TRAFFIC CHARACTERISTICS OF NON-MOTORIZED VEHICLES IN MIXED TRAFFIC

A THESIS SUBMITTED IN THE PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

[Specialization: Transportation Engineering]

By

Saikiran Gunisetty

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Department of Civil Engineering

National Institute of Technology, Rourkela

Odisha – 769008

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Under the guidance of

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Rourkela (India)

CERTIFICATE

This is to certify that the thesis entitled, **"Traffic Characteristics Of Non-Motorized Vehicles in Mixed Stream"** submitted by **Mr. Saikiran Gunisetty** in partial fulfillment of the requirements for the award of Master of Technology in Civil Engineering with "Transportation Engineering" Specialization during session 2014-2015 in the Department of Civil Engineering, National Institute of Technology, Rourkela.

It is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

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I express my special thanks to my friends for their help during the collection of data for the project. I also express my thanks to the staff members of Department of civil Engineering, NIT Rourkela for providing me the necessary facilities that is required to conduct the project and complete my thesis.

DATE: **SAIKIRAN GUNISETTY**

ABSTRACT

In present day scenario, in countries like India we can find mixed traffic conditions, i.e. traffic flow constituting of all sorts of vehicles like cycles, rickshaws, auto and so on. During the peak hours, the flow of NMVs is high. The presence of NMV in the traffic stream affect the traffic characteristics like speed, density and flow of the stream. In order to design a traffic facility, the traffic behavior has to be understood. For the mixed traffic conditions, it is difficult to understand the behavior of the stream. In this thesis, an endeavor is kept to study the traffic characteristics of NMVs in mixed stream.

The entire project work is consists of two parts. The former is the experimental part and the latter is the statistical testing part. The former part of study includes the study of the fundamental diagrams, finding the capacity of the section and the lateral occupancy of the section for the data obtained from the various parts of the Rourkela City. It was seen that with the change in the NMV percentage an adversity is found in the parameters like speed, density and flow. In the study of lateral occupancy, it is observed that in one way divided traffic flow, the maximum number of NMVs are occupying the left two strips and the MVs are occupying the right most strips as our Indian traffic behavior is left handed and it is easy for the MVs to overtake the slow moving vehicles. In the case of undivided two way traffic, the maximum number of traffic is found in the middle portions but a minimum on the right and left strips in the light of fact that the vehicles are present in the opposite directions.

In the statistical analysis part, a comparison is made for the traffic parameters in Rourkela City between 2011 and 2014. The hypothesis testing is conducted between the traffic parameters and variations are found. The hypothesis testing compares the means of the two observed samples. The procedure follows four steps. The first step is of stating the null hypothesis, it is followed by test static, P-value and conclusion and finally decision making. The decision is made on the basis of Z observed and the obtained P-value. The results indicate that the percentage NMV is decreased from 2011 and the speed and flow got increased from 2011.

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NOMENCLATURE

DESCRIPTION	SHORT FORM
Non-Motorized Vehicle	NMV
Motorized Vehicle	MV
Speed	u
Flow	q
Density	K
Passenger Car Unit	PCU
Mean of first sample	μ_1
Mean of second sample	μ_2
Null Hypothesis	H_0
Alternate Hypothesis	H_a
Level of significance	α

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

In the present day scenario almost all the road traffic consists of mixed traffic, i.e. the combination of both Non-Motorized and Motorized traffic. The mixed traffic affects the characteristics of the traffic stream to a great extent.

Non-Motorized Vehicles are the vehicles which will run with the power of human beings or animals. The non-motorized vehicles includes bicycles, rickshaws, and hand drawn vehicles, pull carts and so forth.

Motorized vehicles are those vehicles which run with the power of the engines. The motorized vehicles are divided into light motorized vehicles and heavy motorized vehicles. Light motorized vehicles consists of auto rickshaws, jeeps, taxis, motorcars, three-wheeler conveyance vans and so forth. Motorcycles do not come under this category. Heavy motorized vehicles consists of vehicles with number of wheels more than six. This Heavy Motorized Vehicles consists of Buses, Lorries, and Trucks etc.

As per the World Bank survey about 50 percent of the non-motorized vehicles are present in the south Asian nations like India, Bangladesh. In Bangladesh, the maximum number of trips generated during peak hours is due to non-motorized vehicles like bicycles, rickshaws.

The presence of non-motorized vehicles affect the capacity of the section. With the increase in the Non-Motorized vehicle capacity, the total capacity of the section will be reduced, affects the safety of the total stream and the declining of energy resources (petrol, diesel etc.). In order to minimize the consequences of Non-Motorized vehicles there should be a separate track for Non-Motorized

vehicles like in U.S.A. or else proper study should be made on the Non-Motorized vehicles and its effects on the traffic stream.

In India practically it is not possible to lay a separate track for Non-Motorized vehicles, so proper study has to be conducted on Non-Motorized Vehicles and its characteristics along the mixed stream. Hence Non-Motorized vehicular movement and its effects on traffic characteristics are taken into account in the project.

1.1 TRAFFIC FLOW PARAMETERS:

1.1.1 SPEED:

Speed is defined as the time taken by a vehicle to cross certain distance and is denoted by 'u'. As per traffic terminology, speed is the distance travelled by a vehicle over a certain period of time. While considering a section, individual speed is not considered, average speed is considered.

There are two speeds available. They are time mean speed, space mean speed.

Time mean speed: It is the arithmetic mean of the speeds that occur in the section with the flow of vehicles.

Space mean speed: It is the harmonic mean of the speeds of the vehicles that occurred over the space at instant time or it is the ratio of the length of the section to the average time of vehicles crossing that section.

1.1.2 FLOW:

Flow is defined as the number of vehicles that are traversing a section over a certain period of time. It is denoted by 'q'.

Units: vehicle/time

1.1.3 DENSITY:

The number of vehicles that are occupying a section at a particular time is defined as Density. Density is indicated by 'k'.

Units: vehicle/distance.

These three parameters form a fundamental equation as follows.

$$q = k * u$$

1.2 FUNDAMENTAL DIAGRAMS:

Three fundamental diagrams are available for the traffic flow, namely Speed-Flow curve, Speed-Density curve and Flow-Density curve. These three curves explains the relationship between Speed, Density and Flow.

1.2.1 SPEED DENSITY CURVE:

The relationship between speed and density on a stretch of road is taken as one of the fundamental diagram. This curve shows the relationship between the speed of the section and the relative density.

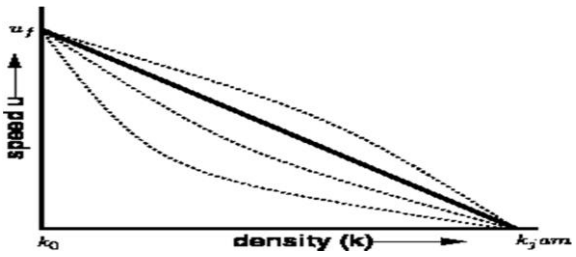


Fig.1.1 speed density diagram

From the speed density curve it can be explained that the speed will be maximum when the density is zero and this speed is known as free flow speed. Similarly density will be maximum when the speed is zero. Both speed and density are linear in variation. The density at zero speed is known as jam density. The speed and density need not to be linear at all times they may vary non-linearly at some critical situations.

1.2.2 FLOW DENSITY CURVE:

Just like the speed density curve, flow density curve explains the relation between flow and density. This is also one of the fundamental traffic flow diagrams.

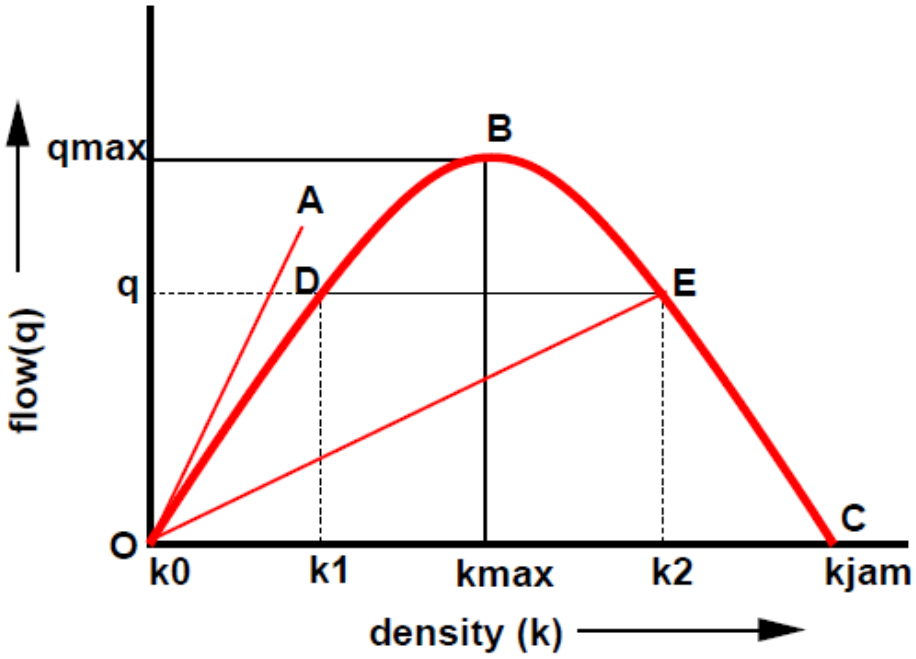


Fig. 1.2 Flow Density diagram

From the above curve, the flow will be maximum when the density is zero this is known as the capacity of the section and the density is maximum when the flow in the section is zero. This density is called jam density. In the figure the flow and density increases monotonically up to a

limit and then starts decreasing. This is due to the fact that as the density of the section is increasing the congestion takes place and there is less room for the vehicles to travel. The density of a section is zero when the flow is zero this is due to non-presence of vehicles on the road.

Here 'O' indicates zero density and zero flow point, 'B' indicates the point of maximum flow and maximum density and 'C' indicates the point of jam density and zero flow. The slope of the lines OA, OD and OE gives free flow speed and mean speed at densities K_1 and K_2 respectively.

From the above fundamental diagrams, the maximum capacity of the section is calculated as

$$Qmax = \frac{1}{4}(Kmax * Umax)$$

1.2.3 SPEED FLOW CURVE:

The relation between speed and flow can be described from the following diagram.

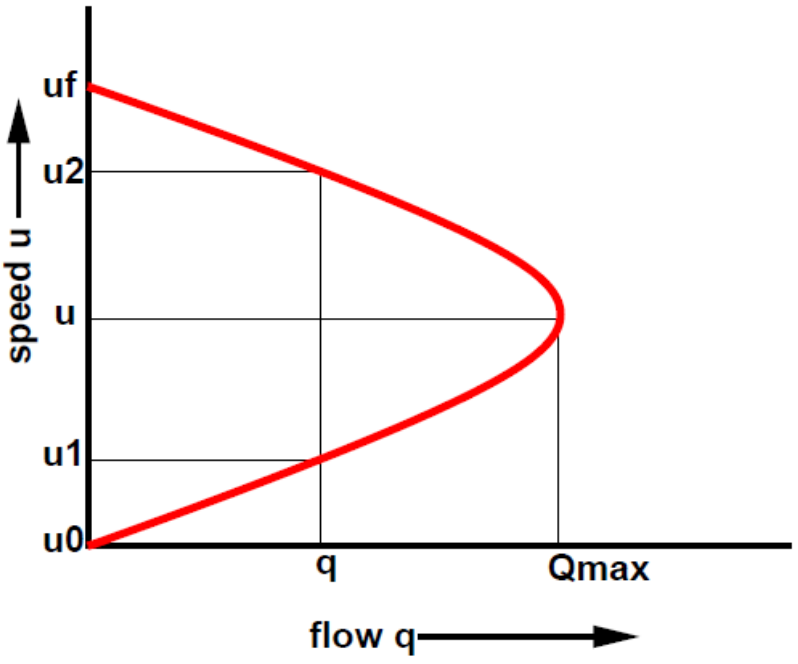


Fig 1.3 Speed Flow curve

From the above diagram the flow is zero when there are no vehicles in the lane or when there exists a number of vehicles so that they create a traffic jam situation. In the above diagram for every flow point there exists two speeds U1 and U2 and for the maximum flow only one speed exists that is taken as the maximum speed.

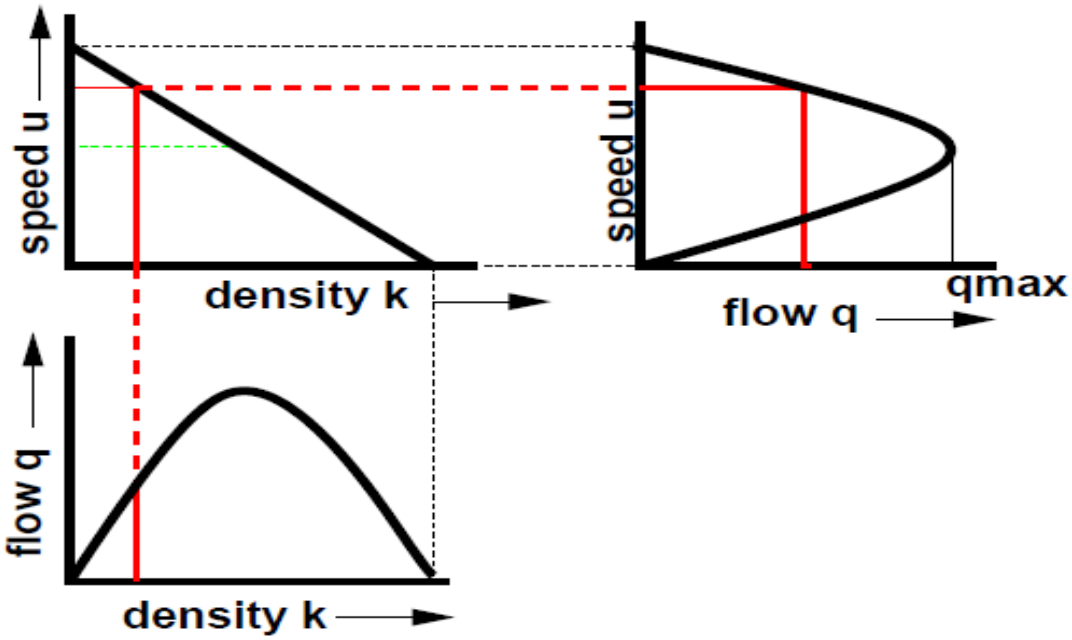


Fig 1.4 Fundamental Diagram of traffic flow

Source: fig 1.2, 1.3 1.4 are taken from Wikipedia http://en.wikibooks.org/wiki/fundamentals

1.3 Passenger Car Unit (PCU):

As the traffic consists of different kinds of vehicles it is not possible to compare one vehicle with the other. To conquer this difficulty we have to represent all the vehicles into one term. This term is known as a Passenger Car Unit (PCU). This PCU represents all the vehicles in terms of single units.

PCU is defined as the ratio of space required for the vehicle class compared to that passenger car under specified roadway and traffic conditions.

As per IRC SP 41 the following are the PCU values that are adopted in India

Table 1.1 Equivalency factors suggested by IRC SP 41

Sl.no	Type of vehicle	Equivalency factor
1	Bicycle, motorcycle	0.5
2	Car, tempo, auto rickshaw	1.0
3	Bus	3.0
4	Cycle rickshaw, LCV	1.5
5	Truck	4.5

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

- Rahman et al (2005) conducted research on "The Effect of Rickshaws and Auto Rickshaws at Signalized Intersections" in Dhaka city. He collected data from four signalized intersections where there is minimum proportion of turning vehicles, no parking, and high traffic volume. Later he developed a model for finding passenger car equivalents of rickshaws and auto rickshaws at signalized intersections do not affect the PCE of rickshaws and auto rickshaws, the vicinity of rickshaws and particles. He concluded the outcome as the green light time, the width of the signalized intersection and auto rickshaws in the mixed traffic lane affects the traffic stream a lot. The number of rickshaws is more the effect is less and vice versa.

- Rahman et al (2003) conducted a study on the "Effect of Non-Motorized Vehicles on Urban Road Traffic Characteristics." The target of this paper is to present analytical procedure of traffic flow and to create models of passing, surpassing and lane utilization for heterogeneous traffic flow. All the data were collected at the mid-block sections located in Dhaka. The vehicle movements were recorded using a portable video camera and the data was decoded using a time code reader software. The data were recorded in five minute interval. The results are shown in the speed-density, speed-flow, and flow-density diagrams. With the increase of non-motorized vehicles the speed, density and flow reduces significantly at a certain rate.

- Rahman of Bangladesh and Fumihiko of japan (2004) conducted a study on "Passing Overtaking Characteristics and Level of Service of Heterogeneous Traffic Flow." This study was conducted in the city of Dhaka, Bangladesh. In this study he developed a passing-overtaking model on heterogeneous traffic flow in urban cities with undivided lanes having more proportion of rickshaws. He attempted to provide level of service (LOS) for this type of roads. He categorized level of service into six categories (A, B, C, D, E and F). Based on the traffic characteristics of the road, he classified into four groups, LOS 1 indicates a free flow condition, LOS 2 shows that it is a partial flow condition where as LOS 3 and LOS 4 represents constraint flow and congested flow conditions respectively. The traffic characteristics considered in this study are average speed of the passenger car and the number of passing and surpassing vehicles in the stream along the section. The results showed that the presence of the rickshaws has an adverse effect on the passing-overtaking characteristics.

- T. Oketch (2003) developed a model on the "Performance Characteristics of Heterogeneous Traffic Streams Containing Non-Motorized Vehicles." In this paper he classified the vehicles into two sorts in particular, standard vehicles and non-standard vehicles. He built up the model to investigate the impact of various non- conventional vehicles in stream performance including lane capacity and saturation flow. The presence of heavy and non-standard vehicles affect the traffic stream performance because of speed capabilities, poor acceleration, etc., this paper says that for heterogeneous traffic streams has the reduced link capacities and saturation flows for traffic stream containing homogenous flow with private cars only. This model was used in the study of speed flow

relationships of the stream and the saturation flows in the traffic stream containing non-motorized vehicles. It was found that the presence of these vehicles results in traffic density and scattered volume. He concluded that the heterogeneous streams have different flows that may not conform fully to the basic theories. In addition, heterogeneous flows are generally associated with higher number of lateral movements as the faster vehicles try to overtake the slower ones.

- Hemant Kumar Sharma, Mansha Swami, Bajrang Lal Swami conducted research on "Speed Flow Analysis" for interrupted oversaturated traffic flow with heterogeneous structures for urban roads and developed a model for heterogeneous traffic under constraints of vehicle characteristics, road geometry, traffic control and driving behavior. The developed model will give the speed, delay, maximum and average queue estimate for the urban traffic and quantify congestion for oversaturated condition. The flows in this paper are classified into the interrupted and uninterrupted flows. Location for data collection is selected so that it consists of two signalized intersections and one un-signalized intersection in between. They developed curves by drawing graphs between travel capacities, travel time, speed versus flow rate so that speed drop due to traffic delay, free flow time and traffic delay are obtained respectively. The capacity can be determined from delay flow curve as the point where oversaturated flow starts. The obtained speed vs. flow rate curve is compared with the BPR, Akcelik speed-flow curves and it resembles the same shape. However, curve obtained in this paper predicts more realistically the performance of an urban network with heterogeneous traffic and interrupted flow.

- Dianhai et al (2007) made a study on bicycle conversion factors. The factors are researched under various traffic conditions. They made a conversion factor model based on motorized vehicles and bicycles and converted into PCU. These bicycle conversion factors are converted and are calculated under four different situations in china. The through and left turn conversion factor is 0.28 and 0.33 respectively at mixed conditions, whereas in the road section with physical separation is 0.22 and without physical separation is 0.24.

- Tiwari, Fazio and Pavitravas developed "Passenger Car Units for Heterogeneous Traffic Using a Modified Density Method." This method is very useful for Indian traffic conditions. At first all the traffic was divided into 8 groups and Indian roads into 6 groups. The camcorder recorded traffic on the video tape along with a time stand during peak hours. From the video tapes the traffic characteristics were obtained on all the roads. This modified density method requires comparison of the density of various traffic types at the same speed. One should ensure that the obtained density must be divided by the lane width to obtain the PCU values.

- Fei Shi and Haiyuan Li of China conducted a study on "The Influence of Non-Motorized Stream on Capacities of Vehicular Streams at Unsignalized Intersections." Usually unsignalized intersections consist of Two Way Stop Controlled (TWSC) and All Way Stop Controlled (AWSC) intersections. The capacity of the non-motorized vehicles is calculated at TWSC and AWSC. The capacity is calculated for minor street vehicular movements at both intersections. The graphs were drawn between vehicular capacity and bicycle volume.

The results shown that at TWSC and AWSC intersections the capacity of vehicular movements reduces gradually with the increase of volumes of bicycle movements.

- Pan and Kerali (2007) conducted a research on the effects of non-motorized traffic flow on motorized vehicle speeds on the basis of field observations of vehicle speeds on Chinese roads. They observed a direct linear relationship between motorized vehicle speeds and non-motorized traffic flow under a range of motorized traffic flow volumes. They developed a model, a general congested speed model for predicting vehicle speeds under various road characteristics and traffic flow volumes, utilizing the relationships of non-motorized flow effects obtained in their study along with free speed and speed-flow relationships investigated in other studies.

- Chandra. S (2004) conducted several studies on "Capacity Estimation Procedure for Two Lane Roads under Mixed Traffic Conditions." In this study, he considered the impact of influencing parameters like lane width, gradient, shoulder width, pavement surface conditions, traffic composition, directional split and slow moving vehicles on capacity of two-lane roads under mixed traffic conditions is evaluated and adjustment factors for each of these conditions are proposed. Based on these adjustment factors, a schematic procedure to evaluate the capacity of a two-lane road under mixed traffic conditions is proposed.

- Minderhoud et al made a research on "Assessment of Road Way Capacity Estimation Methods". The estimation methods were classified into direct empirical and indirect empirical methods. He calculated methods for finding capacities using headways, traffic

volumes and speeds, traffic volumes, speeds and headways. Only two approaches are used in calculating capacity estimation, they are using observed maxima or using a set of flow observations.

2.1 MOTIVATION:

From a lot of research conducted on non-motorized vehicles, it has been observed that a lot of work carried out on finding capacity, Level of Service and a little work on finding the effects of Non-Motorized vehicles on mixed stream in Indian context. Pretty less amount of work done in the field of finding lateral occupancy of the Non-Motorized vehicles and its effects on traffic characteristics.

So in this context, I have chosen certain objectives which are described in the following section.

2.2 OBJECTIVE:

The objective of the work is to find traffic characteristics of Non-Motorized vehicles in mixed stream and its effect on traffic stream.

The entire work is divided into two categories.

- Experimental part
- Statistical Analysis part

2.2.1 EXPERIMENTAL PART:

The experimental part consists of the following objectives

- To study the fundamental diagrams of traffic flow obtained from various locations
- To find the capacity of the sections from fundamental diagrams
- To find the lateral occupancy of the section
- To study the behavior of Non-Motorized vehicles in the stream.

2.2.2 STATISTICAL ANALYSIS PART:

This statistical analysis includes the following objective

- To compare the traffic parameters of the past data with reference to the present data
- To find the variation of capacity with respect to percentage change in Non-Motorized vehicles.

CHAPTER 3

METHODOLOGY

3. METHODOLOGY

As explained in the above section the whole project is divided into two parts.

- Experimental Part
- Statistical Analysis Part.

The experimental part comprises of data collection, data extraction and results of the collected data

The statistical analysis part is described in the following section (Chapter 4)

3.1 DATA COLLECTION:

The data collection consists of video coverage of the data from various locations. The project primarily aims in and around Rourkela city. The data is collected from five different locations in Rourkela. The locations are selected such that they have different traffic conditions and different roadway patterns. The five locations are enlisted below

- Road at Ambagan Chowk, Rourkela.
- Road near Bisra Chowk, Rourkela.
- Road near Daily Market, Rourkela.
- Road near Konark Theatre, Rourkela.
- Road from Sector 2 to NIT, Rourkela.

The sections should contain high traffic volume, minimum number of turning vehicles, no parking zones. The surface of the road should be even and level terrain. The section should not contain bus stops. The data are collected for a minimum of 30 minutes in each section with the help of a high resolution video camera. The camera is placed at one corner of the section so that the entire section is covered. The section is of 5 meters length and the section is fixed by placing markers at each

end. A cellophane paper is placed on the monitor and the section is transferred into the cellophane paper. The video is decoded with the help of KM player software. The cellophane paper is kept because although the section is rectangular, it will get deform while recording. In order to minimize this deformation effect the section was transferred into the paper using markers. The data is decoded at the rate of 25 fps as per requirement.

The dimensions of each section are indicated in the following table.

3.1 Table showing dimensions of each section

Sl.no	Location	Length (meters)	Width (meters)	Time
1	Ambagan Market	5	9	10:00 am to 10:40am
2	Bisra Chowk	7	10	9:30 to 10:15 am
3	Daily Market	5	7	5:00 to 5:45 pm
4	Konark theatre	5	7.5	10:00 to 10:45 am
5	Sector 2	5	7	9:00 to 9:40 am

3.2 DATA EXTRACTION:

As per the objectives of the experimental part, the data extraction or data decoding consists of the following.

- To study the fundamental diagrams of traffic flow obtained from various locations
- To find the capacity of the sections from fundamental diagrams
- To find the lateral occupancy of the section
- To study the behavior of Non-Motorized vehicles in the stream.

3.2.1 Study of fundamental diagram:

Fundamental diagram is the diagrammatic representation of the relationship between various traffic parameters such as flow, speed and density. Data collected for this study is from the following sections

- Road near Ambagan Market.
- Road near Bisra Chowk.
- Road near Konark Theatre.
- Road from sector 2 to NIT.

The data is decoded for single lane and two lane roads separately and noted individually for upstream and downstream vehicles in the section to study the behavior.

Procedure followed:

For the decoding, in KM player software the video was played. A cellophane paper (tracing paper) was fixed to the monitor and the section was transferred onto the tracing paper using broad markers. The video was played and at every minute interval the flow of the vehicles was noted. For every 15 seconds interval the density of the section was taken and the process is followed till the end of the video. The speed of each vehicle is calculated from the fundamental relation U=Q/K. From the obtained speed, density and flow the fundamental diagrams were drawn.

3.2.2 Capacity of the section:

The capacity of the section is the maximum number of vehicles that are occupying a section under specified traffic conditions at a certain time. For finding the capacity, the above mentioned four locations are taken into consideration. The fundamental diagram for each location is plotted and the point at which the maximum flow occurs in the flow density curve is taken as the capacity of the section.

3.2.3 Study of lateral occupancy of the vehicles:

Lateral occupancy of the vehicles is to find the behavior of the vehicles in the stream with respect to the adjacent moving vehicles. For finding this lateral occupancy, four locations were used which are mentioned below.

- Road near Ambagan Market.
- Road near Bisra Chowk.
- Road near Konark Theatre.
- Road from sector 2 to NIT.

The main purpose of this study is to find how the Non-Motorized and Motorized vehicles are varying across the section with the change in percentage of Non-Motorized vehicles.

Procedure followed:

For finding lateral occupancy, the whole section (width of the road) is divided into seven equal strips on the cellophane paper and the video was analyzed at every 10 second interval. The analysis is done in such a way that every non-motorized and motorized vehicle speeds and the strips in which they are entering are noted. For two way traffic roads, the upstream and downstream vehicles are to be noted separately in order to find out the behavior of the vehicles. Relative total for Non-Motorized and Motorized vehicles were found and graphs were plotted between lateral occupancy and the strip number for both non-motorized, motorized and total traffic.

The effect of Non-Motorized vehicles on the lateral occupancy was studied. The results were discussed in the following section.

3.3 RESULTS OF THE EXPERIMENTAL PART:

The results of the experiments conducted were discussed below. The result for each section is presented below with the graphs where ever required.

3.3.1 Fundamental diagrams:

Note: for the following graphs, speed is represented in m/Sec, flow in PCU/Sec and density in PCU/meter.

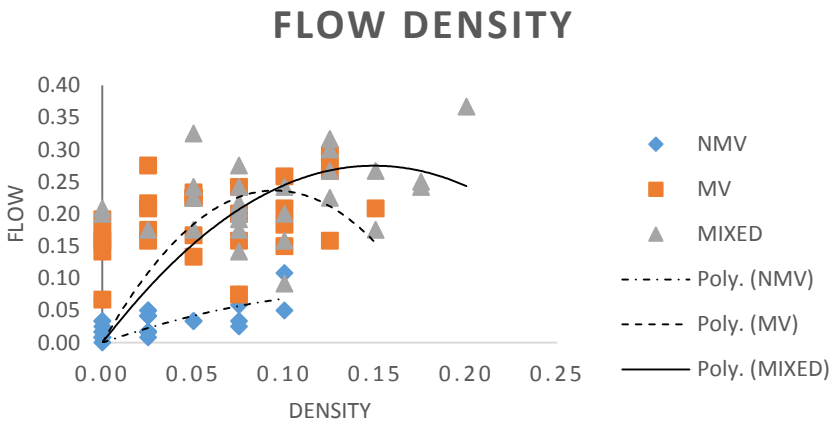


Fig 3.1 Flow density curve for upstream flow near Ambagan

From here onwards, Non-Motorized Vehicles are indicated by NMV and Motorized vehicles are indicated by MV.

In the above graph, the maximum flow of NMV is 0.05 PCU/Sec and the density of NMV in this section is 0.1 PCU/meter. In the case of MV, the maximum flow is 0.23 PCU/Sec and the density of MV is 0.09 PCU/meter. It indicates that in this section the flow of MV is more as compared to that of NMV while the density is decreased for MV. For the total traffic the maximum flow is 0.28 PCU/Sec and the corresponding density is 0.15 PCU/meter.

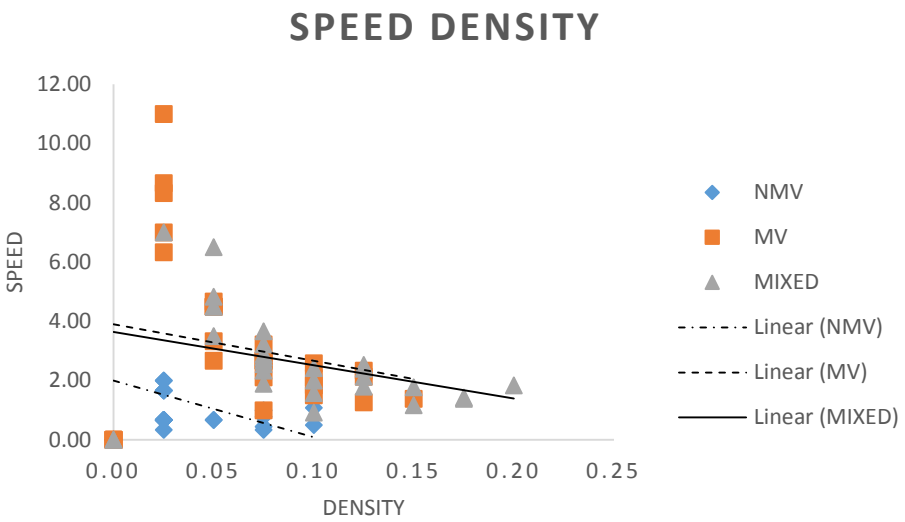


Fig 3.2 Speed density diagram of upstream flow at Ambagan

From the above speed density graph (fig 3.2), it can be observed that for NMV for a density of 0.1 PCU/meter, the speed is 0.02m/Sec and for MV at a density of 0.09 PCU/meter, the speed is 3.5 m/Sec. It can be seen from the above figure that for the total traffic, at a density of 0.15 PCU/meter, the speed is 2.28 m/Sec. The percentage of NMV in the upstream section is 14.35%.

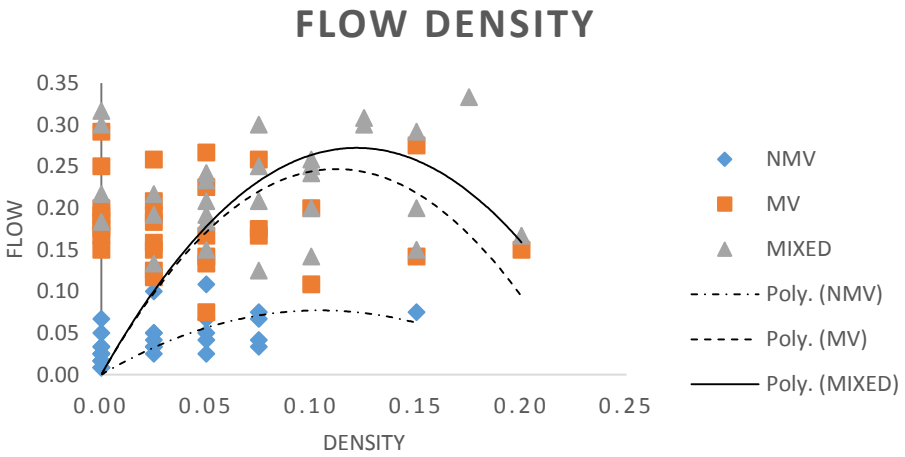


Fig 3.3 Flow density curve for downstream section near Ambagan

In the downstream section, the maximum flow of NMV is 0.07 PCU/Suez and that for MV and total traffic is 0.23 and 0.27 PCU/Sec respectively. And the density corresponding these flows is 0.1, 0.125 and 0.14 PCU/meter respectively.

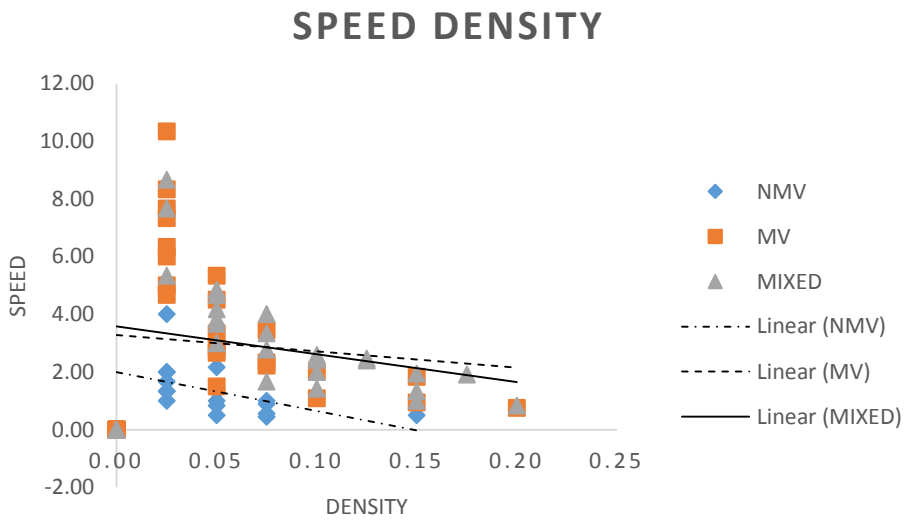


Fig 3.4 Speed density curve for downstream of Ambagan

From the speed density curve (fig 3.4), the speed of NMV corresponding to a density of 0.07 PCU/Sec is 1.2 meters/Sec and for MV and total traffic is 3.0 and 2.4 meter/Sec respectively. Here in the downstream section the flow percentage of NMV is 18.56% and the speed is a bit more for NMV because of the less existence of heavy vehicles in the section.

For the total section taken into consideration instead of taking it as a one way, the percentage of NMV is 16.46%. The flow density diagram (fig 3.5, 3.6) indicates the maximum flow of NMV in this section is 0.1 PCU/sec and the corresponding density is for the flow is 0.13 PCU/meter. For the MV the maximum flow is 0.45 PCU/sec and the density for this flow is 0.15 PCU/meter. Whereas for the whole traffic, the maximum flow is 0.52 PCU/Sec and the density is 0.23

PCU/meter. From the speed density diagram, the speeds for the NMV, MV and total section is 0.8 m/Sec, 3.9m/Sec and 2.7 m/Sec respectively.

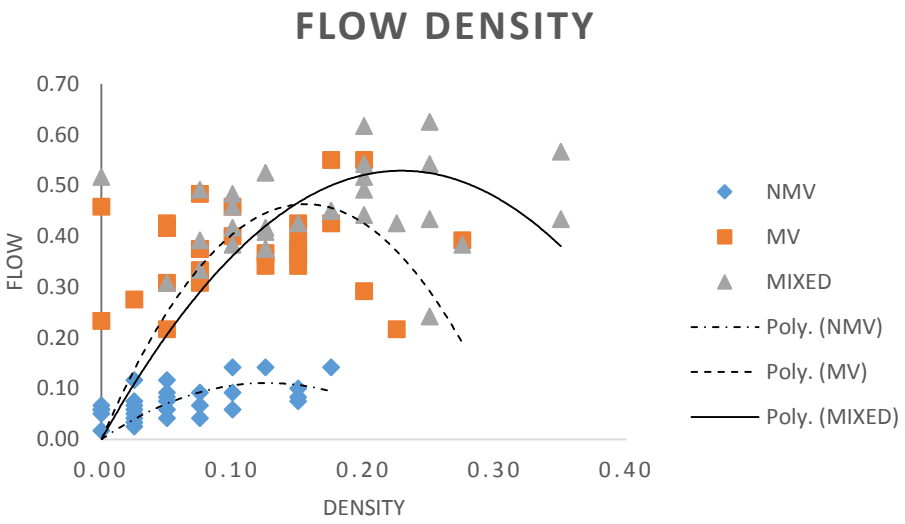


Fig 3.5 Flow density diagram for Ambagan section

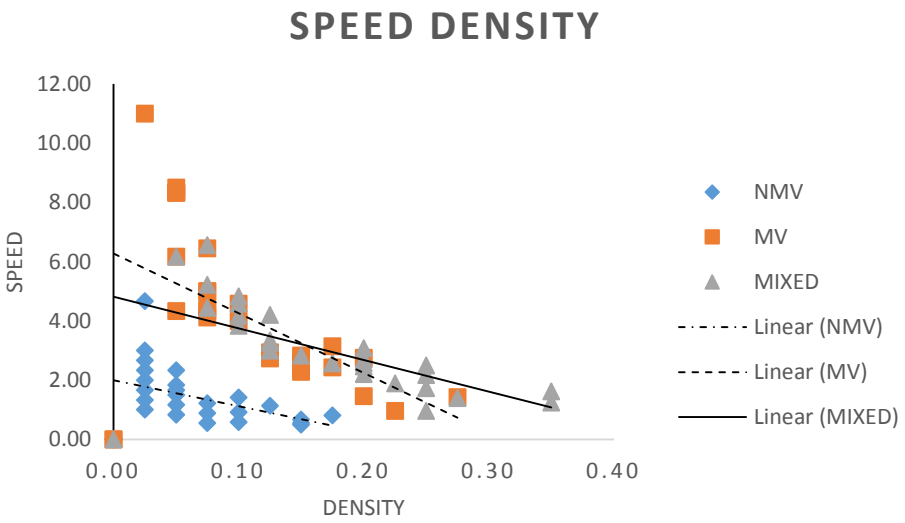


Fig 3.6 Speed density diagram for ambagan section

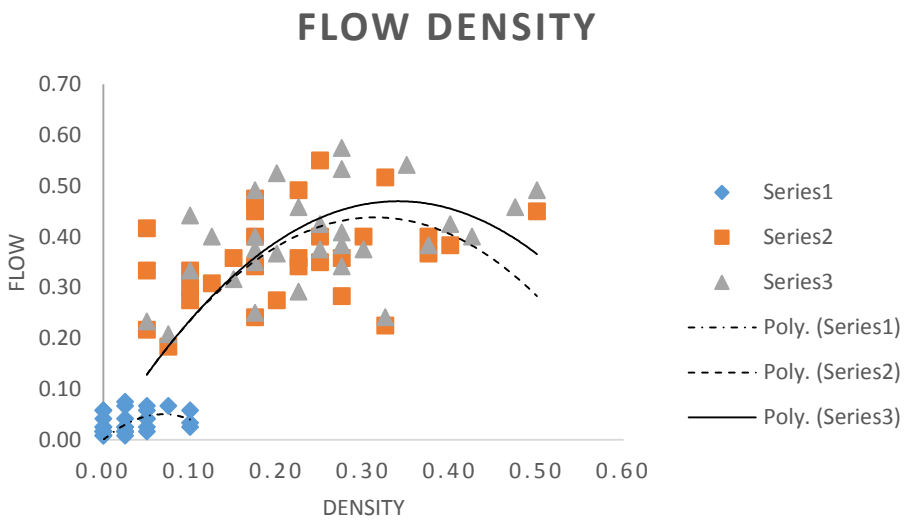


Fig 3.7 Flow density diagram for Bisra Chowk

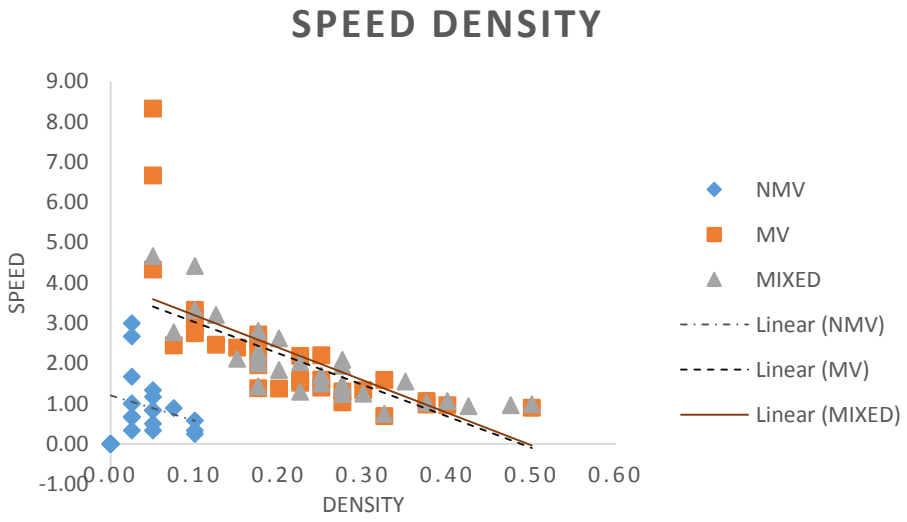


Fig 3.8 Speed density diagram for Bisra Chowk

The bisra chowk is a one way traffic lane and it has the less number of NMV percentage. The maximum flow of NMV in this section is 0.06 PCU/Sec and the density corresponding to this flow

is 0.07 PCU/meter. The percentage of NMV in the section is 8.61 and the speed of the NMV in the section is 0.8 m/sec. In this section, the MV is too high, so the speed of NMV is less.

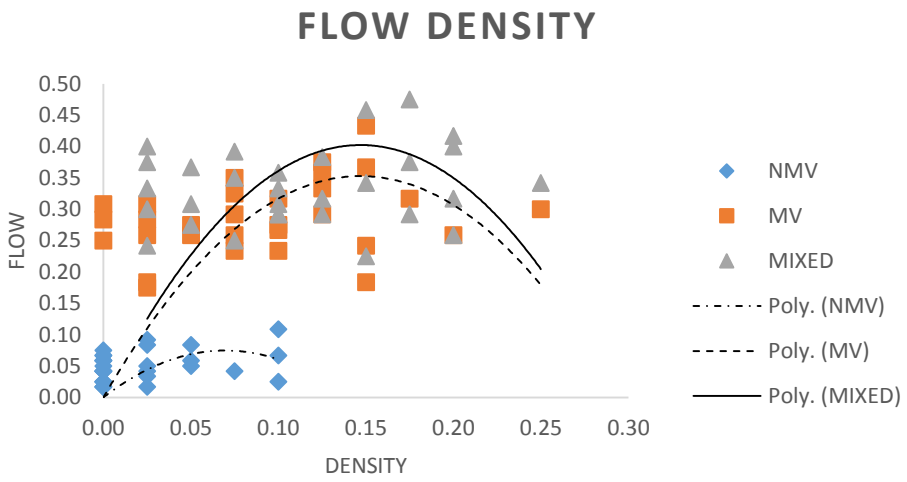


Fig 3.9 Flow density curve for road near Konark Theatre.

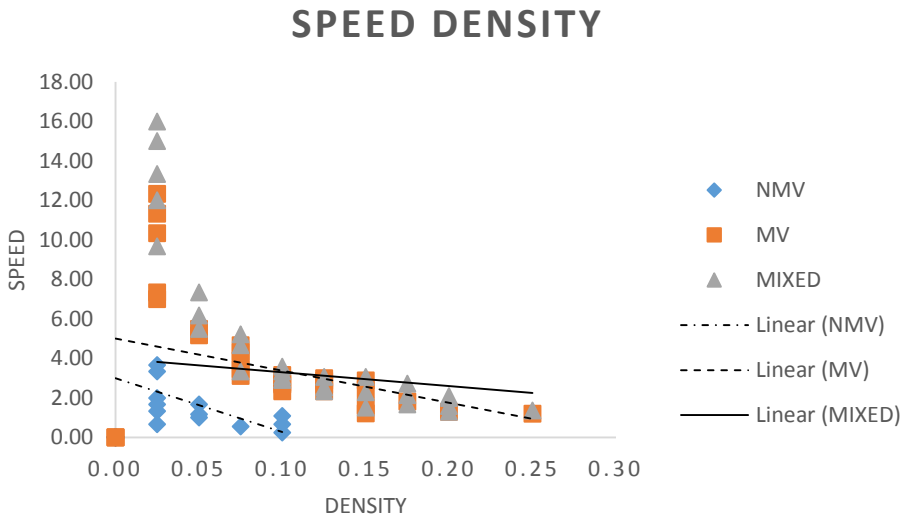


Fig 3.10 Speed density curve for road near Konark theatre.

The above figures indicate the flow density (fig 3.9) and speed density (fig 3.10) curves in the road near Konark theatre. It contains a NMV percentage of 14.65 % and the maximum NMV flow of 0.075 PCU/Sec, maximum density and speed as 0.06 PCU/meter and 0.9 m/Sec respectively.

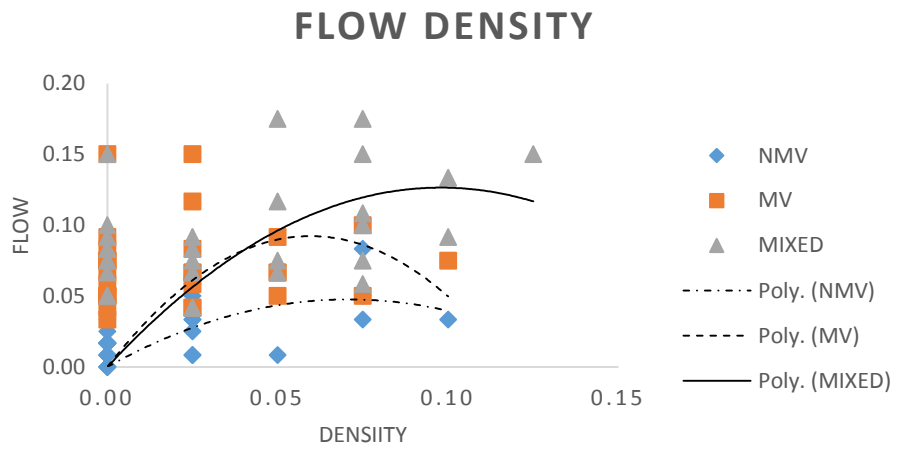


Fig 3.11 Flow density curve for downstream flow of Sector 2

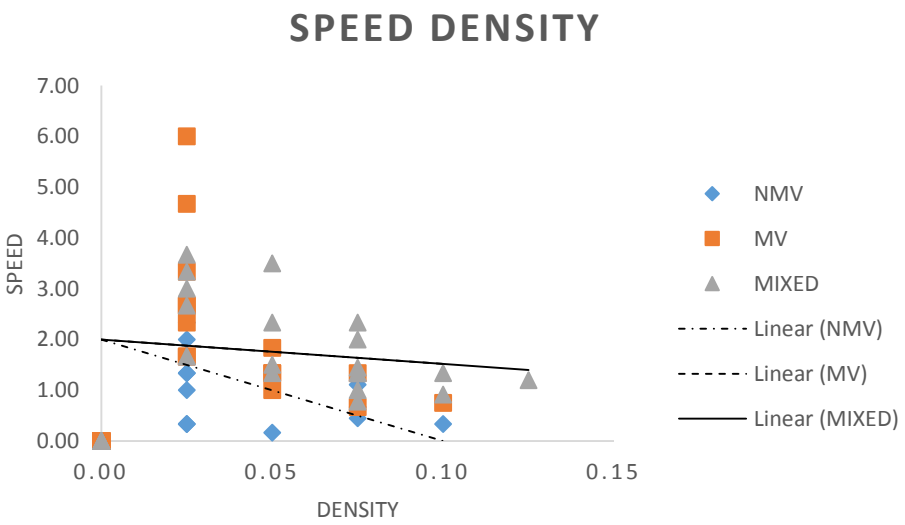


Fig 3.12 Speed density curve for downstream flow of Sector 2

From the above flow density and speed flow diagrams (fig 3.11, 3.12), it can be observed that the maximum flow of NMV in the section is 0.047 PCU/sec with a density of 0.07 PCU/meter. The speed corresponding to NMV in the section is 0.5m/sec. The percentage of NMV in the section is 23.2% so the speed of the section is decreased.

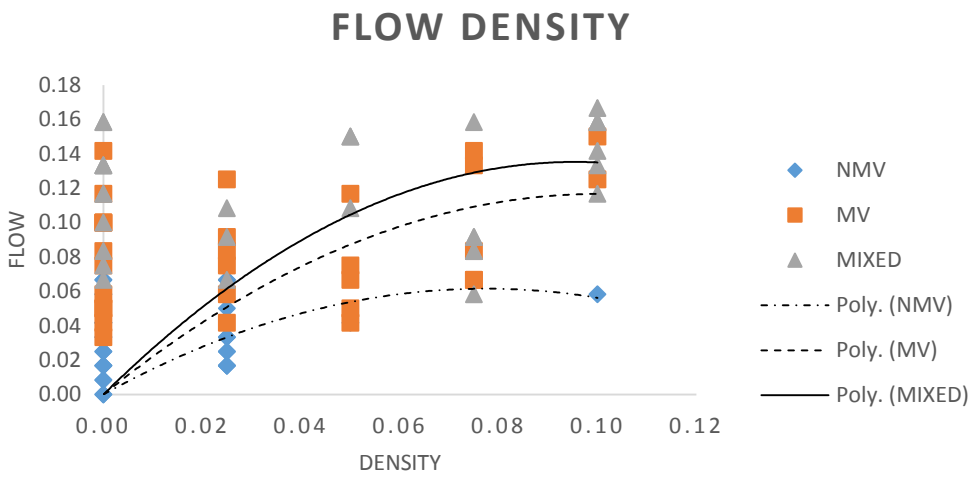


Fig 3.13 Flow density curve for upstream flow of Sector 2

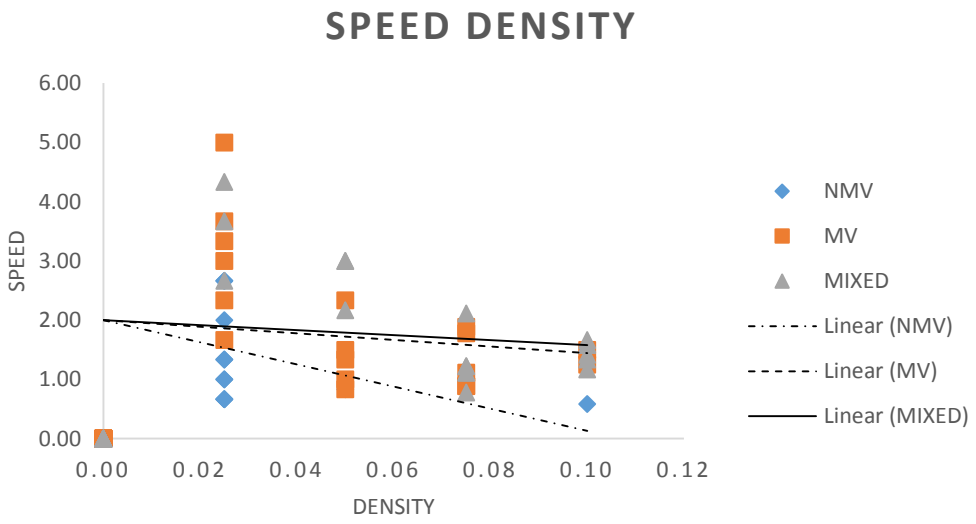


Fig 3.14 Speed density curve for upstream flow of Sector 2

From the above location, the percentage NMV in the section is 28.4% and the flow of NMV is 0.06 PCU/Sec with a density of 0.1PCU/meter. The speed of NMV in the section is 0.2 m/Sec. The speed is too low in this section because the number of NMV is more.

3.3.2 Capacity of the section from the fundamental diagrams:

The capacity of the section is the maximum number of vehicles that are crossing a section over its length in specified period of time under prevailing road, traffic conditions.

From the fundamental diagrams, the capacity is the peak point of flow in the flow density curve and the density corresponding to this flow is the maximum density of the section.

The following table shows the capacities of NMV, MV and mixed traffic at different locations from fundamental diagrams.

3.2 Table showing capacity of different sections

Sl.no	Location	NMV capacity	MV capacity	Total capacity
1	Ambagan upstream	0.050	0.230	0.280
2	Ambagan downstream	0.070	0.230	0.270
3	Bisra chowk	0.060	0.440	0.480
4	Konark theatre	0.075	0.350	0.400
5	Sector 2 upstream	0.060	0.118	0.125
6	Sector 2 downstream	0.047	0.090	0.138

The above mentioned capacities are in PCU/Sec at the respective sections during the morning peak hours.

3.3.3 Study of Lateral Occupancy:

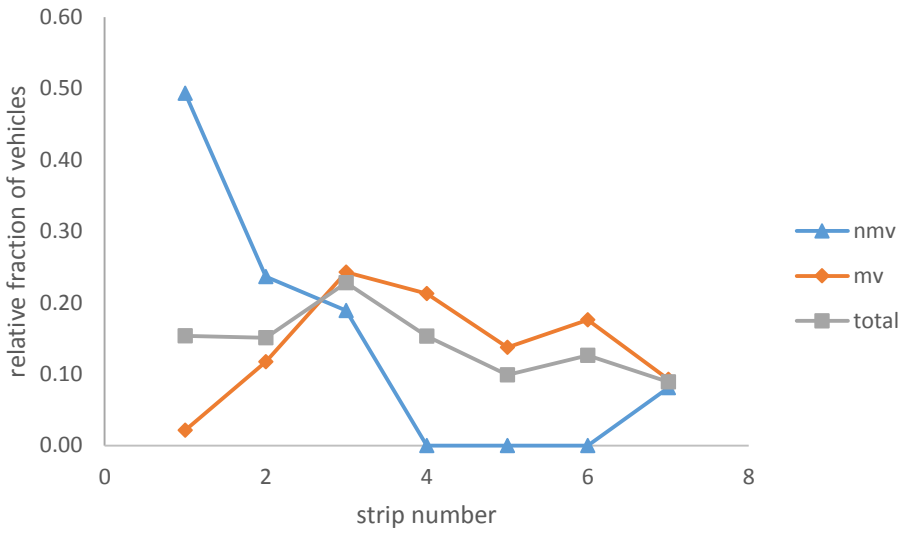


Fig 3.15 lateral occupancy for flow in Ambagan upstream

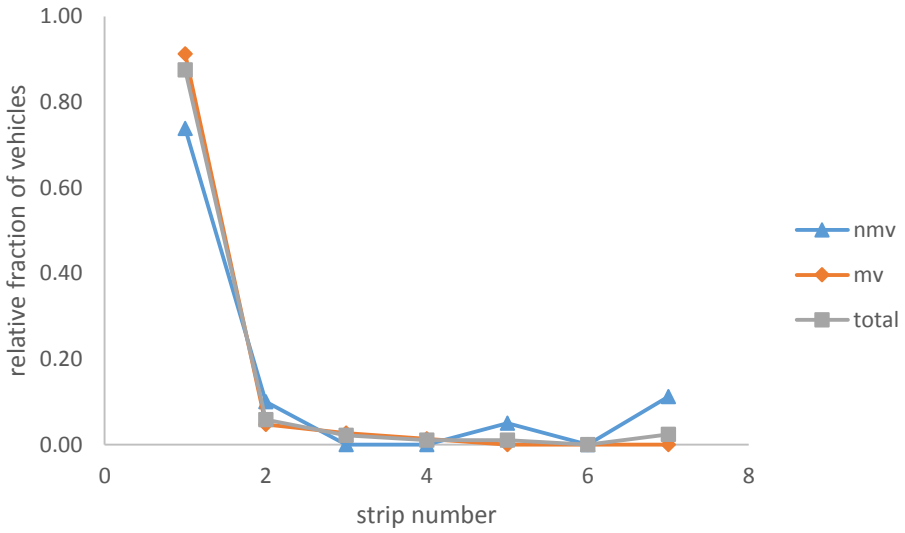


Fig 3.16 lateral occupancy for flow in Ambagan downstream

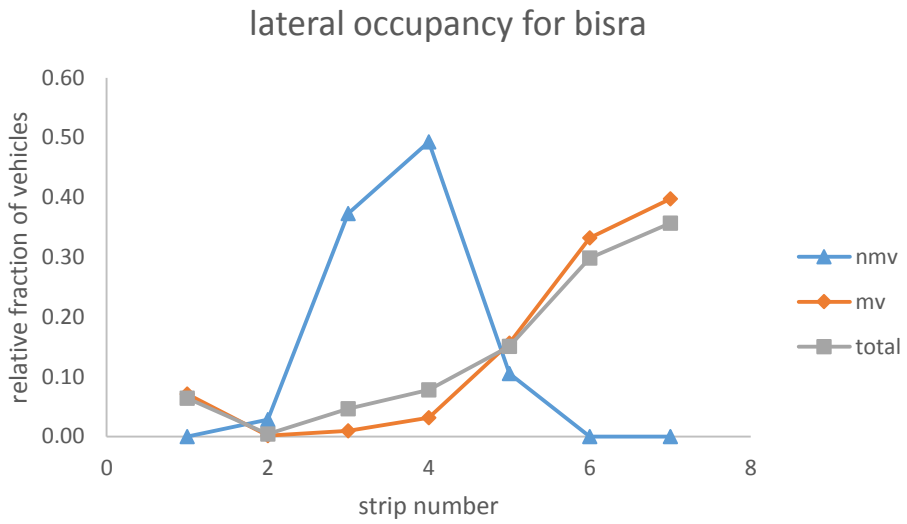


Fig 3.17 lateral occupancy for flow of road near Bisra Chowk

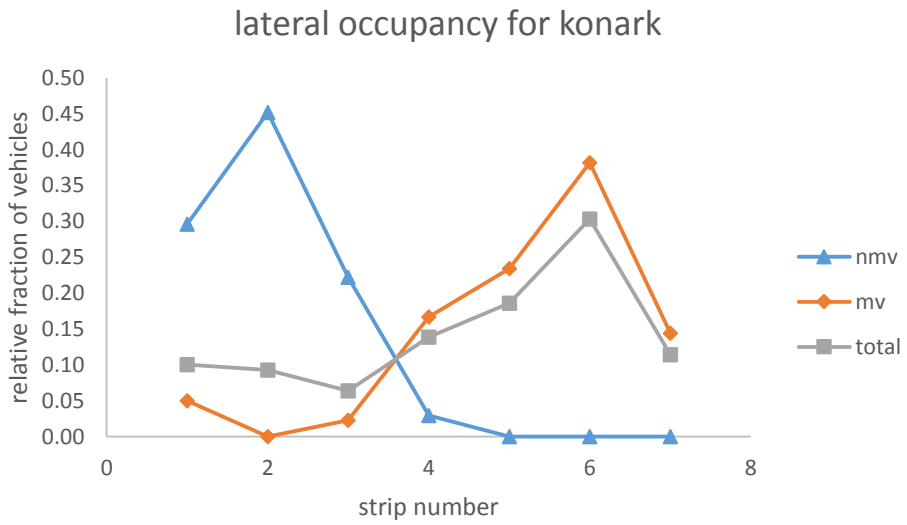


Fig 3.18 lateral occupancy for flow of road near Konark theatre

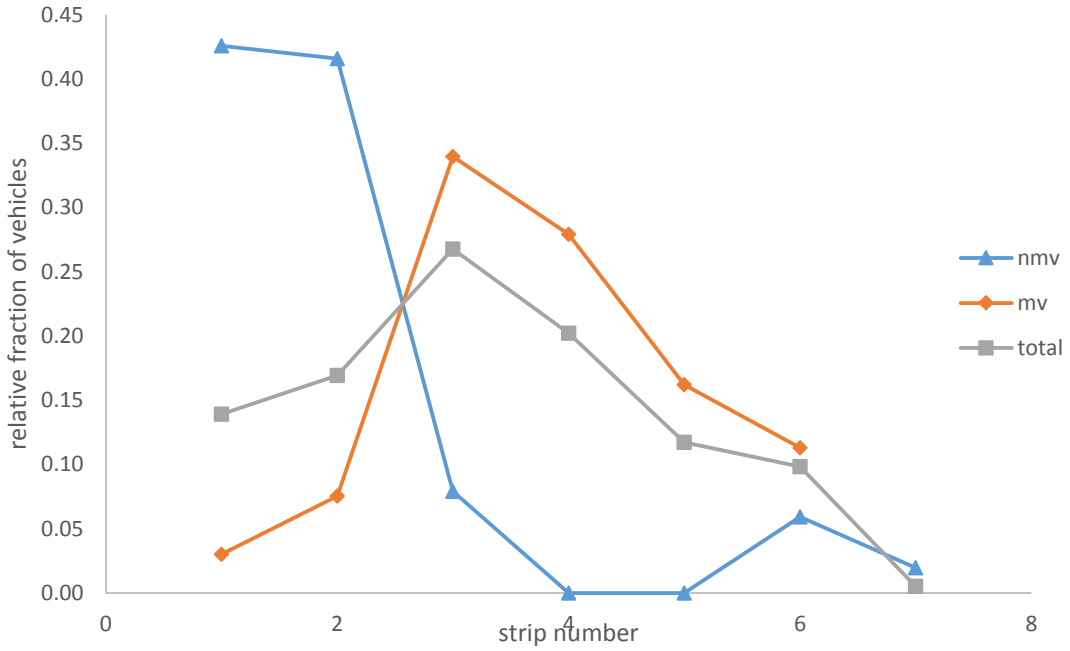


Fig 3.19 lateral occupancy for upstream flow of sector 2

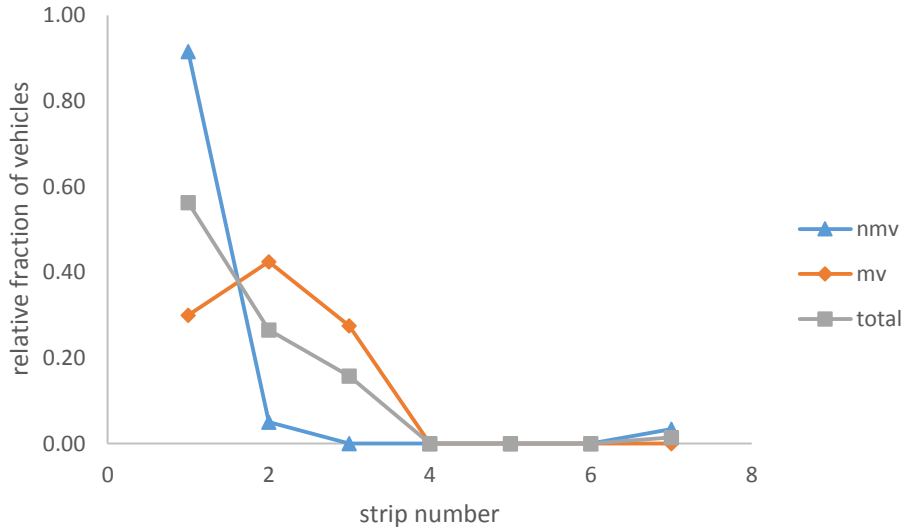


Fig 3.20 lateral occupancy for downstream flow of sector 2

From fig 3.17 and 3.18, the traffic is one way and it can be observed that maximum number of NMV are occupying the first two strips of the section and a minimum amount of NMV are occupying the middle portions. No NMVs are occupying the right portion of the road as our Indian traffic behavior is left handed movement. The MVs are occupying the rightmost part of the road and a minimum are occupying the left two strips because it is convenient to overtake the leading vehicles. The MVs are not occupying the left first strip because it is occupied by the NMVs and it would reduce the travel speed of the journey.

From the figures 3.15, 3.16, 3.19 and 3.20 the section is of two way traffic so the pattern of occupancy is a bit different from the one way traffic as the vehicles are approaching from the opposite end also. In this pattern, the maximum occupancy is in the left and middle strips and the minimum right strips.

3.4 COMPARISON GRAPHS:

3.4.1 Speed vs. %NMV graph:

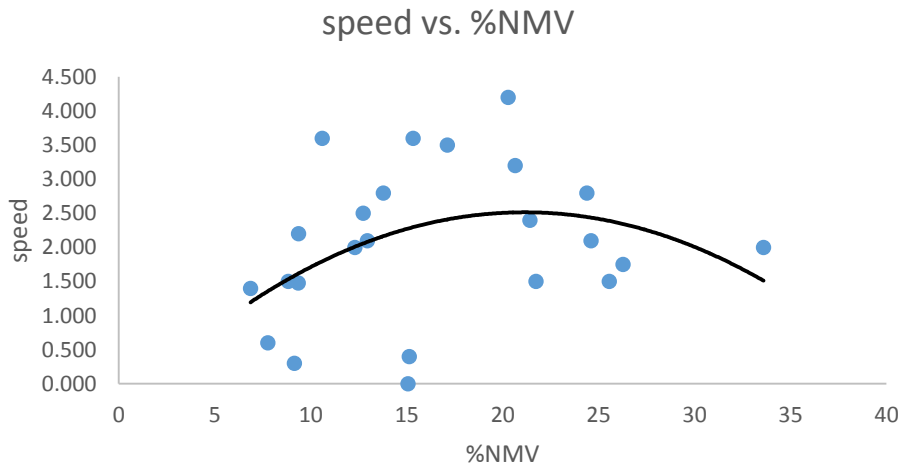


Fig 3.21 speed vs. %NMV graph

From the above figure shown in 3.21, it is observed that the speed of the section is increasing till 20% of NMV and then it starts decreasing. It is due to a reason that with the increase of NMV content in the stream, traffic congestion starts increasing and it reduces the overall speed of the section.

3.4.2 Flow vs. %NMV:

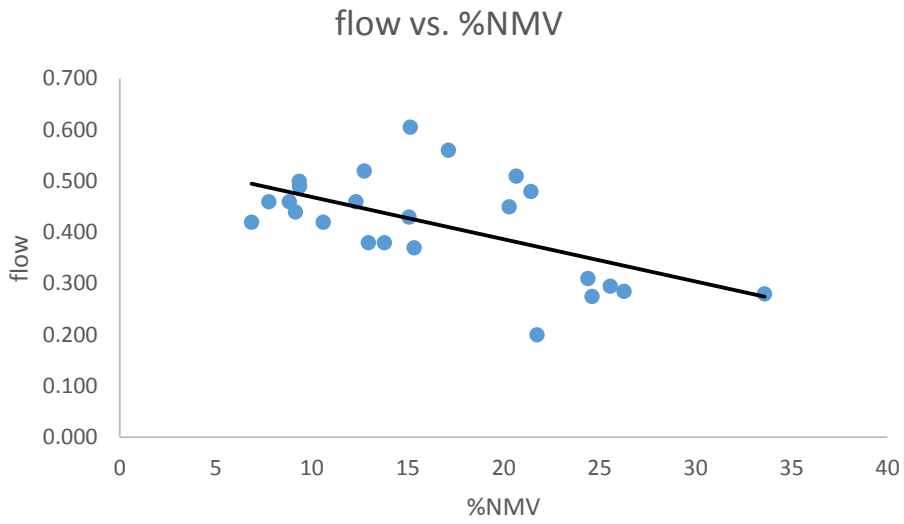


Fig 3.22 Flow vs. %NMV

The figure 3.22 indicates that the flow of the section starts decreasing with the increase of percentage Non-Motorized Vehicles. This is due to the fact that the NMVs are the slow moving vehicles as compared to that of MVs and as the NMV content increases, the room for the other vehicles to pass through the section decreases and it reduces the speed of the following vehicles which results in the decreasing of the flow of the section.

3.4.3 Density vs. %NMV:

The following figure 3.23 indicates the density vs. percentage NMV trend. This shows that the density of the section starts decreasing with the increase of the NMV content.

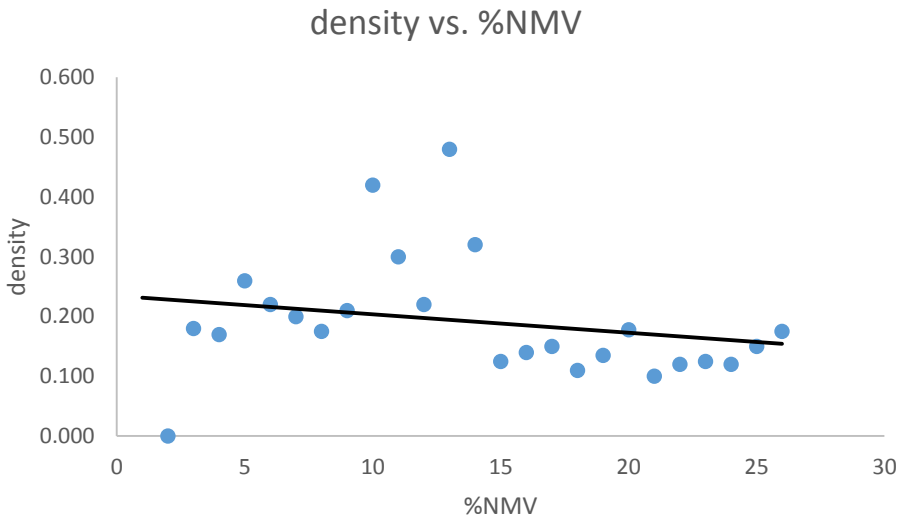


Fig 3.23 density vs. %NMV

3.4.4 Fundamental diagrams for different % NMV:

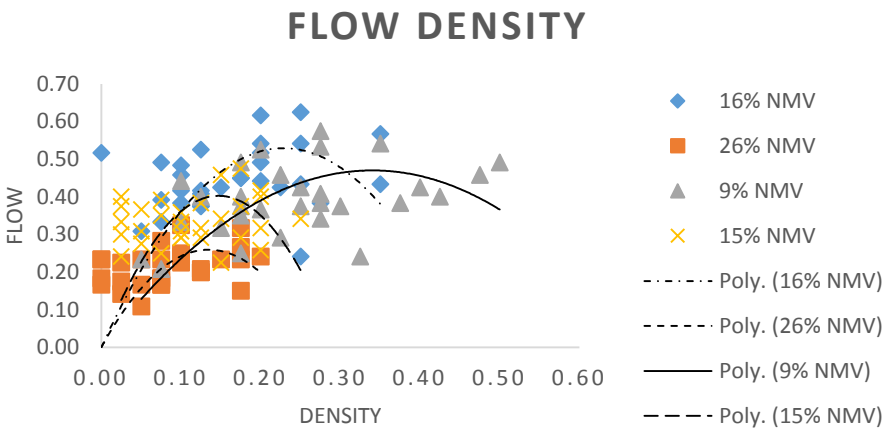


Fig 3.24 flow density curve

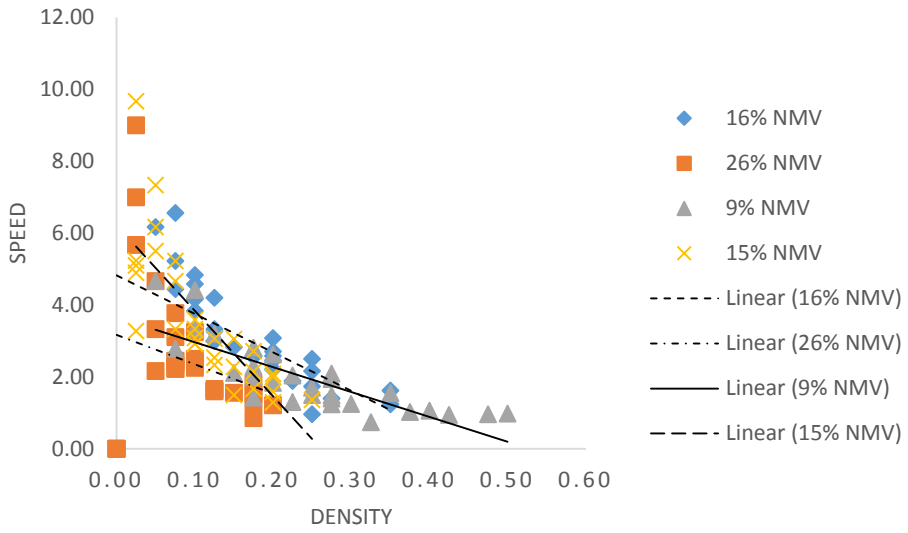


Fig 3.25 speed density curve

In the above fundamental diagrams (fig 3.24, 3.25), %NMV of 9 and 15 are for one way divided traffic and 16 and 26 are for undivided two way traffic. In the case of one way traffic, for 9 % NMV the flow, density and speed are 0.47 PCU/sec, 0.34 PCU/m and 1.6 m/sec and for 15 % NMV, 0.40 PCU/sec, 0.15 PCU/m and 3.20 m/sec respectively. Whereas in the case of two way traffic, for 16% and 26% of NMV flow, density and speed are 0.53 PCU/sec, 0.23 PCU/m and 2.4 m/sec and 0.26 PCU/sec, 0.13 PCU/m and 2.10 m/sec respectively. For one way traffic it is observed that the flow and density decreased and the same pattern is seen for the two way traffic also.

CHAPTER 4

STATISTICAL INFERENCE

4. STATISTICAL INFERENCE

INTRODUCTION TO HYPOTHETICAL TESTING:

Hypothesis testing or statistical testing is used to determine whether the statement is correct or incorrect.

This hypothetical testing is carried out in four steps.

1. Null and alternative hypothesis.
2. Test static
3. P-value and conclusion
4. Decision.

STEP 1:

The primary step of the hypothesis test is to form a question into null hypothesis and the alternate hypothesis. Null hypotheses demonstrate that there is no significant distinction between the observed means. Alternate hypotheses indicate that there is a difference between the observed means.

Null hypotheses (H_0): $\mu_1-\mu_2 = 0$

Alternate hypotheses (H_a): $\mu_1-\mu_2 \neq 0$

Where μ_1 = mean of the first sample

μ_2 = mean of the second sample

Both the null hypothesis and alternate hypotheses refer to population values, but not observed statics.

STEP 2:

We find the **test statistic** from a set of observed data. There are different kinds of test statistics one of them is one-tailed *z*-test. This z test differentiates the detected sample mean μ to an expected population mean μ_0. More number of test statistics demonstrate that information (the data) are a long way from expected, providing confirmation against the H_0 (null hypothesis) and for H_a (alternative hypothesis).

STEP 3:

The test measurement (test static) is changed over to a conditional probability called P-value. The *P*- value answers the inquiry "If the null hypothesis were genuine, what is the likelihood of observing the present data or data that is more extreme?"

Little P values provide proof against the null hypothesis in the light of the fact that they say the observed data are far-fetched when the null hypothesis is valid.

STEP 4:

Alpha (α) is the probability threshold for a decision. If $P \leq \alpha$, then we will not accept the null hypothesis. Else we will accept the null hypothesis.

ONE-SAMPLE *Z* TEST:

A test in which the alternative hypothesis indicates that the population parameter lies altogether above or below the value specified in H_0 is a one-sided (or one-tailed) test.

TWO-SIDED ALTERNATIVE:

An alternative hypothesis that predefined that the parameter can lie on either side of the value specified by H_0 is called a two-sided (or two-tailed).

Whether to utilize a 1-tailed or 2-tailed test relies on upon the way of issue. Typically we use a 2-tailed test. A 1-tailed test regularly obliges somewhat more hypothesis. Two tailed test is more generalized as compared to that of one-tailed test. For one tailed test, it requires a stronger reason that in which direction it is varying where as in the case of two tailed test no such reason required.

In this hypothetical testing we compared two test results of 2011 and 2014 and the variation of the means in the traffic parameters like flow, density and speed were found

A two tailed z test is conducted on the traffic parameters as we do not know whether they are increasing or decreasing.

STEP 1:

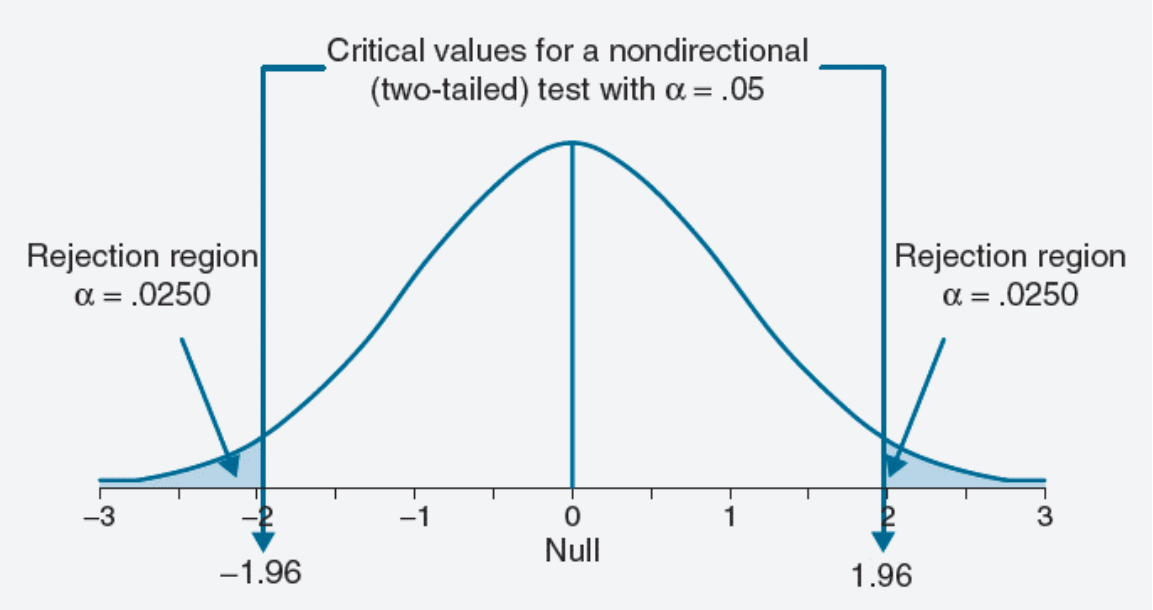
H_0 is stated as the difference between the means of traffic parameter (speed or flow or density) is zero

H_a is the alternative hypothesis and is stated as the difference between the parameters is non zero.

STEP 2:

The level of significance (α) is taken as 0.05. To find the probability of getting a sample mean from a given population, we use the standard normal distribution. We will find the *z* scores in a standard normal distribution that are the limits, or **critical values,** for test mean values with not

as much as a 5% likelihood of occurrence if the value expressed in the null is true.



As it is a two tailed test we have to divide α value into two equal halves so that an equal portion of the area is placed between upper and lower tails. The z critical value for this α value is ±1.96 from unit normal tables. If the values fall beyond these critical regions, then we reject the null hypothesis else we retain the null hypothesis.

The z_{stat} is calculated from the following mathematical equation

$$Z_{stat} = \frac{M-\mu}{\sigma_M}$$

where M= sample mean,

μ= populated mean,

σ_M = standard error of the mean.

$$\text{where}\,\sigma_M = \frac{\sigma}{\sqrt{n}}.$$

STEP 3:

The probability of getting z_{stat} is defined by P value. To find the *p* value or probability of getting the z_{stat}, we look into the normal distribution table. To get the *p* value of a *z* statistic, find its probability (toward the tail) in the normal distribution table and multiply this probability with the number of tails for alpha.

Table 4.1 showing the Z observed values for different locations

	AMBAGAN (Z observed)			BISRA (Z observed)			KONARK (Z obs)		
	Speed	Flow	Density	Speed	Flow	Density	Speed	Flow	Density
NMV	-1.68	3.25	5.22	1.97	2.22	2.84	4.27	4.04	3.29
MV	-5.43	-2.73	8.38	-0.78	-2.25	-0.26	-0.21	5.17	1.5
TOTAL	-6.84	-0.62	10.87	-1.53	-1.55	0.42	-2.36	6.05	3.22

STEP 4:

The decision to reject the null hypothesis if the Z observed is more than Z stat and if the P value is less than α value. The following table indicates the results of the P values for the compared data.

Table 4.2 showing P values

	AMBAGAN			BISRA			KONARK		
	Speed	Flow	Density	Speed	Flow	Density	Speed	Flow	Density
NMV	0.0093	0.001	$<10^{-4}$	0.049	0.026	0.005	$<10^{-4}$	$<10^{-4}$	$<10^{-3}$
MV	$<10^{-3}$	0.006	$<10^{-4}$	0.436	0.025	0.792	0.831	$<10^{-4}$	0.135
TOTAL	$<10^{-3}$	0.534	$<10^{-4}$	0.127	0.121	0.675	0.018	$<10^{-4}$	$<10^{-3}$

From the above tables the speeds at the ambagan got reduced and the density increased as compared to 2011 and at Bisra chowk the speed of NMV is increased and the remaining (MV and total) speeds decreased

CHAPTER 5

CONCLUSIONS

5. CONCLUSION

- From the fundamental diagrams, it can be observed that the traffic parameters in the section are affected largely by the percentage of non-motorized vehicles in the section. For both the divided and undivided lanes the pattern remains same, i.e., as the percentage non-motorized vehicles increasing the parameters like density, flow and speed of the total section decreased. In divided lanes the effect is less as compared to the undivided lanes as there exists the effect of vehicles coming in the opposite direction.
- It can be observed from the lateral occupancy graph that the NMVs are occupying the left hand side of the road. As we follow left hand side drive in India and the MVs try to overtake them from the right hand side of the road. Also in the left first strip or 1 m from the left edge no vehicles are present as the vehicles try to keep away from road edges as far as possible and it is the psychological behavior of drivers, they try to avoid moving at the edge when there are no shoulders or raised kerbs. Roads in which there are shoulders the vehicles are found in the first strip from left side also.
- In the case of divided one way traffic, the vehicles occupies in all the strips equally. As the NMVs are the slow moving vehicles they try to occupy the first two strips and the last two strips (6^{th} and 7^{th}) are occupied by the overtaking vehicles. The flow is maximum in the last two strips.
- In the case of undivided two way traffic, the occupancy pattern is not the same as that of the one way divided traffic. The vehicles will try to occupy the left three strips and rarely the fourth strip as there are the vehicles coming in the opposite direction. In this undivided two way traffic the maximum occupancy is in the middle 3^{rd}, 4^{th} and 5^{th} strips and the minimum in the remaining strips as they are mostly occupied by the slow moving vehicles.

- From the percentage NMV point of view, there exists a uniform pattern of distribution of NMVs if the NMV percentage is moderate, the NMV occupies the left two strips if there is less percentage of NMV and if the NMV content is high then the MVs try to overtake from the right strip of the NMVs.
- From the comparison graphs, it is observed that the speed of the section is increased up to 15% NMV and then starts decreasing. This indicates that up to a certain limit of NMV in the stream there is no effect on the traffic parameters and as the NMV content increased more than this limit, the adversity in the traffic parameters occurs. The flow and density will decrease with the increase in NMV content.

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