STUDY OF TRAFFIC STREAM PARAMETERS ON NATIONAL HIGHWAY 44(NH-44) UNDER HETEROGENEOUS TRAFFIC CONDITIONS

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Abstract— The mathematical description of the complex traffic flow system for the purpose of characterizing as well as predicting the behaviour of traffic is referred to as Traffic flow modelling. Traffic stream models serve as the basic building blocks of numerous number of the traffic flow models. Traffic stream models point out the underlying relationships among the three basic traffic flow variables i.e speed, flow and density. Understanding the traffic flow variables, their interrelationships and techniques to model traffic are very vital in the planning, design and operation of transportation systems. Various research papers have been published proposing different traffic stream models. Planning of road transport infrastructure is a complicated process. One of the main issues is determining the design elements of road infrastructure (road type and number of traffic lanes, cross-sectional profile, etc.). When designing of roads takes place, parameters from the international literature are considered, containing values derived empirically from local data on traffic flow (mostly from northern American cities). The motive of this project is to explore traffic flows in order to develop a model which will allow scientifically exact description of traffic flows on the National Highway in J&K. Study of basic parameters of traffic flow includes the selection of road location, survey time, traffic survey, analysis of video recordings, as well as statistical analysis and calculation of basic parameters of traffic flow. The project will be conducted on the National Highway under heterogeneous traffic conditions and in this manner the basic parameters of traffic flow will be derived. These parameters will be used to develop diagrams of relations between speed, traffic density and volume, resulting in cumulative functions of traffic flow parameters for the traffic network. This will allow me to develop some new equations which will enable theoretical determination of flow volume, speed and density for a prescribed road. Using these equations I can develop a model for the National Highway (NH- 44).

Keywords— **Traffic stream models, traffic stream parameters, calibration of model, regression analysis, SPSS.**

INTRODUCTION

The planning and designing of road infrastructure is based on the determination of traffic flow parameters and their distribution in the area under observation in terms of space and time. For the purpose of choosing the ideal solution for the planned period, it is very important to conduct a research of relevant traffic flow parameters in characteristic conditions on the observed road network. This research then allows the suitable traffic flow model to be determined. The concept of traffic flow modelling implies defining of relations between the basic parameters of traffic flow: speed, density and volume. Determination of values of traffic parameters is based on surveying the traffic flow samples, i.e. sampling on relevant sections in characteristic peak and off-peak loads. Generally, the most frequently applied sampling procedure includes measurement of vehicle flow, i.e. by conducting traffic counts. However, on the other side of the coin, this procedure is not sufficient in the process of determining the actual and available capacity of future roads, as the capacity typically depends on specific conditions of traffic operation on the road infrastructure. Reliable information on the capacity of any road and road infrastructure can be obtained by traffic count only after the road has been constructed. It is, therefore, important to conduct measurements and calculate coefficients and factors that will be used for determining road capacity in planning documentation that will meet the need of the future infrastructure. In addition to traffic flow indicators, an important factor in all stages of creating and evaluating design solutions is road capacity. Capacity is the core indicator of a rational and deliberate policy for road construction, maintenance and operation. Not only does it directly influence the selection of road design elements and its cross section, but it also has a huge impact on operational costs of vehicles through the application of adequate designs of access roads. Road capacity is a vital planning tool for finding adequate criteria in order to determine the optimal peak hour traffic volume relevant for the design of road cross section based on programmed traffic volumes. Descriptive capacity parameters from the international literature are used for road design purposes, with values derived by empirical methods from local traffic flow data. For the purpose of defining adequate traffic model that will enable a more accurate description of local characteristic of traffic flows on the National Highway (NH 44) I have conducted this research in the Lethpora area which lies on NH 44. Basic traffic flow parameters measurements and computation of values of relevant coefficients characteristic categories of roads in the observed road network will be conducted.

TRAFFIC STREAM MODELS

In order to determine the exact relationship between the traffic parameters, a huge number of researches have taken place over the past many decades. The outcome of these researches have yielded a number of mathematical models.

Greenshield's Macroscopic Stream Model:- Macroscopic stream models show how the behaviour of one parameter of traffic flow changes with respect to the other. Most vital among them is the relation between speed and density. The first and simpliest relation between them was proposed by Greenshield. Greenshield assumed a linear speed-density relationship as illustrated in Figure 8 to derive the model. The equation for this relationship is shown below.

$$v = v_f - \left[\frac{v_f}{k_j}\right].k \qquad (1.1)$$

Where v represents the mean speed at density k, v_f the free speed and k_j the jam density. This equation is sometimes also called as the Greenshield's model. It shows that when density becomes zero, speed approaches free flow speed (i.e. $v \rightarrow v_f$ when $k \rightarrow 0$). Once the relation between speed and flow is determined , the relation with flow can be obtained. This relation between flow and density is parabolic in shape and is shown in Figure 10.

Also, we know that,

$$q = k.v \qquad (1.2)$$

Substitute the (1.1) in (1.2), we get

$$q = k.v_f - \left[\frac{v_f}{k_j}\right].k^2 \qquad (1.3)$$

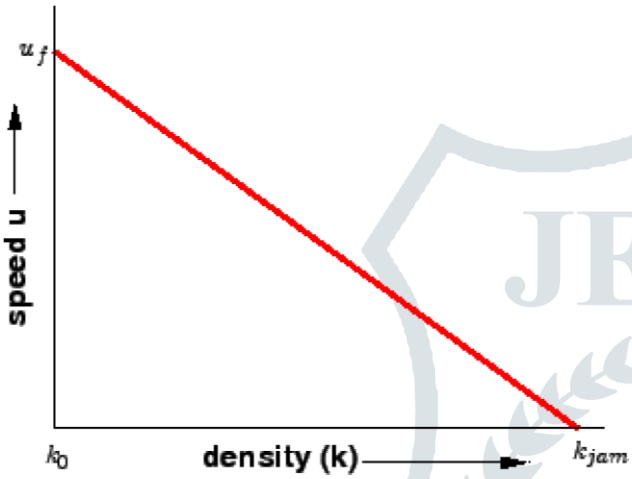

Figure 1: Relation between Speed and Density

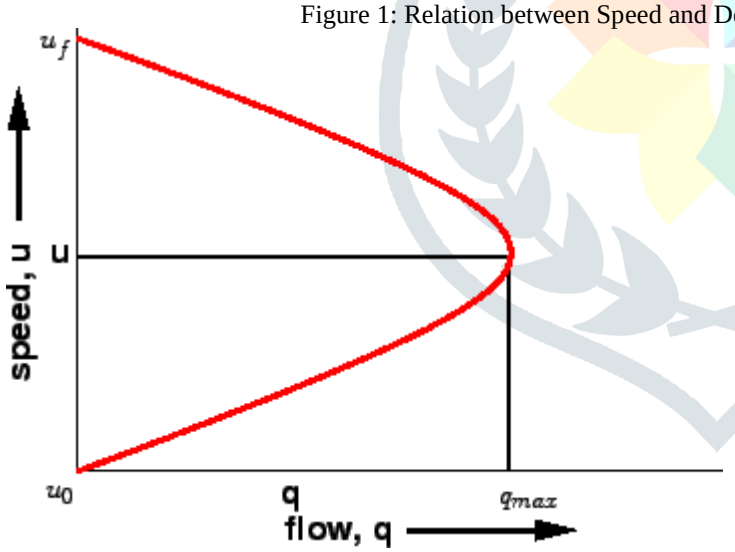

Figure 2: Relation between Speed and Flow

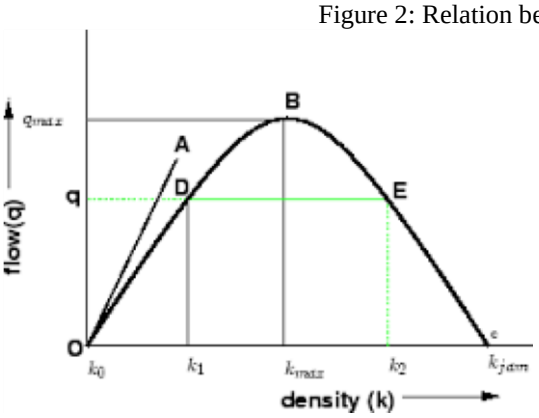

Figure 3: Relation between Flow and Density

Further we can find the relation between speed and flow. For this, put k = q/v in (1.3) and solving, we get

$$q = k_j v - \left[\frac{k_j}{v_f}\right].v^2 \qquad (1.4)$$

This relationship is also parabolic and is shown in Figure 2. Once the relationship between the fundamental variables of traffic flow is deetermined, the boundary conditions can be obtained. The boundary conditions that are of use are jam density, free-flow speed, and maximum flow. In order to find density at maximum flow, differentiate equation (1.3) with respect to k and equate it to zero, i.e.

$$\frac{dq}{dk} = 0$$

$$v_f - \frac{v_f}{k_j}.2k = 0$$

$$k = \frac{k_j}{2}$$

Denoting the density corresponding to maximum flow as k_0,

$$k_0 = \frac{k_j}{2} \qquad (1.5)$$

Therefore, density corresponding to maximum flow is half the jam density. Once we obtain k_0, we can also derive maximum flow, $q_{max.}$ Substituting equation 1.5 in equation 1.3

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

$$= v_f.\frac{k_j}{2} - v_f.\frac{k_j}{4}$$

$$= \frac{v_f.k_j}{4}$$

Thus the maximum flow is one fourth the product of free flow and jam density. Finally to get the speed at maximum flow, v_0, substitute equation 1.5 in equation 1.1 and solving we get,

$$v_0 = v_f - \left[\frac{v_f}{k_j}\right].\frac{k_j}{2}$$

$$v_0 = \frac{v_f}{2} \qquad (1.6)$$

Therefore, speed at maximum flow is half of the free speed.

Calibration of Greenfields Model

For using this model for any traffic stream, one has to obtain the boundary values, especially free flow speed (v_f) and jam density (k_j). This has to be derived by field survey and this is referred to as calibration process. It is difficult to determine exact free flow speed and jam density directly from the field, however approximate values can be derived from a number of speed and density observations and then putting a linear equation between them. Let the linear equation be y = a + bx such that y is density k and x denotes the speed v. Using linear regression method, coefficients a and b can be solved as,

$$b = \frac{n\sum_1^n x_i y_i - \sum_1^n x_i.\sum_1^n y_i}{n\sum_1^n x_i^2 - (\sum_1^n x_i)^2} \qquad (1.7)$$

$$a = \bar{y} + b\bar{x} \qquad (1.8)$$

Other method of solving for b is,

$$b = \frac{\sum_1^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_1^n (x_i - \bar{x})^2} \qquad (1.9)$$

In which x_i and y_i are the samples, n is the number of samples, and $\bar{x}$ and $\bar{y}$ are the mean of x_i and y_i respectively.

REGRESSION ANALYSIS

Regression analysis may be defined as a form of predictive modelling technique that investigates the relationship between a dependent (target) and independent variable(s) (predictor). This technique is extensively used for forecasting, time series modelling as well as finding the causal effect relationship between the variables. For example, relationship between rash driving and number of road accidents by a driver is properly studied through regression.
Regression analysis is an vital tool for modelling and analysing data. In this, we fit a curve / line to the data points, in such a manner that the differences between the distances of data points from the curve or line is kept minimum.
Regression analysis also determines the relationship between two or more variables. Let's understand it with the following example: If one wants to estimate growth in sales of an industry based on current economic conditions, he/she must have the recent company data that indicate the growth in sales is around two and a half times the growth in the economy. Using this insight, he/she can predict future sales of the industry based on current & past information.
There are many advantages of using regression analysis. Some of these are:

1. It shows the significant relationships between dependent variable and independent variable.

2. It shows the strength of impact of multiple independent variables on a dependent variable.

In addition, Regression analysis also allows us to compare the effects of variables measured on various scales, like the effect of price changes and the number of promotional activities. These advantages are quite helpful for market researchers / data analysts / data scientists to eliminate and evaluate the topmost set of variables to be used for building predictive models.

WORK CARRIED

Selection of the Site:-

I choose a particular stretch, after going through each characteristic of the road. The stretch chosen is 5km in length and is two lane road with shoulder provided on one side of the road, for each traffic direction. The chosen stretch includes an intersection and several horizontal and vertical curves.

Traffic Survey for Calibration of Model:-

For the purpose of traffic survey I had initially made up my mind to go for videography method. However it did not work out as because there were no high spots in the stretch where I could fix the cameras for the surveys. Moreever there is a lot of military and security forces movement and it isn't allowed to record or film the convoys passing on the highway. So I had to go for the basic method for the survey purpose.
Traffic survey was done in both the directions, i.e. the traffic moving in the direction of Srinagar to Jammu and the traffic moving in the direction of Jammu to Srinagar as well.
The traffic Survey was done at several times of the day. The overall time frame of my survey was between 8:00 a.m. to 6:00 p.m., of which 8:00 a.m. to 10:30 a.m. was the morning peak hour and 3:30 p.m. to 6:00 p.m. was the evening peak hour.
I marked a section of 50 meters on the road and to measure the speed of the vehicles moving I used the stopwatch method. When a vehicle would pass the start point, I would start the stopwatch and at the end point stop the stopwatch. I noted down the time taken by the vehicle to cover a distance of 50 meters. Similarly time was noted for other vehicles also. From the time noted, i could calculate the speed of the vehicles using the following equation.

$$v = \frac{d}{t}$$

In order to measure the flow on the highway, i manually counted the number of vehicles passing through the section during that time. I divided the traffic in categories; Light Motor Vehicles (LMV), Heavy Motor Vehicles (HMV), Light Commercial Vehicles (LCV), Two Wheelers (2W) and Three Wheelers (3W). Density was measured indirectly from the flow and speeds, already measured, using the following equation.

$$q = k.\,v$$

The procedure was repeated for the other chosen 39 points.

Analysis of Data Collected:-

The data gathered from the surveys was analysed at my home. From the various values of the time taken by the different types of vehicles to cover a distance of 50 meters, I calculated the average time taken by all the vehicles and hence calculated the average speed of the vehicles at that point. Moreever I also calculated the average speeds of the different types of vehicles. Then the flow was derived from data collected during the survey. In order to get the Passenger Car Unit values, i multiplied the flow, in vehicle/hour, with their corresponding Passenger Car Unit factors to obtain the values in PCU/hour. The Passenger Car Unit factors for different types of vehicles are shown in the Table A.

Table A:- PCU Values for Different Types of Vehicles

S.No.	Type of Vehicle	PCU Value
1.	Light Motor Vehicle (LMV)	1
2.	Heavy Motor Vehicle (HMV)	3
3.	Light Commercial Vehicle (LCV)	1.5
4.	Two Wheeler (2W)	0.5
5.	Three Wheeler (3W)	0.8

Density was calculated from the Speed and Flow using the relevant Equation and the values were multiplied with PCU values to obtain the data in PCU/km. Similarly we calculated the values of Speed, Flow and Density for all the 40 points.

After gathering all the data ,i calculated average speed of vehicles on the highway in km/hr, average flow on the highway in veh/hr as well as PCU/hr and average density on the highway in veh/km and PCU/km as well. I also calculated the average traffic composition on the National Highway.
From the average value of flow, i calculated the time headway using the equation given below.

$$h_{av} = \frac{1}{q}$$

Similarly from the average value of density, I calculated the space headway using the equation given below.

$$s_{av} = \frac{1}{k}$$

Regression Analysis of Data:-

After obtaining all the data, i performed the regression analysis of the data with the help of the software SPSS. I obtained the relation between Speed and Density. Similarly developed models for the values in PCU and for the different types of vehicles as well. From the models developed, we can calculate the jam density of the highway and the free flow speed of the vehicles as well.

Traffic Survey for Validation of the Model:-

After the model was developed, I performed the traffic survey for another 10 points similarly like I did earlier. To validate the model I compared the data collected from the survey and the values estimated from the model, computed the error and hence determined the accuracy of the model developed.

Observations

Traffic Moving in the Direction from Srinagar to Jammu:-

From the survey conducted on the NH-44 for the traffic moving in the direction from Srinagar to Jammu, the following observations made:-

1. **Average Speed of Vehicles:-** It was learnt that the traffic from Srinagar to Jammu was moving with an average speed of 48.03 km/hr. The traffic under consideration was heterogeneous in nature that involved all types of vehicles such as Light Motor Vehicles, Heavy Motor Vehicles, Light Commercial Vehicles, Two Wheelers and Three Wheelers. The average speed of different types of vehicles is given in the Table B, given below.

$$v_{av} = 48.03 \frac{km}{hr}$$

Table B: Average Speed of Different Types of Vehicles in Srinagar- Jammu Direction

Type of Vehicle	Average Speed

Light Motor Vehicle (LMV)	56.36 km/hr
Heavy Motor Vehicle (HMV)	44.37 km/hr
Light Commercial Vehicle (LCV)	46.8 km/hr
Two Wheeler	45.55 km/hr
Three Wheeler	31.25 km/hr

2. **Average Traffic Flow:-** The average flow of the traffic was found to be 645 veh/hr. In terms of PCU/hr, it was found to be 862.37 PCU/hr.

$$q_{av} = 645\frac{veh}{hr} = 862.37\frac{PCU}{hr}$$

3. **Average Traffic Density:-**The density of the traffic was observed to be pretty low. The average value was observed to be 13.45 veh/km and in terms of PCU/km, the value was 18.17 PCU//km.

$$k_{av} = 13.45\frac{veh}{km} = 18.17\frac{PCU}{km}$$

4. **Traffic Composition:-**The traffic composition of the various types of the vehicles moving in the direction from Srinagar to Jammu is shown below in Figure 4.

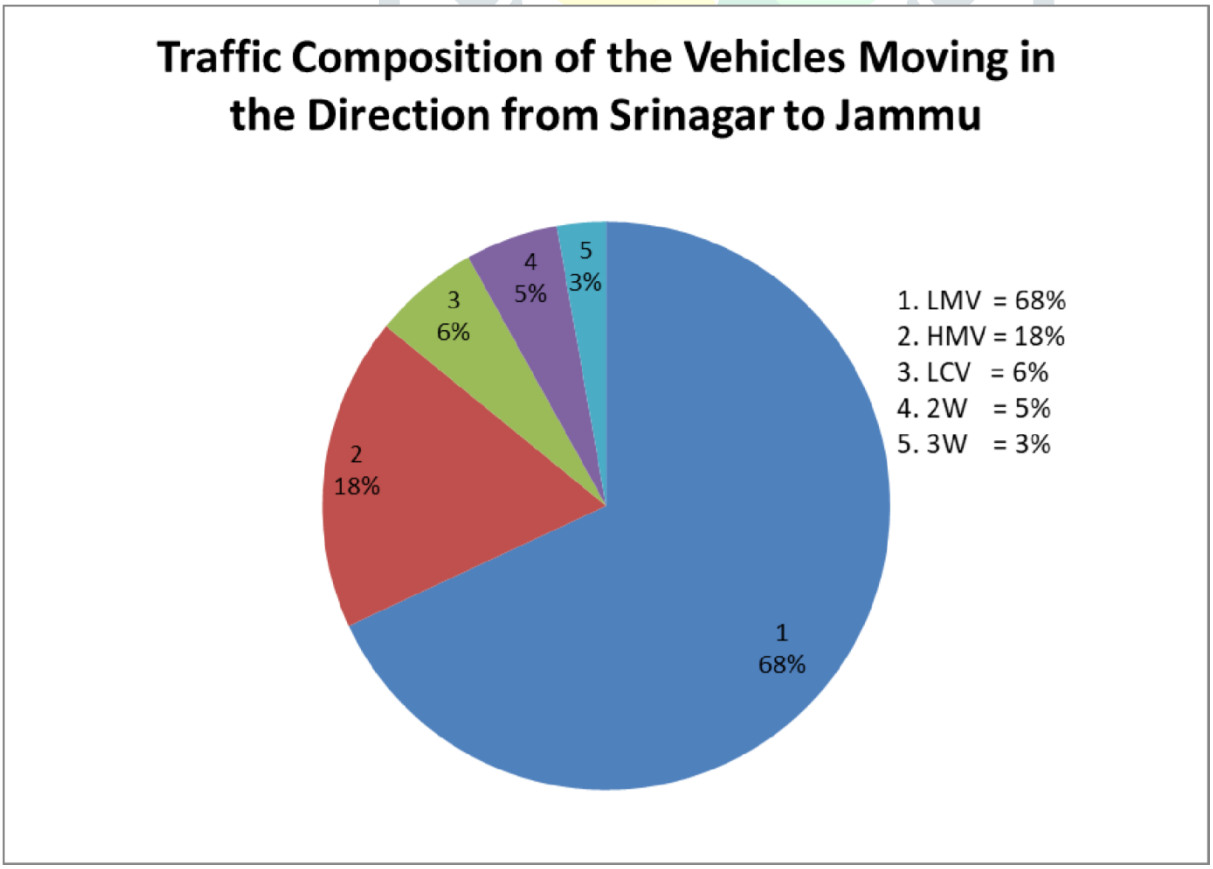

Figure 4: Traffic Composition of Vehicles Moving from Srinagar to Jammu

5. **Time Headway:-**The data obtained from the traffic survey done on the highway, was used to indirectly measure the time headway of the vehicles using the average traffic flow. It was found to be equal to 5.64 sec/veh which means that after every 5.64 seconds a vehicle passes a particular point on the highway.

$$h_{av} = 5.64 \frac{sec}{veh}$$

6. **Space Headway:-**By using the average traffic density of the National Highway NH 44, we also calculated the space headway of the vehicles. It was equal to 74.35 meter/veh which means that the space between two consecutive vehicles is 74.35 meters.

$$s_{av} = 74.35 \frac{meter}{veh}$$

7. **Development of Model:-** From all the data made available during the traffic survey conducted on the NH 44 for the vehicles moving in the direction from Srinagar to Jammu, the following model was developed (after performing the regression analysis of the data collected).

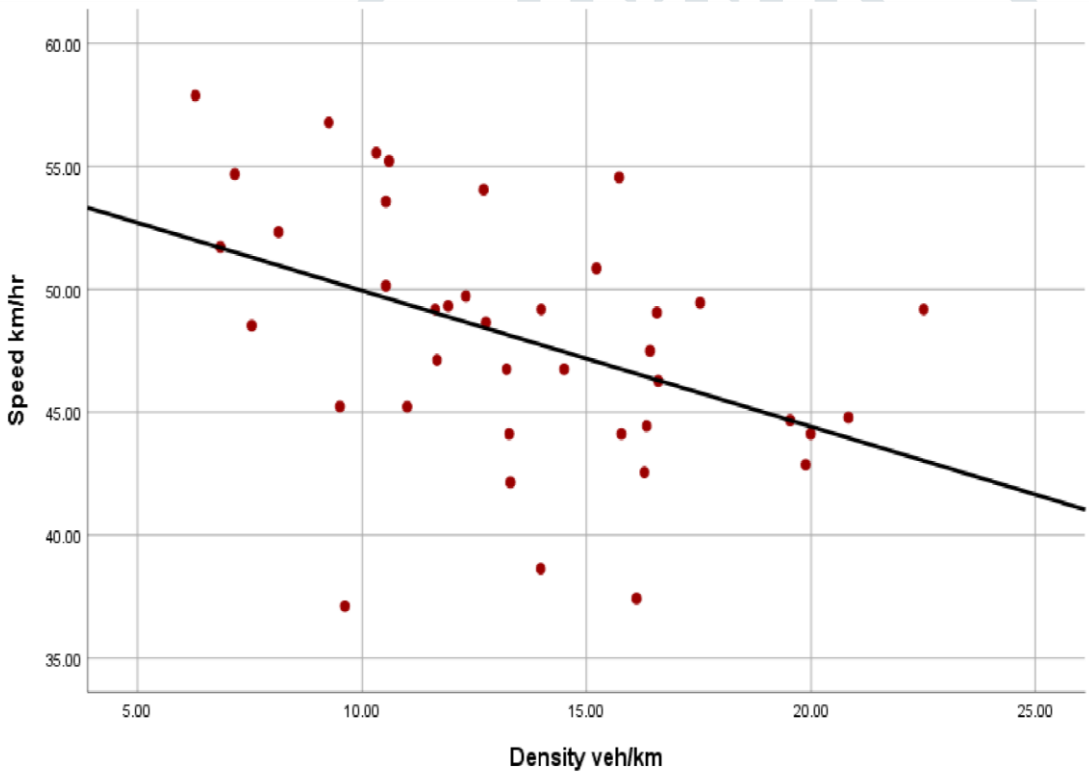

Figure 5: Speed (km/hr) vs Density (veh/km) Plot in Srinagar- Jammu Direction

Figure 5 shows the relation between the traffic density (along x- axis) and the speed of the vehicles (along y- axis). The equation for the plot is as follows

$$v = 55.47 - 0.55k$$

Where v = speed in km/hr and k = density in veh/km

The flow-density curve and the speed-flow curve are given in Figure 6 and Figure below:

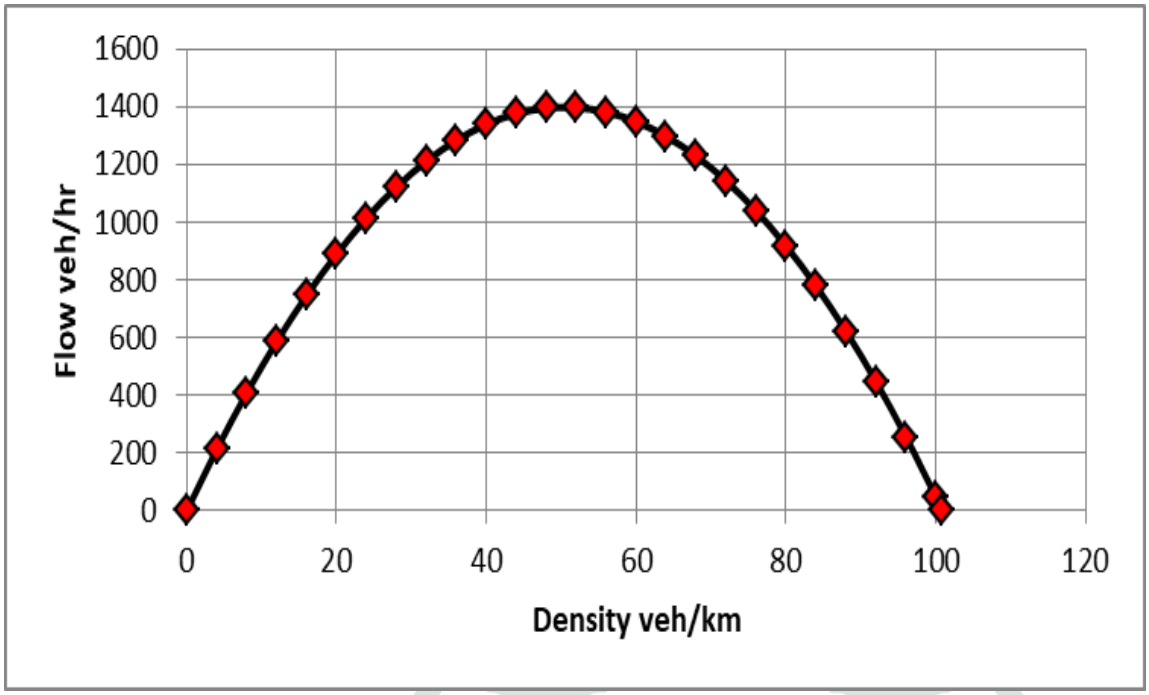

Figure 6: Flow (veh/hr) vs Density (veh/km) Plot in Srinagar- Jammu Direction

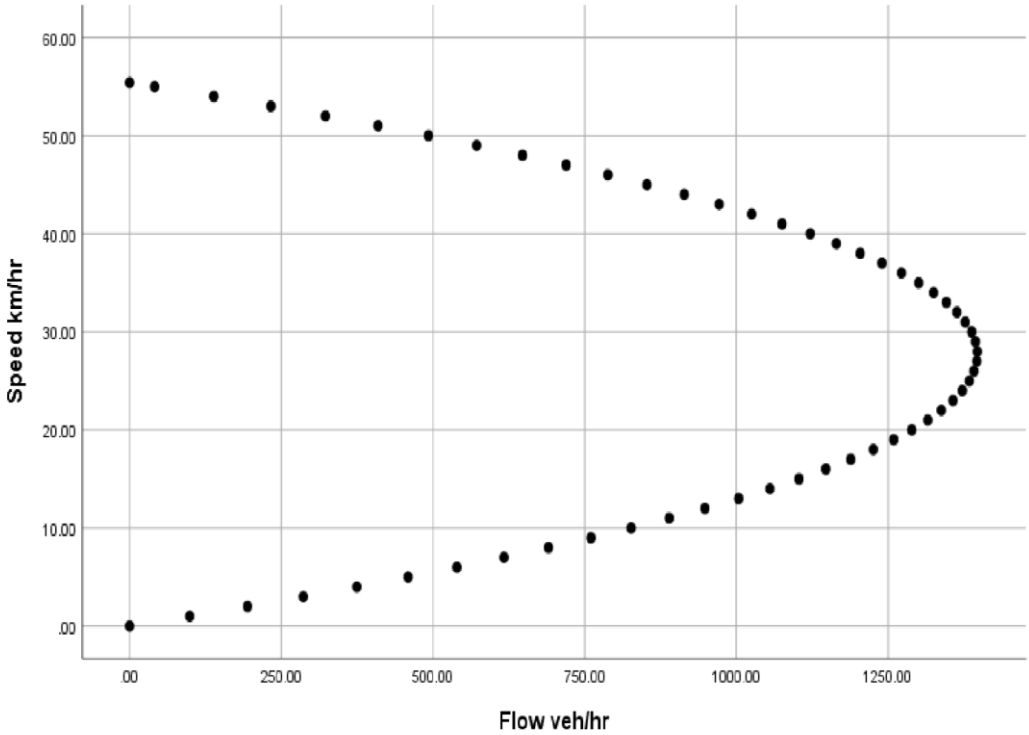

Figure 7: Speed (km/hr) versus Flow (veh/hr) Plot in Srinagar- Jammu Direction

The relation between the traffic flow in veh/hr and traffic density in veh/km was found out to be as below:

$q = 55.47k - 0.55k^2$(14.1.2)

Where q is flow in veh/hr and k is density in veh/km.

The relation between the traffic speed and traffic flow was found out to be as below:

$q = 100.85v - 1.82v^2$ Where q is traffic flow in veh/hr and speed in km/hr.

The traffic on the highway is extensively heterogeneous and we developed individual models for various types of vehicles. The main plot of speed-density curve has been plotted for Light Motor Vehicles, Heavy Motor Vehicles, Light Commercial Vehicles, Two Wheelers and Three Wheelers separately. It will be useful to understand the characteristics of various types of vehicles in a nice way.

The models for LMVs, HMVs, LCVs, Two wheelers and Three wheelers with their corresponding relations are given below:

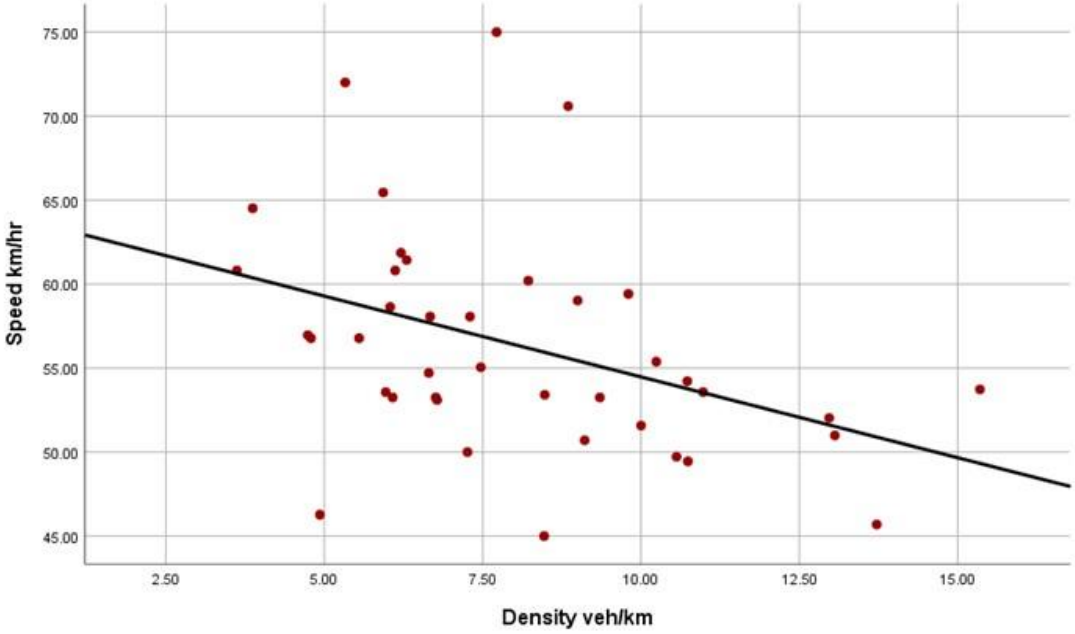

Figure 8: Model for LMVs in Srinagar- Jammu Direction

$v = 64.1 - 0.96k$

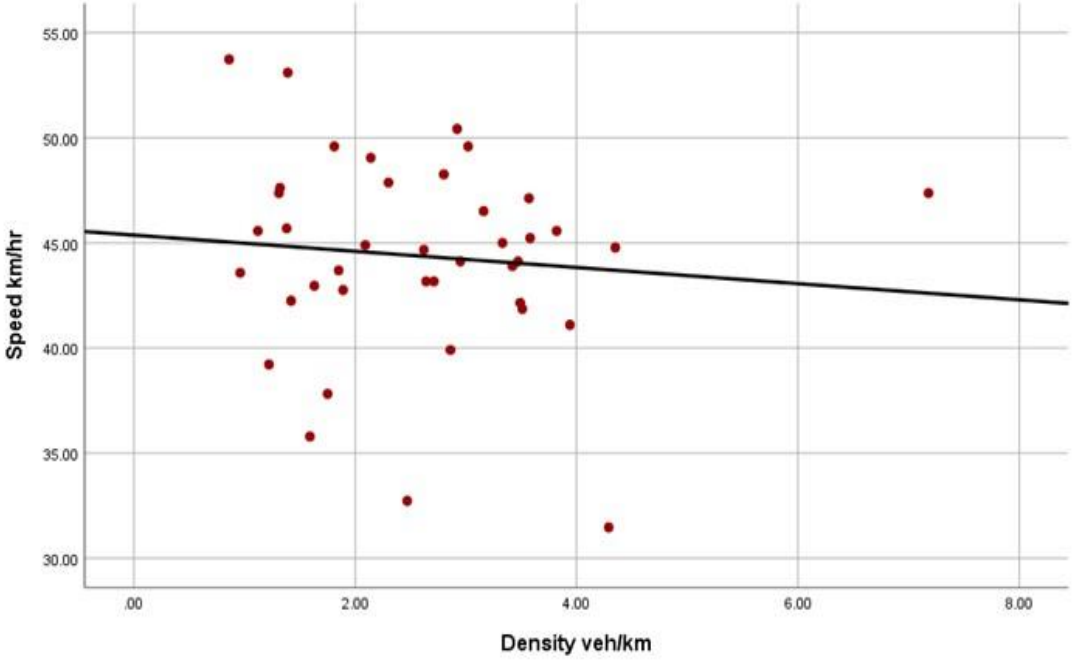

Figure 9: Model for HMVs in Srinagar- Jammu Direction

$v = 45.37 - 0.38k$

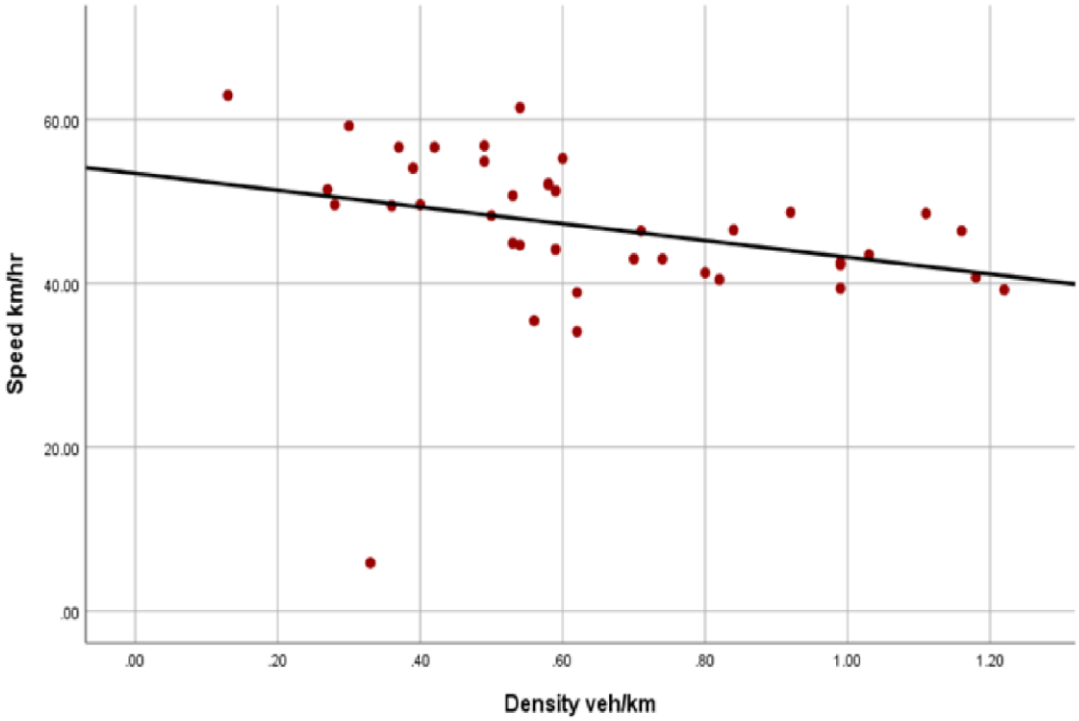

Figure 10: Model for LCVs in Srinagar- Jammu Direction

$v = 53.4 - 10.23k$

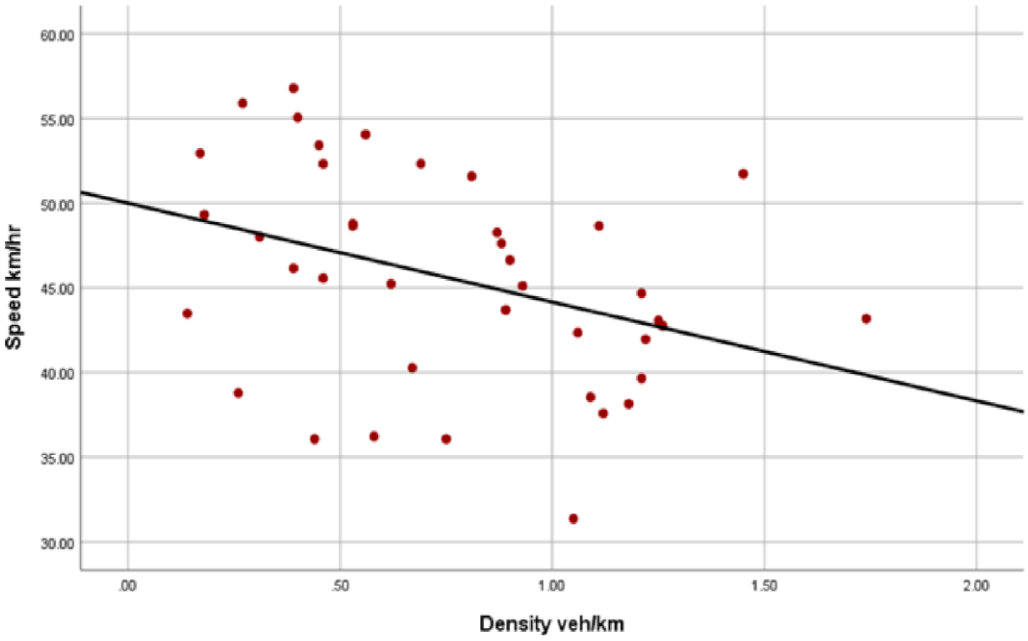

Figure 11: Model for 2 Wheelers in Srinagar- Jammu Direction

$v = 49.99 - 5.84k$

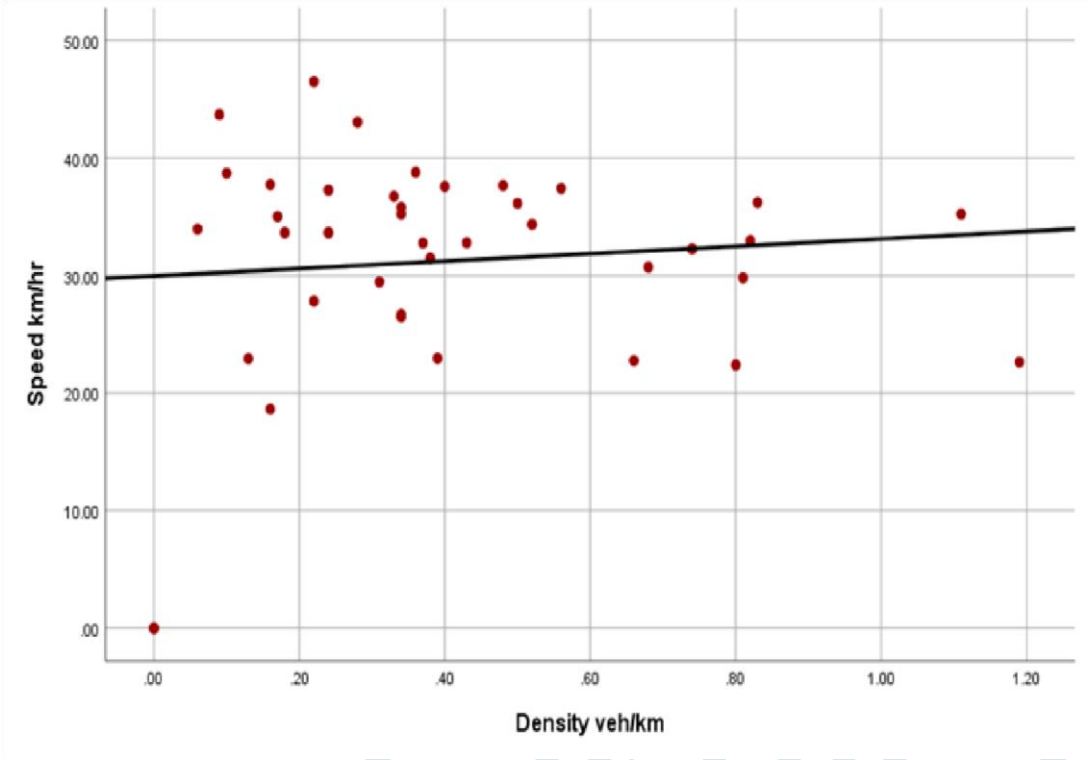

Figure 12: Model for 3 Wheelers in Srinagar- Jammu Direction

$v = 29.96 + 3.16k$

As the traffic on the highway is extremely heterogeneous, I multiplied the vehicles with their corresponding PCU values and therefore developed a model for traffic moving in the direction of Srinagar to Jammu in terms of Passenger Car Units (PCUs) and it is shown as follows in Figure 13.

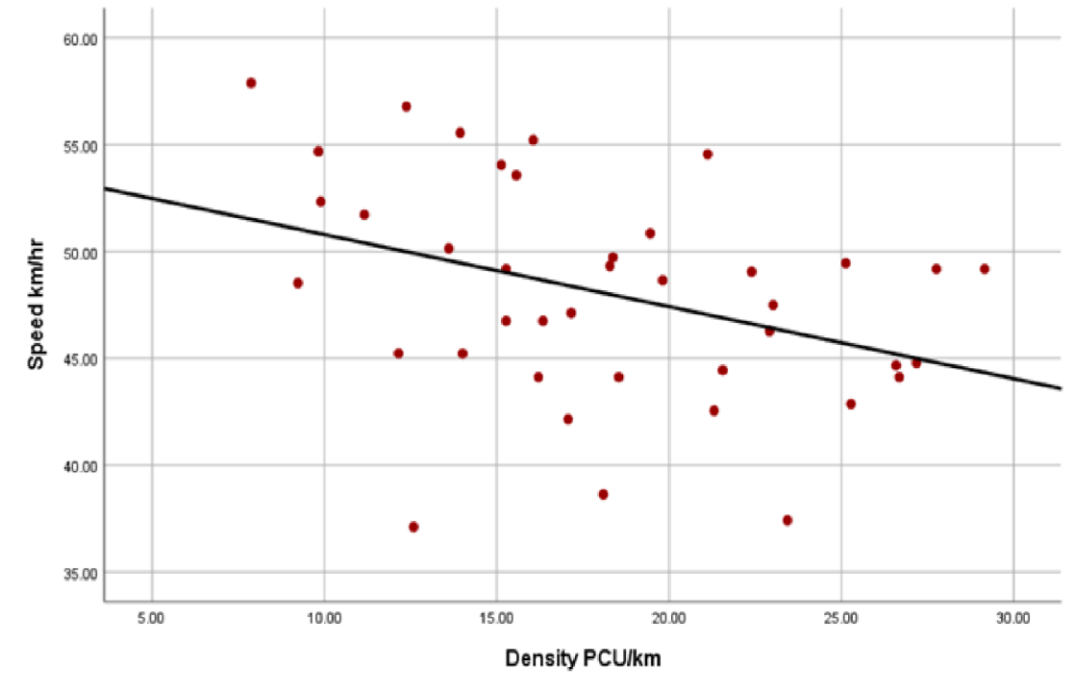

Figure 13: Speed (km/hr) vs Density (PCU/km) Plot in Srinagar- Jammu Direction

The relation that is obtained from the Figure 13 is

$v = 54.15 - 0.34k$

Where v is speed in km/hr and k density in PCU/km.

The Flow-Density curve and Speed- Flow curve are shown in Figure 14 and Figure 15 respectively.

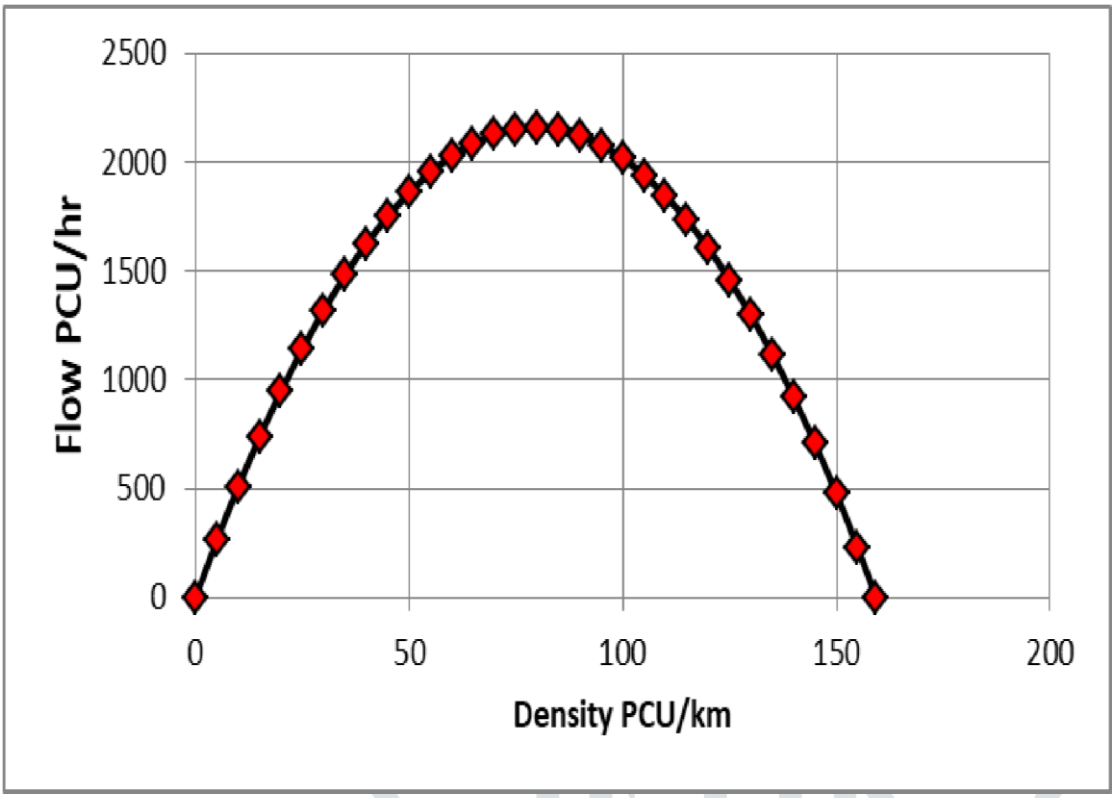

Figure 14: Flow (PCU/hr) versus Density (PCU/km) Plot in Srinagar- Jammu

Direction

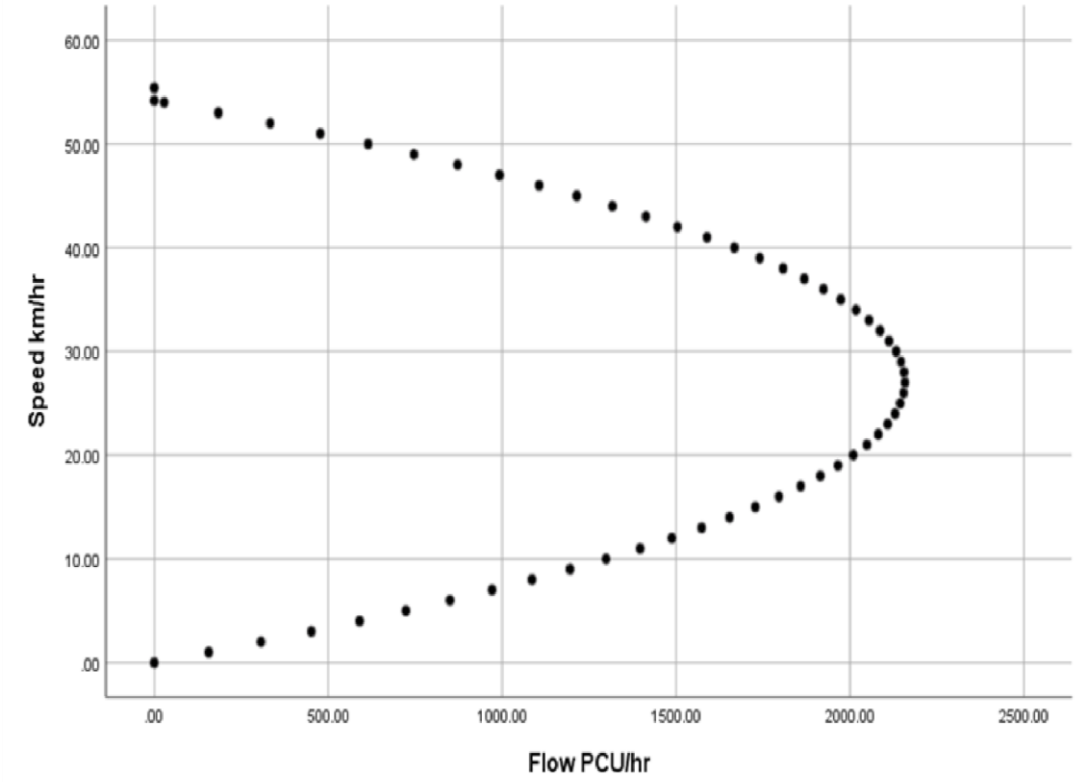

Figure 15: Speed (km/hr) versus Flow (PCU/hr) Plot in Srinagar- Jammu Direction The relation between the traffic flow and traffic density is as follows:

$q = 54.16k - 0.34k^2$

Where q is the traffic flow in PCU/hr and k is the traffic density in PCU/km.

The relation between the traffic speed and traffic flow is as follows:

$q = 159.29v - 2.94v^2$ Where q is the traffic flow in PCU/hr and v is traffic speed in km/hr.

8. Validation of Developed Model:-For the validation of the model that was developed and is shown in Figure 5 and equation, another survey was done and the observed values of traffic density were compared with the traffic density obtained from the equation and the error is noted. All the observations are given in Table C below:

Table C: Validation of Developed Model in Srinagar- Jammu Direction

S.No	Speed of Vehicle (v in km/hr)	Observed Traffic Density (veh/km)	Traffic Density obtained from eqn (6.1.1) $(k = \frac{(55.47 - v)}{.55})$	Percentage Error
1	51.72	6.84	6.82	0.29%
2	49.18	11.63	11.44	1.66%
3	53.16	6.29	4.2	49.76%
4	48.03	13.45	13.53	0.59%
5	49.32	11.92	11.18	6.62%
6	50.14	10.53	9.69	8.67%
7	52.45	9.51	5.49	73.22%
8	47.55	12.71	14.4	11.74%
9	44.67	19.54	19.64	0.51%
10	45.55	22.51	18.04	24.78%

From Table C, we observe the average error, in the measurement observed values of density and the values of density obtained from the equation , is 17.78%, hence, we can conclude that the model we developed is 82.22% accurate. Hence the developed model is validated.

9. Free Flow Speed:-From the model developed, one can calculate the free flow speed of the vehicles on National Highway NH-44 moving in the direction of Srinagar to Jammu. It was found to be as follows:

$$free\ flow\ speed = v_f = 55.47\frac{km}{hr}$$

10. Jam Density:- Again I calculated the jam density of the National Highway NH-44 for the traffic moving in Srinagar to Jammu direction from the model that I developed and it was found to be equal to:

$$jam\ density = k_{jam} = 100.85\frac{veh}{km} = 159.29\frac{PCU}{km}$$

11. Maximum Flow:- Further from the model developed, I can calculate the maximum flow of traffic moving on National Highway NH-44 in the direction of Srinagar to Jammu. It was found to be:

$$maximum\ flow = q_{max} = 1398.54\frac{veh}{hr} = 2156.79\frac{PCU}{hr}$$

Corresponding to this maximum flow, we can also find out the density and speed at maximum flow and is equal to:

$$density\ corresponding\ to\ maximum\ flow = k_0 = 50.43\frac{veh}{km} = 79.65\frac{PCU}{km}$$

$$speed\ corresponding\ to\ maximum\ flow = v_0 = 27.73\frac{km}{hr}$$

Traffic Moving in the Direction from Jammu to Srinagar:-

From the survey conducted on the NH-44 for the traffic moving in the direction from Jammu to Srinagar, the following observations made:-

1. **Average Speed of Vehicles:-** It was found that the traffic from Jammu to Srinagar was moving with an average speed of 49.20 km/hr. The traffic under consideration was a also heterogeneous traffic that involved all types of vehicles like Light Motor Vehicles, Heavy Motor Vehicles, Light Commercial Vehicles, Two Wheelers and Three Wheelers. The average speed of different types of vehicles is given in the Table D, given below.

$$v_{av} = 49.20\frac{km}{hr}$$

Table D: Average Speed of Different Types of Vehicles

Type of Vehicle	Average Speed
Light Motor Vehicle (LMV)	59.46 km/hr
Heavy Motor Vehicle (HMV)	44.00 km/hr
Light Commercial Vehicle (LCV)	48.85 km/hr
Two Wheeler	46.13 km/hr
Three Wheeler	35.53 km/hr

2. **Average Traffic Flow:-** The average flow of the traffic was found to be 604 veh/hr. In terms of PCU/hr, it was observed to be 853.93 PCU/hr.

$$q_{av} = 604\frac{veh}{hr} = 853.93\frac{PCU}{hr}$$

3. **Average Traffic Density:-**The density of the traffic was observed to be pretty low. The average value was found to be 12.52 veh/km and in terms of PCU/km, the value was 17.91 PCU//km.

$$k_{av} = 12.52\frac{veh}{km} = 17.91\frac{PCU}{km}$$

4. **Traffic Composition:-**The traffic composition of the various types of the vehicles moving in the direction from Jammu to Srinagar is shown below in Figure 16.

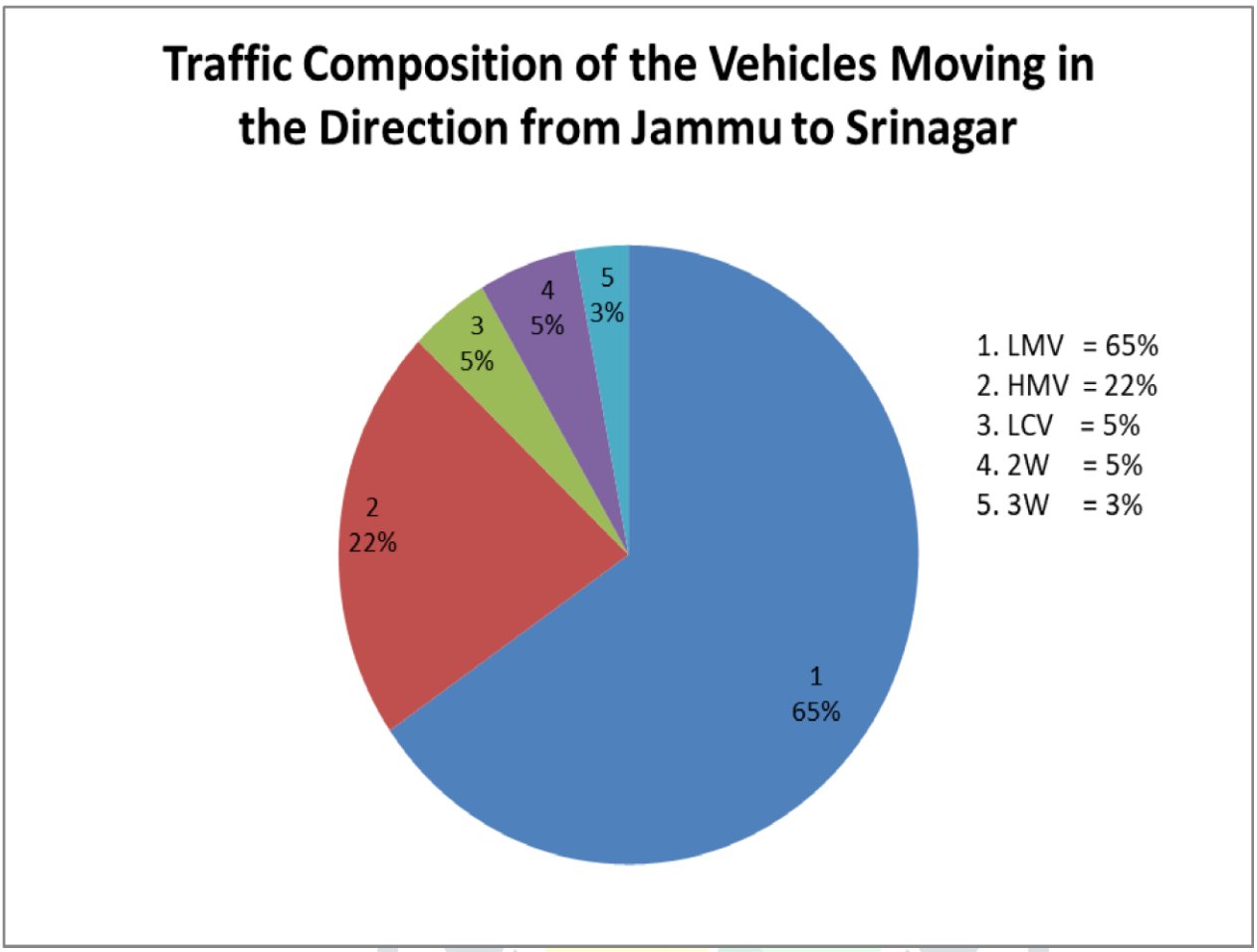

Figure 16: Traffic Composition of Vehicles Moving from Jammu to Srinagar

5. **Time Headway:-**From the data, collected from the traffic survey conducted on the highway, I indirectly measured the time headway of the vehicles using the average traffic flow. It was calculated to be equal to 5.99 sec/veh which means that after every 5.99 seconds a vehicle passes a particular point on the highway.

$$h_{av} = 5.99 \frac{sec}{veh}$$

6. **Space Headway:-**With the help of average traffic density of the National Highway NH 44, I calculated the space headway of the vehicles. It was equal to 79.87 meter/veh which means that the space between two consecutive vehicles is 79.87 meters.

$$s_{av} = 79.87 \frac{meter}{veh}$$

7. **Development of Model:-** From all the information that was collected during the traffic survey done on the NH 44 for the vehicles moving in the direction from Jammu to Srinagar, the following model was developed (after performing the regression analysis of the data collected).

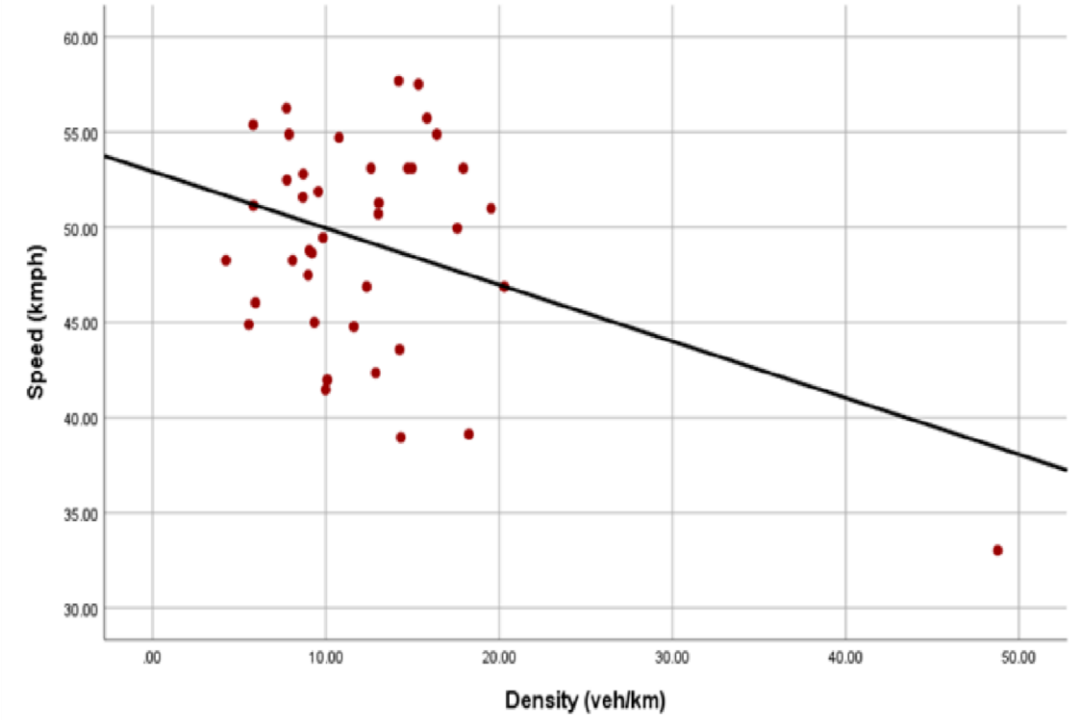

Figure 17: Speed (km/hr) vs Density (veh/km) Plot in Jammu- Srinagar Direction

Figure 17 shows the relation between the traffic density (along x- axis) and the speed of the vehicles (along y- axis). The equation for the plot is as follows

$$v = 52.92 - 0.3k$$

Where v = speed in km/hr and k = density in veh/km
The flow-density curve and the speed-flow curve are given in Figure 18 and Figure 19 below:

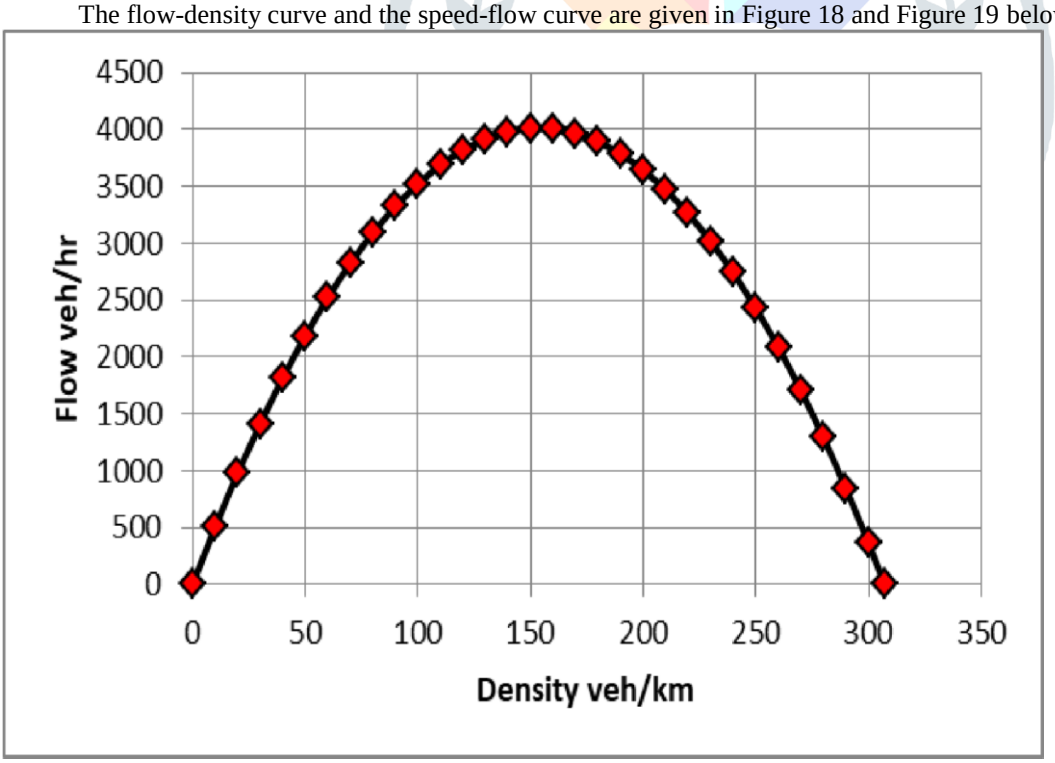

Figure 18: Flow (veh/hr) vs Density (veh/km) Plot in Jammu- Srinagar Direction

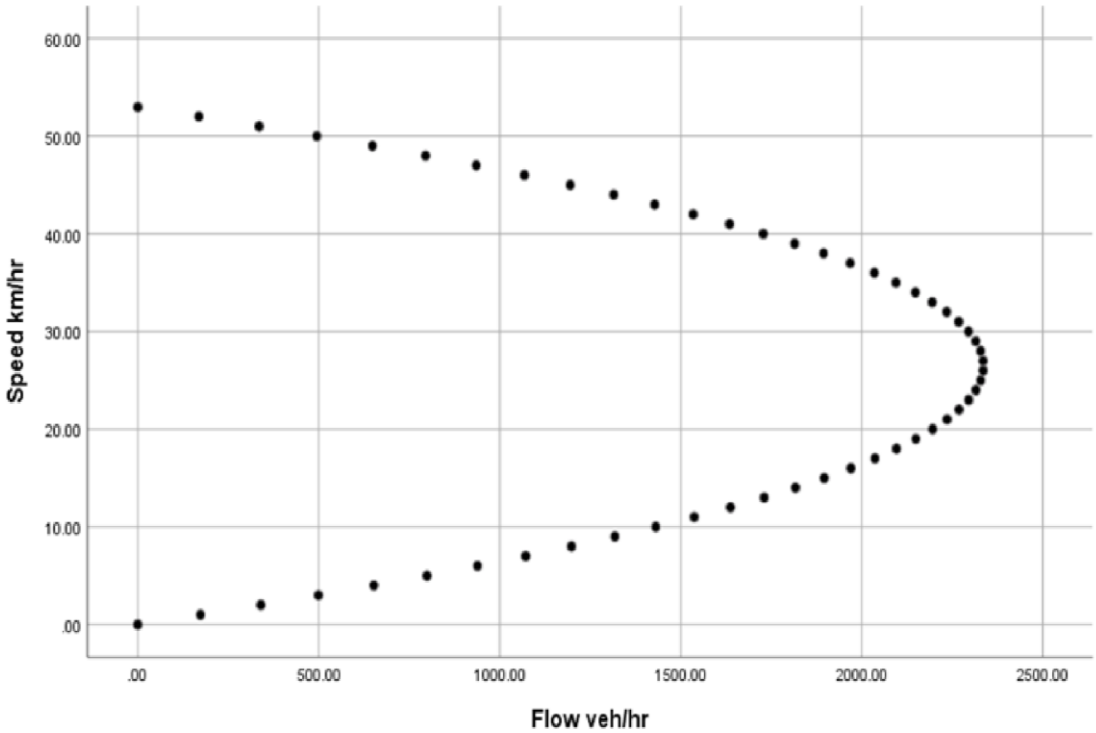

Figure 19: Speed (km/hr) vs Flow (veh/hr) Plot in Jammu- Srinagar Direction

The relation between the traffic flow in veh/hr and traffic density in veh/km was observed to be as shown below:

$q = 52.92k - 0.3k^2$(14.2.2)

Where q is flow in veh/hr and k is density in veh/km.

The relation between the traffic speed and traffic flow was found out to be as below:

$q = 176.4v - 3.33v^2$ (14.2.3)

Where q is traffic flow in veh/hr and speed in km/hr.

The traffic on the highway is very heterogeneous and we could develop individual models for different types of vehicles. The main plot of speed-density curve has been plotted for Light Motor Vehicles, Heavy Motor Vehicles, Light Commercial Vehicles, Two Wheelers and Three Wheelers separately. It will be beneficial to understand the characteristics of various types of vehicles in a better way.

The models for LMVs, HMVs, LCVs, Two wheelers and three wheelers with their corresponding relations are given below:

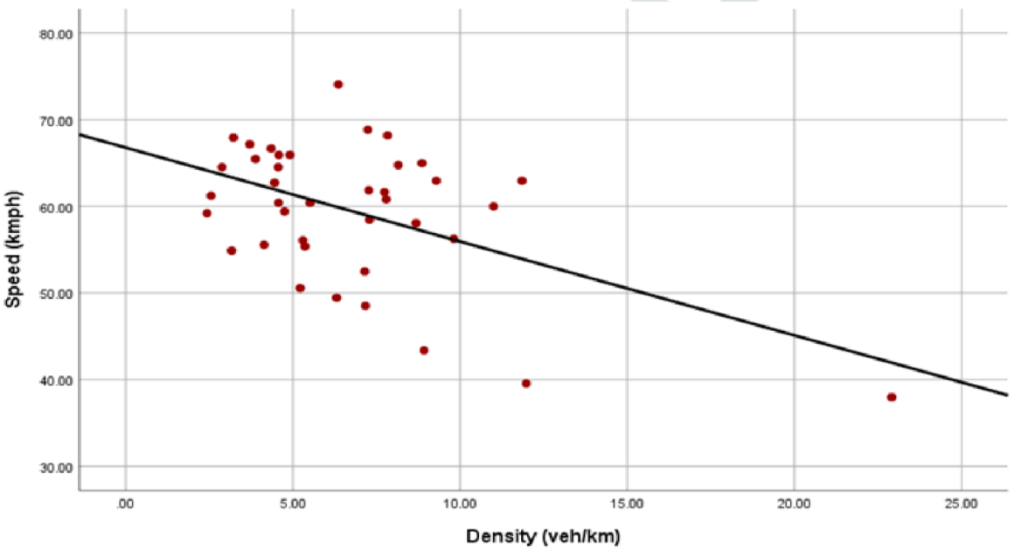

Figure 20: Model for LMVs in Jammu- Srinagar Direction

$v = 66.77 - 1.08k$

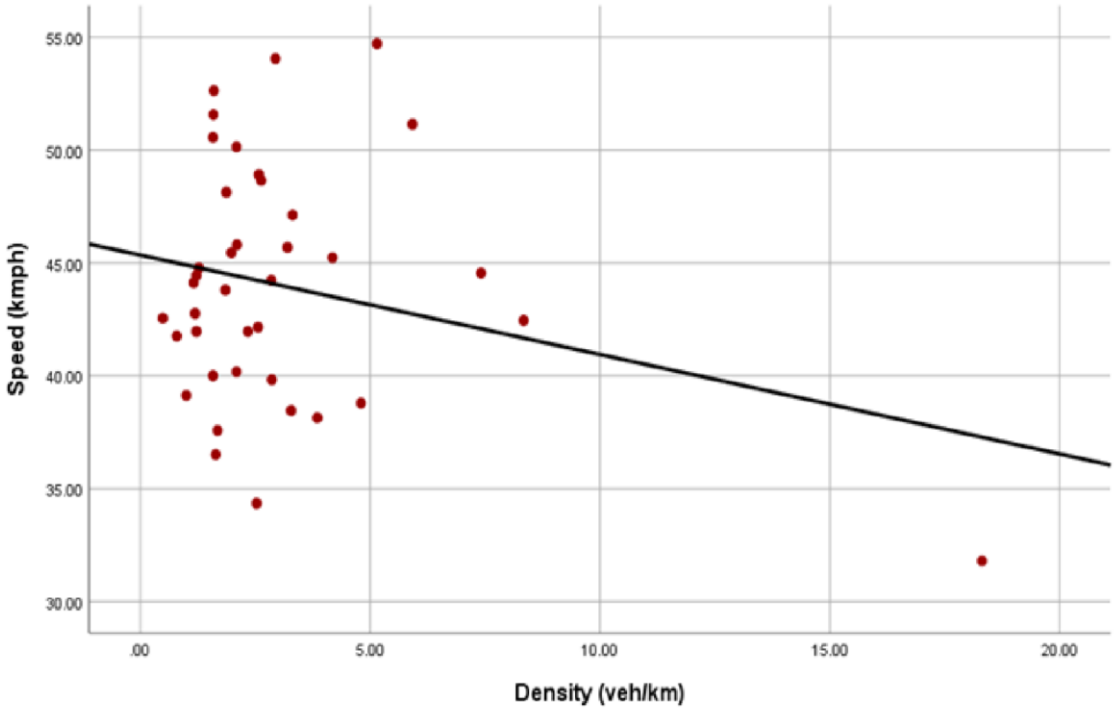

Figure 21: Model for HMVs in Jammu- Srinagar Direction

$v = 45.35 - 0.44k$

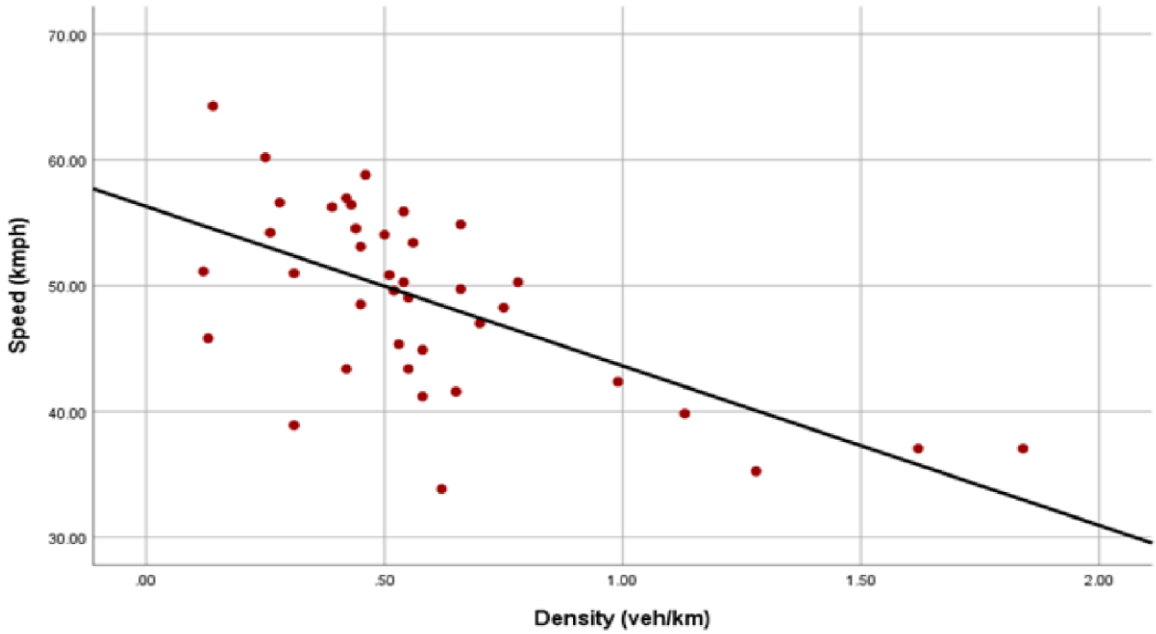

Figure 22: Model for LCVs in Jammu- Srinagar Direction

$v = 56.3 - 12.68k$

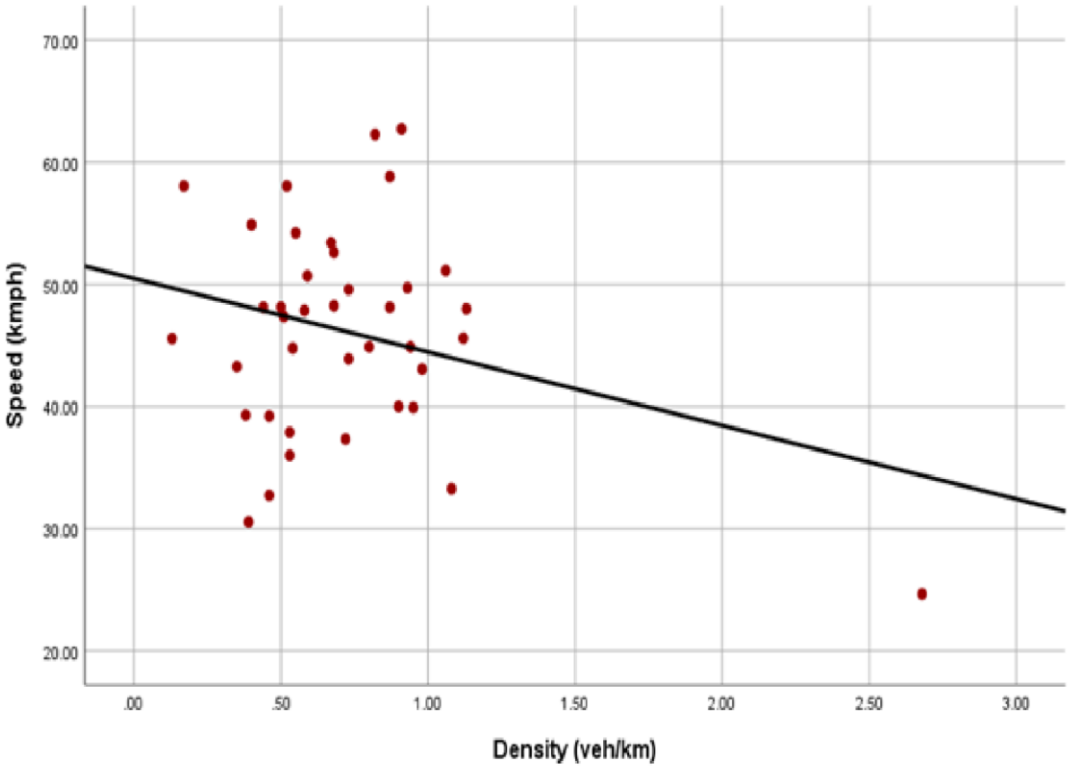

Figure 23: Model for 2 Wheelers in Jammu- Srinagar Direction

$v = 50.49 - 6.02k$

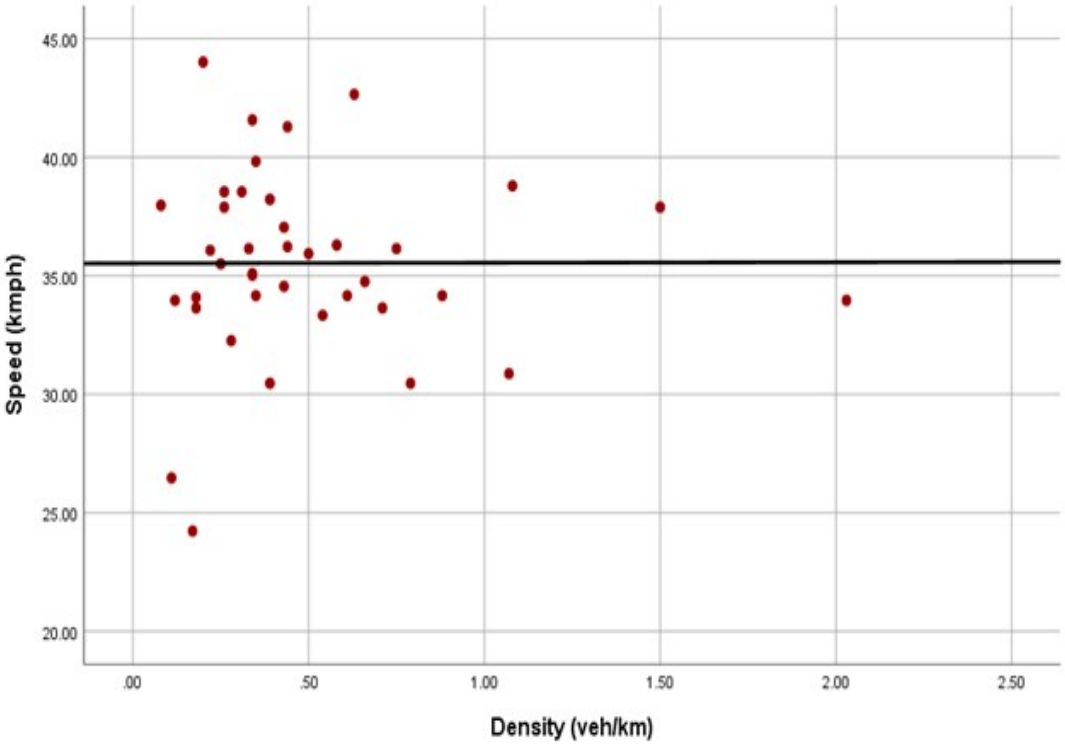

Figure 24: Model for 3 Wheelers in Jammu- Srinagar Direction

$v = 35.52 + 0.02k$

As the traffic on the highway is extremely heterogeneous, I multiplied the vehicles with their corresponding PCU values and hence developed a model for traffic moving in the direction of Jammu to Srinagar in terms of Passenger Car Units (PCUs) and it is given as shown in Figure 25.

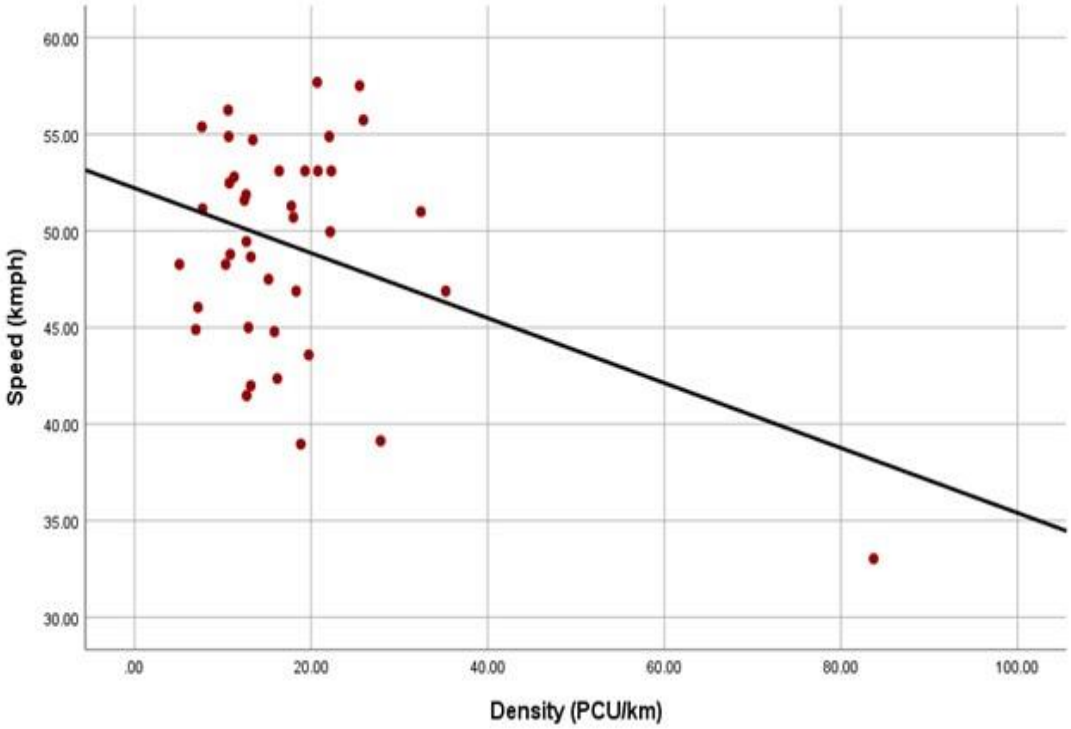

Figure 25: Speed (km/hr) vs Density (PCU/km) Plot in Jammu- Srinagar Direction

The relation that is obtained from the Figure 25 is

$v = 52.21 - 0.17k$

Where v is speed in km/hr and k density in PCU/km.

The Flow-Density curve and Speed- Flow curve are shown Figure 26 and Figure 27 respectively.

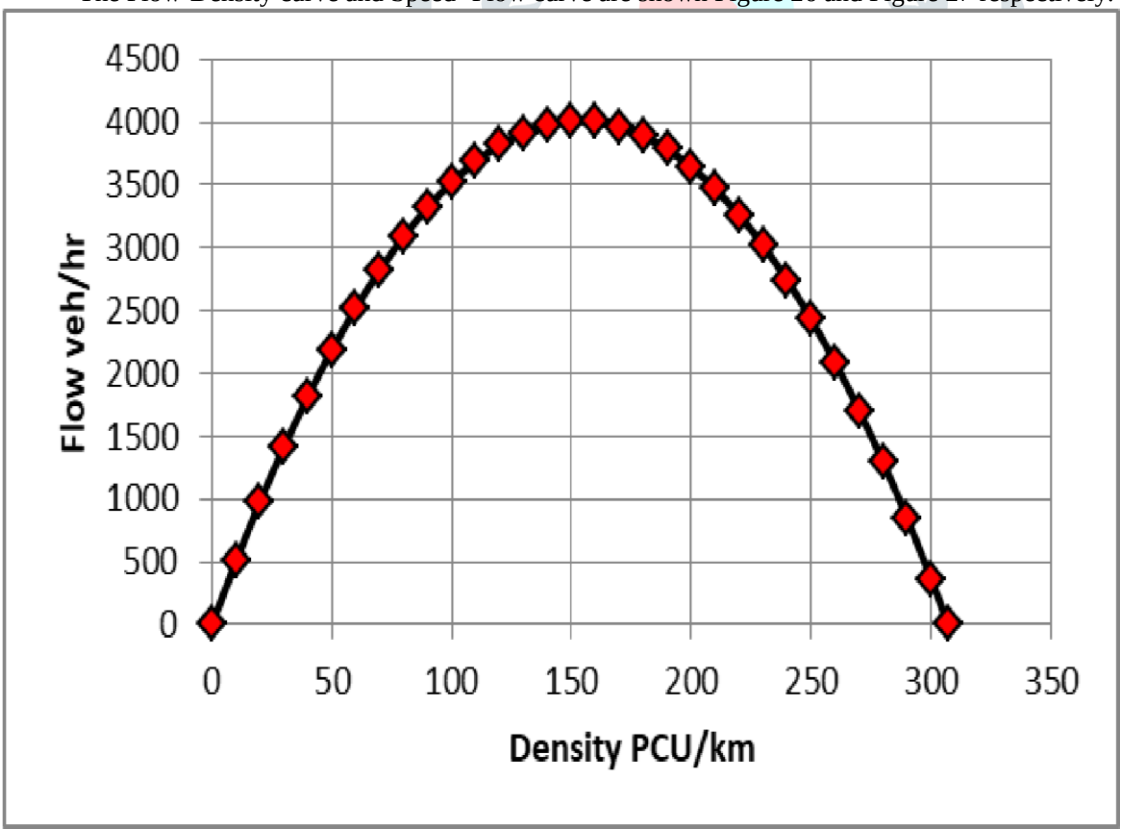

Figure 26: Flow (PCU/hr) vs Density (PCU/km) Plot in Jammu- Srinagar Direction

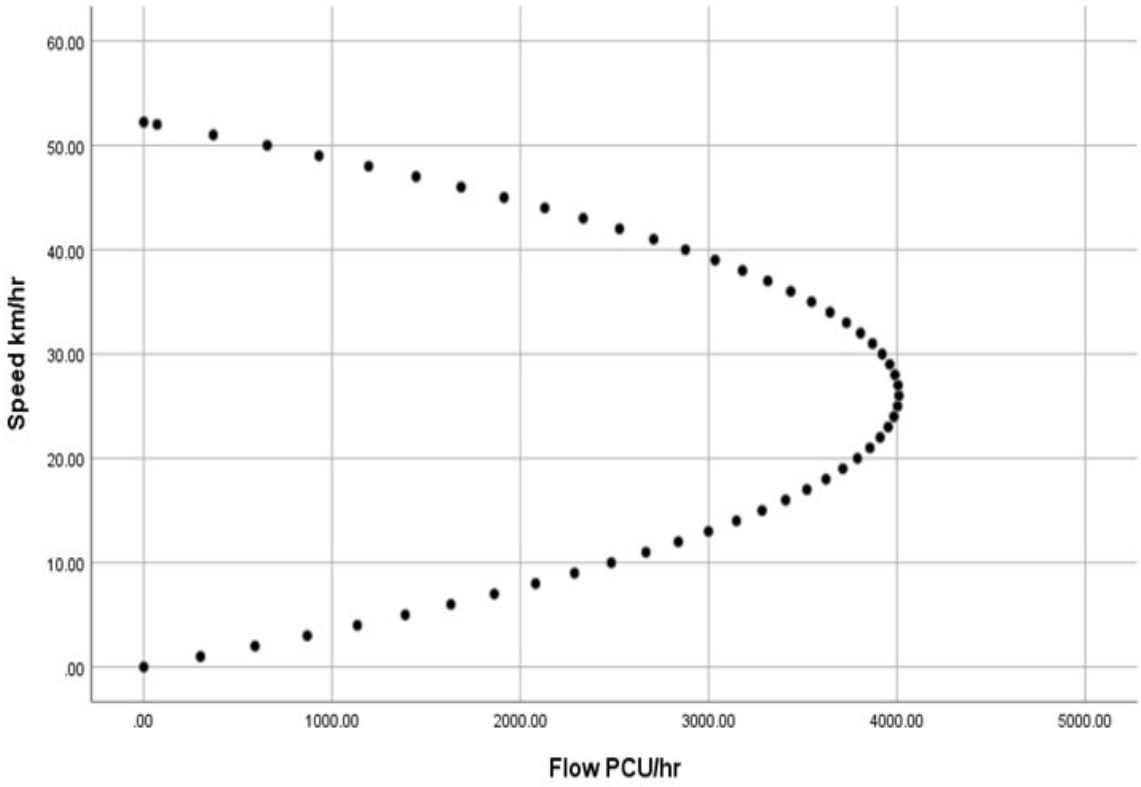

Figure 27: Speed (km/hr) vs Flow (PCU/hr) Plot in Jammu- Srinagar Direction

The relation between the traffic flow and traffic density is as follows:

$q = 52.21k - 0.17k^2$

Where q is the traffic flow in PCU/hr and k is the traffic density in PCU/km.

The relation between the traffic speed and traffic flow is as follows:

$q = 307.12v - 5.88v^2$ Where q is the traffic flow in PCU/hr and v is traffic speed in km/hr.

8. Validation of Developed Model:-For the validation of the model that was developed and is shown in Figure 17 and equation , one more survey was done and the observed values of traffic density were compared with the traffic density obtained from the equation and the error is noted. All the observations are given in Table E shown below:

Table E: Validation of Developed Model in Jammu- Srinagar Direction

S.No	Speed of Vehicle (v in km/hr)	Observed Traffic Density (veh/km)	Traffic Density obtained from eqn (6.2.1) $(k = \frac{(52.92 - v)}{.3})$	Percentage Error
1	51.58	8.67	4.47	93.96%
2	48.65	9.19	14.23	35.42%
3	51.14	5.81	5.93	2.02%
4	49.45	9.83	11.57	15.04%
5	46.88	20.29	20.13	0.79%
6	49.20	12.52	12.4	0.97%
7	50.55	7.72	7.9	2.28%
8	47.67	17.93	17.5	2.46%

9	48.55	15.83	14.57	8.65%
10	49.99	10.08	9.77	3.17%

From Table E, we observe that the average error, in the measurement observed values of density and the values of density derived from the equation , is 16.48%, hence, we can conclude that the model we developed is 83.52% accurate. Therefore the developed model is validated.

9. **Free Flow Speed:-**From the model developed, one can calculate the free flow speed of the vehicles on National Highway NH-44 moving in the direction of Jammu to Srinagar. It was observed to be as follows:

$$free\ flow\ speed = v_f = 52.92\frac{km}{hr}$$

10. **Jam Density:-** I calculated the jam density of the National Highway NH-44 for the traffic moving in Jammu to Srinagar direction from the model that I developed and it was observed to be equal to:

$$jam\ density = k_{jam} = 176.4\frac{veh}{km} = 307.12\frac{PCU}{km}$$

11. **Maximum Flow:-** Further from the model developed, I can calculate the maximum flow of traffic moving on National Highway NH-44 in the direction of Jammu to Srinagar. It was equal to:

$$maximum\ flow = q_{max} = 2333.77\frac{veh}{hr} = 4008.68\frac{PCU}{hr}$$

Corresponding to this maximum flow, we can also obtain the density and speed at maximum flow and is equal to:

$$density\ corresponding\ to\ maximum\ flow = k_0 = 88.20\frac{veh}{km} = 153.56\frac{PCU}{km}$$

$$speed\ corresponding\ to\ maximum\ flow = v_0 = 26.46\frac{km}{hr}$$

CONCLUSIONS

Macroscopic relations play a significant role in traffic flow modeling and speed-density relation is extensively used as the basic relation to estimate the other macroscopic relations. Estimation of Speed-density model itself depends on how the corresponding field data is collected or predicted on these variables. The estimated parameters of speed-density model depend also on the methodology adopted for model estimation. Greenshield's linear speed density model widely used for modeling the heterogeneous traffic stream behaviour.

The traffic conditions in India are very heterogeneous, so a study was conducted to understand the traffic conditions and characteristics of traffic in India.

The traffic flow on National Highway is low, which results in low traffic density but high speeds of the vehicles. Our study also concentrated on the types of vehicles that normally occupy the highway.

It was also found that Light Motor Vehicles (LMVs) and Heavy Motor Vehicles (HMVs) form the majority of the traffic that moves on the National Highway NH-44 with approximately 66.5% and 20% of the total traffic respectively. Light Commercial Vehicles, Two Wheelers and Three Wheelers form a very small percentage of the total traffic that moves on the National Highway NH-44, with just 5.5%, 5% and 3% of the total traffic respectively.

The traffic flow also varies at different hours of the day. During the survey, I observed that the during the morning peak hour, i.e. time between 7:00 am to 9:30 am in the morning, the maximum traffic movement was observed in the Srinagar- Jammu Direction and the at the evening peak hour, i.e. time between 4:00 pm to 6:00 pm in the evening, the maximum traffic movement was observed in the Jammu- Srinagar traffic. During the nonpeak hours, i.e. from 10:00 am in the morning to 3:00 pm in the evening, the traffic stream was found to be very low and the traffic flow came down to as low as 200 vehicles per hour.

The average speed of vehicles on the National Highway NH-44 is 48.62 km/hr. While majority of the Light Motor Vehicles (LMVs), Light Commercial Vehicles (LCVs) and two wheelers tend to move very fast but the average of the total traffic is low because of the low speeds of three wheelers and Heavy Motor Vehicles (HMVs). From the surveys conducted, I can conclude that the stream speed of the vehicles vary as low 25 km/hr and as high as 120 km/hr.

The density of the National Highway NH-44 is low as well because of very low traffic and the average value of density is approximately 13 veh/km. In other words it means only 13 vehicles occupy 1 km length of road. The traffic density on the National Highway NH-44 has been observed to vary from 4 vehicles per km to 44 vehicles per km.

The micro parameters of traffic also play an vital role to understand the characteristics of the traffic moving on the National Highway NH-44 better. The average time headway of the traffic moving on the highway is 5.82 seconds per vehicle which means that after every 5.82 seconds a new vehicle passes a particular point on the highway.

Further the average space headway was found out to be 77.11 meter per vehicle which means that the distance between two consecutive vehicles at a particular time is 77.11 meters. Morever the travel time of the vehicles on the National Highway NH-44 is very low as free flow speed can be achieved by the vehicle easily.

The relation between the macro parameters of traffic stream is given in this report in the previous section and from the model that we developed we can conclude that the average free flow speed of the vehicles moving on the National Highway is pretty low at just 53 km/hr, which is just little more than the average speed of the vehicles running on the road.

Also from the developed model, I can conclude that the jam density of the highway is quite high and is much greater than the highest density observed during the traffic survey conducted on the highway.

Similarly the maximum flow that can be accommodated on the National Highway is extremely high with approximately 2000 veh/hr, whereas from the survey conducted the maximum flow observed did not even cross the 1000 veh/hr mark. All these values have been converted to their corresponding Passenger Car Units as well in the previous section.

I have developed two separate models for the traffic moving in Srinagar- Jammu direction as well as the Jammu- Srinagar direction. But on comparing both the models, I observed that both the models are very much similar with just little differences. I can finally conclude from the study of traffic stream parameters on National Highway NH-44 under heterogeneous conditions that the highway caters to the present day demands of the traffic very well and will continue to do so atleast for another 15-20 years.

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