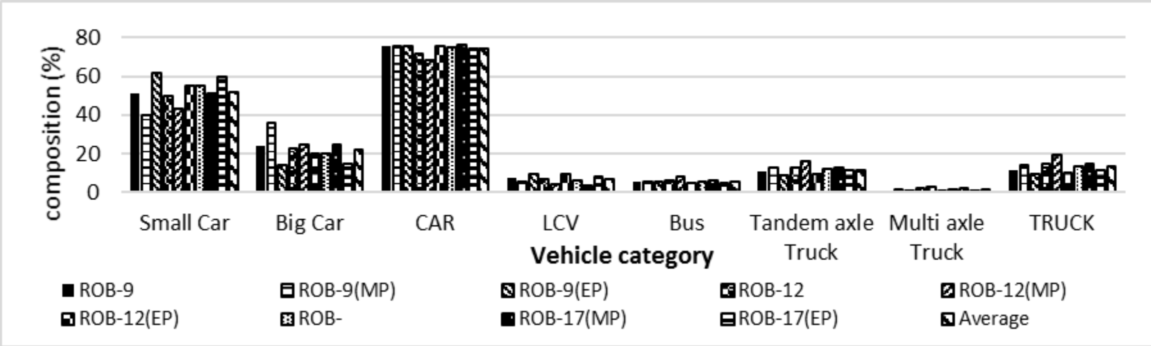

Figure 14: Comparison of vehicle composition over different sections on different time

Traffic flow is the number of vehicles passing a specified point during a stated period of time. Figure 15 shows that, flow is fluctuating and maximum hourly traffic is observed at morning 9:08 am (1104 vehicles/hour) and evening 5:06 pm (1056 vehicles/hour).

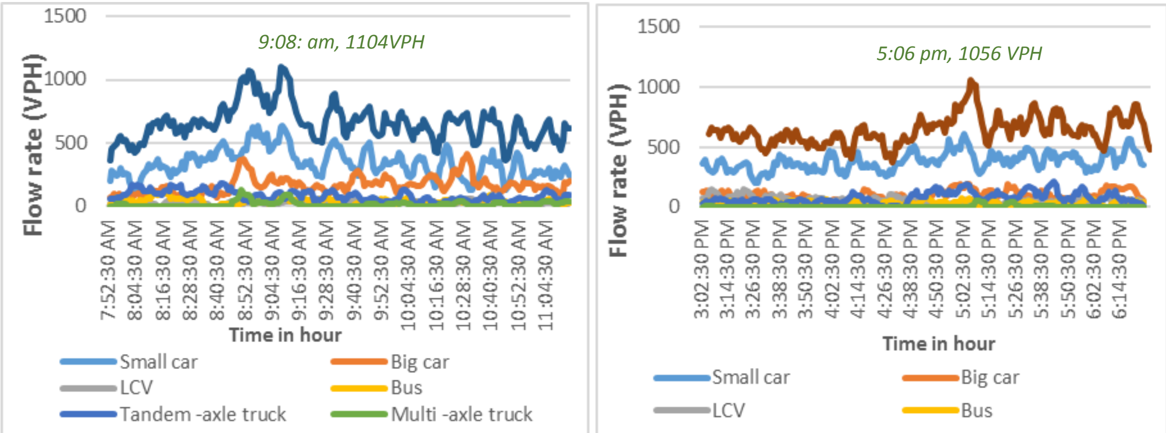

Figure 15: Hourly traffic flow through a section over a day

Figure 16 shows the average flow rate at different sections at different time. Average flow rate on the selected stretches is 668 vehicles/hour. The average hourly volume is higher for evening time than morning for the sections located between Nadiad- Ahmedabad and lower for evening for section located between Vadodara and Nadiad as shown. It may be due to the influence of interchange at Nadiad or due to the difference in traffic at weekday (Friday) and weekend (Saturday).

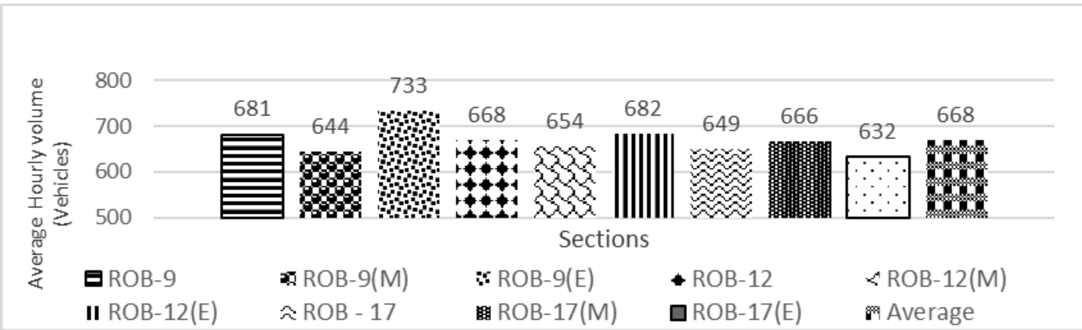

Figure 16: Average traffic flow in different sections at different time

4.2 Lane distribution and Lane changes

While analyzing the distribution of vehicles on lanes (figure 17), it was found that above 97.5 % of vehicles are following lanes and remaining 2.5 % vehicles are not following one particular lane. They are found to move across the lane marking between two lanes on road way sections. It is observed that, lane changes are present for both the lanes. It will affect the Capacity, LOS and safety. From the figure 18, it is clear that lane change is more on location near ROB 12 (5-6.5%) than the remaining 2 sections (2 to 5%). In all the sections, lane changing behaviour is more during morning hours and less in evening hours (figure 18). The table 1 shows that almost 66 % of both small cars and big cars are preferring the median side lane (MSL). Remaining category of vehicles (heavy vehicles) are preferring shoulder side lane (SSL), (i)a minimum of 65 % of buses,(ii) 79% of LCV and (iii)90 % of trucks for their traffic movement.

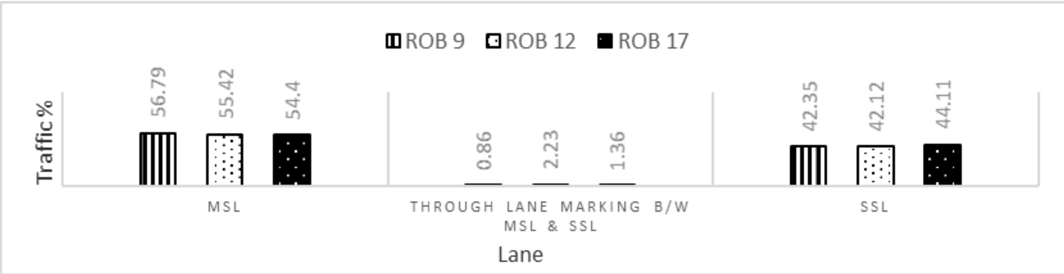

Figure 17: Vehicle distribution over carriageway

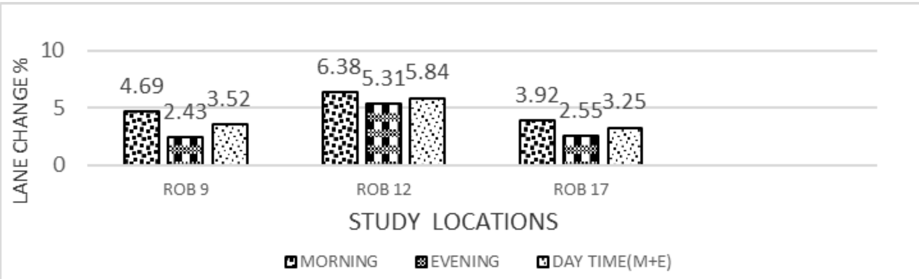

Figure 18: Lane changes at different sections

Table 1: Lane preferences of vehicle category on different study sections

Max % on	Median side lane(MSL)		Shoulder side lane (SSL)			
Vehicle type	Small Car (%)	Big Car (%)	LCV (%)	Bus (%)	Tandem-axle Truck (%)	Multi-axle Truck (%)
ROB 9	71	70	86	71	93	94
ROB 12	71	70	79	65	90	92
ROB 17	69	66	80	77	95	93

4.3 Speed

Speed analysis for different vehicle categories shows that, ‘car’ is having highest speed and ‘truck’ is having a lowest speed. The frequency distribution curve of speed for different vehicles on different locations is shown in figure 19. The curves exhibit a similar fluctuating trend at all the three locations. Cumulative plot (figure 20) of speed on different locations are showing same trend. Curves of small car and big car coincide. This indicates their similar speed trend. The lowest speed is for trucks and it increases for LCV, bus and car respectively. Figure 21 shows that, speed is higher in median side lane for all category of vehicles. Average speed of same vehicle on different locations are almost same for a particular lane. It is noticed that, speed of all categories of vehicles on ROB 12 is slightly less than other two locations, which may be due to the higher lane change near ROB 12.

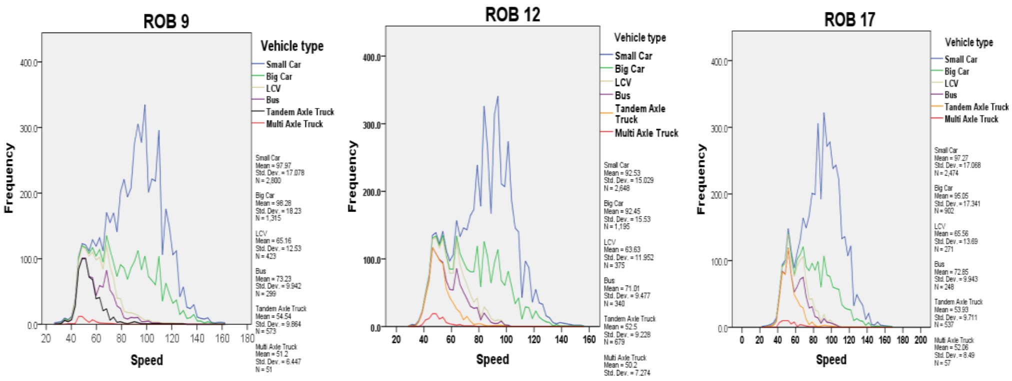

Figure 19: Frequency distribution of each vehicle category on different sections

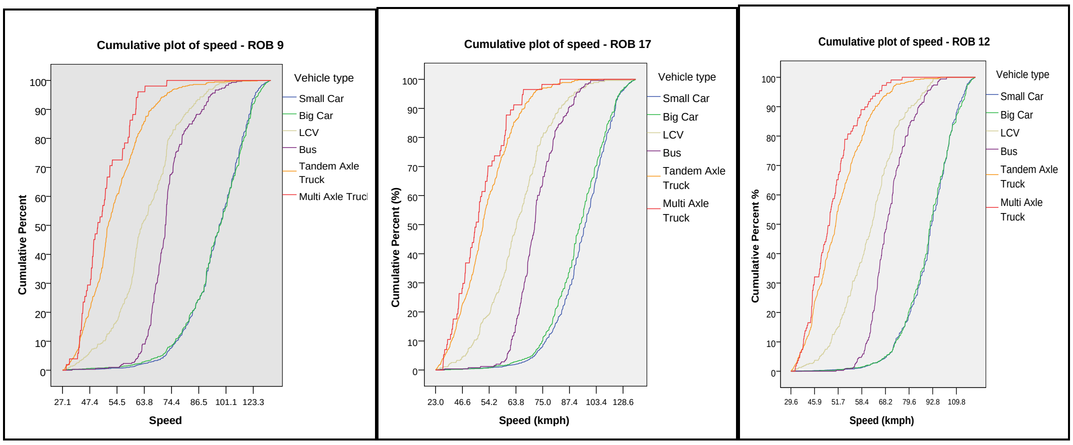

Figure 20: Cumulative plot of speed of different vehicles on different sections

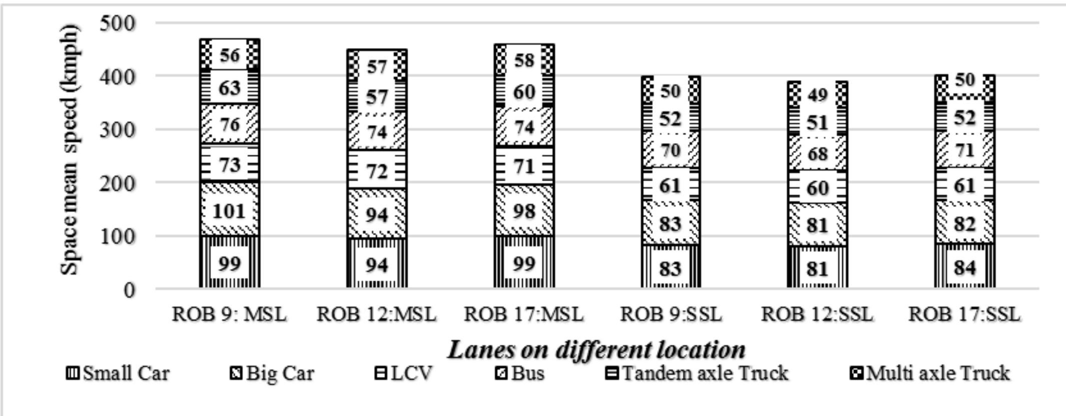

Figure 21: Lane wise space mean speed of different vehicles on different sections

5. CONCLUSIONS

Traffic data collection under mixed traffic conditions is one of the major problems faced by researchers as well as traffic regulatory authorities. Study and analysis of traffic behavior is critically dependent on the availability of observed traffic data. Video graphic data collection is widely used in traffic engineering for the purpose of detailed data collection. The video, as an observational technique proves to be quite effective as compared to the observations made by the naked human eye and it appears more detailed, complete and accurate. The data extraction through video images are found to be more accurate and each frames are representing 1/25th seconds, which will reduce manual observational errors appears in direct recording of travel time. Also, frame number noting down seems more suitable than recording of time especially for the expressway with fast moving traffic. The paper explains different stages behind the extraction of various traffic parameters like speed, headway and lateral and longitudinal gaps from the videos using various software's such as Ulead Video Studio, Irfan View, and Auto CAD. Data analysis is carried out on SPSS and MS Excel platform. For traffic flow analysis, lane utilization and lane changes are also studied. Analysis result shows that, traffic flow is fluctuating and maximum hourly traffic is 1104vehicles/hour at the section located near ROB 17. Majority of Cars are preferring median side lane and most of the trucks and LCVs are choosing kerb side lane. Average stream speed of the expressway is 85kmph were median side lane shows 97 kmph and shoulder side lane shows 70 kmph. Median lane is having high speed traffic. Lane changes on the 100 m stretches are relatively high during the morning hours (5-7%) than in the evening hours (2.5-5%). At section near ROB 12, lane changes & movement across lane marking are more and speed is less for both the lanes when compared with sections located near ROB 9 and ROB 17.

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