Study on Mixed Traffic Flow Behavior on Arterial Road

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***Abstract-* Arterials in metropolitan cities are expected to provide flexibility to the high volume of traffic. A realistic understanding of traffic flow behaviour for such essential urban roads is necessary for traffic operation planning and management for ensuring the desired level of service. Metro politan cities in India carry different types of vehicles with different static and dynamic characteristics with a majority of two wheelers. In the present study, the traffic characterization on a dynamic scale is carried out by considering two-wheeler and car as reference vehicles. Speed, flow, density relationships are developed.**

The present case study is an examination of the behaviour of mixed traffic flow speed and flow rate on an access controlled in six-lane divided Jaipur city in Rajasthan state of India. Field traffic surveys are carried out to record the different volume and speed data through manual as well as video graphic technique. The different speed-flow relation is developed based on the 15-min. Data obtained from the field survey. The inception of level of service based on volume to capacity ratio is established. The results are very applicable for estimation of traffic quality for access controlled urban arterials in mixed traffic flow.

Keywords: Arterial road, Flow density model, Traffic surveys, Video graphic technique

I. INTRODUCTION

1.1 General

The state highways, district roads, rural roads, national highways and arterial roads together form the road network in India. An arterial road is a high-capacity urban road. The main function of an arterial road is to supply traffic from collector roads to arterial roads, and between urban centers at the highest level of service possible [1].

Traffic flow models are basically categorized into three groups: namely microscopic models, mesoscopic models, and macroscopic models. Microscopic traffic flow models simulate single vehicle-driver units, so the dynamic variables of the models represent microscopic properties like the position and velocity of single vehicles [2]. A Macroscopic traffic flow model is a mathematical traffic model that formulates the relationships among traffic flow characteristics like density, flow mean speed of a traffic stream, etc.. Such models are conventionally arrived at by integrating microscopic traffic flow models and converting the single-entity level characteristics to comparable system level characteristics. Mesoscopic modeling is a balance between macroscopic and microscopic modeling. It describes the microscopic vehicle dynamics using macroscopic functions (such as a speed-density relationship).

The relationships among traffic flow characteristics (flow (q), speed (v), and density (k)) are typically represented graphically and referred to as fundamental diagram. The fundamental diagram plays an effective role in traffic flow theory and transportation engineering [3,4]. Among the three pair-wise‟ relationships" (e.g., speed-density, flow-density, and speed-flow), the speed-density relationship appears to be fundamental. Some of the popular macroscopic models are Green shield's Model, Greenberg's Model, Drake Model, Underwood Model, Pipe's generalized model, Modified Green Shield Model, Drake model with Taylor series expansion, Underwood model with Taylor series expansion.
The capacity of basic freeway segment under base condition varies with the free-flow-speed, FFS. Free-flow-speed is exactly defined as the conceptual speed when the density and flow rate on the study segment are both zero. These values represent national norms. It is believed that basic freeway segments reach a density of approximately 45 passenger cars per mile per lane (PC/mi/ln), which may change moderately from location to location [1,3-5].

LOS on a basic freeway segment is defined by density. Density describes the proximity to other vehicles and is related to the freedom to maneuver within the traffic stream [8]. Unlike speed, however, density is sensitive to flow rates throughout the range of flows. LOS is defined to represent reasonable ranges in three critical flow variables: speed, density, and flow rate. There are six LOS defined for basic freeway segments [7]. They are LOS A, LOS B, LOS C, LOS D, LOS E and LOS F.

II. LITERATURE REVIEW

Arasan V. T. & Arkatkar S. S. (2011**)** studied the effect of variation in traffic volume expressing capacity as number of vehicles passing a given section of road or traffic lane per unit time, road width and magnitude of upgrade and its length on PCU value of vehicles and developed capacity guidelines using the derived PCU values. They calculated PCU value by microscopic simulation for the various types of vehicles of heterogeneous traffic, for a wide range of traffic volume and roadway conditions. It was observed that the PCU value of a vehicle outstandingly changes with a change in traffic volume, the magnitude of an upgrade, width of the roadway and its length and found that, for vehicles in heterogeneous traffic, the PCU value increases remarkably with an increase in the magnitude of grade as well as its length. It was also found that the capacity increases with a number of lanes and decreases with increase in upgrades.

Arasan V. T. and Dhivya G. (2010) gives a new Method for the Calculation of Concentration of mixed Traffic by suggesting a new method i.e., “area-occupancy” and confirmed the same using Simulation technique. Traffic density gives a sign of the level of service being provided to the road users. It was noted that the traffic density, expressed as a number of vehicles per unit length of roadway, cannot be suitable for correct measurement of traffic concentration as length and speed of the vehicles in a traffic stream varies remarkably. They also noticed that concept of occupancy, other than density, is more suitable to report traffic concentration as it takes into account the speed variation and traffic composition is an authentic measure of the extent of the road being used by vehicles. It was observed that The idea of occupancy cannot be straightly executed under mixed traffic flow conditions, as the traffic has no lane discipline since occupancy relies on the size of the detection zone. They also found that the area-occupancy is a better replacement and instead occupancy and it can be used as a measure of road traffic concentration at any flow level because of its ability to correctly replicate the extent of usage of the road. Authors found the fact that area-occupancy continue unchanged on changes in the length of the detection zone and is denoted as the proportion of the area of the detection zone covered by all the vehicles traversing the zone during the inspection time. It considered the horizontal projected area of the vehicle, without any restriction on the length of the detection zone and width of the road. Area-occupancy and traffic stream relationship is found to be logical (a linear relationship) which indicates that the concept is suitable for both homogeneous and heterogeneous traffic flow conditions.

Arasan, V. T. & Dhivya, G. (2010) have given a model of mixed traffic flow, i.e., HETEROSIS to imitate heterogeneous traffic flow. Then this model was approved and applied to calculate on the basic characteristics of traffic flow, namely concentration. They suggested a new concept, i.e., ‘area-occupancy’ to calculate traffic flow concentration. In this study, authors suggested a dynamic stochastic type discrete event technique in which the aspects of interest are analyzed numerically with the aid of a computer program. After then, the model has been applied for a wide range of traffic conditions (free flow to congested flow conditions) and has been found that it is replicating the field observed traffic flow to a satisfactory extent. From the relationship developed between area occupancy speed and flow, using the simulation model, they found that, for the representative traffic composition, the trend of the curves are logical which is shows the suitability of the area-occupancy concept for mixed traffic conditions.

Arasan, V. T., & Koshy, R. Z. (2005) discovered the method of modeling on highly mix traffic flow to reproduce flow with wide-ranging static and dynamic. Authors found that the method of treating the whole road space as a single unit, for the purpose of simulation, and representing the various types of vehicles as rectangular blocks on the surface, is suitable for simulating highly heterogeneous traffic flow. According to authors view, representing the positions of vehicles on the road surface, and improving their positions using a coordinate system on an origin, is helpful to simulate the field conditions of heterogeneous traffic flow.

Siamak A. Ardekani, et al. (2011) has given a macroscopic speed-flow models for characterization of the freeway and managed lanes. They calculated operating speeds on freeway managed lanes as a function of predicted demands, speed-density. Models were determined using data at a freeway site (USA). Nine different speed-density models, including four conventional models (Green shields, Greenberg, Underwood, and Drake) as well as five modifications of these models (modified Underwood model with Taylor series expansion, a modified Greenberg model, a polynomial model, a quadratic model and the Drake model with Taylor series expansion)were calibrated for a freeway site in Dallas, Texas. Authors found that the conventional Drake model proved to be the best fit model with reasonable estimates of free.

III. REASERCH METHODOLOGY

The methodology to carry out research work consists of the following major steps:

a) Problem Identification
b) Literature Review
c) Selection of the Study Stretch
d) Data Collection and Retrieval
e) Development of Model
g) Conclusion

IV. EXPERIMENTAL WORKOUT

A. Field Studies

The arterial corridor considered in this study is located in the Jaipur Metropolitan area and located in Jawahar Lal Nehru Marg. Jawahar Lal Nehru Marg is six-lane divided (i.e. 3-lane road segment in one direction of traffic flow) arterial road corridor designed and constructed by the Jaipur Development Authority which connects Jaipur City with its Jaipur International Airport (JAI), Gaurav Tower (GT), Jawahar Circle and World Trade Park (WTP). The most of the famous shopping malls and cinema theater are also alongside this corridor. Since most of the residents of Jaipur city probably choose these as an entertainment destination, therefore evening peak traffic is higher than average daily traffic.

Two sections of the Jawahar Lal Nehru Marg were selected for the present study. The first section is a combination of four-lane divided carriageway (i.e. 2-lane road segment in one direction of traffic flow) having 545 m length and six-lane divided carriageway of length 700 m. The four-lane divided carriageway is flyover part of this section. Though the traffic flow at the end of flyover section is diverging but is not significant and hence it is not taken into consideration, and traffic flow is considered uninterrupted [6]. The second section is a six-lane divided carriageway (i.e. 3-lane road segment in one direction of traffic flow) having a length of 615 m. The second section is having two bus stops, namely, ‘Jawahar Circle' and ‘Bus Stop Kamal Paradise.' These two study sections are shown in figures given below using Google image.

B. Data Analysis

General

The field survey has been done for traffic flow data on the two stretches of Jawahar Lal Nehru Marg. Data are extracted for random selection of cars, LCV, buses for the entire selected hours. Later, it has been compiled for the fifteen-minute duration, and the analysis is carried out to study traffic composition during morning and evening hours separately, hourly traffic volume studies and space mean speed. Analysis for travel time and their frequency distribution has also been carried out. Data analysis is carried out on MS Excel. This chapter discusses the various travel time, traffic flow characteristics and the analysis results for two selected stretches separately.

Study Section 1: Peacock Garden To Keshav Marg

Hourly Traffic Hour Volume

Traffic volume count is being carried out to determine the number of vehicles at a given section. It will help to identify traffic volume trends. From the collected traffic video, manual counting has been done to obtain the classified traffic volume and data is compiled in 15-minute interval. Average Hourly traffic volume variation for the section is given in the fig 1.

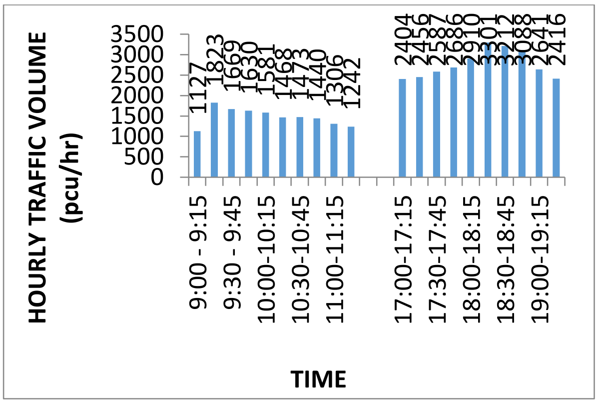


Fig.1 Average Hourly traffic volume variations

The result shows that, the maximum hourly volume is 3301 PCU/hour and it is occurring at evening 6:15 pm- 6:30 pm. Similarly, morning traffic is more at 9:15 am – 9:30 am and is observed as 1823 PCU/ hour.

Vehicle Composition

The vehicle categories present on the study section are two wheelers, three wheelers, car, light commercial vehicle (LCV), bus and trucks. The traffic composition of vehicles is being analyzed for the section for 5 hours duration. Vehicle composition is analyzed during morning hours and evening hours separately for a comparative study.

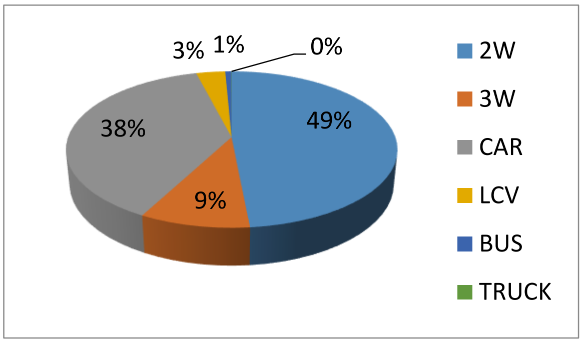


Fig.2 Vehicle Composition from Peacock Garden to Keshav Marg during Morning Hours

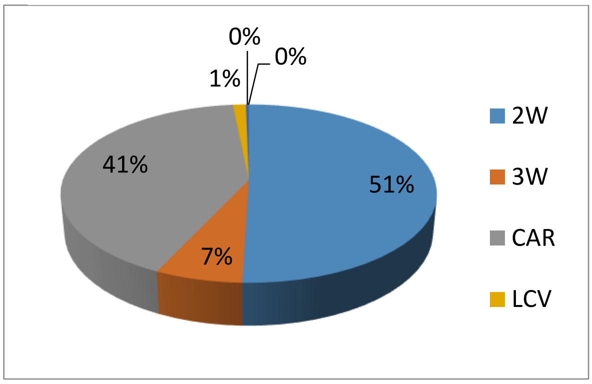


Fig.3 Vehicle Composition from Peacock Garden to Keshav Marg during Evening Hours

In traffic composition, two wheelers have highest share around (50%) followed by a car, three-wheeler, LCV, Bus, and trucks.

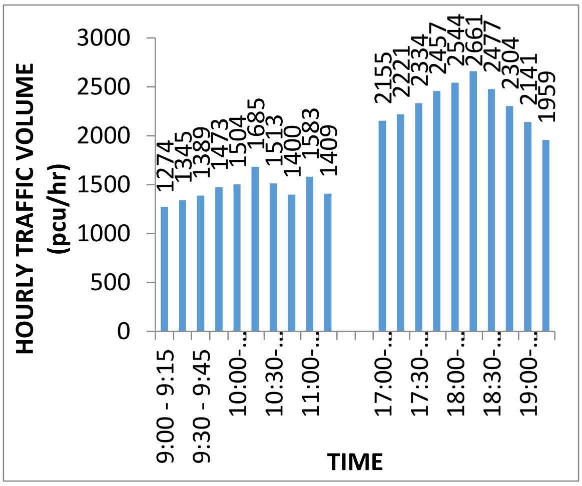
Study Section 2: Girdhar Marg To Jawahar Circle

Fig. 5 Vehicle Composition from Girdhar Marg to Jawahar Circle during Morning Hours

Hourly Traffic Hour Volume

Traffic volume count is being carried out to determine the number of vehicles at a given section [11, 12]. It will help to identify traffic volume trends. From the collected traffic video, manual counting has been done to obtain the classified traffic volume and data is compiled in 15-minute interval. Average Hourly traffic volume variation for the section is given in fig. 4.

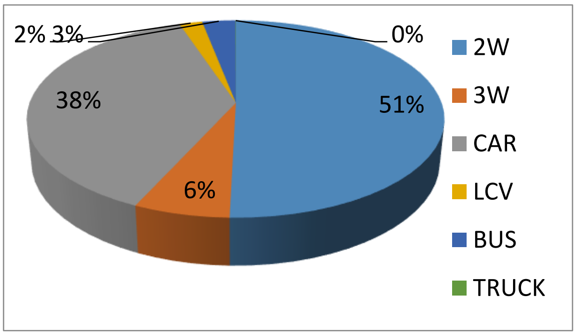
Fig. 4 Average Hourly traffic volume variations



The result shows that maximum hourly volume is 2661 PCU/hour and it is occurring at evening 6:15 pm- 6:30 pm. Similarly, morning traffic is more at 10:15 am – 10:30 am and is observed as 1685 PCU/ hour

Vehicle Composition

The vehicle categories present on the study section are two wheelers, three wheelers, car, light commercial vehicle (LCV), bus and trucks. The traffic composition of vehicles is being analyzed for the section for 5 hours duration. Vehicle composition is analyzed during morning hours and evening hours separately for a comparative study.



C. Traffic Flow Model Development

Flow (Q)-Density (K) Curve

The flow- density model is developed through traffic characteristics regarding PCU per hour using Excel curve fitting technique and quadratic equation. The model is derived with a high value of co-efficient of determination (R2) as shown in fig. 7.

Fig. 6 Vehicle Composition from Girdhar Marg to Jawahar Circle during Evening Hours

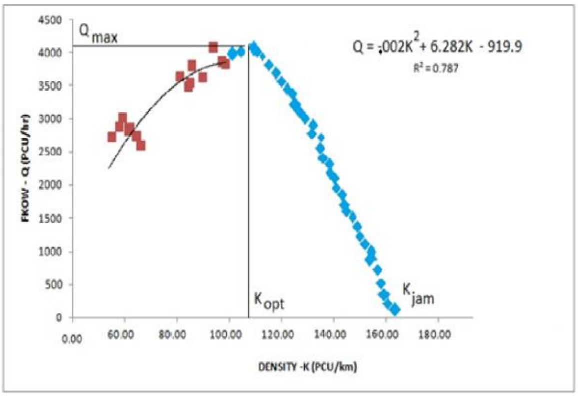


Fig. 7 flow- density curve

The field observed data points are represented in red color, where blue color depicts the uncongested and congested flow regime that is found by putting the different value of density (K) to the flow equation obtained from the graph. Flow and density equation is shown below.

$$Q = -0.002K^2 + 6.282K - 919.9 \ (R^2 = 0.787)$$

Differentiating the Flow and Density equation on density will give zero at optimal density [9]. Accordingly, optimum density is found by equation

$$K_{opt} = 113 \text{ PCU/km}$$

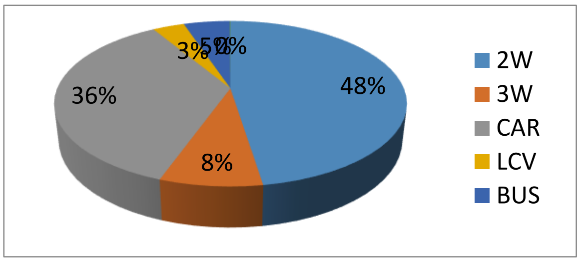
Maximum flow discharge (Capacity) is found by the equation when density is equal to optimal density.

$$Q_{max}(C) = 4180 \text{ PCU /hour}$$

Similarly, jam density is obtained by equating the equation to zero, i.e., Q=0 will give jam density.

$$K_j = 165 \text{ PCU/km}$$

Speed (V)-Density (K) Curve



Greenshield's model, green berg's model, Underwood model and Drake model are the popular speed- density models. As per green shield model, speed and density are linearly related. Green Berg proposed logarithmic speed-density relationship. Whereas Underwood and Drake models are assuming speed and density are exponentially related. The speed- density model is developed through traffic characteristics regarding PCU per hour using Excel curve fitting technique and linear, exponential and logarithmic equations. Fig. 8 shows a linear speed-density relationship, whereas fig. 9 & 10 shows exponential and logarithmic speed- density relationship respectively.

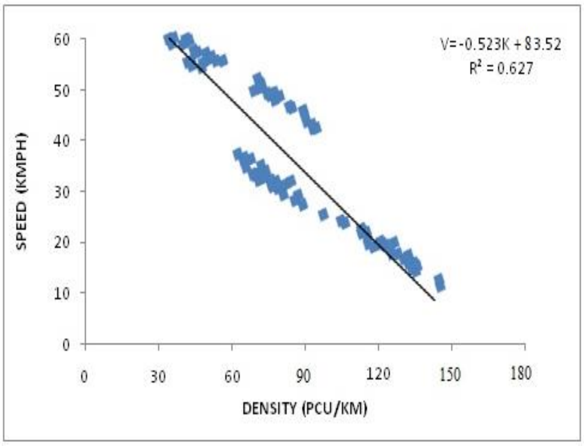


Fig. 8 Speed-Density Curve- using Green shield's linear model

Green shield model is derived with co-efficient of determination (R2) as 62.7 % [10].

$$V = -0.523K + 83.52 \ (R^2 = 0.627)$$

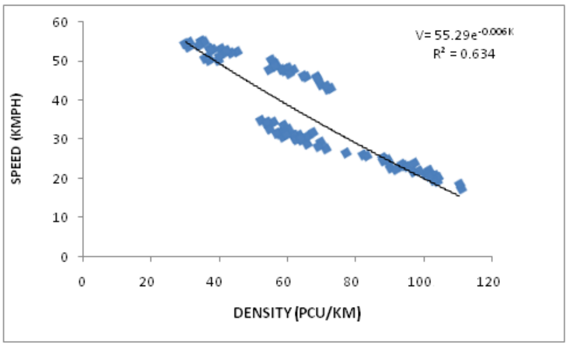


Fig.9 Speed-Density Curve- using exponential model

The model is derived with co-efficient of determination (R2) as 63.40 % [10].

$$V = 55.29 * e^{-0.006k} (R^2 = 0.634)$$

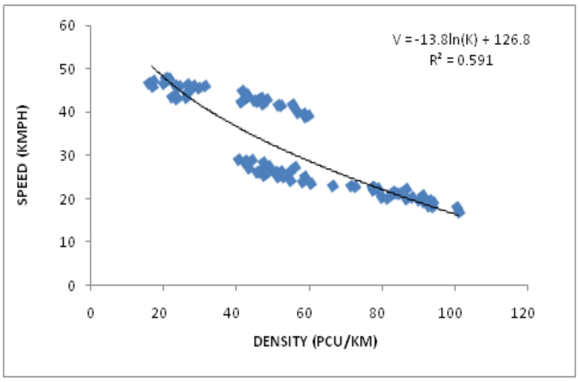


Fig. 10 Speed-Density Curve- using Green berg's logarithmic model

Green berg model is derived with co-efficient of determination (R^2) as 59.10 %.

$$V = -13.8\ln(k) + 126.8 \ (R^2 = 0.591)$$

It was observed that exponential relation between speed & density shows higher co-efficient of determination (R^2) value. Linear speed-density model is derived with co-efficient of determination (R^2) as 59.10 %. The speed-Density relationship for both congested and uncongested regime are plotted in the fig. 11.

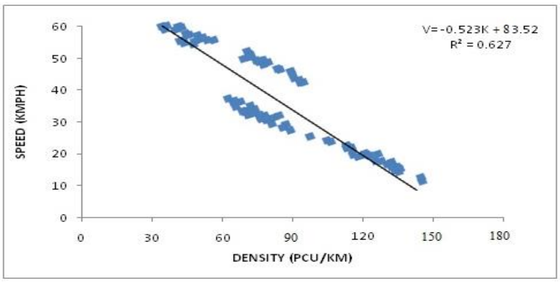


Fig. 11 Speed-Density Curve- using Green shield's model

The field observed data points are represented in blue color, where yellow color depicts the speed obtained using flow-density model data points [14].

Speed, V=Q/K

Speed –density model is derived for both the regimes which are linear in nature. The modal gave a good co-efficient of determination (R^2) of 62.70 %.

$$V = -0.523K + 83.52 \ (R^2 = 0.627)$$

Speed – Density Curve shows that as the density is increased speed will be decreased. In this equation, at a density equal to zero given the free flow speed as 84 kmph.

Speed (V)-Flow (K) Curve

A quadratic equation for speed- flow model is developed in terms of PCU per hour using Excel curve fitting technique [12]. The model is shown in the fig. 12.

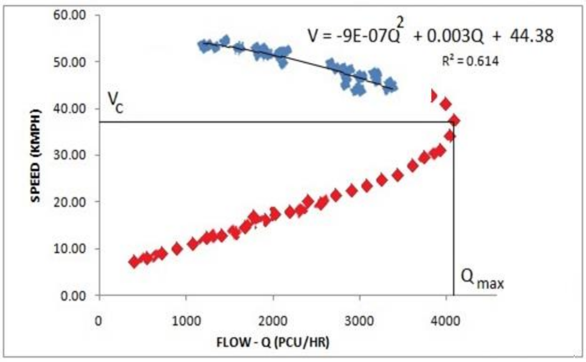


Fig. 12 Speed- Flow curve

The field observed data points are represented in blue color, where red color depicts the points of speed obtained using flow-density model data points [11].

$$V = -9E{-}07Q^2 + 0.003Q + 44.38 \ (R^2 = 0.614)$$

From the equation, Speed at capacity was found as 38.5 kmph

V. RESULT AND DISCUSSION

A. Traffic Flow Characteristics
Hourly traffic volume studies

Hourly traffic volume count is being carried out for the two study sections regarding vehicles per hour for each five-hour duration data. It was found that hourly flow is higher from Peacock Garden to Keshav Marg as compared to Girdhar Marg to Jawahar Circle.

On the first section i.e. from Peacock Garden to Keshav Marg result shows that maximum hourly volume is 3301 PCU/hour and it is occurring at evening 6:15 pm- 6:30 pm. Similarly, morning traffic is more at 9:15 am – 9:30 am and is observed as 1823 PCU/ hour.

On the second section i.e. Girdhar Marg to Jawahar Circle result shows that maximum hourly volume is 2661 PCU/hour and it is occurring at evening 6:15 pm- 6:30 pm. Similarly, morning traffic is more at 10:15 am – 10:30 am and is observed as 1685 PCU/ hour.

Vehicle composition

The vehicle categories present on the study section are two wheelers, three wheelers, car, light commercial vehicle (LCV), bus and trucks. The traffic composition of vehicles is being analyzed for the section for 5 hours duration. Vehicle composition is analysed during morning hours and evening hours separately for a comparative study.

On the first section i.e. from Peacock Garden to Keshav Marg result shows that in traffic composition, two wheelers has highest share around (50%) followed by car, three-wheeler, LCV, Bus, and trucks. The results also show that LCV and three wheeler proportion is high during morning hours and less during evening hours. At the same time, two wheeler and car proportion are increasing from morning to evening.

On the second section i.e. Girdhar Marg to Jawahar Circle result shows that, in traffic composition, two wheelers has highest share around (49%) followed by a car, three-wheeler, LCV, bus, and trucks. Also, in this section, there is significant number of buses because low floor bus and city bus give their services in this section. The results also show that two wheeler and car proportion is slightly high during morning hours and less during evening hours. At the same time LCV, three wheelers and bus proportion is increasing from morning to evening.

VI. CONCLUSION

Understanding of traffic stream flow characteristics and their inter-relationships is per-requisite for an efficient design of traffic facilities and realistic assessment of the quality of service provided to the road users.

The study is carried out to analyse the traffic and flow characteristics of Indian Arterial road by taking six-lane divided JLN Marg connecting Jawahar circle arterial road as a study area. Traffic data is collected by video graphic technique from two road stretches. The required traffic parameters are extracted from these videos manually for better accuracy.

Flow-density-speed models are developed in the study can explain the behaviour of traffic stream precisely with very high values of R^2 under heterogeneous traffic environment. Speed- density model is linear in nature whereas flow-density and speed-flow models are following second order polynomial quadratic relation.

The developed models can be applied to assess the traffic flow characteristics like speed and volume for a similar type of arterial roads under identical traffic composition. Also, the level of service of transport facility can be established via these models so that transport planners and engineers can utilize them as a tool for planning and design of arterial roads

VII. FUTURE SCOPE OF WORK

The detailed study of various traffic characteristics is carried out using data of two selected basic arterial road segment stretches for a duration of 5 hours each. Uninterrupted traffic flow is studied and analysed. To capture the complete behaviour of the arterial road, merging, diverging and weaving traffic have to be studied which are not providing uninterrupted traffic flow. From the developed Q-K-V model qualitative measure in terms of the level of service can be established.

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