The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 5 || Pages || 33-39 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Analysis and Development of Traffic Stream Parameters of Heterogeneous Traffic at Signalized Intersection

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ABSTRACT
The rapid increase in the volume of traffic in most of the countries containing the heterogeneous traffic demands a more efficient and intelligent system to be dealt with. A heterogeneous traffic stream consists of vehicles that have different speeds, sizes, operating characteristics, and vehicle spacing. The Indian traffic is heterogeneous traffic. Homogeneous design methods do not fit the heterogeneous situation, especially in non-lane-based roadways that populate the developing world. This paper reviews the status of heterogeneous mixes worldwide, and what factors need to be considered in such mixes. This paper presents a macroscopic stochastic model of traffic movements at signalized intersection. To study macroscopic traffic parameters (flow, speed and density) and to establish new models for the Indian highway. A heterogeneous traffic stream consists of vehicles that have different speeds, sizes, operating characteristics, and vehicle spacing. It reviews the status of heterogeneous mixes world traffic, and which factors need to be considered in such traffic. The Indian roads are constructed on European equation of homogeneous traffic and different LOS, which are not applicable to heterogeneous traffic of India. So, there is a need to model the new equation for Indian highways. In these traffic parameters were identified by using the video recording technique at just after the signalized intersection. And found out the relation between macroscopic parameters of traffic and compared with the fundamental diagrams. SPSS software is used to define the relationship between the traffic parameters.

KEYWORDS: - *Signalized intersection, Flow, density, speed, heterogeneous traffic, traffic flow etc...*

Date of Submission: 02 May 2014 Date of Publication: 15 May 2014

I. INTRODUCTION

India is the fifth largest automobile manufacturer in the world. The development of highway infrastructure and the transport sector have subsequently been receiving a much goes on increasing. The National highways run across the length and breadth of the country measure 70,934 kilometers and have become the lifeline of India.

A heterogeneous traffic stream consists of vehicles that have different speeds, sizes, operating characteristics, and vehicle spacing. The Indian traffic is heterogeneous traffic. Homogeneous design methods do not fit the heterogeneous situation, especially in non-lane-based roadways that populate the developing world. This paper reviews the status of heterogeneous mixes world traffic, and which factors need to be considered in such traffic. The issues of safety, modeling, and non-motorized transport are considered, and solutions for these are discussed. These are important because the need for an understanding of heterogeneous mixes will grow in the future due to their presence in developing world mega cities and growth in the developed world.

Intersection may be signalized for a number of reasons, most of which relate to the safety and effective movement of conflicting vehicular and pedestrian flows through intersection. The level of service (LOS) of India is “A”. The Indian roads are constructed on European equation of homogeneous traffic and different LOS, which are not applicable to heterogeneous traffic of India. So, we have to construct new model for Indian highways.

II. CONTINUITY EQUATION FOR HOMOGENEOUS TRAFFIC

Density is calculated by using continuity equation (Gerlough and Huber 1975), as follows,

$$K=q/u \qquad (1)$$

Where, k= traffic density in lanes in vehicles/km.
q=traffic flow across the lane in a vehicle/hr.
u=weighted average speed in km/hr.

III. EXISTING TRAFFIC STREAM MODELS

To figure out the exact relationship between the traffic parameters, lots of researches is carried out over the past several decades. The result of these researches yielded many mathematical models. Some important model amount them are discussed below.

Green shield's macroscopic stream model (1935)

Relation between speed and density:-

Macroscopic stream models represent how the behavior of one parameter of traffic flow changes with respect to another. The first and most simple relation between them is proposed by Green shield (TRB Monograph). Green shield assumed a linear speed-density relationship as illustrated in figure 1 to derive the model.

The equation for this relationship is shown below.

Fig-1: Relation between Speed and Density

This relationship is described using equation 1.

$$v = v_f - \left[\frac{v_f}{k_j}\right].k$$

Where, v =mean speed, m/s
k = density corresponding to speed (veh/m)
v_f=free flow speed (m/s)
k_j =jam density (veh/m)

This equation is often referred to as the Greenshield model. It indicates that when density becomes zero, speed approaches free flow speed (i.e. $v \rightarrow v_f$ when $k \rightarrow 0$).

Relation between speed and flow

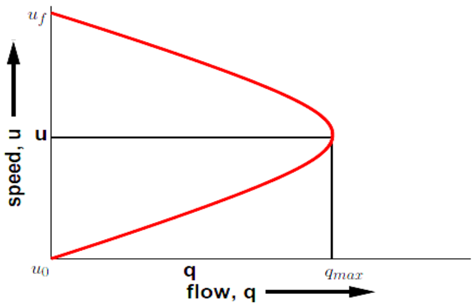

Fig-2: Relation between speed and flow

$$q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$$

Relation between flow and density

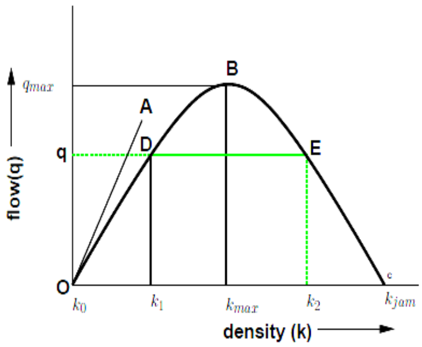

Fig-3: Relation between flow and density

$$q = v_f.k - \left[\frac{v_f}{k_j}\right] k^2$$

Limitations

In order to use this model for any traffic stream, one should get the boundary values, especially free flow speed (v_f) and jam density (k_j). But it is difficult to determine exact free flow speed and jam density directly from the field. In Green shield model, linear relationship between speed and jam density was assumed. But in field one can hardly find such a relationship between speed and density. Therefore, the validity of Green shield model was questioned and Greenberg's model has come up.

Greenberg's logarithmic model (1959)

Greenberg assumed a logarithmic relation between speed and density.

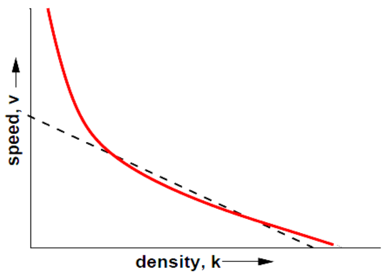

Fig-4: Greenberg's logarithmic model

Greenberg has given the following equation,

$$v = v_0 \ln \frac{k_j}{k}$$

Limitation:

A main drawback of this model was that as density tends to become 0 (zero), speed tends to infinity. This shows the inability of the model to predict the speed at lower densities which puts forward a new model.

Underwood's exponential model (1971)

Trying to overcome the limitation of Greenberg's model, Underwood put forward an exponential model as shown below.

Sr. No.	Types of vehicles
1	Heavy vehicle
2	Big car
3	Small car
4	Three wheelers
5	Two wheelers

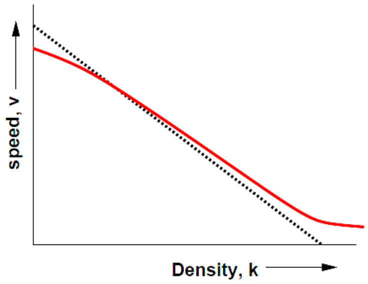

Fig-5: Underwood's exponential model

$$v = v_f . e^{\frac{-k}{k_0}}$$

Where , v_f = free flow speed

k_o is the optimum density, i.e. the density corresponding to the maximum flow.

In this model, speed becomes zero only when density reaches infinity which is the drawback of this model. Hence this cannot be used for predicting speeds at high densities.

IV. DATA COLLECTION AND PROCESSING

Traffic data was collected on Nagpur roadways section at three intersections i.e. at pratap nagar square, RBI square and Ravi nagar square in Nagpur city. The data was collected by using digital video camera. A 35m length was marked on roadway section to locate the distance travelled and to record time taken by vehicle to travel the 35m distance to calculate the speed.

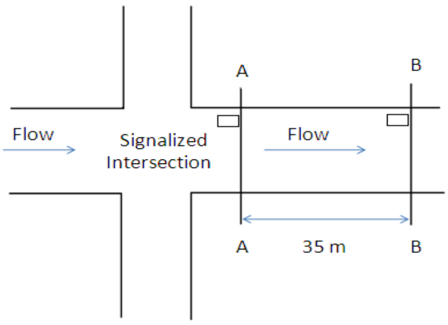

Fig-6. 35m marking on road

Time Interval (min.)	(q) (veh/hr)	(v) (kmph)	(k)(veh/km/hr)
0-5 min	1731	28.37	76
6-10 min	1260	33.6	38
11-15 min	1392	30.26	46
16-20 min	972	30.24	32
21-25 min	1452	30.43	48
26-30 min	1536	34.17	45
31-35 min	1872	29.2	64
36-40 min	1212	32.54	37
41-45 min	1308	34.33	38
46-50 min	1488	30.58	49

Table -2: Sample data of Pratap nagar square

This covered peak flow and off peak flow condition. The time required by each vehicle to cover the distance of 35m was recorded from the video clip and the number of vehicles of each entity type crossing a particular section in 5 minute was recorded.

V. ANALYSIS AND RESULT

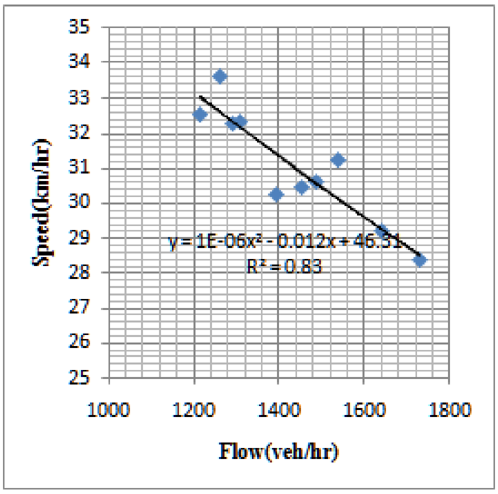

Fig-6: Speed-Flow Curve

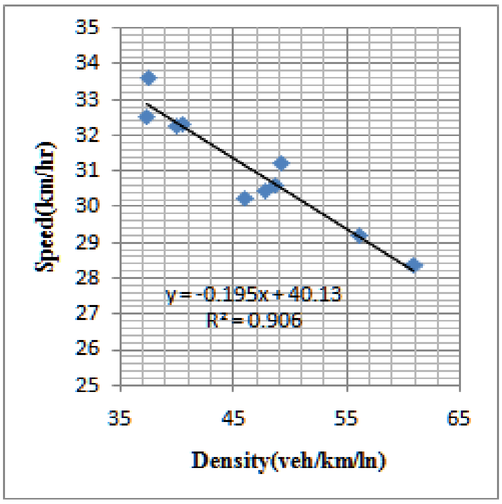

Fig-7: Speed-Density Curve

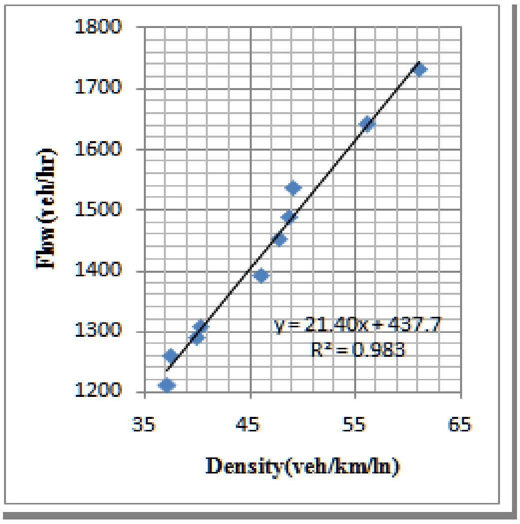

Fig-8: Flow-Density Curve

VI. MATHEMATICAL MODEL

In this study it is observed that the data points in congestion region do not exist. This is due to lesser no. of vehicles utilizing facility. Hence the data points on congested or infeasible region are not observed. By using SPSS software, we find out the correlation between traffic stream parameters of observed data. And we get the following regression equations:

Flow-Density relationship:-

$$k = 0.046q - 19.331 \quad (1)$$

Speed-Density relationship:-

$$k = -4.6334u_s - 190.397 \quad (2)$$

Speed-flow relationship:-

$$k = q/u_s$$

Therefore eq^n (2) becomes,

$$q = -4.633u_s^2 - 1190.397u_s \quad (3)$$

Density is the dependent variable and speed and flow are independent variable. Flow-density curve and speed-density curve shows the linear relationship and we get non-linear regression model. –Ve sign in flow-speed equation shows the negative behavior of the curve.

Speed-Flow-Density relationship is given by

$$k = 0.034*q - 1.334*u_s + 38.647 \qquad (4)$$

Where, k= traffic density in lanes in vehicles/km.
q=traffic flow across the lane in a vehicle/hr.
u_s=weighted average speed in km/hr.

VII. CONCLUSION

From the survey we find out that our Indian traffic is heterogeneous traffic. It is concluded that existing equation of traffic stream are not suitable for these Heterogeneous traffic. Thus we need to create new equation for this Heterogeneous traffic of Indian scenario. According to our complete analysis we found the traffic stream parameters. We get standard relationship between traffic stream parameters. We get a simple regression equation for heterogeneous traffic of Nagpur city.

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