MODELLING SIGNAL DESIGN PARAMETERS UNDER HETEROGENEOUS TRAFFIC CONDITION

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MARCH 2019

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by

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A thesis submitted in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING
(TRANSPORTATION)

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
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MARCH 2019

Dedicated to

My Family Members

The thesis titled "Modelling Signal Design Parameters under Heterogeneous Traffic Condition" submitted by Rummana Nazia, Roll No: 100604405 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering on 27 March, 2019.

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Acknowledgements

All praises be to Allah, the most gracious, the most merciful.

The author has immense pleasure to acknowledge her gratefulness, sincere appreciation, deep regards and gratitude to Dr. Md. Shamsul Hoque, Professor, Department of Civil Engineering, BUET Dhaka under whose keen supervision, constant guidance, inspiration, noteworthy endurance and invaluable instructions the study has been completed.

I am indebted to the Department of Civil Engineering library, BUET, Central library of BUET, Traffic Engineering Lab for their facilities provided to carry out the study.

I also wish to acknowledge the kind of cooperation of the many people of Dhaka city especially the owners and the residents who gave permission to carry out the video recording from their property.

I would like to thank my parents and my child whose continuous encouragement and support was of vital importance in the production of this work. Finally, I also would like to express my sincere gratitude to my spouse Syed Sarwar Moorshid as he helped me during the writing stage of this manuscript.

Abstract

This study is aimed at the determination of PCU values, saturation flows, and quantifies their impacts in traffic stream at selected signalized intersection of Dhaka city. This paper is also focused on the process of research work, particularly on the general methodology, site selection, data collection and analysis. Saturation flow and PCU factors were determined using total width concept instead of lane-based concept. Data were obtained by video recording and analyzed by regression analysis. The paper also discusses the effect of geometric and local environmental factors, traffic conditions and vehicle-related factors on saturation flow and PCU values at signalized intersections. Proportion of motorized and non-motorized vehicles, approach width, turning radius and turning proportions are the principal factors for which saturation flow and PCU factors are varied.

The results and analysis show that PCU values are not unique for a particular vehicle type, rather it is dependent on traffic movement, geometric features, vehicle performance etc. It is observed from the analysis that the presence of NMV in the traffic stream influences PCU and saturation flow values significantly. The PCU conversion factor of any type of vehicles varies with the proportion of traffic composition. It is observed that PCU values of Bus and Utility are less than unity in few cases although they are bigger in size than the cars. This is because of their proportions in the traffic stream which are very low compared to the passenger cars. Unusually lower PCU values for instance, less than unit for buses and less than zero for Auto Rickshaw and Utility are found at some locations. The possible explanations would be their insignificant presence during the period of data collection. On the other hand, saturation flow expressed in PCU/hr is found to increase with approach width, turning radius, whereas decrease with increasing percentages of Utility.

Traffic in Bangladesh consists of both motorized and non-motorized vehicles, as in many other developing countries. The static and dynamic characteristics of the different vehicles vary widely even within the same class. Also, the lack of lane discipline and unrestricted mixing of the various types of vehicle in the same right of way makes the traffic stream heterogeneous in nature.

In order to study the non-lane based mixed traffic in a comprehensive manner as well as to estimate the signal design parameters, three models have been developed. The method adopted to consider non-lane disciplined traffic streams, where vehicles can occupy any position across the carriageway. Extensive field observations were made in order to formulate the mixed traffic behavior with a good approximation.

Statistical analysis of traffic data obtained from both direct field measurement and video recording of traffic data enabled the estimation of parameters of the model.

Comparisons between simulated results from the calibrated model and observations from six signalized intersections in Dhaka, Bangladesh indicate that the model is capable of replicating the mixed traffic behavior in a satisfactory manner.

The model has been run with different road widths and varying proportion of the different types of vehicles which make up the stream. Results have shown that in mixed traffic operation, the proportion of non-motorized vehicles (NMV) in the traffic stream and the width of approach influence pcu or saturation flow values greatly. The pcu conversion factor for any type of vehicle is not a single value but varies with road width, proportion of NMVs and traffic composition. By increasing number of sites, considering time variations, effect of counting period, variation in site characteristics a general model can be built in future. For further research hopefully this study would be helpful in this regard.

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Chapter 1
INTRODUCTION

1.1 Background

The prediction of saturation flow is an essential element in the design of traffic signal systems, whether for isolated junctions or for networks of linked junctions. Many standard relationships and factors are used as inputs into urban transport planning models and are utilized in the design of various elements of the transport system. But most of the equations are calibrated mainly to suit the local conditions and features of the transport system of the developed world. Transfer of the standardized relationship and factors for use in the developing cities such as Dhaka are sometimes not practical. Urban travel characteristics, street system and local constraints are very different in different cities. It is of vital importance that research in the developing countries should be directed towards establishing relevant models that are suitable in local urban transport system characteristics. One of such model is the determination of saturation flow at approaches for signalized intersections.

The most important parameters in the planning, design, and control of a signalized intersection are saturation flows and passenger car unit (PCU). These factors are generally measured in the traditional way i.e. based on the car dominated traffic flow existing in the western countries with clearly defined lanes. But the traffic movement in Bangladesh and in other developing countries is rendered to be more complex due to the heterogeneous characteristics of the traffic stream using the same right of way. This stream consists of slow moving bicycles to fast moving passenger cars and even large size Double-Decker muses, with many intermediate types of vehicles depicting a wide variation in static and dynamic characteristics. Prediction of saturation flow is sensitive because of this mixed traffic operation where no single vehicle type dominates the flow.

Another distinctive feature of the study is driving behavior and specially the lack of lane discipline. In mixed traffic condition, traffic usually does not use the lanes in an appropriate manner. Furthermore, lane markings on pavements along the road and near approaches are often not clear or are missing. If they exist, drivers rarely conform to them. Due to this lack of lane discipline, the vehicles can occupy any position across the road and form a vehicle movement with no clear pattern as seen in lane based western cities traffic and hence the lane based analysis falls apart.

Due to these fundamental differences, the standard western relationships for predicting the values of saturation flows PCU factors are not appropriate for developing countries. For correct design and planning purpose these parameters should be estimated based on the local prevailing traffic conditions.

1.2 Objectives

This study is concerned with the investigations of passenger car units and saturation flow values of isolated signal-controlled intersections in Dhaka city under various traffic conditions.

The principal objective of the study is to determine PCU values and Saturation Flow at different signalized intersections of Dhaka city. The specific objectives are as following:

- Determination of saturation flow at signalized intersection.
- Determination of PCU values.
- To obtain a better understanding of non-lane based mixed or heterogeneous traffic operation and signal design parameters;
- To analyze the effect of various road geometric and traffic operational factors on different signal design parameters viz. PCU values and saturation flow;
- To develop asynchronous multiple linear regression model for saturation flow under non-lane based heterogeneous traffic operation.

It is expected that the output of the thesis will be helpful to planners, traffic engineers in order to determine intersection capacity, signal design and other parameters of signalized intersections.

1.3 Organization of the Thesis

The thesis consists of five chapters and one appendix, which are outlined in this section.

Chapter 1: This chapter contains general background to the research program and summary of objectives and scopes and significance of the study.

Chapter 2: This chapter includes comprehensive review of the literature, as well as other important topics related with the study. The available approaches to the work are also discussed here.

Chapter 3: In this chapter methods for the determination of the principal parameters are projected. The reasons behind the selection of the method, and the steps for implementing the work are stated descriptively.

Chapter 4: The detailed procedures for data collection, the measured data and observed nature of different traffic parameters are described here. The investigation of the result from statistical analysis, their interpretations are also included here. The observed pattern of the result and their possible reasons are explained in the findings of the study.

Chapter 5: Conclusions drawn from the results and Recommendations for further improvement are presented in this chapter.

In addition to these five chapters, references of different authors and journals are given in the reference section. Additional information is presented in the Appendix.

Chapter 2
LITERATURE REVIEW

2.1 Introduction

In this chapter extensive studies were carried out for better understanding of the topic. Various literatures regarding the thesis were studied in order to precede the work. It includes the definitions of the basic parameters of the concerned topic as well as different factors affecting the PCU values and Saturation Flow. The methods suggested by many authors and researchers are also described with their suitability.

2.2 Definitions

Here definitions of the principal parameters related to the thesis topic are given.

2.2.1 Passenger Car Equivalent (PCE)

It is the method of expressing various types of vehicles having different characteristics in a common equivalent unit. It is needed to remove the effects of traffic composition from flow calculation. One car is considered as one unit. In respect of it road occupancy and operational requirements each type of vehicle is equivalent to a number of passenger cars and this is called the Passenger Car Equivalent/Unit (PCE/PCU).

The PCE of vehicles may be determined by measuring the mean time headway from head to head of each successive vehicles discharging from queue as they cross the stop line. The first several vehicles are skipped to avoid the effect of vehicles inertia in the initial seconds of green time. In respect of its road capacity requirements each type of vehicle is equivalent to a number of passenger cars and this is called 'passenger car unit' (PCU). **Scraggs** **[(2)]** defined PCU factor as under saturated conditions if a particular type of vehicle requires 'X' times as much time at an intersection as is required by an average passenger car then that type is equivalent to

X PCU. It is needed to remove the effects of traffic composition from saturation flow calculations.

2.2.2 Saturation Flow

When the green period commences vehicle take some time to start and accelerate to normal running speed, but after a few seconds the queue discharges at a more or less constant rate called the saturation flow. The saturation flow is the flow which would be obtained if there was a continuous queue of vehicles and they were given a 100 percent green time.

2.3 Factors Affecting Saturation Flow and PCU

These factors can be classified as:

- Geometric factors
- Signal operation
- Traffic factors
- Environmental factors
- Driver and vehicle characteristics
- Other factors

2.3.1 Geometric Factors

These factors usually control the capacity of an approach and are the physical layout of the approach. Some geometric factors are described below with their effects.

I) Approach and Lane Width

The saturation flow (s), expressed in terms of passenger car units with no turning traffic and with no parked vehicles present, is given by,

$$S = 525W \text{ PCU / h}$$

Where W is the approach width in meters (measured from curb to inside of pedestrian refuge or center line, whichever is nearer or to inside of central reserve in the case of a dual carriageway).

This result is applicable for approach width varying from 5.5m to 18m (the maximum width tested). For widths between 3m and 5.5m the saturation flow shows a slight step effect and the saturation flow can be estimated from the following table.

W (meters)	**3.0**	**3.5**	**4.0**	**4.5**	**5.5**
S (PCU/hr)	**1850**	**1875**	**1975**	**2175**	**2900**

The width is assumed to be constant for at least the length of the approach (defined as the length which will accommodate the queue which can just pass through the intersection during a fully saturated green period). These rules given above are considered sufficiently accurate for most practical cases for both peak and off- peak periods .But it has been found that saturation flow in off-peak periods is lower than the peak period values by nearly 6 percent.

U.S highway capacity manual proposed a standard saturation flow of 1800 p.c.u/hr based on a 3.65m lane width, a correction of 3 percent for each foot deviation from the standard lane width is applicable.

II) Effect of gradient

For each 1 percent of uphill gradient the saturation flow was found to decrease by 3 percent, and for was 1 percent of downhill gradient the saturation flow increased by 3 percent. The gradient was found as the average slope between the stop line and a point on the approach 61m before it. The results were based on gradients not exceeding 10 percent uphill and 5 percent downhill and referred to sites where the slope continued through the intersection.

On the other hand American HCM recommended an adjustment of 0.5 percent for each percent of gradient.

It has been observed that there is no visible relationship between saturation flow and the downhill gradient. Moreover, saturation flows are higher in offside lanes than in near side lanes. **(Kimber, TRRL)[(3)]**

III) Effect of curvature or turning radius

It is easier for drivers to turn around a larger radius than a small one. Vehicle headways following a curved path are greater on average than those for traffic following a straight path and the saturation flow is correspondingly less. When a stream contains a mixture of turning and non-turning vehicle vehicles, the turners impede the straight ahead vehicles. The net saturation flow of the mixture then depends on the path radius and the proportion of turners.

2.3.2 Signal Operation

The principal factors are

- The number of vehicles crossing the stop line in a given period of time
- The proportion of time during which the signal is effectively green.
- The cycle length (hence the number of cycles per hour)
- Load factor (defined by the ratio of the number of green phases that are loaded or fully utilized by traffic, usually during the peak hours).

2.3.3 Traffic Factors

There are several traffic actors governing saturation flow.

I) Effect of traffic composition

The effect of various types of vehicles is dependent on the different vehicle sizes. The effect of different types of vehicles on saturation flow at traffic signal is allowed for the use of passenger car units, which represent the effect of varying vehicle types relative to passenger.

According to **Kimber et al** [(3)]

Vehicle Types	Factors
Light vehicle	1.0
Medium commercial vehicles	1.5
Buses & coaches	2.0
Motor cycles	0.4
Pedal cycles	0.2

The American method is to apply a factor which reduces or increases the capacity and service volumes 1 percent for each percentage of trucks (medium or heavy goods vehicles) and through buses in the approach stream above or below 5 percent.

A part from this, Highway Capacity Manual states that one truck can be considered to be equivalent to two passenger cars.

II) Effect of turning vehicles

If the right turning movements from opposite directions cause the intersection to lock then the capacity of the intersection cannot be easily be assessed. In practice, locking should be prevented by using one of the methods described earlier. Under non-locking conditions the effects of right turning traffic depend on whether or not conflicting traffic moves on the same phase and on whether or not the right turning traffic is given exclusive lanes. There are four possibilities:

a. No opposing flow, no exclusive right turning lanes: An overall Figure foe saturation flow for the approach (irrespective of turning movements) can be obtained using the already defined rules.
b. No opposing flow, exclusive right turning lanes: The saturation flow of the right turning stream should be obtained separately. It has been found that the saturation flow(s) of a stream turning through a right angle depends on the radius of curvature(r)and is given by

$$S = 1800/ (1+1.5/r) \text{ p.c.u/hr for single file stream}$$

$$S = 3000/ (1+1.5/r) \text{ p.c.u/hr for double file stream;}$$

Where r is measured in meters

c. Opposing flow, no exclusive right turning lanes: The effect of right turners under these circumstances are three fold. Firstly, because of the opposing traffic, they are delayed themselves and consequently delay other (non-right turning) vehicles in the stream; secondly, their presence tends to inhibit the use of the offside lane by straight-ahead vehicles owing to the risk of being delayed and thirdly, those right turning vehicles which remain in the intersection at the end of the green period take a certain time to discharge and may delay the start of the cross- phase.

The first of these two effects can be allowed for by assuming that on the average each right turning vehicle is equivalent to 1.25 of straight-ahead vehicles. The third effect is more complicated. Right turners may discharge through suitable gap in the opposing stream. Observations indicate that a gap of 5 to 6 seconds is typical. **Kimber and et. al** [(3)] have produced a formula combined with the proportion of turning vehicles in the following equation :

$$S = So / (1+1.5f/r)$$

Where, S is adjusted saturation flow, So is the basic saturation flow, f is the proportion of turning vehicles, r is the radius of curvature of vehicle path in meter.

The following adjustment factors are used to cater for unopposed turning vehicles by multiplying with the basic saturation flow.

fRT = 0.85 for unopposed left turn

fLT = 0.90 for unopposed right turn

In Road Note 34, the effect of turning vehicles are treated by the provision of correction factor

$$F = 1 + (0.75\ nr) / (n1+n2+n3+n4)$$

Where, nr is flow of right turning vehicles, n1, n2, n3, n4 is flow of cars, medium buses and tram respectively.

d. <u>Effect of Left-turning Traffic: </u>The effect of left turners on saturation flow depends on the sharpness of turn and on the pedestrian flow. The rules regarding the effect of curvature given for right turning traffic can equally well be held o well-defined left turning streams. Where, however, left-turners in small numbers are intermixed with straight ahead vehicles it is unnecessary to make a correction for them as the general saturation flow relations given earlier include the effects of the left-turning traffic (forming about 10 percent of the whole traffic) present when the studies were made. If left-turners form appreciably more than 10 percent of the traffic a correction could b made for the excess over 10 percent by assuming each left-turner is equivalent to 1 ¼ straight- ahead vehicles.

2.3.4 Environmental Factors

Effect of Site Characteristics

The effect of site characteristics and pedestrians are allowed for by designating a site classification as good, average or poor. Sites are classified according to the description given in table:

Table 2.1: Off Site Characteristics on Saturation Flow

Site designation	Description	Percentages of standard saturation flow
Good	Duel carriageway. No noticeable interference from pedestrians, parked vehicles, right turning traffic. Good visibility and adequate turning radii. Exit of adequate width and alignment.	120
Average	Average sites. Some characteristics of ‘Good’ and ‘Poor’.	100
Poor	Average speed low. Some interference from standing vehicles, pedestrians, right-turning traffic. Poor visibility and/or poor alignment of intersection. Busy shopping street.	85

2.3.5 Driver and Vehicle Characteristics

I) Effects of Drivers Characteristics

During the rush hour drivers may behave differently from off peak hours, and this will affect the saturation flow. **Webster and Cobbe, L.A. (1986)** [4] revealed a 6% difference between saturation flow values in peak and off peak hours. Branston who worked on the asynchronous regression method indicate that there was a variation of saturation flow between peak and off peak periods.

II) Effects of Motorcycles and Bicycles

The presence of motorcycles and bicycles in the traffic stream presents a unique departure process in the signalized intersection approaches. This effect s more obvious when their proportion is large as is the case in most of the developing countries. Based on nine sites, **Holroyd** [7] worked out a regression analysis in which he found that the pcu values for two wheeled vehicles for the first 0.1 min tend to be lower than those for the remainder saturation period.

III) Effect of Parked Vehicles

It has been found that the reduction of saturation flow caused by the parked car nearest to the stop line to the particular approach is equivalent to a loss of carriageway width at the stop line, and can be expressed approximately as follows:

Effective loss of carriageway width = $5.5 - 0.9(z - 25)/k$ ft (if positive)

Where, z = clear distance between stop line and parked vehicles in ft, k = green time in seconds

A factor of 1.5 is used if a lorry or wide van is parked. If the whole expression becomes negative the effective loss should be taken to be zero.

2.3.6 Other Factors

I) Effects of Pedestrians

Few literatures have been found to be dedicated to the analysis of the influence of pedestrians on the saturation flow. Usually this effect is expected to appear more intensively at the left turning movement. It has been dealt with as a factor describing the general condition of the site rather than a separately quantified parameter. Special measurements, however, have been suggested in the case of high pedestrian flows, which can justify the adoption of a special phase of the signals for pedestrians.

II) Effect of Surface Condition

Effect of Surface Condition was investigated by **Kimber et al** [3] who recommended a and in Hong Kong in an reduction of 6% of wet surfaces. McDonald et al indicated that road markings and road surface conditions, which generally are less than in the study area, do effect the vehicular flow at signalized intersections although such factors are less easily definable.

2.4 Methods of Measurement of PCU Factors

The passenger car unit factors are usually computed by comparing the departure time of cars at the stop line and the identical measure for all other types of vehicles. Methods developed for the calculation of PCU factors are discussed in the following section.

2.4.1 Webster Method

This method is based on public road observations and controlled test track experiment, carried out by Webster using cars, taxis, light, medium, and heavy commercial vehicles and some double-decker buses. The average number of light and goods vehicles per cycle was calculated as follows:

$$N_1 = 1/N \,/\, \sum_{i=1}^{N} n1$$

$$Ng = 1/N \,/\, \sum_{i=1}^{N} ng1$$

Where,

N_1 = average number of light vehicles per cycle

n_1 = number of departing light vehicles per cycle

N = number of cycles in a set

Ng = average number of goods vehicles per cycle

$ng1$ = number of departing goods vehicles per cycle

The PCU values are estimated as a reciprocal of slope of the straight line drawn through the values of n1 and ng1. This method is consequently unable to estimate more than two types of vehicles at a time.

2.4.2 The Average Headway Method

The most common method of determining PCU factor is known as the headway ratio and used by many researchers viz. Scraggs, Webster, Miller, Kimber. In this method the PCU values of different vehicle types are obtained by comparing the headways of these vehicle types with those of straight ahead passenger cars. For accurate results headways should be measured on a vehicle to vehicle to vehicle basis of possible combinations for a large sample of each vehicle type. Because of the complication involved in collecting data from a large number of possible combinations, a simple calculation procedure has been developed so long as there is no biasness doing so. Assuming in the traffic stream the proportion of heavy vehicles is low, the number of headways between heavy vehicles is small and headways are in many cases almost independent of the class of vehicle preceding and following it. The formula for this is given below is a simplification of that used by **Scraggs** [(2)]

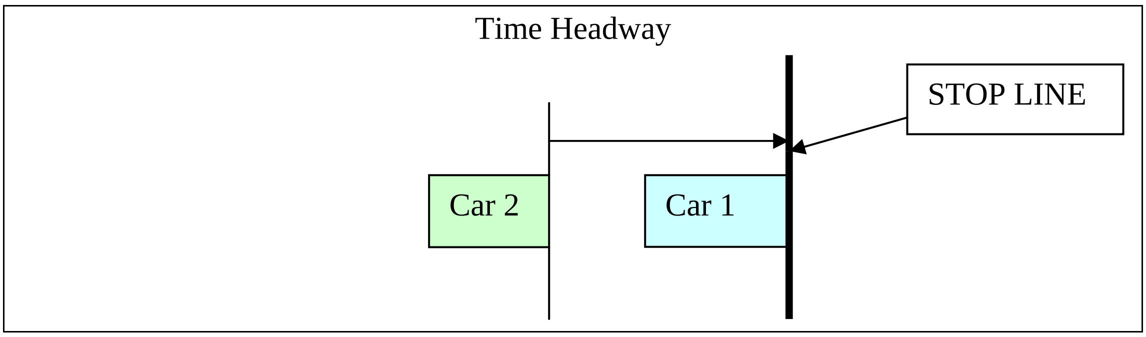
Passenger car unit of vehicle type h = h_1-h /h_1-1

Where, h_1-h = Mean headway between light vehicle and a following vehicle of type h

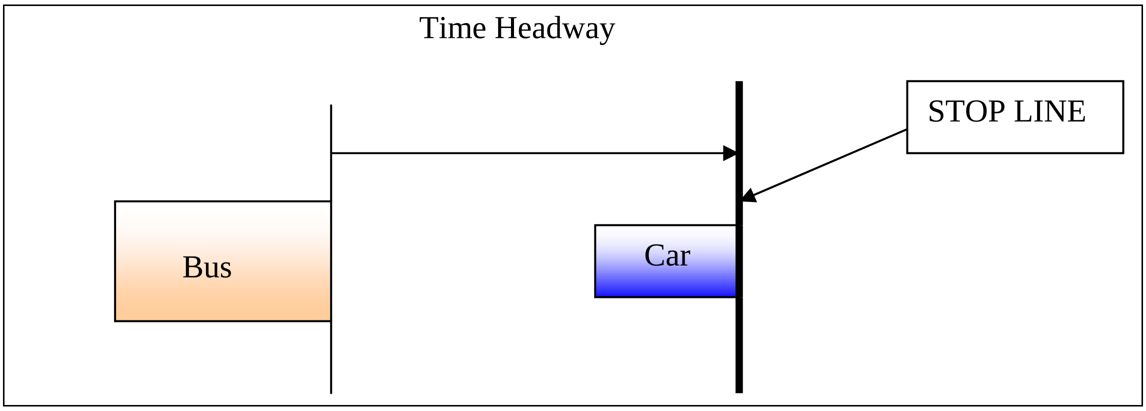
h_1-1 = Mean headway between two consecutive light vehicles

The schematic diagram showing the time headway between different types of vehicle pair is given below:

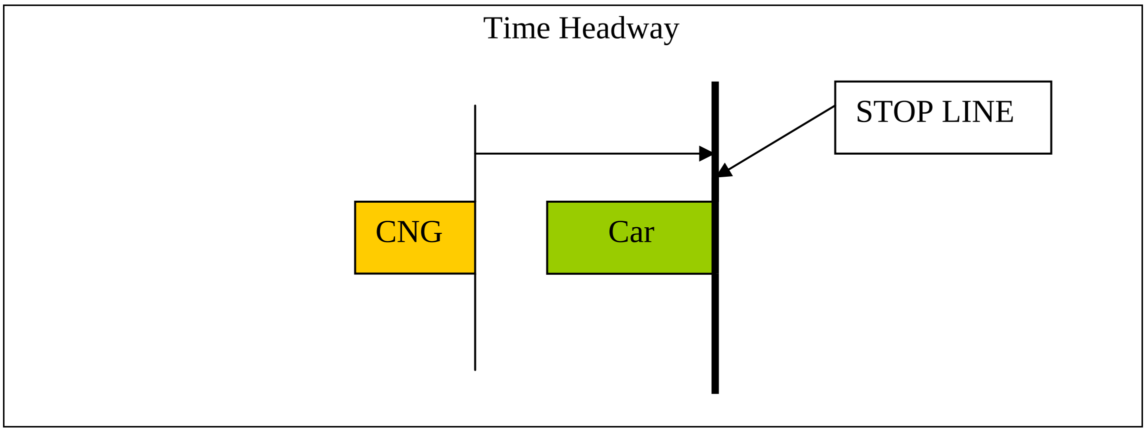
SCHEMATIC DIAGRAM OF TIME HEADWAY



Schematic Diagram- 1: Car Following Car



Schematic Diagram -2: Bus Following Car



Schematic Diagram -3: Auto Rickshaw Following Car

2.4.3 Multiple Linear Regression Method

Passenger car unit of various classes of vehicles can be simultaneously obtained with the saturation flows. These types of regression techniques are used to estimate p.c.u factors, saturation flows at sites where data has been collected in the form of six second intervals.

L = ST- A1X1 – A2X2- A3X3- A4X4…………….. AnXn

Here, ST = saturation flow in pcu in time T secs

L = Light vehicle, X1, X2, X3, X4………….Xn are vehicle types in six second interval, A1, A2, A3, A4 ……An are the p.c.u factors for each vehicle type.

By regressing L on X1, X2, X3, X4………………..Xn, estimates of A1, A2, A3, A4 ……An are obtained simultaneously.

However it has been found that multiple regression techniques of these forms lead to underestimates of PCU factors and saturation flows.

2.5 Methods of Measurement for Saturation Flow

The three methods available for the calculation of saturation flows are describe below.

2.5.1 The Road Note 34 Method [1]

The procedures used in this method consists of taking classified counts of vehicles crossing the stop line within the width of an approach in six second intervals during the green and amber periods of cycle under saturated flow condition. An average number of 30 cycles is recommended to be counted for each lane. For calculating saturation flow the counting in six second intervals is recorded until the last fully saturated interval before the queue has finished. Vehicles passing after the time are recorded, but not in the six second format. Starting lost times are assumed to occur only in the first six seconds interval of each phase, while the ending lost times are taken to occur in the last interval of the amber period.

These initial and end lost time intervals are then excluded from the estimation of saturation flow. In this method, vehicles are usually identified by type and converted into passenger car units by using standard conversion factor. The saturation flow is then calculated as the total no of passenger cars in all relevant six seconds intervals divided by the no of intervals considered in PCU/hr.

This method is suitable for traffic not moving in lanes themselves is not distinguishable. Obviously this method can be applied on a lane-by-lane basis. A drawback of this method is that it does not show PCU values of different vehicles types to be calculated from observed data.

2.5.2 The Average Headway Method

It is the most commonly used alternative to the TRRL counting method based on **Scraggs** [(2)] this method requires data in time headways between vehicles as they cross the stop line. Time headway of a vehicle is measured as the time between the crossing of the stop line by the rear wheels of the vehicle preceding it and its own rear wheels. Saturation flow is calculated directly from equation (1) below in PCU/hr as the reciprocal of the average headway of saturated straight on passenger cars.

$$S = 3600/h_{i-j} \quad \text{PCU/hr}$$

Where h_{i-j} is he average headway between light vehicles in seconds

At the beginning of discharge as the headways of few front vehicles of a saturated stream are longer due to the fact that these vehicles are still accelerating when they cross the stop line, the first three or four vehicles are excluded from the calculation of saturation flow. Vehicles that cross the stop line during the amber or red periods are also excluded from the calculation.

2.5.3 Multiple Linear Regression Method

In the recent years a number of alternative methods of processing the data collected in classified vehicle counts format have been developed. These methods involved multiple linear regression techniques which have been used by a number of researchers. **Branston and Zuylen** [(6)] introduced two methods known as 'asynchronous' and 'synchronous' multiple regressions based on counting methods which are described in the following articles.

i. Asynchronous Multiple Regression

In this method vehicle departures are recorded over time periods T which begin and end at an arbitrary point of time. A typical mathematical expression of this model is given below

$$L = ST - S\delta l_1 - a_1M - a_2H - a_3BC - a_4MC - a_5C$$

Where

L = number of light vehicles recorded in time interval T

M = number of medium vehicles recorded in time interval T

H = number of heavy vehicles recorded in time interval T

BC = number of buses or coaches recorded in time interval T

MC = number of motorcycles recorded in time interval T

C = number of bicycles recorded in time interval T

S = saturation flow in time interval T (in pcu/hr)

δ = dummy variable

l_1 = initial lost time in seconds

a_1 to a_5 = passenger car equivalents for the corresponding vehicle types

ii. Synchronous Multiple Regression

A number of researches have used 'synchronous' regression in their studies as an alternative technique to asynchronous regression for their calculation of saturation flows and lost times. In this method the no of vehicle departures of each class are recorded over time periods beginning and ending with the instant of departure of a vehicle (the first vehicle departed being excluded) and the counting periods are defined as

$$T = h_L L + h_M M + h_H H + h_{BC} BC + h_{MC} MC + h_C C$$

Where

T = length of vehicle counting period

L = number of light vehicles recorded in time interval T

M = number of medium vehicles recorded in time interval T

H = number of heavy vehicles recorded in time interval T

BC = number of buses or coaches recorded in time interval T

MC = number of motorcycles recorded in time interval T

C = number of bicycles recorded in time interval T

h_L to h_C =co-efficients representing the average headway for different vehicle class

2.6 Previous Study

Zegeer (1986) conducted field survey to find saturation flow throughout the United States at signalized intersection. He verified the saturation flow rates and traffic volume adjustment factors used in various capacity analysis procedures by collecting relatively extensive database. Saturation flow headways for more than 20,000 observations were collected for series 12 geometric, traffic characteristic, and environmental factors and compared with baseline saturation flow headways for various signal cycle length and phase combinations. Vehicle blockage and lane distribution surveys were conducted for 1900 additional observations. He suggested series of modified adjustment factors to determine modified saturation flow rates when calculating signalized intersection capacity.

Lee and Chen (1986) studied the entering headways in small city Lawrence, Kansas and six factors were examined. Entering headway values from total of 1,899 traffic queues were recorded by using video camera equipment. From the data, mean entry headway of vehicle 1 through 12 were found to be 3.80, 2.56, 3.25, 2.22, 2.16, 2.03, 1.97, 1.94, 1.94, 1.78, 1.64, and 1.76. He found that

- Signal type has little influence on entering headway at signalized intersections
- Time of the day (a. m. or p. m.) has little influence on entering headways.
- The inside lane of an approach has slightly lower entering headways than does outside lane.
- The entering headways at approaches with speed limits of 20 mph are significantly higher than those at approaches with higher speed limits. (>=30 mph). For approaches with speed limits higher than 30 mph, the influence of speed limit on the headway is noticeable.
- In general, streets that have higher speed limits and less roadside friction have lower entering headway values.
- When queue lengths increases, the general observation is that the entering headway values decreases.

Taylor et al (1989) used video-based equipment to estimate the character speeds and headway. This technique provided cheap, quick, easy, and accurate method of investigating traffic systems. Investigation of headways on freeway traffic allows the potential of this technology in a high-speed environment to be determined. Its application to the study of speeds in parking lots enabled its usefulness in low-speed environments to be studied. The data obtained from the video was compared to traditional methods of collecting headways and speed data.

Hoque (1994) developed micro simulation model, MIXSIM to study the non-lane based mixed traffic in a comprehensive manner as well as to estimate the signal design parameters. The model was calibrated and validated on the basis of data collected from Dhaka, the capital of Bangladesh. The method adopted to consider non-lane disciplined traffic streams, where vehicles can occupy any position across the carriageway, is to divide the whole width of approach into smaller lanes or strips. Extensive field observations were made in order to formulate the mixed traffic behavior with a good approximation. Dynamic graphical display of simulated traffic stream is used to develop a collision-free traffic model and also to analyze some results instantaneously.

HCM 2000 has suggested the following equation for the determination of saturation flow rates,

$$S = s_0 N f_w f_{HV} f_g f_e f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$$

where

S = saturation flow rate for the lane group, veh/hr

s_0 = base saturation flow rate per lane, pc/hr/lane

N = no. of lanes in a lane group

f_W = adjustment factor for lane width

f_{HV} = adjustment factor for heavy vehicles

f_g = adjustment factor for approach grade

f_e = adjustment factor for parking activity

f_{bb} = adjustment factor for blocking effect of local buses

f_a = adjustment factor for area type

f_{LU} = adjustment factor for lane utilization

f_{LT} = adjustment factor for left turn

f_{RT} = adjustment factor for right turn

f_{Lpb} = pedestrian adjustment factor for left turn

f_{Rpb} = pedestrian adjustment factor for right turn

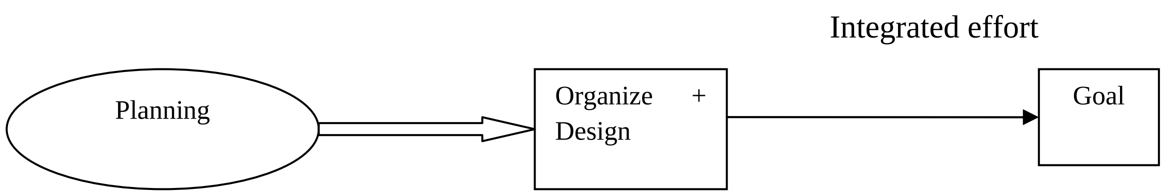
Overview

In estimating the PCU factors for different classes of vehicle the methods described in this literature are suitable in different situation. PCU factors cannot be obtained by Road Note 34 method. Among the three methods direct measurement of headway or synchronous regression model produces the best estimates of PCU factors. **University of Southampton work** [5] has shown that asynchronous multiple regression models give slightly lower values of PCU factors than the other methods. But in non-lane based traffic condition it was difficult to measure PCU factors by headway method. About the prediction of saturation flows by multiple linear regression techniques, different conclusions have been found in many studies. It has been found that the regression model produces more accurate prediction of saturation flow than the Road Note 34 method while **Kimber, McDonald and Hounsell** [3] and the **Southampton University Study**[5] have proved that the asynchronous regression model produces lower estimates of saturation flows than those obtained by other methods.

Chapter 3
METHODOLOGY

3.1 Introduction

Methodology incorporates the planning and organization of entire project work. In fact correct planning process intends to understand the nature of problem and organizes the entire work towards achievement of predefined goal.



Initially the assigned problem is identified and a suitable approach to solve the problem has been selected. There after data collection is carried out from the field in order to analyze and obtain required result.

3.2 Selecting the Topic

For any thesis or project work topic selection is of paramount importance. Capability under existing system, fund involvement, future utility, present requirement, availability of time and resources etc. directs the selection of a suitable topic. In view of these constraints a practical and field oriented topic has been selected and assigned by the respective thesis supervisor.

Considering all attributes, “Modeling Signal Design Parameters under Heterogeneous Traffic Conditions” has been selected. This project is systematically planned as represented by the following flow chart.

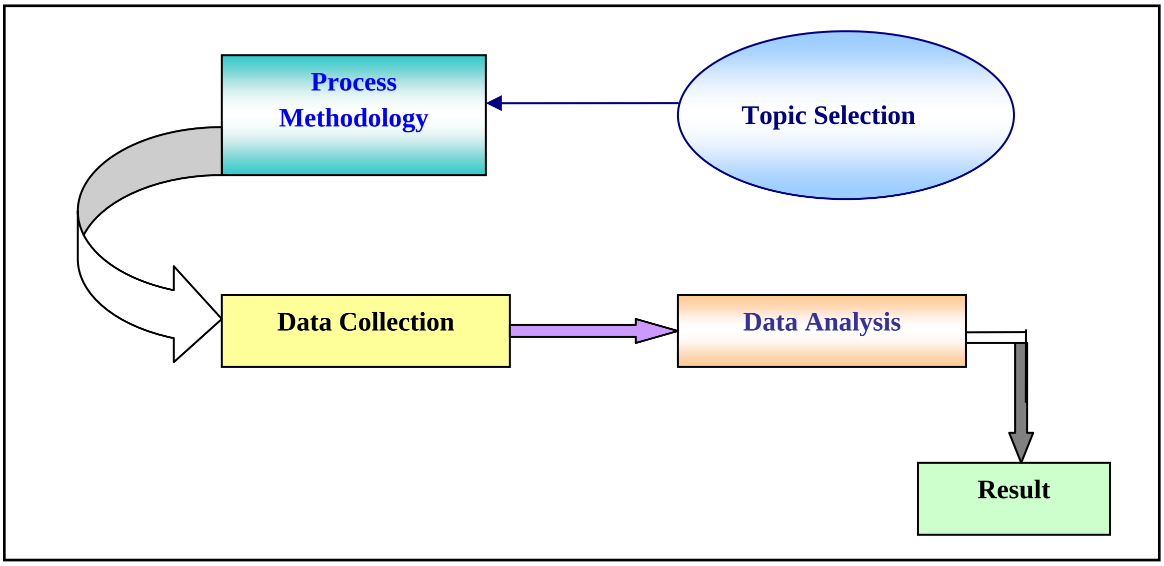


Figure 3.1: Flow Chart of the Process

3.3 Site Selection

The main criteria for site selection are:

1) Availability of vintage point for video recording.
2) Reasonably flatter area for eliminating the effect of gradient.
3) Lanes with mixed traffic movements should be allowed. These should include lanes shared between both left turning and straight-ahead traffic and between right turning and straight ahead traffic.
4) Approach with sufficiently long length so that intersection can be considered as isolated and vehicle arrival pattern at upstream can occur randomly
5) The sites should be relatively free from traffic disturbances such as parked vehicles and bus stops, excessive pedestrian activity etc, as they tend to make the subject more complex to be studied.

In order to select suitable sites, it was necessary to conduct a preliminary survey of all the available sites in the study area. The aim is to identify the sites which were most suitable for final study.

3.4 Proposed Method of Measurement

This chapter has concentrated primarily on the concept, measurement procedures and techniques of the three key parameters of signal control intersection and then effects of various factors on saturation flow values. Broadly speaking, to measure these parameters two different approaches are found i.e. lane-by-lane approach and total width approach. In non lane based mixed traffic operation, instead of lane-by-lane approach a total width approach would be more appropriate for measuring these parameters.

It has been found that the average headway method is the best for estimating saturation flows and pcu values. The Road Note 34 also gives good prediction of saturation flows. But compared to these two methods the former one requires data in time headway format which is usually very difficult to collect, specially in mixed traffic condition where due to the lack of lane discipline, vehicles form queue with no clear pattern and during subsequent discharge due to penetration effect narrower vehicles occupy the front of the queue and discharge in a group. The problem is that vehicles are not moving in a lane and one vehicle may have more than one leader. Consequently, the headway ratio method cannot be applied for this study purpose.

Although the Road Note 34 method requires data in simple classified format it does not allow to calculate pcu values which are essential for saturation flow (in PCU) measurement. Due to this limitation it was also not considered here as an alternative method.

The option left is the regression method which gives saturation flow and PCU values simultaneously and is therefore attractive. Asynchronous regression method is proposed for this study purpose. As this method is based on vehicle count data, it would be an appropriate measurement technique for the non-lane discipline traffic operation where analysis would be done based on the total width of the road.

3.5 Vehicle Classification

Detailed vehicle classification is needed to represent all types of vehicles available in the study area adequately. Each vehicle in the study area is considered to be under one of the following headings so that the composition of the traffic could be accurately determined. Traffic has been classified into two major groups. The two major groups have also been sub- divided into seven classes as follows:

a. Motorized

1. Passenger Car
2. Auto Rickshaw
3. Large Bus
4. Small Bus
5. Utility
6. Motorcycle

b. Non-motorized

7. Rickshaw, rickshaw van (NMV)

3.6 Preliminary Survey

The sites were inspected in terms of above mentioned criteria and a total of six intersections were chosen for the final survey work. The characteristics of these sites are given in table. The overall objectives of this survey were-

1) To get the best position for vehicle recording related to the visibility of the approach to be surveyed of the stop line and the signals.
2) To fix the best time for data collection.
3) To identify the best suitable locations for video recording to cover discharge process.
4) To see whether the study can hamper pedestrian and other local activities, if so then changing the recording position.
5) To observe the sites carefully, to determine if there were any special condition prevailing in the area during the study. And also to find if any abnormality occurred during the preliminary survey.

3.7 Pilot Survey

To meet up any unforeseen problem during the actual survey work a rehearsal is necessary. This is achieved through trial survey. Trial survey was carried out basing on the feasibility of followings:

- Placement of video camera.
- Existence of lanes, traffic control devices.
- Suitability of smooth data collection.
- Avoidance of too much pedestrians and bus stoppage.

3.8 Objectives of Data Collection

The objectives of the field survey were:

1. To obtain a better understanding of the nature of the traffic in non-lane based mixed traffic operation, especially in relation to car following, lane changing, queue formations and discharge operations.
2. Preliminary observation of saturation flow for selected sites from the study area.
3. To estimate different mixed traffic stream parameters.
4. To obtain comprehensive data from selected intersections.

3.9 Method of Data Collection

Data necessary for the calculation of saturation flow and associated parameters were collected by fully automatic recording events. Generally the more sophisticated the data collection process, the more detailed the results. In this study the main approach of collection of onsite information is:

Recording the numbers of vehicles discharging inset time intervals, usually of 6 seconds. Estimation of saturation flows and PCU values were done excluding the first period in which startup effects occur.

Another approach was to record the times at which vehicles discharged across a junction (usually measured at the stop -line). This enabled the average time headway between vehicles and hence the saturation flow to be calculated from the inverse of the mean headways.

Data collection procedure is given below-

1. First a suitable intersection is selected.
2. From the traffic signal a total cycle time and green plus amber period is counted. The combined green plus amber time is divided to number of periods of 6 seconds interval.
3. Video recording was done for the counting of classified vehicles.
4. From the vehicle stop line different types of vehicle are counted separately at the commencement of green signal and continued till the end of amber period. This counting is done separately for each section of 6 seconds interval.
5. For counting purpose, when rear wheel of a vehicle will cross the stop line, it will be included in the count for that particular interval.
6. Although the counting must stop at the end of the amber, any vehicle crossing on the red must include in the last interval.
7. Any vehicle that cross the observation point but fails to complete their journey through the intersection must not be counted until the next green period has started.
8. Oversaturated and nearly saturated time intervals were chosen for vehicle counting. Any intervals with under saturated flow were avoided.

In order to get a detailed and comprehensive picture of the mixed traffic behavior it was decided to use a video camera which has the advantage of providing a permanent and comprehensive record of traffic movements, which can readily be used to obtain the repeated field picture as many times as required during analysis. An added advantage is that one may obtain many sets of information regarding mixed stream characteristics from the same recorded film.

3.10 Problems Identified

Based on the preliminary survey, the following problems were identified-

1) During the preliminary survey video transportation of the discharge process a problem was noticed when there was a large vehicle blocking the view, judgment

could not be made accurately whether there was any vehicle discharging behind the blocking area. So to avoid this problem, most practical solution was to choose a suitable place for video recording, so that the chances of blocking the view were least

2) Although video recording provides the most detailed and accurate information regarding the flow of vehicles at traffic signals, especially for the classified vehicles count for the total approach, the extraction of data in a workable format is a tedious and time consuming occupation. To study the various mixes of traffic behavior video recordings were undertaken at selected sites.

3) In most of the intersections under our study pedestrian performances. Generally pedestrians cross the road at any random point near the approach, even during the green period. In some instances pedestrian barriers have been broken through. These types of random walks decrease the possible saturation flow since a part of the green period would be lost due to the obligatory slowing down of the traffic stream.

4) It is believed in dealing with total width may be more appropriate in existing conditions of Dhaka city. This is mainly because traffic does not use lanes in an appropriate manner. Furthermore, lane markings on pavements along streets and near the approaches are often not clear or straight, and do not exist in some cases.

3.11 Site Characteristics

The following tables (Table 3.1-3.7) list several site characteristics of the selected locations. In these tables the variations of geometric characteristics and other details of all sites can be found.

Selected sites are:

- Moghbazar Intersection
- Banglamotor Intersection
- Bata Signal Intersection
- Katabon Intersection
- Scince Lab Intersection
- Razarbagh Intersection

Table 3.1: Site Characteristics of Banglamotor (W To S, E To W Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	1851, 1734
Stop line width	M	10.50 m, 10.25
No. of lanes	-----	2
Gradient	%	0
Time of day	-----	10.00-11.00 am
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[A], [R]

Table 3.2: Site Characteristics of Moghbazar (E To W , W To S Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	1476, 1976
Stop line width	M	10.00 m, 09.50
No. of lanes	-----	2
Gradient	%	0
Time of day	-----	11.00-12.00 am
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[A, L], [A,R];

Table 3.3: Site Characteristics of Science-Lab (W To S, N To S Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	1379, 2361
Stop line width	M	11.89 m, 11.05
No. of lanes	-----	3
Gradient	%	0
Time of day	-----	12.00-01.00 pm
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[A], [R];

Table 3.4: Site Characteristics of Bata Signal (E To S, E To W Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	533, 495
Stop line width	M	8.50 m, 9.25
No. of lanes	-----	2
Gradient	%	0
Time of day	-----	11.00-012.00 pm
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[AL], [AL];

Table 3.5: Site Characteristics of Rajarbagh (W To S, E To W Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	1604, 2516
Stop line width	M	9.15 m, 9.25m
No. of lanes	-----	2
Gradient	%	0
Time of day	-----	02.00-03.00 pm
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[AL], [AR]: [AL], [AL];

Table 3.6: Site Characteristics of Katabon (E To W, E To S Approach)

Variable	Unit	Value
Saturation Flow (W to S, E to W)	PCU/hr	911, 1185
Stop line width	M	9.12 m, 8.60m
No. of lanes	-----	2
Gradient	%	0
Time of day	-----	11.00-12.00 pm
Road condition	-----	Dry
Movements *([A]: ahead only; [AL]: ahead left; [AR]: ahead right; [L]: left; [R]: right-right hand rule of the road-)*		[A], [R]:

Chapter 4
DATA COLLECTION AND ANALYSIS

4.1 Introduction

In this chapter the concept, measurement techniques of these design parameters and more importantly how various factors may affect saturation flow are presented. The work involves an evaluation of the effects of composition of vehicles on saturation flow by assessing variations in passenger car unit (PCU) factors. The aim of this study was to observe and identify non-lane based mixed traffic situation, their behavior, enabling to investigate different aspects of the system.

4.2 Qualitative Observations of the Study

The recorded film was observed thoroughly to get a clear view of the pattern of queue formation, the vehicle performance, their behavior during the discharge period and overall their impact on the performance of the intersection. The overall nature and general tendency of the traffic flow during the discharge period which affects saturation flow as well as the capacity of the junction was a prime concern of our study. The information related to these factors and aspects are required to understand the non-lane based mixed traffic movement. The findings are summarized below:

a) It was observed that traffic in most of the intersections was controlled by the traffic police rather than the traffic signal. There is a tendency of the motorized vehicles to occupy the right part of the road and the non-motorized vehicles consequently move along the left parts of the road. The possible reason is that motorized vehicles having higher speed and ease to move faster than NMV show this predicted nature.

b) During the formation of the queue the factor which decides and affects the drivers' nature to occupy the road is the front gap irrespective of the lane in which it is available. Due to the arbitrary position of the vehicles across the road width, not all the spaces can be filled up during the queue formation. The most distinctive feature here is that smaller sized vehicles such as pedal cycles, motorcycles use inter- vehicular space to come in front of the queue. Moreover as there is an absence of lane concept or to follow the proper position in a lane, vehicles having a tendency to gather in a scattered manner. This results in reducing the efficient usage of the road width. Because unnecessary gap are formed when a larger vehicle follows a smaller vehicle or there are smaller vehicles between larger vehicles. These not only delay the movement but also block the position in between them which could be utilized properly if there was a same type of larger vehicle.

c) During discharge process red violation is very common in Dhaka city. Most of the time vehicles do not stop crossing the stop line after the onset of red signal. The faster vehicles at the back of the formed queue usually increase their speed and violate the red period to cross the junction. When there are NMV present i.e. in mixed traffic situation the slower vehicles such as Rickshaw, cycles, holding the front position just near the stop line hampers the movement of the faster vehicles waiting behind them, despite of having speed to cross the junction. In this case the faster vehicles try to cross junction as soon as they can even after the red signal is on.

d) Due to the lack of lane discipline car following and lane changing operations are performed differently from that in lane base case. It has been observed that during car following operation a follower specially wider vehicle may have more than one leader and it’s response (acceleration /deceleration) and decision (lane changing) is made based on the leader (not necessarily the nearest leader) which gives the most restrictive condition . For example, if one of the remote leaders happens to be non-motorized or a turn vehicle and the nearest leader is a fast flowing then the follower responds according to the performance of the remote leader.

e) In non-lane based operation lane changing is a gradual and discontinuous. Unlike lane based operation, here lane changing cannot be completed in one attempt. Sometimes this lane changing maneuver is partial and time consuming. But on the contrary in lane concept movement there are no provisions for partial lane changing or to take any discontinuous attempt during moving from its own lane to the desired lane. As there are no fixed rules or restriction of positioning the vehicle anyplace across the road width drivers usually changes lane in more than one attempt. Depending on the available opportunity, gradually this maneuver is completed.

f) It has been evident that based on the available front gaps both left and right sides are used for overtaking purpose although motorized vehicles prefer right side, as there are lass chances of getting onto conflict with non-motorized vehicles which usually inhabit the left part of the road. It has also been observed that lane changing takes place even within the intersection.

g) When motorized vehicles are blocked by NMV and are obstructed, then tend to blow the horn to draw the attention of the NMV so that it leave the space and the faster motorized vehicle can easily change the lane. These types of demand for lane changing is a distinctive feature of the existing mixed traffic operation, where hierarchy of the vehicle according to the speed and structure often helps in lane changing and other decision-making maneuver.

h) In almost all the intersections left turn is allowed. But left turning vehicles are generally obstructed by the straight ahead NMV which occupy the left part of the road during the discharge process. Not only that both motorized and non-motorized vehicle often block the positions near the stop line and the left turners cannot move smoothly.

4.3 Collected Data

Videography technique was used for data collection. Data collection was done during peak hours at the intersections. All observations were taken in good weather conditions and during weekdays when the people familiar with the facilities were using them. Video cameras were deployed at vantage points to record the vehicular movement along the intersection approaches.

To ensure the effectiveness of the data analyzed, certain precautions were taken.

- To ensure the validity of results, a representative and a statistically accepted sample was chosen.
- The initial vehicles for the first few seconds discharging from the queue were rejected and excluded from the analysis. They contributed to the start-up lost time.
- Also, the vehicles that were not part of the saturation flow were excluded from the study.

Classified vehicle count data at six intersections of Dhaka metropolitan city have been collected at six seconds interval from video recording. After sampling, final data are presented in the Table (Table 4.1-4.12) in Appendix. Analysis of the sampled data is given in the section 4.4.

4.4 Regression Analysis

The traffic in Dhaka city consists of various categories of vehicles. Each vehicle needs its own space on the road. They move at different speeds and have different range of accelerations. Moreover, the behavior of the drivers of different vehicle categories may vary considerably. Also, these vehicles do not tend to move in definite lanes. They move according to their own conveniences and occupy any part on the road. This highly mixed state of traffic composition, with each vehicle having its own static or dynamic characteristic, and their no-lane discipline behavior poses difficulties in the estimation of traffic flow rate. It also leads to problems in the designing of various traffic facilities.

Regression analysis was used to compute PCU values and saturation flow considering the non-lane-based traffic in Bangladesh. The collected data given in section 4.3 were evaluated to find PCU values and saturation flow. For this purpose, the statistical package for social sciences software (SPSS 18.0 versions) was used by the enter method of multiple regression analysis and observed results of selected sites are presented in the following Tables.

Variables Entered/Removed[b]

Model		Variables Entered	Variables Removed	Method
	1	M.Cycle, NMV, Auto Rickshaw, Utility, L.bus, S.Bus[a]		Enter

a. All requested variables entered.
b. Dependent Variable: P.car

Table 4.1: PCU Values of Vehicles at Different Intersections

Intersections	Constant	P.Car	Auto Rickshaw	L.bus	S.Bus	Utility	NMV	M.Cycle
Bangla Motor (E To W)	2.889	1.000	0.114	-0.56	-0.035	0.099	0.066	-0.087
Bangla Motor (W To S)	3.085	1.000	0.109	0.315	-0.1	-0.024	0.146	0.006
Moghbazar (E To W)	2.404	1.000	0.490	0.156	0.254	0.006	-0.109	0.05
Moghbazar (W To S)	2.404	1.000	0.490	0.156	0.254	0.006	-0.109	0.025
Razarbagh (E To W)	2.674	1.000	-0.027	-0.024	-0.069	0.195	0.077	-0.105
Razarbagh (W To S)	4.194	1.000	-0.023	0.296	-0.226	0.056	-0.191	-0.063
Katabon (E To W)	1.518	1.000	0.113	-0.140	-0.010	0.105	0.06	0.035
Katabon (E To S)	1.975	1.000	0.060	-0.171	-0.269	0.189	0.012	1.975
Bata Signal (E To W)	0.828	1.000	0.328	0.068	0.156	-0.169	0.09	-0.044
Bata Signal (E To S)	0.888	1.000	-0.165	-0.161	-0.056	0.218	0.165	0.084
Science Lab (W To S)	2.299	1.000	0.071	0	0.165	-0.097	0.119	0.176
Science Lab (N To S)	3.935	1.000	-0.028	-0.146	-0.105	0.298	-0.07	0.021

4.5 Observations on PCU Values

It is observed that PCU values of a particular vehicle are not constant as they vary with traffic situations, static and dynamic characteristics of vehicles, queue formation and queue discharge behavior at the approaches.

From the above Table it was observed that PCU value of Utility was very low and that of motorcycle was negative. It may be due to the low proportion of these vehicles. Weighing coefficient of motorcycle was found negative. As these vehicles are narrow and have high maneuver power, due to lack of lane discipline they can avail any trapped gaps in the vehicular gaps. Moreover, as their initial acceleration rates are higher than any other type of vehicle, they can discharge quickly when green starts, as a result they have no effect on saturation green time rather they increase the flow more than the capacity of the approach in terms of PCU. Hence to adjust the flow negative weighing factor has been obtained during regression and consequently negative PCU value has been measured. Again, for the vehicle whose proportion is very low the method does not give proper values.

PCU refers to the relative value of different categories of vehicles with respect to a passenger car. This value is based on the impact that these vehicle categories have on the traffic stream. Generally, researchers tend to Utility values from different standards or codes like the HCM or the IRC (Indian roads congress). But the values given in these standards are static in nature. And over time, various methods like the velocity area ratio etc. have shown that PCU is dynamic in nature. It depends on the traffic composition and flow characteristics of different vehicle categories. This dynamic PCU values may also differ if calculated by different methods.

The motorcycle PCU values are less than one because their small size enables them to form a compact pack and occupy less space and cause less hindrance to surrounding vehicles. The Auto Rickshaw are a little bigger than the motorcycles but smaller than cars and therefore produce a lager hindrance effect compared to motorcycles, thus Auto Rickshaw have larger PCU values than motorcycles. The low PCU values for the buses/trucks are attributed to their low percentage compared to passenger car, large size and their relatively difficult maneuver ability in the non-lane based conditions. The PCU values obtained is different from that of the Indian Road

Congress values used in the initial determination of the saturation time. This is attributed to the different vehicle mix, driver characteristics and the intersection geometry.

4.6 Traffic Composition Data

In this section Vehicle compositions at different intersections are presented in the form of pie charts. From these charts proportion of different classes of vehicle were used in setting relationship with other parameters

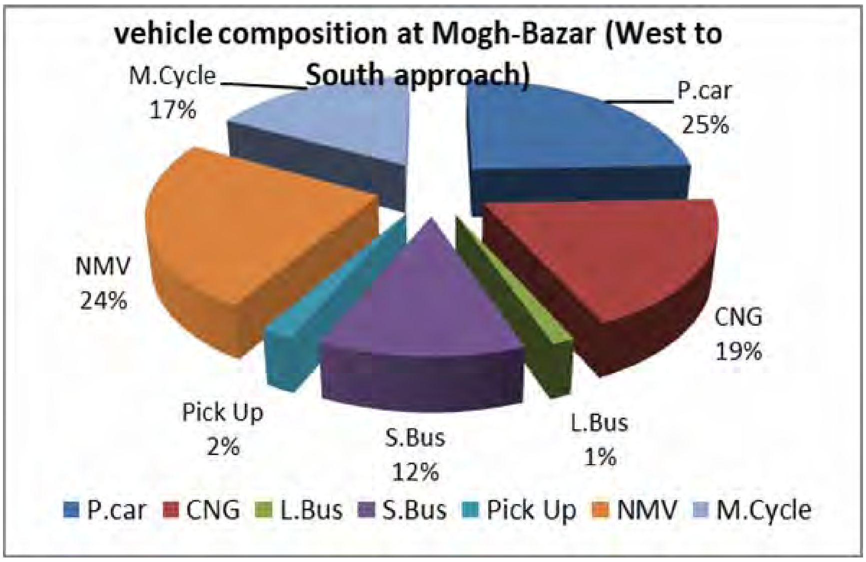


Figure 4.1.1: Vehicle Composition at Moghbazar (West to South)

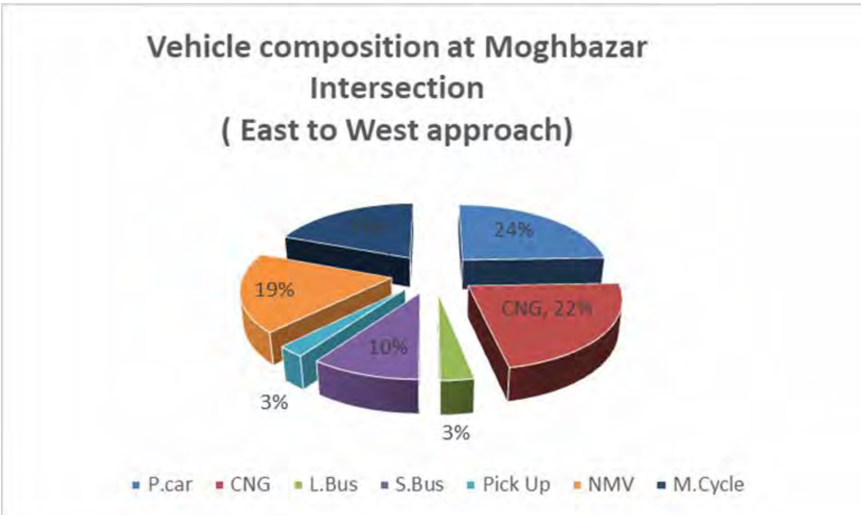


Figure 4.1.2: Vehicle Composition at Moghbazar (East to West)

In moghbazar intersection it was observed that proportion of passenger car was high and that of large bus was low. Due to the lower proportion of bus, PCU value obtained from the software was also low.

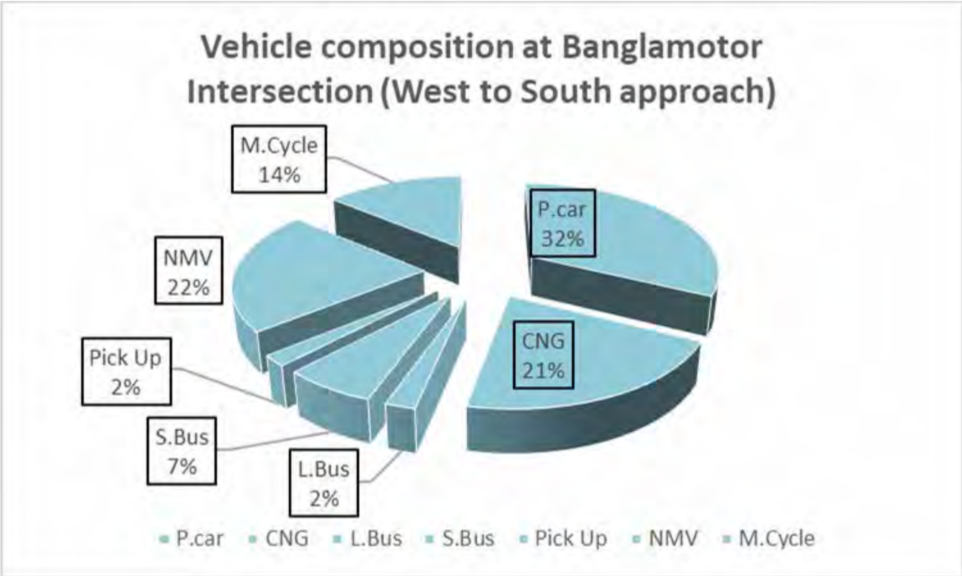


Figure 4.1.3: Vehicle Composition at Banglamotor (West to South)

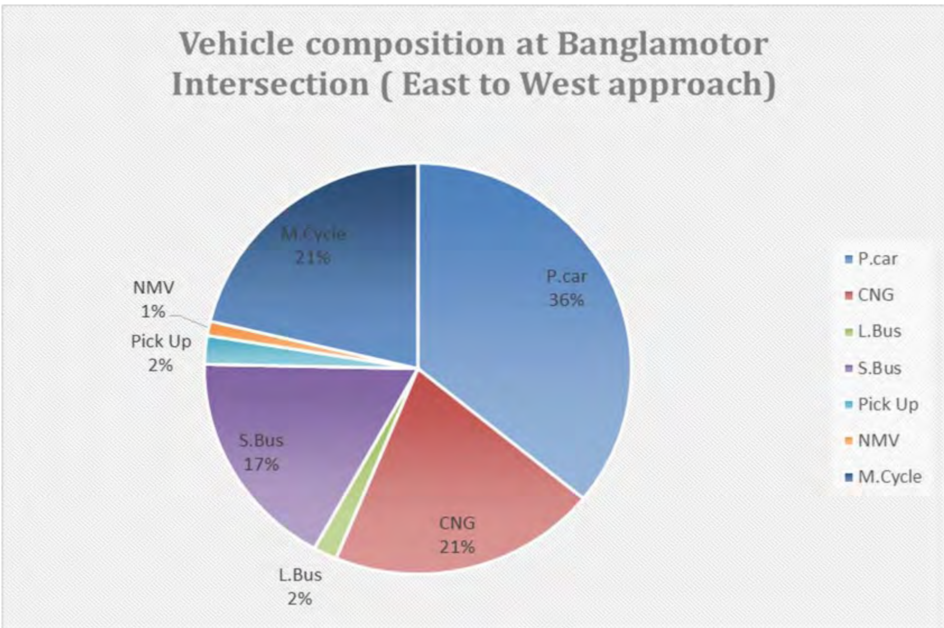


Figure 4.1.4: Vehicle Composition at Banglamotor (East to West)

In Bangla motor proportion of passenger car was highest and large bus was lowest.

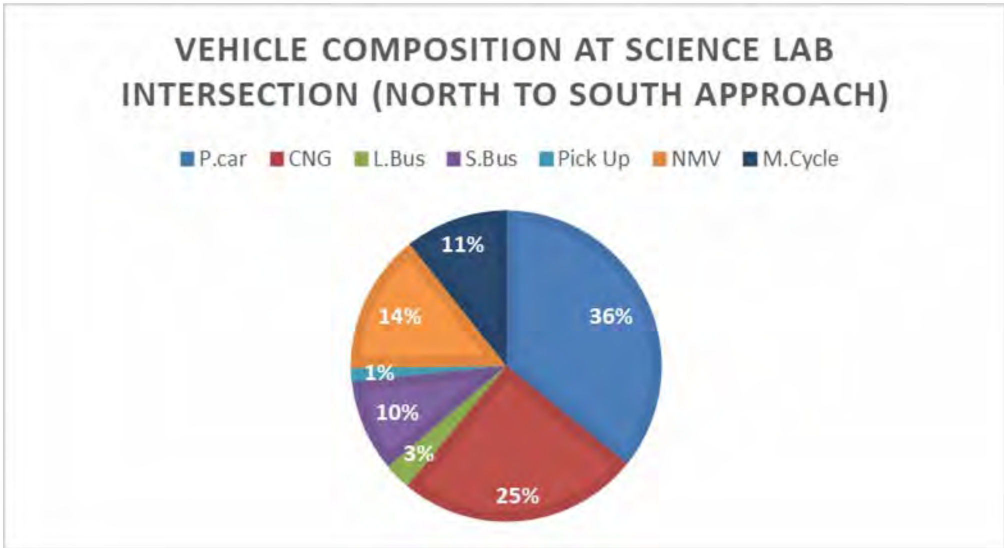


Figure 4.1.5: Vehicle Composition at Science Lab (North to South)

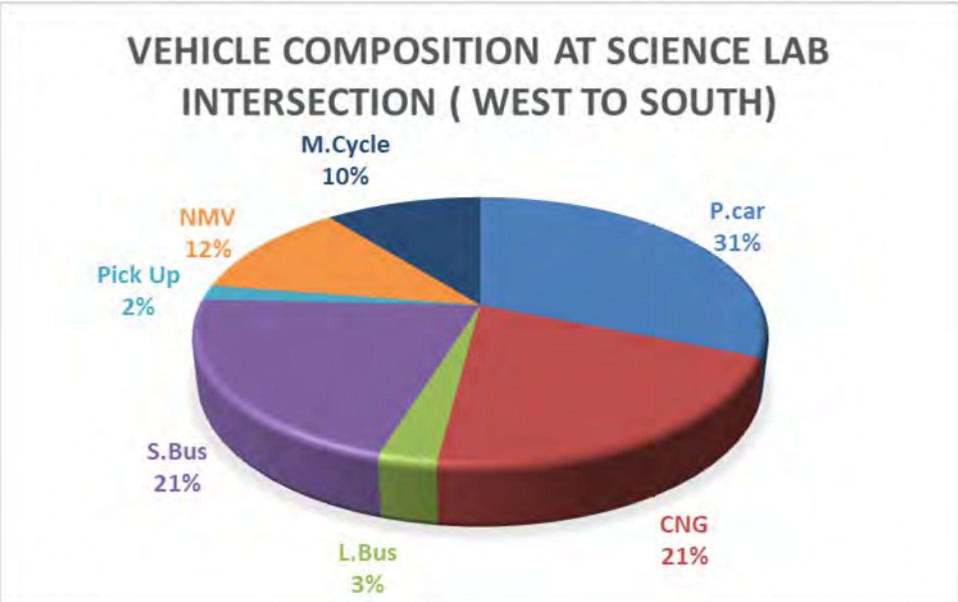


Figure 4.1.6: Vehicle Composition at Science Lab (West to South)

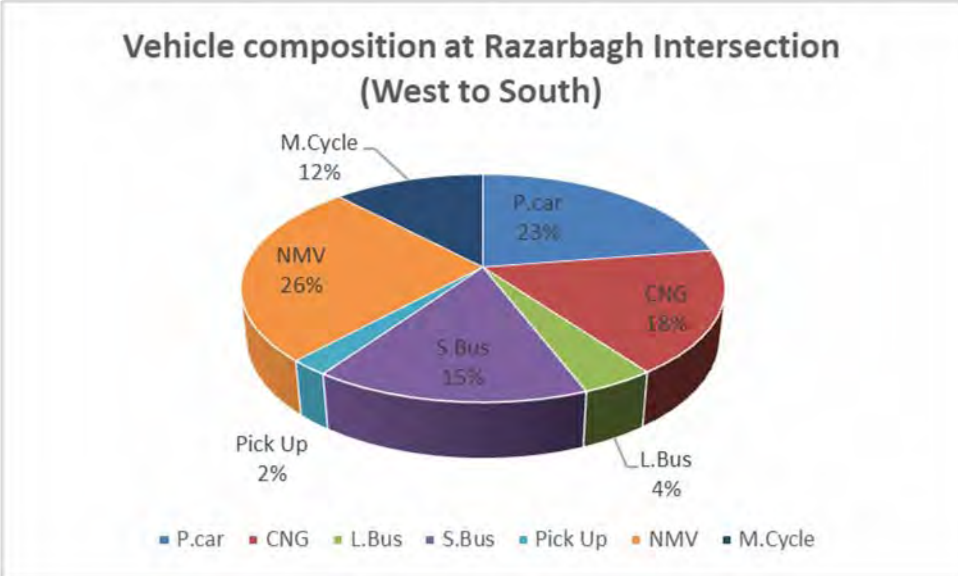


Figure 4.1.7: Vehicle Composition at Razarbagh (West to South)

The dominating vehicle type at both North and south approach during the time of study was Auto Rickshaw.

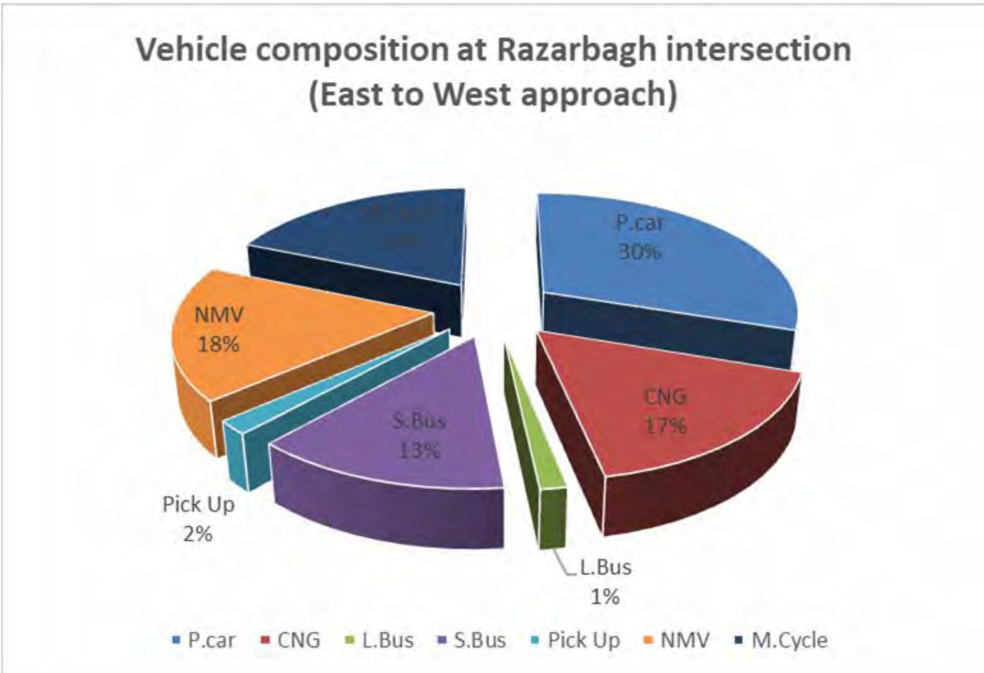


Figure 4.1.8: Vehicle Composition at Razarbagh (East to West)

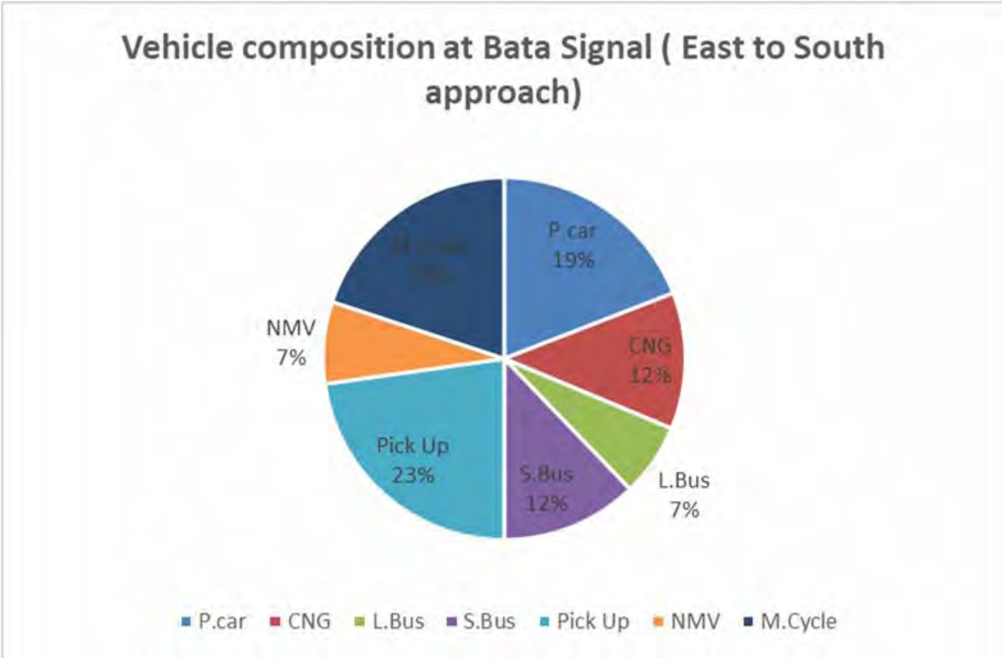


Figure 4.1.9: Vehicle Composition at Bata Signal (East to South)

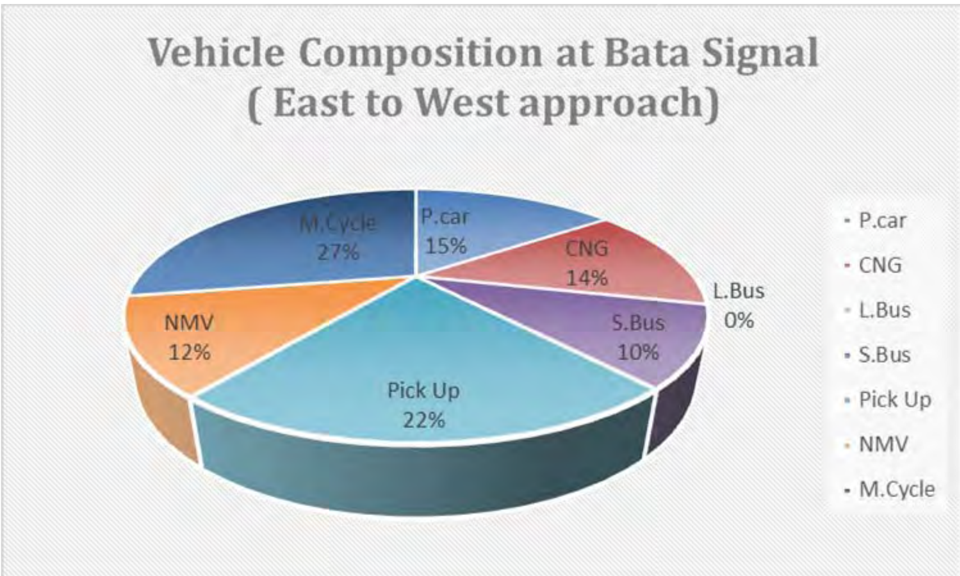


Figure 4.1.10: Vehicle Composition at Bata Signal (East to West)

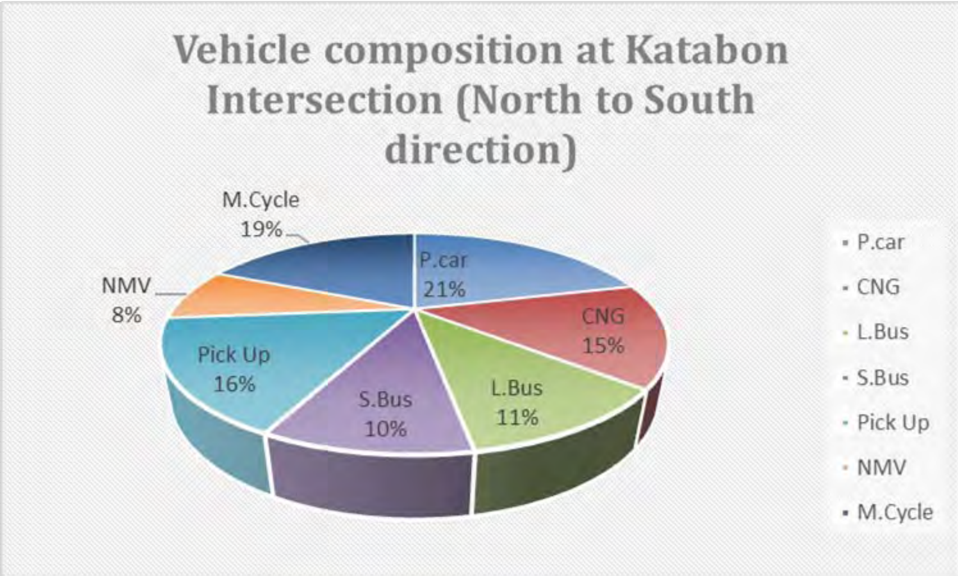


Figure 4.1.11: Vehicle Composition at Katabon (North to South)

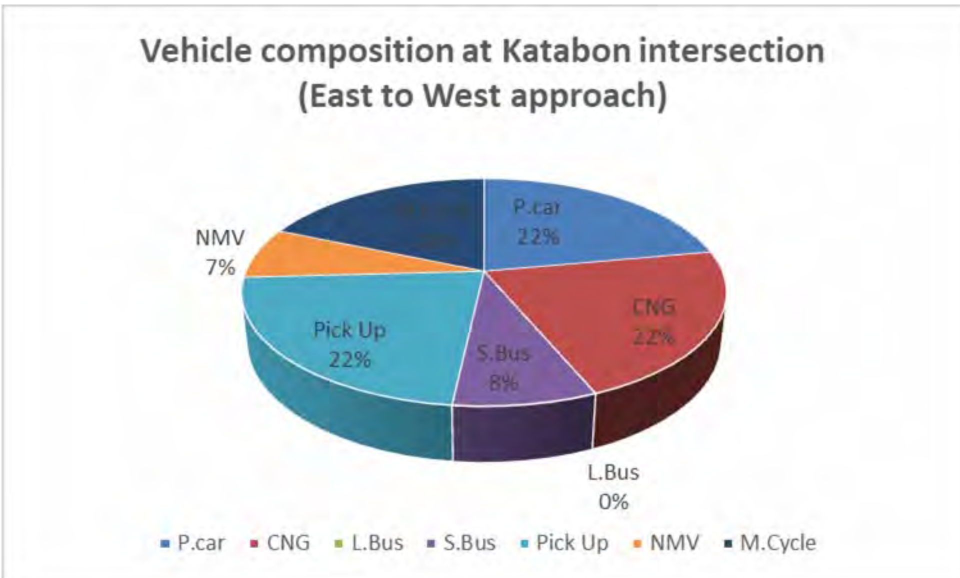


Figure 4.1.12: Vehicle Composition at Katabon (East to West)

4.7 Data Summary

The necessary parameters obtained either from the field study and regression analyses are summarized in the form of table as following.

Table 4.2: Data Summary

Location	Stop Line Width (m)	Saturation flow (Pcu/hr)	P.Car	AUTO RICK SHAW	L.Bus	S.Bus	Utility	NMV	M. Cycle
Bangla Motor (W to S)	10.50 m	1851	151 (32%)	98 (21%)	10 (2%)	31 (7%)	9 (2%)	103 (22%)	65 (14%)
Bangla Motor (E to W)	10.25m	1734	160 (36%)	91 (21%)	8 (2%)	77 (17%)	10 (2%)	5 (1%)	95 (21%)
Mogh Bazar (W to S)	10 m	1476	127 (25%)	97 (19%)	7 (1%)	63 (12%)	10 (2%)	126 (24%)	89 (17%)
Mogh Bazar (E to W)	9.50m	1976	136 (24%)	125 (22%)	17 (3%)	55 (10%)	14 (3%)	103 (19%)	107 (19%)
Kata Bon (E to W)	9.12m	911	82 (22%)	80 (22%)	0 (0%)	30 (8%)	83 (22%)	27 (7%)	69 (19%)
Kata Bon (E to S)	8.6m	1185	88 (21%)	63 (15%)	46 (11%)	42 (10%)	68 (16%)	33 (8%)	77 (19%)
Bata Signal (E to S)	8.5m	533	47 (19%)	30 (12%)	16 (7%)	30 (12%)	56 (23%)	18 (7%)	49 (20%)
Bata Signal (E to W)	9.25m	497	44 (15%)	40 (14%)	0 (0%)	29 (10%)	64 (22%)	35 (12%)	81 (27%)
Rajar Bagh (W to S)	9.15m	1604	131 (31%)	102 (18%)	24 (4%)	90 (15%)	13 (2%)	152 (26%)	70 (12%)
Rajar Bagh (E to W)	9.25m	2516	168 (30%)	93 (17%)	8 (1%)	75 (13%)	10 (2%)	99 (18%)	104 (19%)
Science Lab (W to S)	11.89m	1379	155 (31%)	104 (21%)	14 (3%)	104 (21%)	9 (2%)	59 (12%)	53 (10%)
Science Lab (N to S)	11.05m	2361	182 (36%)	128 (25%)	14 (3%)	49 (10%)	7 (1%)	74 (14%)	54 (11%)

- It is observed that except Bata Signal intersection, passenger car dominates rest of the intersections (above 20%). It may be due to the fact that in passenger car private car, taxi cab and rent a car also included.
- Proportion of large bus is low. If we combine large bus and small bus than the ratio would be increased.
- NMV proportion has large ranges from 1% to 26% where do motorcycles range from 10% to 27%. Auto Rickshaw shows almost nearly equal % on all intersections.

4.8 Saturation Flow Model

Assumptions for the Regression Model:

- Value of Vehicle composition must be in percentage, (e.g. 10%, 20%)
- Width of approach should be measured as carriageway width only in meter.
- Negligible composition should be neglected.
- Model 1: To develop saturation flow model considering only width criteria by regression method.
- Model 2: To develop saturation flow model considering width and vehicle composition (% of p.car, Auto Rickshaw and NMV) for non-lane based traffic condition.
- Model 3: To develop saturation flow model considering vehicle composition (% of p.car, Auto Rickshaw and NMV)for non-lane based traffic condition.

4.8.1 Model 1 (Width Only)

Table 4.3: Model 1 (Width only)

Intersections	Saturation Flow (PCU/hr)	Width (m)
Bangla Motor (W to S)	1851	10.50
Bangla Motor (E to W)	1734	10.25
Mogh Bazar (W to S)	1476	10.00
Mogh Bazar (E to W)	1976	9.50
Kata Bon (E to W)	911	9.12
Kata Bon (E to S)	1185	8.60
Bata Signal (E to S)	533	8.50
Bata Signal (E to W)	497	9.25
Rajar Bagh (W to S)	1604	9.15
Rajar Bagh (E to W)	2516	9.25
Science Lab (W to S)	1379	11.89
Science Lab (N to S)	2361	11.05

Variables Entered/Removed[b]

Model		Variables Entered	Variables Removed	Method
	1	Width		Enter

a. All requested variables entered.
b. Dependent Variable: Saturation flow

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1067.050	1794.891		-.594	.565
	Width	263.349	183.089	.414	1.438	.181

a. Dependent Variable: saturation.flow

Model 1: S = -1067+263W

Where,

S = saturation flow in PCU/hr

W = width of road in meter

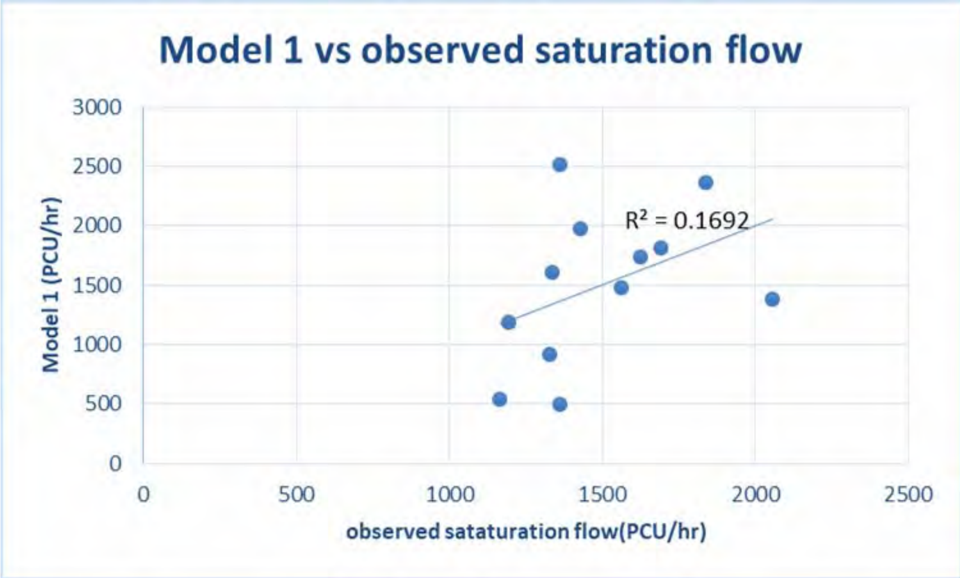


Figure 4.2: Model 1 vs. Observed Saturation Flow

4.8.2 Model 2 (Multi Variants)

Table 4.4: MODEL 2 (MULTI VARIANTS)

Intersections	Saturation Flow (PCU/hr)	Width (m)	% of P Car	% of Auto Rickshaw	% of NMV
Bangla Motor (W to S)	1851	10.50	32	21	2
Bangla Motor (E to W)	1734	10.25	36	21	2
Mogh Bazar (W to S)	1476	10.00	25	19	2
Mogh Bazar (E to W)	1976	9.50	24	22	3
Kata Bon (E to W)	911	9.12	22	22	22
Kata Bon (E to S)	1185	8.60	21	15	16
Bata Signal (E to S)	533	8.50	19	12	23
Bata Signal (E to W)	497	9.25	15	14	22
Rajar Bagh (W to S)	1604	9.15	23	18	2
Rajar Bagh (E to W)	2516	9.25	30	17	2
Science Lab (W to S)	1379	11.89	31	21	2
Science Lab (N to S)	2361	11.05	36	25	1

Variables Entered/Removed[b]

Model		Variables Entered	Variables Removed	Method
	1	NMV, P.Car, Auto Rickshaw, Width		Enter

a. All requested variables entered.
a. Dependent Variable: Saturation flow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	985.575	983.314		1.002	0.35
	Width	-316.96	142.187	-0.498	-2.229	0.061
	P.Car	97.804	22.442	1.022	4.358	0.003
	Auto Rickshaw	28.224	36.692	0.167	0.769	0.467
	NMV	36.365	12.055	0.436	3.017	0.019

a. Dependent Variable: saturation.flow

Model 2: S = 985.57-317W+97.8 P.Car+28.2 Auto Rickshaw+36.36 NMV

Where, S= saturation flow in PCU/hr
W= width of road in meter
P.Car = proportion of passenger car in percentage
Auto Rickshaw = proportion of Auto Rickshaw in percentage
NMV = proportion of NMV in percentage

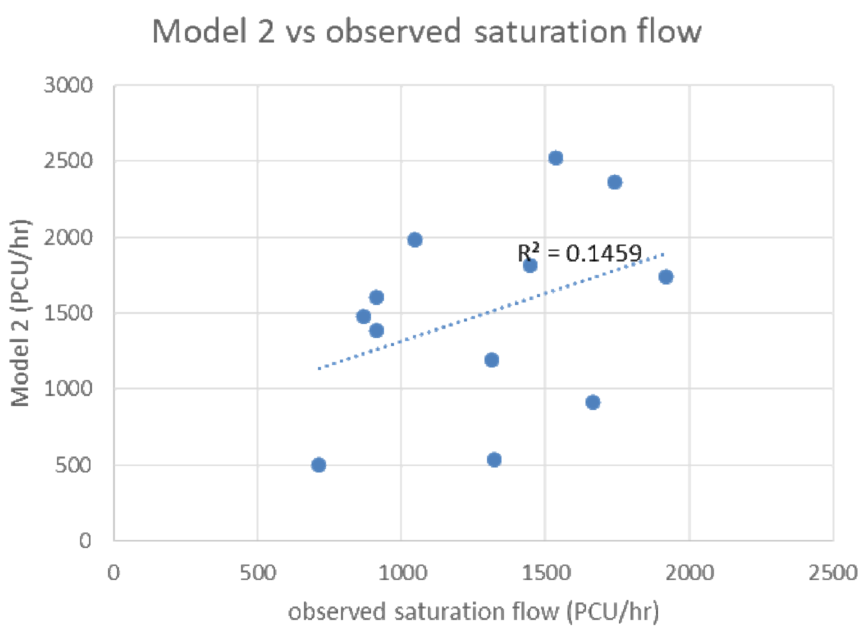


Figure 4. 3: Model 2 vs. Observed Saturation Flow

Model 2 (PCU/hr)	Observed Saturation flow (PCU/hr
1451.59	1815
1922.04	1734
869.09	1476
1050.75	1976
1666.45	911
1317.93	1185

Model 2 (PCU/hr)	Observed Saturation flow (PCU/hr
1323.95	533
715.04	497
914.74	1604
1539.44	2516
913.16	1379
1744.88	2361

4.8.3 Model 3 (Multi Variants)

Table 4.5: Model 3 (Multi Variants)

Intersections	Saturation Flow (PCU/hr)	% of P Car	% of Auto Rickshaw	% of NMV
Bangla Motor (W to S)	1851	32	21	2
Bangla Motor (E to W)	1734	36	21	2
Mogh Bazar (W to S)	1476	25	19	2
Mogh Bazar (E to W)	1976	24	22	3
Kata Bon (E to W)	911	22	22	22
Kata Bon (E to S)	1185	21	15	16
Bata Signal (E to S)	533	19	12	23
Bata Signal (E to W)	497	15	14	22
Rajar Bagh (W to S)	1604	23	18	2
Rajar Bagh (E to W)	2516	30	17	2
Science Lab (W to S)	1379	31	21	2
Science Lab (N to S)	2361	36	25	1

Variables Entered/Removed[b]

Model		Variables Entered	Variables Removed	Method
	1	NMV, P.Car,Auto Rickshaw		Enter

a. All requested variables entered.
b. Dependent Variable: Saturation flow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-932.788	581.904		-1.603	.148
	P.Car	73.125	23.878	.764	3.062	.016
	Auto Rickshaw	2.130	42.535	.013	.050	.961
	NMV	33.950	14.686	.407	2.312	.050

a. Dependent Variable: saturation.flow

Model 3: S= -933+73 P.Car+2 Auto Rickshaw + 34 NMV

Where, S= saturation flow in PCU/hr
P.Car = proportion of passenger car in percentage
Auto Rickshaw = proportion of Auto Rickshaw in percentage
NMV = proportion of NMV in percentage

Model 3(PCU/hr)	Observed Saturation flow (PCU/hr)
1513	1815
1805	1734
998	1476
965	1976
1465	911
1174	1185

Model 3(PCU/hr)	Observed Saturation flow (PCU/hr)
1260	533
938	497
850	1604
1359	2516
1440	1379
1779	2361

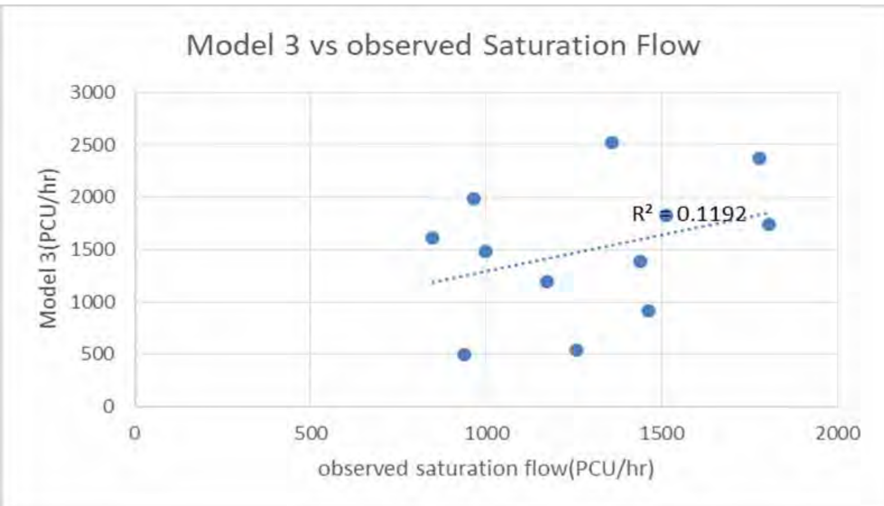


Figure 4. 4: Model 3 vs. Observed Saturation Flow

4.8.4 Comparison of Observed Saturation Flow and Model Output

Table 4. 6: Comparison of Model 1, Model 2 And Model 3

Observed saturation flow (PCU/hr)	Model 1 (PCU/hr)	Model 2 (PCU/hr)	Model 3 (PCU/hr)
1815	1695	1452	1513
1734	1629	1922	1805
1476	1563	869	998
1976	1432	1051	965
911	1332	1666	1465
1185	1195	1318	1174
533	1169	1324	1260
497	1366	715	938
1604	1340	915	850
2516	1366	1540	1359
1379	2060	913	1440
2361	1839	1744	1779

From the comparison of observed saturation flow and model output it was observed that all three models are having least difference as shown in table but the model 1 is giving more fair results compared to other two models. Except four approach, the difference between the model output and observed capacity are very less. Due to small sample size, R2 Values of all models are less than 0.3.

4.8.5 Comparison of Regression Model Saturation Flow with the Previous Study

Variations in the effect of the approach and lane widths on saturation flow have been reported in a number of studies. Observations of traffic flow made by the Road Research Laboratory at intersections in the London area and also in some larger cities, supplemented by controlled experiments at the Laboratory test track, have shown that the saturation flow(S) expressed in passenger car units per hour with no parked vehicles is given by the equation: $S = 525\ W$ pcu/hr; where W is the width of the approach in metres.

This formula is applicable to approach widths from 5.5m to 18m(the maximum width tested). For widths between 3m and 5.5m the relationship is not linear but shows a slight step effect and the saturation flow can be estimated from following table.

W(metres)	3.0	3.5	4.0	4.5	5.5
S(PCU/hr)	1850	1875	1975	2175	2900

The width is assumed to be constant for at least the length of the approach (defined as the length which will accommodate the queue which can just pass through the intersection during a fully saturated green period).

Branston[7] who investigated the variations of peak periods on saturation flow in lane width base, formulated the following relationships between saturation flow and lane width:

$S = 885 + 222\,W$ for off-peak period

$S = 1045 + 222\,W$ for peak period

where S is saturation flow in pcu/hr and W is width in meters.

Working on lane width varying from 3.0 - 4.3 meters, he observed that there is a variation of saturation flow with lane width for individual lanes although the values for nearside and offside lanes of two-lane approaches were not significantly different.

In a full scale TRRL test track experiment, Kimber and Semmens[14] found no significant differences between nearside, central and offside lanes at multi-lane approaches. For approach widths ranging from 2.5m to 12m and lane width varying from 2.5m to 4m, they found that saturation flow per lane increased non-linearly with lane width:

$$Sl = 196wl^2 - 9791wl + 2964 \quad \text{pcu/hr}$$

where $2.5m < wl < 4.0m$.

In order to obtain saturation flow for the whole approach at stop line they suggested using as many narrow lanes as possible.

Similar model was also derived for non lane based traffic condition for Javanese (Indonesia) cities by Sutomo 1992 and Turner et al. 1993. Equations below represent the regression equation of the above two studies respectively.

$$S = -376 + 627w$$

$$S = 964 + 349w$$

4.9 Effect of Factors on Saturation Flow and PCU Values

In our study, the observed factors influencing saturation flow were,

Vehicle composition: A vehicle may be motorized and non-motorized, with different operating performances and congestion of different types of vehicles affect the saturation flow.

Width of approach: Saturation flow increases with the increase of approach width.

Driver behavior: Poor lane discipline and observation of traffic signals; Public transport - varied mix of bus types, stopping places and driving styles also affect the saturation flow.

Roadside activity: Roadside land uses generate parking and non-transport activities that reduce effective lane width and also decreases discharge rate.

Approach Speed: Approach speed is varies with different approach of intersection. There is one probability, saturation flow rate increase with increase approach speed.

Right-turn movements: Which is directly affect the saturation flow rate, generally right turn movement obstruct the traffic flow.

It is natural that in the mixed traffic situation with increasing road width motorized vehicles (MV) get different degrees of conflicts with non-motorized vehicles (NMV).

Due to the lack of lane discipline classified vehicle counts data were collected for the whole width of the road, which is more appropriate and reasonable compared to lane based counting. Saturation flows measured at approaches of different width were converted into per unit width to compare and plot different relations.

4.10 Observations from the Graph

In this section the results found from the field observation and regression analysis are explained by using excel or SPSS software. Relations between saturation flows and PCU values with different factors are determined by plotting graphs. The corresponding Tables with each Figure contain the related data of all the sites and the graphs are plotted using the combined data of all approaches.

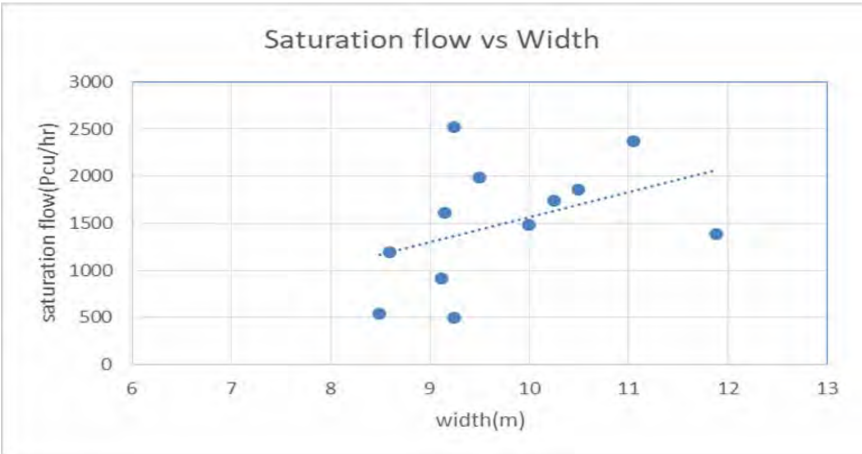


Figure 4.5: Saturation Flow vs. Width

The **Figure 4.5** representing the relation between saturation flows vs. approach width shows the pattern observed Saturation flow values varied with the approach width in the stream. Generally saturation flows increased with increasing approach width.

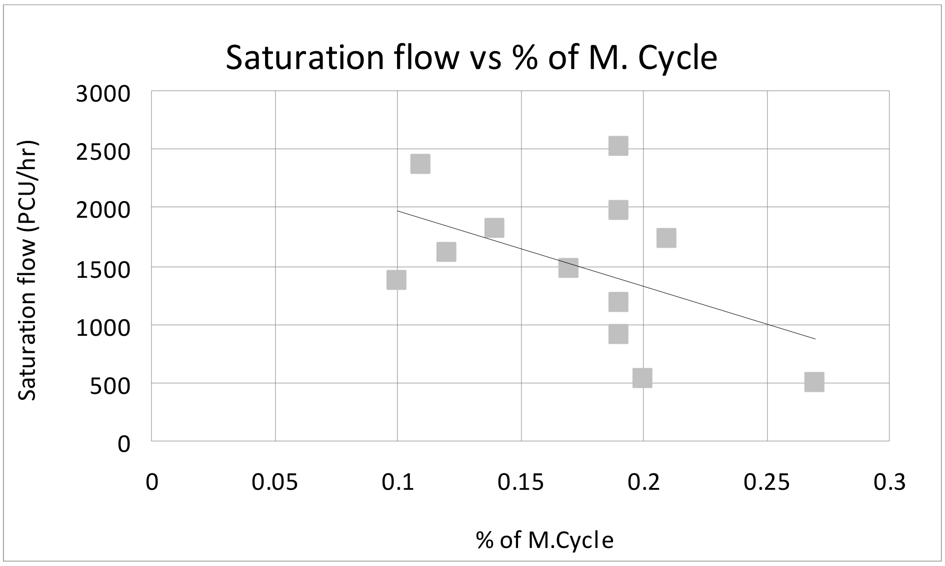


Figure 4.6: Saturation Flow vs. Percentage of M.Cycle

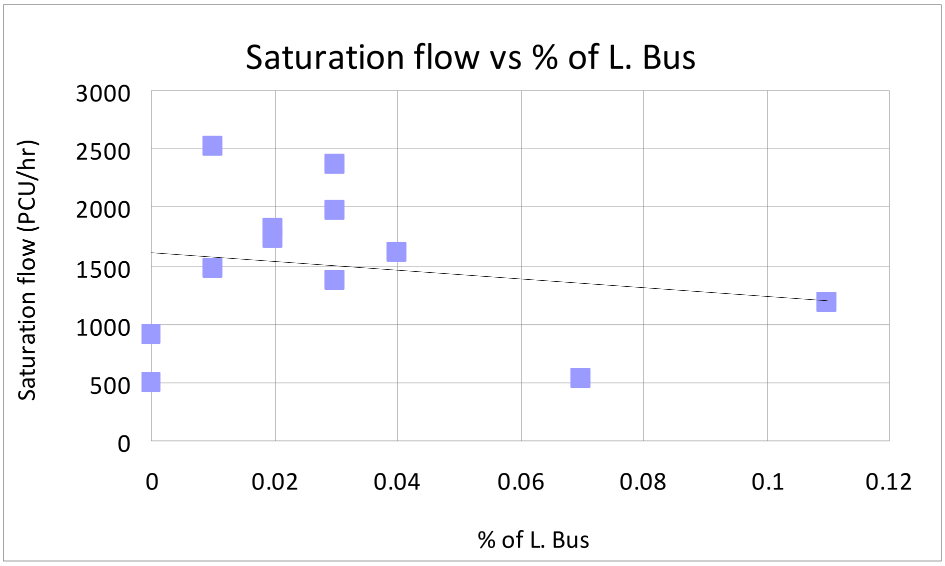


Figure 4.7: Saturation Flow vs. Percentage of L.Bus

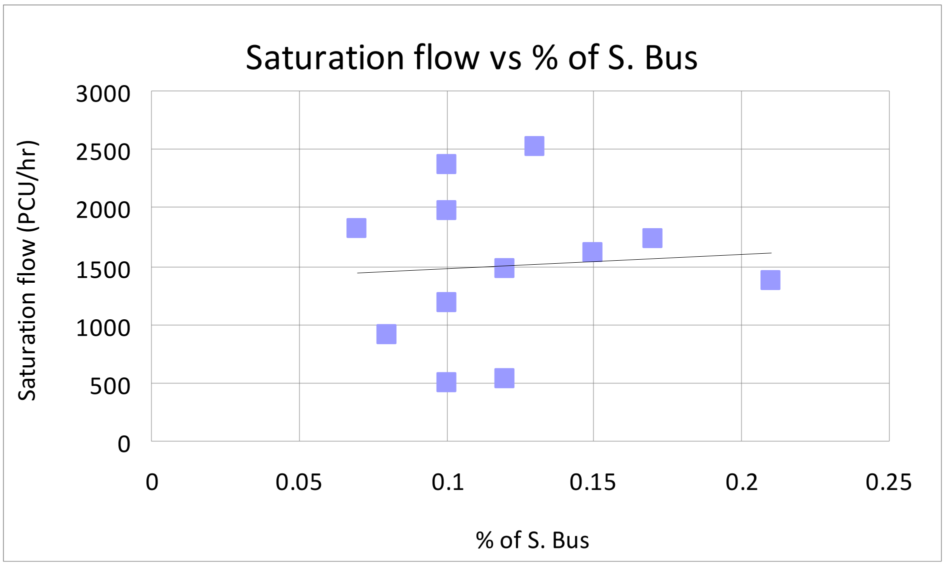


Figure 4.8: Saturation Flow vs. Percentage of S.Bus

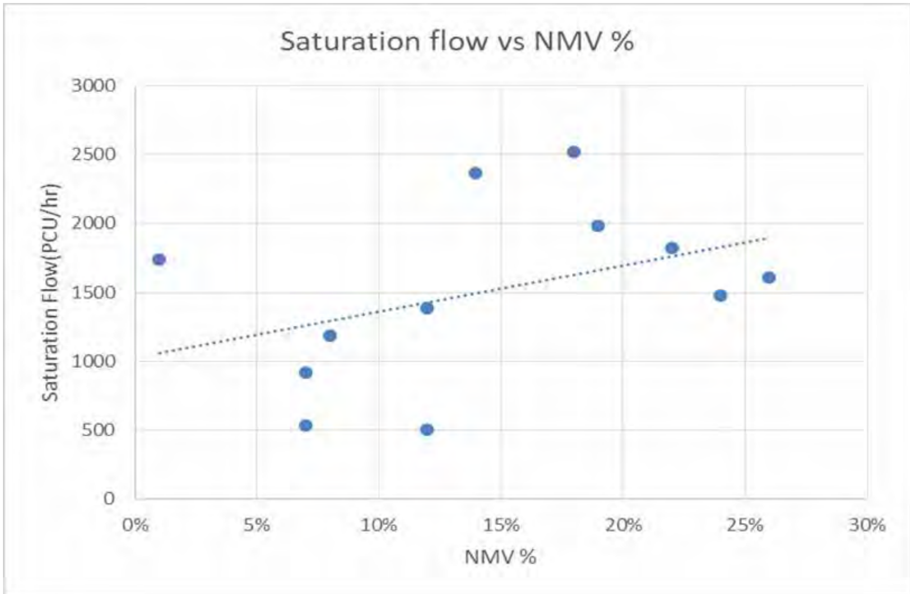


Figure 4. 9: Saturation Flow vs. Percentage of NMV

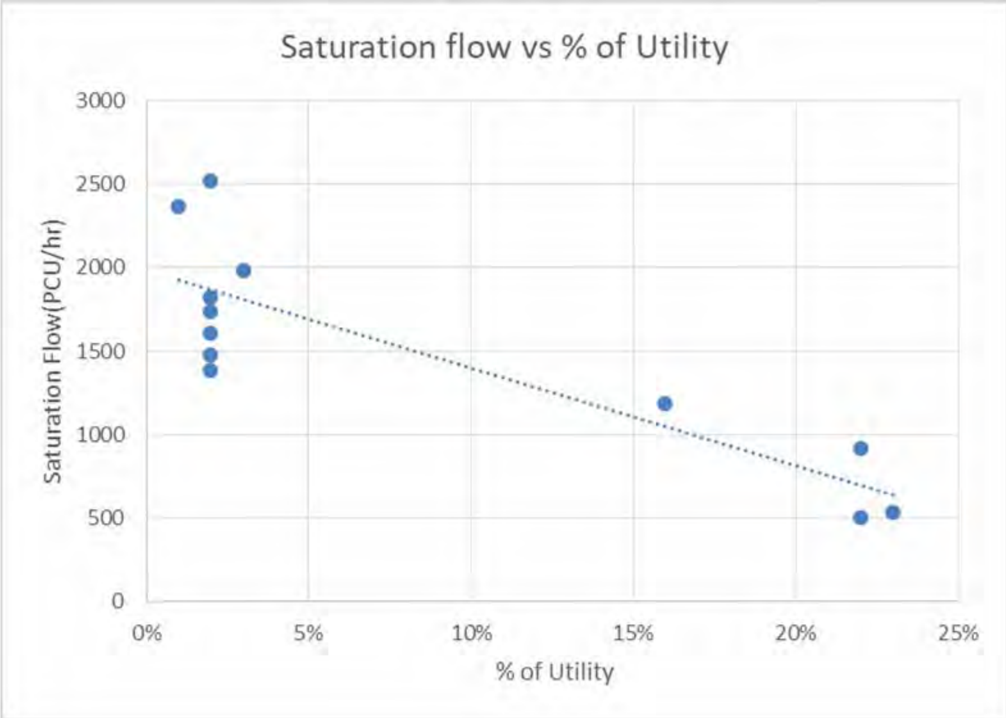


Figure 4.10: Saturation Flow vs. Percentage of Utility

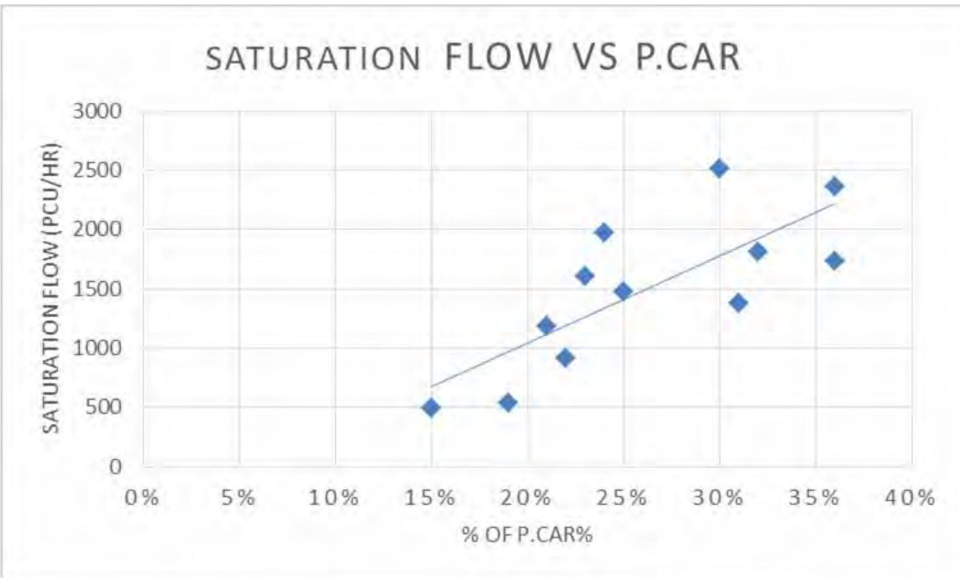


Figure 4.11: Saturation Flow vs. Percentage of Passenger Car

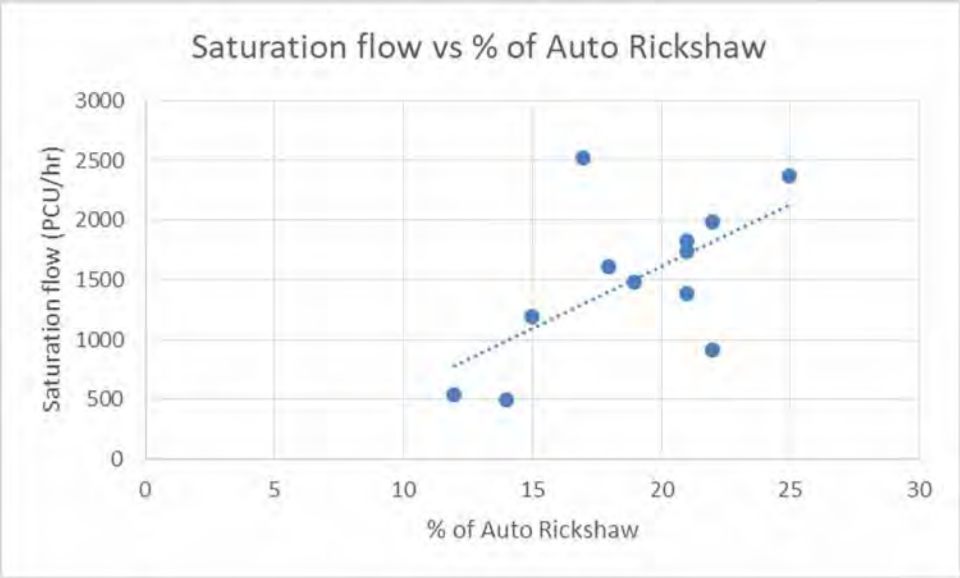


Figure 4.12: Saturation Flow vs. Percentage of Auto Rickshaw

Here it was observed that saturation flow increases with increasing proportion of passenger car, Auto Rickshaw and NMV whereas decreases with increasing proportion of Utility. This is because the lower percentage of Utility compare to passenger car and its lower maneuver capability.

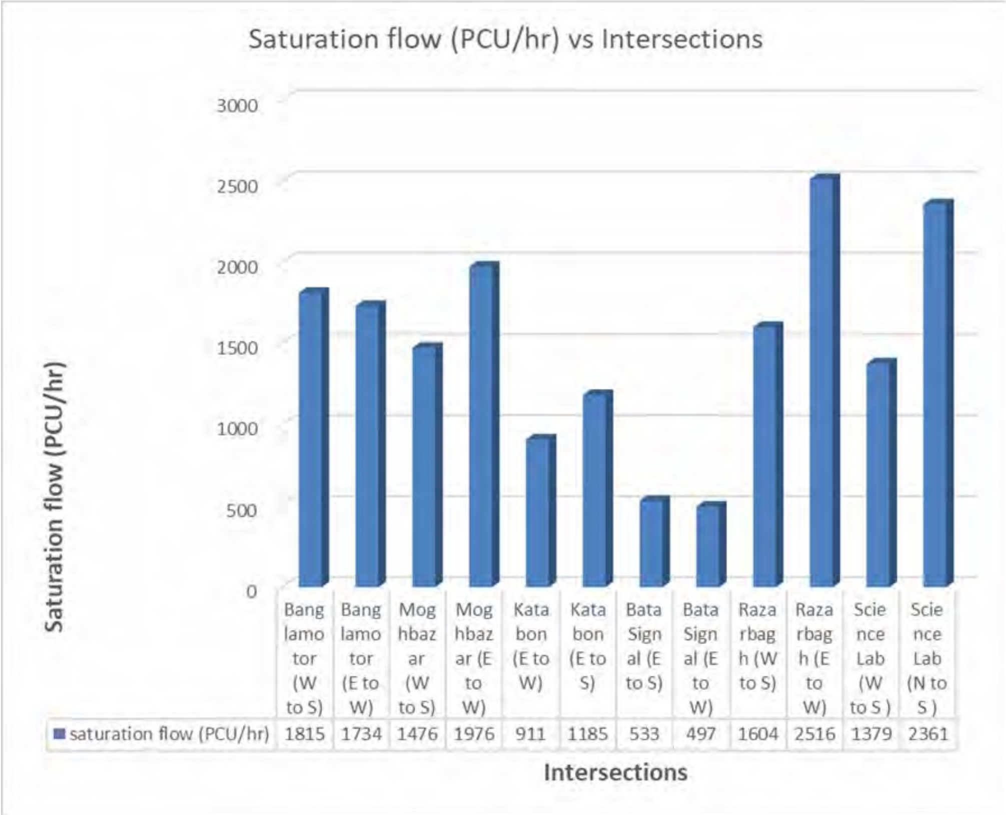


Figure 4.13: Saturation Flow (PCU/Hr) vs. Intersections

Saturation flows measured at approaches of different width were converted into per unit width to compare and plot different relations.

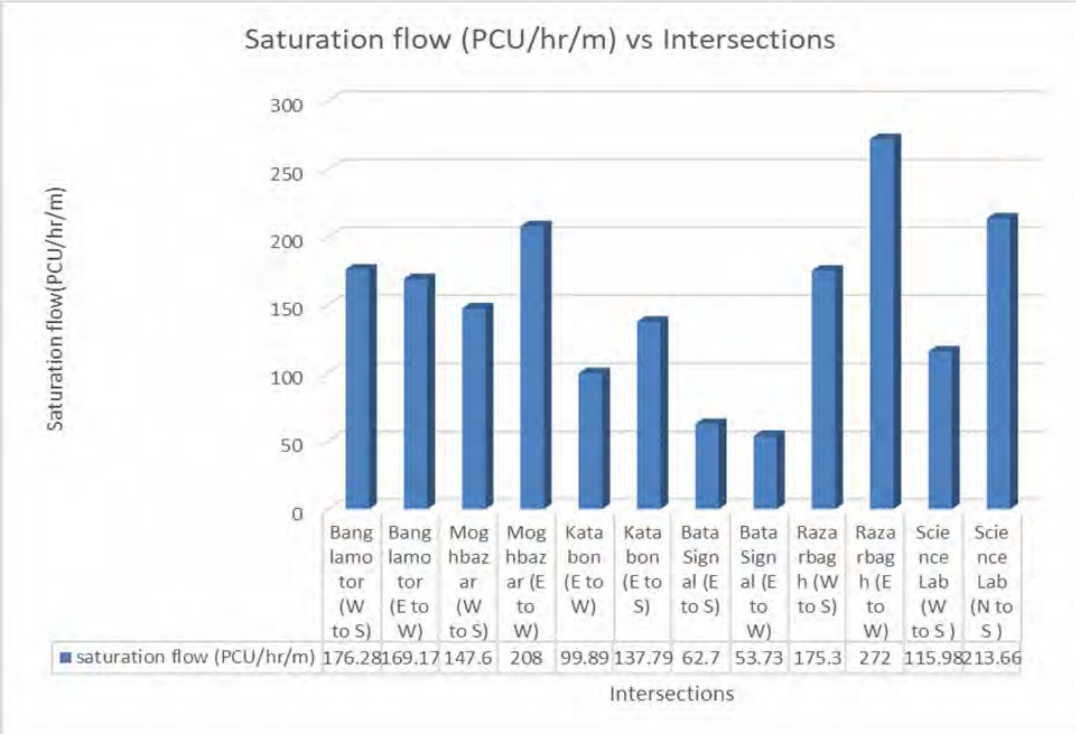


Figure 4.14: Saturation Flow (PCU/Hr/M) vs. Intersections

From the above Figures it was observed that Razarbagh intersection has highest saturation flow and Science lab intersection has second highest.

4.11 Observations on PCU Values

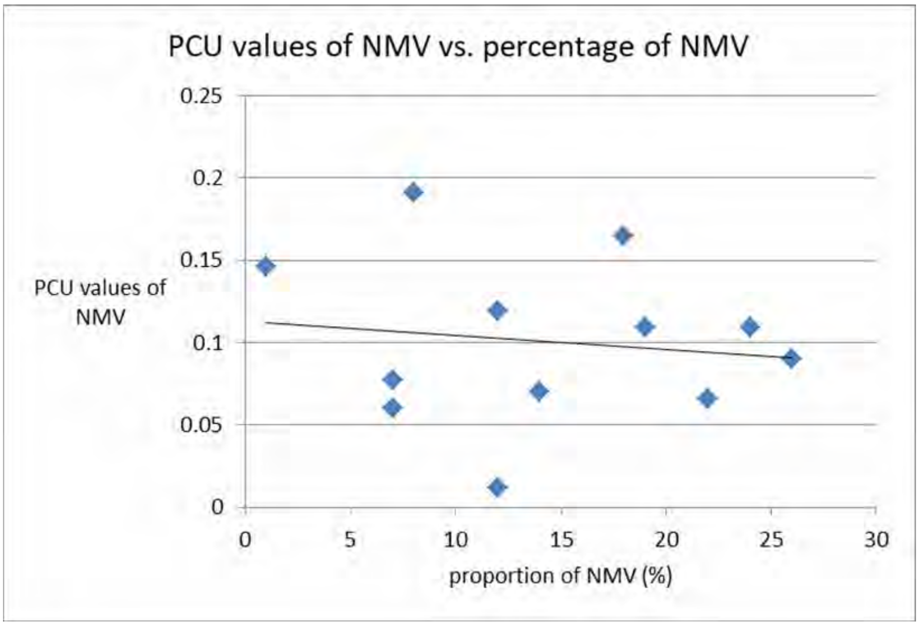


Figure 4.15: PCU Values of NMV vs. Proportion of NMV

The effect of varying proportions of non-motorized vehicles on PCU is evident. The PCU values of non-motorized vehicles consistently decreased with an increase in their proportion, because they tend to form closely together and discharge together. No clear pattern has been observed for motorized vehicles, although results have shown that their PCU values varied considerably due to the presence of non-motorized vehicles in the traffic stream.

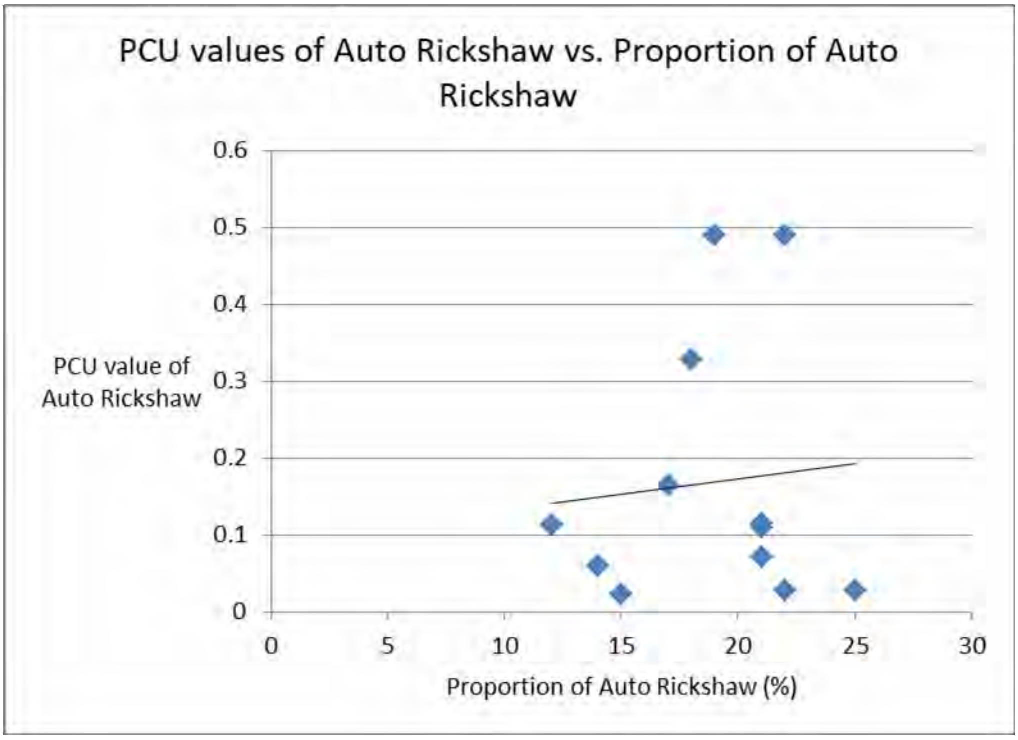


Figure 4.16: PCU Values of Auto Rickshaw vs. Proportion of Auto Rickshaw

During saturation, as proportion of vehicles increases, more distraction of movement to other vehicles occurs, hence PCU values of Auto Rickshaw increases.

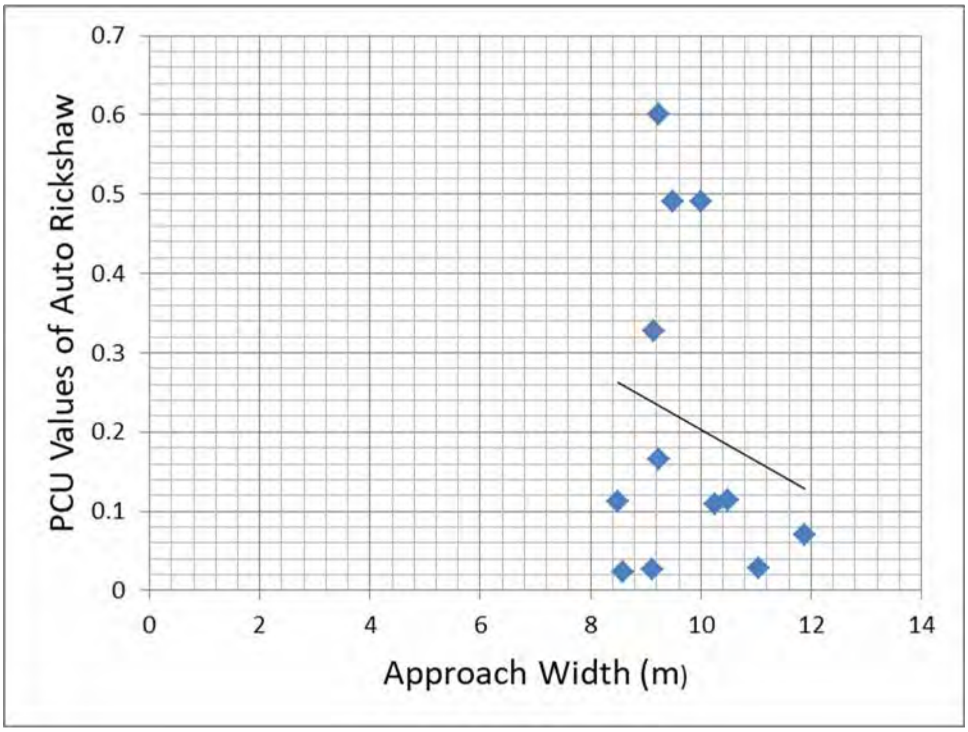


Figure 4.17: PCU Values of Auto Rickshaw vs. Approach Width

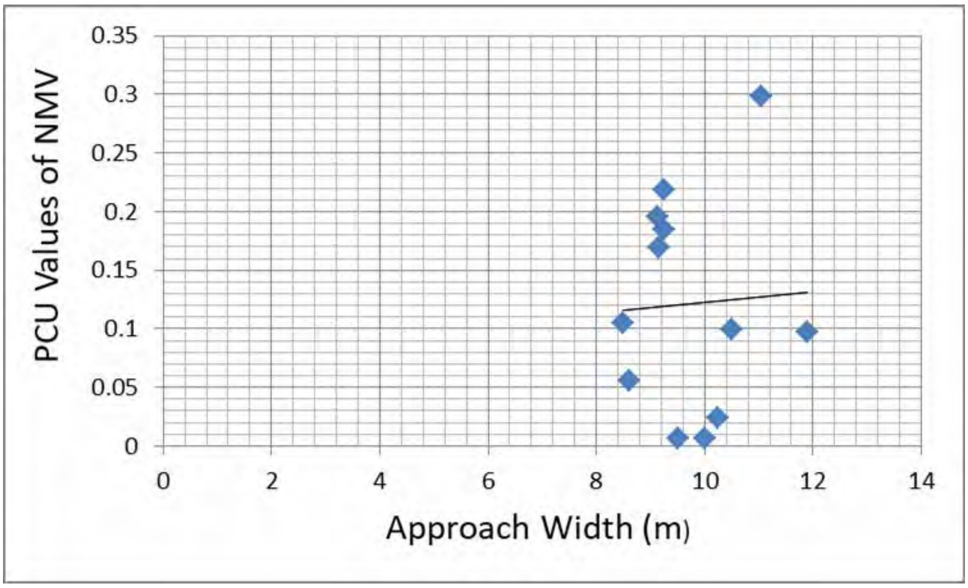


Figure 4. 18: PCU Values of NMV vs. Approach Width (m)

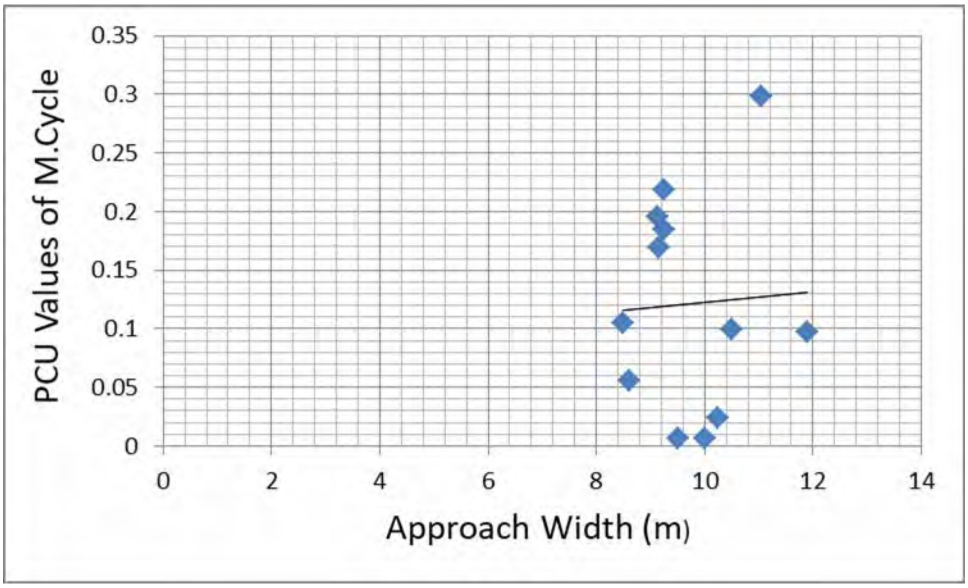


Figure 4. 19: PCU Values of M.Cycle vs. Approach Width

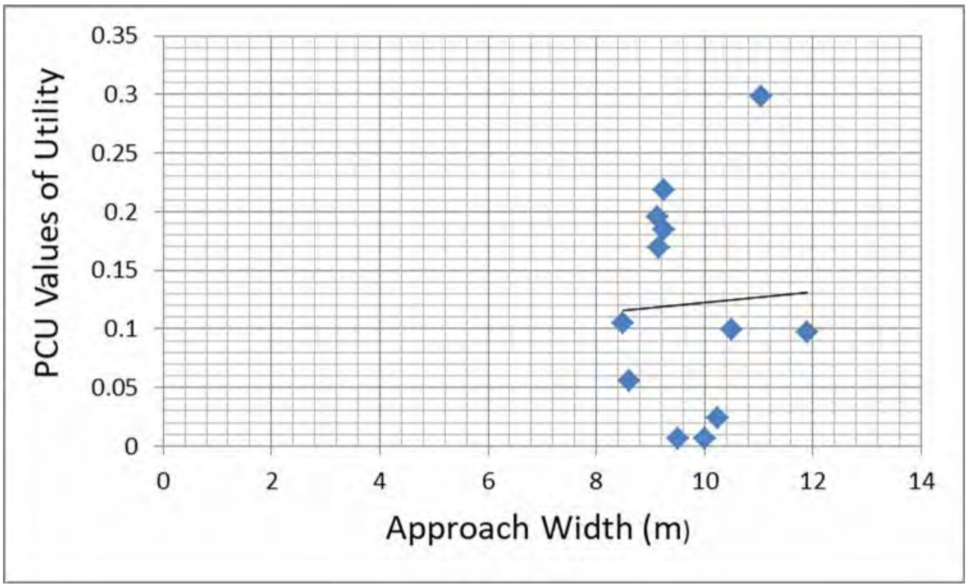


Figure 4. 20: PCU Values of Utility vs. Approach Width

It shows that as the width increases, the PCU value also increases for all categories of vehicles. This behavior is due to the freedom of movement experienced by the individual vehicles at wider approach.

4.12 Overview

Following are the main observations drawn from the PCU values determined at the signalised intersections under mixed traffic conditions.

HCM 2000 suggests measurement of saturation flow should start after 10 second of green initiation which is considered as startup lost time. From the present study, it was found that Auto Rickshaw and motor cycle find way in between heavy vehicles and try to come near stop line. Most of the times these vehicles cross stop line before green starts. During red period large number of vehicles accumulates near stop line. This causes to discharge large amount of traffic during initial 10 seconds. and hence it is suggested that count for measurement of saturation flow should start after 3 seconds of green initiation for non-lane based traffic condition. Regression model developed to estimate saturation flow shows good correlation with field values. It is observed that PCU values of a particular vehicle are not constant as they vary with traffic situations, static and dynamic characteristics of vehicles, queue formation and queue discharge behavior at the approaches. Higher percentage of two-wheelers was observed at the approaches of intersections. The minimum PCU value of 0.006 for two-wheelers have been observed due to seepage action by them, and that is affected on speed of the car which in turn to reduction of two-wheelers PCU. This finding re-establishes the fact that the unified passenger car unit concept for different vehicles do not hold well for the mixed traffic condition.

Chapter 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 General

Traffic in Bangladesh, as in other developing countries, consists of two distinct categories of vehicles i.e. motorised vehicles and non-motorised vehicle. The static and dynamic characteristics of these vehicles differ widely even within the same class, even though they all use the same right of way(total approach). An almost total lack of lane discipline makes the traffic stream mixed and heterogeneous in nature.

The summary of the data analysis and results are briefly described in this chapter. The overall output of the study and the possible explanations are presented in this chapter.

5.2 General Conclusions

1. It has been observed that the motorized vehicles are the most affected by the presence of non-motorized vehicles with substantial reduction in operating speeds. Whereas the non-motorized vehicles do not suffer because of the presence of other fast moving vehicles in the stream.
2. One important aspect here is that effect of NMV even in few numbers decreases the effective road width and reduces the saturation flow. With the increasing proportion of NMV, a grouping tendency seems to develop, generally on the left part of the road which in turn has less effect on reducing the saturation flow.
3. Relationship with width, proportion and other factors for Motorcycle were not analyzed. This is mainly because of their negligible presence in the traffic stream.
4. From the observation, it is found that right turning proportion has an increasing tendency with increasing radius. The possible reason could be that vehicle maneuvering becomes easier. Because it is difficult to turn along a sharp curve of tight radius.

5. Interactions between motorised and non-motorised vehicles are highest during the queue formation and subsequent discharge process. Upstream, the effect of non-motorised vehicles on the performance of motorised vehicles is not significant.
6. During discharge, motorised vehicles face different degrees of conflicts with the non-motorised vehicles and thus discharge speed of individual motorised vehicles vary widely.
7. In mixed traffic operations, such as during the discharge process the performance of motorised vehicles largely depends on the proportion of non-motorised vehicles.
8. The effect of varying proportions of non-motorized vehicles on PCU is evident. The PCU values of non-motorized vehicles consistently decreased with an increase in their proportion, because they tend to form closely together and discharge together.
9. The saturation flow values varied both with the proportion of non-motorised vehicles and with the approach widths. In general, saturation flows increased with higher approach width.
10. Since the discharge performances of passenger car, i.e. the common basis of PCU value determination, varies significantly with the proportion of non-motorized vehicles, it is very difficult to predict PCU conversion factors as well as saturation flow values for general use. Moreover, in mixed traffic operation, PCU values of different types of vehicles are found to be a varying parameter under different percentages of non-motorized vehicles in the stream.

5.3 Conclusions on PCU Values

1. From the present study it was found that PCU value for particular types of vehicle does not remain constant for all the selected intersection approaches. This indicates that analysis should be specific for non lane based traffic condition. Hence PCU values those have been measured from the present study can be used for similar traffic characteristics.

2. PCU value of Motorcycle show exceptionally lower values in Banglamotor, and Bata signal intersection. As these vehicles are very narrow and have high

maneuver power, due to the lack of lane discipline they can easily avail any trapped gaps in the stream and come to the front of queue. Moreover, as their initial acceleration rates are higher than the passenger cars, they can discharge quickly when green time starts. As a result their effect on the discharge process becomes negligible.

3. The discharges performances of passenger cars, which are the common basis of PCU value determination, varied significantly with the proportion of NMV.
4. It is observed that in most of the cases PCU values of bus and Utility are less than unity, although they are bigger than the cars. These is because as their proportions are very low compared to the passenger cars so these inconsistent results are associated.
5. Unusually lower values for instance such as less than unit for buses and less than zero for Auto Rickshaw and Microbuses are found at some locations. Our approach of PCU estimation was 'how many vehicles can pass the stop line of signalized intersection in a time interval'. So the values depend on the capability of the drivers, average aped and their significant presence in the traffic stream. One of the possible explanations would be their insignificant presence during the time period of data collection.

5.4 Conclusions on Saturation Flows

1. To reflect the actual effect on saturation flow, it was measured in terms of PCU/hr. The PCU factors used were derived from the regression analysis for each particular site.

2. Saturation flow values varied with the approach width in the stream. Generally saturation flows increased with increasing approach width.
3. From the collected data of saturation flow and their respective measured turning radius, it is clear that saturation flow has a tendency to increase with turning radius.
4. Saturation flow values varied with the proportion of NMV in the stream. Generally saturation flows increases with increasing percentage of NMV presence.

5.5 Problems Faced During Study

1. Frequent movement of pedestrian caused disturbances in counting.

2. Due to non availability of adequate persons the entire process was time consuming.

3. The entire video recording operation was weather susceptible. It was difficult and time consuming to find the suitable mountainous position for video recording.

4. It took a long time for data transcription. For sampling one minute of video recording it took more than five minutes because of counting interval was small.

5. Vision was obstructed during video recording, when large vehicles such as double Decker buses block the view.

6. Parking of vehicles and loading and unloading passengers near the stop line hampered the process of vehicle counting.

5.6 Limitations of the Study

1. Impact of intersection layout configuration on saturation flow has not considered in this study.
2. The variation of saturation flow and degree of saturation with time and was not considered in this study.

5.7 Recommendations for Future Studies

a. Recommended model of Saturation flow must be verified by applying it in other cities. In present study analysis has been carried out for only six intersections in Dhaka city. Similar analysis should be carried out for large number of intersection approaches.

b. It is recommended to use greater number of observational cycles including greater number of intersections for model calibration and validation.

c. Saturation flow also gets affected by parking facility, bus blockage, turning radius, roughness etc. near intersection. All these factors need to studied and numbers of sites should be increased

d. Day to day variations of a particular site can be determined. Several data during peak hours for each site should have produces more reliable results.
e. For better results data should be collected at different times of the day.
f. In order to see the effect of counting period, sampling should be done by changing counting interval such as 8 sec and 12sec interval.
g. Vehicles should be classified in broader categories, to reflect the variation in sizes on the capacity. It will give more appropriate PCU values.
h. Other methods can be applied to determine PCU values and saturation flow. The comparison of the methods can identify the most suitable method.
i. Effect of gradient can be found if video recording has been done at hill tract areas such as Sylhet and Chittagong.

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Appendix

A. Collected Data

Table A.1: Moghbazar W to S Approach

[LOCATION: Moghbazar Intersection, DIRECTION: W to S (right turn), WEATHER: Bright sunny day, DATE :03.10.2018, DURATION: 10:00 a.m.-11:00 a.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMV	M.cycle
6	3	4	0	0	0	5	2
6	2	3	0	0	0	5	3
6	4	1	0	2	0	4	3
6	5	2	0	1	1	5	2
6	3	2	1	2	0	4	2
6	4	3	0	3	0	3	0
6	3	2	0	1	0	5	1
6	4	0	0	0	0	0	1
6	2	3	0	0	0	2	3
6	4	2	1	2	2	3	2
6	2	0	0	0	0	0	2
6	1	2	0	1	0	2	3
6	2	1	0	2	0	2	3
6	1	3	0	0	0	4	1
6	3	2	0	3	0	3	0
6	2	2	1	0	0	4	1
6	3	3	0	2	1	3	0
6	2	1	0	3	0	2	1
6	3	1	0	2	0	0	2
6	3	0	0	4	0	3	3
6	2	1	0	1	0	2	3
6	3	0	0	0	0	1	2
6	4	1	0	0	0	2	2
6	2	3	1	0	0	3	1
6	4	3	0	2	1	2	2
6	2	2	0	3	0	3	2
6	2	1	0	3	0	2	3
6	4	2	1	2	0	3	1
6	1	1	0	0	0	2	3
6	2	2	0	0	0	2	0
6	2	2	0	0	0	3	3
6	3	3	0	1	0	0	2
6	1	1	0	1	0	2	1
6	3	3	1	0	2	0	3
6	2	2	0	0	0	2	2
6	3	3	0	3	0	2	3
6	2	2	0	2	0	0	0
6	1	1	0	0	0	3	2
6	4	3	0	4	0	2	2
6	3	2	0	0	0	3	1
6	2	3	0	4	3	4	3
6	3	0	1	0	0	0	2
6	2	4	0	0	0	4	1
6	1	2	0	2	0	3	3
6	4	2	0	2	0	2	1
6	1	2	0	3	0	1	0
6	3	3	0	0	0	3	1
6	2	3	0	0	0	4	2
6	2	1	0	2	0	4	2
6	1	2	0	0	0	3	1
Total	127	97	7	63	10	126	89

Table A.2: Moghbazar E to W Approach

[LOCATION: Moghbazar Intersection, DIRECTION: E to W(Straight, WEATHER: Bright sunny day, DATE : 03.10.2018, DURATION: 10:00 a.m.-11:00 a.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	3	3	0	0	0	0	2
6	4	1	0	1	0	2	0
6	3	4	0	0	0	3	2
6	2	2	0	0	0	0	4
6	4	5	0	0	0	2	3
6	1	1	1	0	1	3	0
6	3	2	0	0	0	3	0
6	2	3	0	0	0	3	3
6	4	2	2	2	1	4	2
6	3	3	0	3	0	3	1
6	4	1	0	1	0	2	2
6	3	3	0	2	1	0	0
6	1	4	0	0	0	4	5
6	3	2	1	0	0	2	0
6	2	1	0	0	1	1	2
6	4	4	0	2	0	3	3
6	2	3	0	0	0	3	4
6	1	3	0	0	1	2	1
6	4	3	0	0	0	1	3
6	3	1	0	1	0	2	2
6	3	2	0	2	0	4	1
6	4	4	0	2	0	2	2
6	3	3	0	1	0	1	0
6	4	2	0	2	1	3	3
6	2	2	1	0	0	0	3
6	2	3	0	0	1	2	1
6	4	1	0	2	0	4	3
6	3	4	0	5	0	2	2
6	1	1	2	2	1	2	4
6	3	2	0	3	0	0	3
6	2	4	0	4	1	3	2
6	3	2	0	2	1	4	4
6	2	4	1	0	0	3	3
6	3	2	1	0	1	3	5
6	3	3	1	5	0	4	2
6	4	1	0	2	0	4	3
6	1	5	0	4	0	3	1
6	3	1	1	0	1	2	2
6	2	3	0	1	0	1	4
6	3	2	1	2	0	3	2
6	2	4	0	0	0	6	3
6	3	3	1	0	1	4	2
6	4	3	0	0	0	0	4
6	3	2	0	0	0	0	3
6	4	1	1	1	0	0	4
6	3	2	1	1	0	0	1
6	2	3	0	1	0	0	1
6	1	2	1	1	0	0	0
6	3	3	1	0	1	0	0
Total	136	125	17	55	14	103	107

Table A.3: Bangla Motor South Approach

[LOCATION: Bangla motor, DIRECTION: W to S(right turn, WEATHER: Bright sunny day, DATE: 02.10.2018, DURATION: 10:00 a.m.-11:00 a.m.]

Time (s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	4	1	0	1	0	0	4
6	3	5	0	0	0	1	2
6	2	3	1	1	1	0	1
6	5	0	0	1	0	3	0
6	4	3	0	1	1	2	0
6	4	2	0	0	0	0	0
6	3	0	0	0	0	1	0
6	4	1	0	1	0	0	1
6	2	1	0	1	0	3	0
6	4	3	0	1	0	0	0
6	4	4	0	1	0	2	0
6	1	2	0	3	0	0	0
6	2	3	1	0	1	2	0
6	3	3	0	1	0	0	0
6	3	1	0	1	0	3	2
6	4	0	0	0	0	0	2
6	3	1	1	0	0	3	2
6	2	0	0	0	0	4	0
6	3	1	0	1	0	2	0
6	3	2	0	1	0	0	4
6	2	3	0	1	0	2	4
6	4	3	0	1	1	4	4
6	4	2	0	0	0	4	0
6	2	2	0	0	0	3	3
6	4	1	2	0	0	5	0
6	2	2	0	0	0	4	2
6	4	2	0	0	0	3	0
6	4	3	0	0	0	5	3
6	1	1	0	0	0	1	2
6	2	3	0	0	0	4	1
6	2	0	0	0	0	4	2
6	4	3	0	0	2	3	1
6	4	2	0	1	0	0	2
6	3	1	0	1	0	3	3
6	4	3	0	3	0	0	1
6	3	2	0	0	3	0	2
6	2	3	0	1	0	0	0
6	1	0	1	2	0	0	0
6	5	5	0	1	0	1	0
6	3	2	1	0	0	3	0
6	2	1	0	0	0	4	0
6	5	3	0	0	0	3	2
6	4	2	0	1	0	5	0
6	1	4	1	1	0	2	1
6	4	3	0	0	0	3	0
6	4	1	0	0	0	2	3
6	3	0	1	2	0	2	2
6	2	1	0	0	0	1	4
6	2	2	1	1	0	4	3
6	1	2	0	0	0	2	2
Total	151	98	10	31	9	103	65

Table A.4: Banglamotor E to W Approach

[LOCATION: Banglamotor, DIRECTION: E to W, WEATHER: Bright sunny day, DATE: 02.10.2018, DURATION: 10:00 a.m.-11:00 a.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMV	M.cycle
6	4	3	0	0	0	0	5
6	2	0	0	1	0	0	2
6	2	3	0	0	0	0	2
6	3	0	0	4	0	0	4
6	4	3	0	5	1	0	3
6	3	2	1	3	0	0	1
6	1	4	0	1	0	0	3
6	3	3	0	0	0	0	2
6	2	1	1	1	0	0	4
6	4	1	1	1	1	0	1
6	3	0	0	1	0	0	1
6	4	2	1	2	0	0	1
6	3	4	0	3	0	0	0
6	3	0	0	2	0	0	4
6	4	3	0	2	0	0	0
6	1	1	0	2	0	0	3
6	2	1	0	1	0	0	4
6	4	3	0	1	0	0	2
6	5	2	0	1	1	0	4
6	4	2	0	1	0	0	0
6	4	1	0	1	0	0	0
6	3	2	0	1	0	0	0
6	2	3	0	1	0	0	0
6	3	3	0	1	0	0	0
6	3	1	0	1	0	0	0
6	4	0	0	1	0	0	0
6	3	0	0	0	0	0	1
6	4	1	0	3	0	0	1
6	3	0	0	1	0	0	0
6	4	1	0	1	0	0	2
6	4	2	0	1	1	0	2
6	2	3	0	1	0	0	2
6	5	3	0	2	0	0	4
6	5	2	0	1	0	0	4
6	4	2	0	3	0	0	0
6	3	1	0	0	0	0	0
6	1	2	0	4	0	0	0
6	4	2	0	1	0	0	0
6	2	3	0	1	0	0	4
6	3	1	0	1	0	0	3
6	5	5	0	0	0	0	1
6	1	0	0	2	3	0	2
6	4	3	2	1	0	0	4
6	4	2	0	1	0	0	5
6	3	1	0	1	0	0	1
6	4	2	0	1	0	3	2
6	3	3	0	2	0	2	3
6	3	3	1	3	0	0	1
6	2	1	0	5	1	0	3
6	4	0	1	3	2	0	4
Total	160	91	8	77	10	5	95

Table A.5: Science Lab N to S Approach

[LOCATION: Science Lab, DIRECTION: E to W, WEATHER: Bright sunny day, DATE: 30.09.2018, DURATION: 12:00 p.m.-1:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	2	3	0	1	0	2	0
6	4	1	0	1	0	1	1
6	5	2	0	0	0	2	2
6	6	3	0	0	0	0	0
6	3	3	1	2	0	0	0
6	5	4	0	0	0	0	0
6	3	0	0	1	0	2	4
6	5	0	1	3	2	3	3
6	6	3	0	2	0	3	0
6	4	4	1	3	0	4	0
6	1	3	0	2	0	2	1
6	4	2	0	1	0	4	2
6	1	0	0	0	0	3	2
6	4	5	0	0	0	2	0
6	4	2	0	1	0	0	0
6	3	4	0	2	0	0	0
6	5	4	1	2	0	1	1
6	4	2	1	0	0	1	1
6	3	5	0	1	1	2	1
6	2	2	0	0	0	2	1
6	3	5	2	0	0	2	1
6	3	3	0	2	0	0	0
6	2	4	0	0	0	0	0
6	4	2	0	0	0	3	0
6	3	4	0	1	0	2	2
6	4	3	2	1	1	1	0
6	4	4	0	2	0	3	3
6	3	3	0	0	0	2	0
6	7	0	0	0	0	4	2
6	3	0	0	1	0	0	1
6	3	1	1	0	0	3	0
6	6	4	1	2	0	0	0
6	3	0	0	0	0	2	0
6	3	2	0	0	0	1	1
6	2	3	0	3	0	1	1
6	1	2	2	1	0	2	2
6	5	2	0	0	1	0	2
6	4	0	0	2	0	0	3
6	3	3	0	1	0	2	4
6	5	4	0	0	0	1	0
6	3	1	1	2	0	1	0
6	6	3	0	0	0	0	3
6	5	0	0	2	0	0	0
6	1	5	0	1	0	0	2
6	3	4	0	1	2	2	1
6	3	3	0	1	0	2	1
6	4	2	0	2	0	3	2
6	6	4	0	0	0	0	2
6	5	3	0	1	0	2	2
6	3	2	0	1	0	1	0
Total	182	128	14	49	7	74	54

Table A.6: Science Lab W to S Approach

[LOCATION: Science Lab, DIRECTION: W to S (right turn), WEATHER: Bright sunny day, DATE: 30.09.2018, DURATION: 12:00 p.m.-1:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	3	0	0	1	0	2	2
6	3	1	0	0	0	3	1
6	6	2	0	2	0	2	1
6	3	4	0	2	0	1	0
6	2	3	1	0	0	0	0
6	5	3	0	3	0	4	0
6	4	2	0	1	0	3	3
6	3	2	2	2	1	2	2
6	3	5	0	0	0	1	0
6	1	3	0	0	0	0	0
6	5	2	0	2	0	0	2
6	3	3	0	5	0	0	0
6	2	3	0	0	2	0	1
6	1	0	1	2	0	1	0
6	5	2	0	4	0	2	2
6	3	2	1	3	0	1	0
6	5	3	1	1	0	0	3
6	2	3	0	2	0	0	0
6	6	3	0	2	1	0	0
6	4	2	0	3	0	2	2
6	3	3	0	0	0	0	1
6	0	1	0	1	0	1	2
6	2	2	0	2	0	2	1
6	3	0	0	3	0	2	0
6	2	1	0	3	0	3	0
6	2	3	0	4	0	0	3
6	4	2	2	5	0	1	0
6	2	5	0	2	2	1	2
6	3	1	0	3	0	3	2
6	4	2	0	2	0	0	0
6	3	2	0	1	0	2	0
6	0	4	0	2	0	0	1
6	2	3	0	0	0	2	1
6	5	3	1	3	0	0	2
6	3	1	0	3	0	0	0
6	4	2	1	2	0	2	2
6	3	3	1	2	0	2	0
6	6	2	0	4	1	3	1
6	3	0	0	4	0	2	0
6	6	1	0	0	0	0	2
6	3	0	0	2	0	0	0
6	3	2	0	2	0	1	2
6	2	0	1	2	0	1	3
6	2	1	1	3	2	1	1
6	4	3	0	1	0	0	0
6	2	3	0	5	0	2	0
6	4	1	0	3	0	0	2
6	2	2	0	2	0	0	4
6	3	1	1	1	0	2	2
6	1	2	0	2	0	2	0
Total	155	104	14	104	9	59	53

Table A.7: Razarbagh W to S Approach

[LOCATION: Razarbagh, DIRECTION: W to S (right turn), WEATHER: Bright sunny day, DATE: 20.10.2018, DURATION: 2:00 p.m.-3:00 p.m. (over saturated)]

Time(s)	**P.car**	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	3	2	1	2	1	4	0
6	3	2	0	1	0	5	2
6	2	3	0	0	0	3	2
6	3	2	1	3	1	3	0
6	2	3	0	4	0	4	2
6	4	1	1	3	1	5	0
6	3	2	0	2	0	2	2
6	2	2	0	0	0	4	0
6	2	2	2	2	0	3	2
6	3	1	0	1	1	3	1
6	2	1	0	2	0	2	2
6	2	2	2	3	0	3	2
6	3	3	0	3	0	2	0
6	1	2	1	1	1	2	1
6	3	1	0	2	0	4	0
6	4	3	0	2	0	3	2
6	2	3	1	1	0	3	2
6	2	2	0	1	0	4	1
6	4	2	0	2	0	3	0
6	3	1	2	2	0	3	1
6	2	2	0	1	0	1	0
6	5	3	0	2	1	2	2
6	3	2	1	1	0	2	1
6	2	1	0	2	0	3	2
6	3	2	1	3	0	4	0
6	2	3	0	1	0	2	2
6	3	1	2	0	1	3	0
6	2	2	0	3	0	4	3
6	2	1	2	2	0	2	2
6	3	2	0	1	0	3	0
6	4	3	0	2	0	4	3
6	3	2	1	1	0	2	1
6	1	3	1	2	1	2	2
6	3	2	1	1	0	3	2
6	2	3	0	2	0	3	1
6	5	1	0	0	0	3	2
6	2	2	0	3	2	4	3
6	2	1	1	1	0	2	1
6	3	3	0	2	0	2	2
6	2	2	0	1	0	3	2
6	2	2	0	3	1	4	3
6	4	3	1	2	0	3	0
6	2	2	0	1	0	4	0
6	1	2	0	2	0	3	2
6	4	1	1	2	1	2	2
6	2	2	0	1	0	2	1
6	3	3	0	2	1	3	3
6	3	2	1	3	0	4	3
6	1	3	0	4	0	3	1
6	2	1	0	2	0	5	2
Total	131	102	24	90	13	152	70

Table A.8: Razarbagh E to W Approach

[LOCATION: Razarbagh, DIRECTION: E to W, WEATHER: Bright sunny day DATE:20.10.2018, DURATION: 2:00 p.m.-3:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	4	4	0	0	0	2	4
6	2	0	0	1	0	3	2
6	2	3	0	0	0	1	2
6	3	0	0	4	0	0	4
6	5	3	0	3	1	2	3
6	3	2	1	3	0	2	1
6	1	4	0	1	0	3	3
6	3	3	0	0	0	2	2
6	2	1	1	1	0	3	4
6	5	1	1	1	1	4	1
6	3	0	0	1	0	2	1
6	4	2	1	2	0	0	1
6	3	5	0	3	0	1	0
6	5	0	0	2	0	2	4
6	4	3	0	2	0	1	0
6	1	1	0	2	0	3	3
6	2	1	0	1	0	4	5
6	4	3	0	1	0	2	2
6	5	2	0	1	1	0	4
6	4	2	0	1	0	2	0
6	4	1	0	1	0	2	1
6	3	2	0	1	0	3	0
6	2	3	0	1	0	3	2
6	3	3	0	1	0	0	0
6	3	1	0	1	0	4	2
6	4	0	0	1	0	3	0
6	3	0	0	0	0	2	1
6	4	1	0	3	0	0	1
6	5	0	0	1	0	1	0
6	4	1	0	1	0	1	2
6	4	2	0	1	1	2	2
6	2	3	0	1	0	3	2
6	5	3	0	2	0	0	4
6	5	2	0	1	0	4	4
6	4	2	0	3	0	3	0
6	3	1	0	0	0	3	2
6	1	2	0	4	0	2	0
6	4	2	0	1	0	2	0
6	2	3	0	1	0	0	4
6	3	1	0	1	0	0	3
6	5	5	0	0	0	4	1
6	1	0	0	2	3	4	2
6	4	3	2	1	0	2	4
6	4	2	0	1	0	3	5
6	5	1	0	1	0	3	1
6	4	2	0	1	0	2	2
6	3	3	0	2	0	1	3
6	3	3	1	3	0	0	1
6	2	1	0	5	1	2	5
6	4	0	1	3	2	1	4
Total	168	93	8	75	10	99	104

Table A.9: Bata Signal W to S Approach

[LOCATION: Bata Signal, DIRECTION: E to S, WEATHER: Bright sunny day, DATE: 30.09.2018, DURATION: 11:00 a.m.-12:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	2	1	0	0	1	0	1
6	2	0	1	0	1	1	1
6	1	1	0	1	0	0	1
6	1	0	1	0	0	1	0
6	1	1	1	1	2	0	0
6	1	1	0	1	2	1	1
6	3	1	1	2	1	1	1
6	2	0	1	1	0	1	1
6	2	1	0	0	1	0	0
6	2	0	0	1	2	0	1
6	1	0	0	0	1	0	0
6	1	0	1	1	0	1	0
6	1	1	0	1	2	0	1
6	1	1	1	1	2	1	2
6	0	1	1	0	2	0	1
6	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0
6	1	0	0	0	0	0	0
6	2	1	0	0	1	0	1
6	0	0	1	0	1	0	0
6	1	0	1	0	1	0	1
6	1	1	0	1	2	1	1
6	0	1	0	1	1	0	1
6	0	0	0	1	1	1	1
6	2	2	0	0	1	0	1
6	1	1	0	1	2	0	2
6	0	1	0	1	2	1	1
6	0	1	0	1	1	0	2
6	1	1	0	1	1	0	1
6	1	1	0	0	1	0	2
6	2	1	0	0	1	0	1
6	2	0	0	1	1	0	1
6	0	0	0	0	1	1	1
6	1	0	1	1	1	0	2
6	1	1	0	0	2	1	3
6	1	0	0	1	2	1	2
6	1	0	1	1	1	0	1
6	1	1	0	1	2	2	2
6	1	1	0	2	1	0	1
6	1	1	1	1	1	0	0
6	0	0	0	0	1	0	1
6	0	1	1	0	0	0	1
6	1	1	1	0	1	1	1
6	0	1	1	1	1	0	2
6	0	0	0	0	1	0	1
6	0	0	0	1	2	1	0
6	1	1	0	1	1	0	1
6	0	0	0	0	2	1	1
6	1	1	0	1	1	0	0
6	1	1	0	1	1	0	2
Total	47	30	16	30	56	18	49

Table A.10: Bata Signal E to W Approach

[LOCATION: Bata Signal, DIRECTION: E to W, WEATHER: Bright sunny day DATE:30.09.2018, DURATION: 11:00 a.m.-12:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	1	1	0	0	2	0	3
6	2	0	0	1	1	1	1
6	0	1	0	1	1	0	2
6	1	1	0	0	3	0	1
6	0	1	0	0	1	0	1
6	0	2	0	1	2	0	2
6	1	0	0	2	1	1	2
6	2	0	0	1	0	1	2
6	1	1	0	1	1	2	0
6	0	0	0	0	2	0	1
6	1	1	0	0	1	0	2
6	0	2	0	1	0	1	3
6	3	1	0	0	1	1	1
6	1	0	0	1	1	0	2
6	0	1	0	0	2	0	1
6	2	2	0	1	1	1	1
6	0	1	0	0	0	2	2
6	1	0	0	1	1	0	1
6	3	1	0	0	0	1	2
6	0	1	0	1	1	1	1
6	1	0	0	0	1	0	2
6	1	1	0	1	1	1	0
6	0	1	0	0	0	0	0
6	1	2	0	0	2	1	1
6	1	1	0	1	3	2	2
6	1	0	0	1	1	0	3
6	1	1	0	2	0	1	2
6	0	0	0	0	1	2	1
6	1	1	0	1	2	0	2
6	1	1	0	0	0	1	1
6	0	1	0	1	2	1	2
6	2	0	0	0	2	1	1
6	2	1	0	1	1	1	2
6	1	0	0	0	0	0	2
6	0	1	0	1	1	0	3
6	1	0	0	0	2	2	1
6	0	1	0	1	3	0	0
6	1	1	0	0	2	1	2
6	0	2	0	0	1	0	1
6	1	0	0	1	1	1	2
6	1	0	0	1	0	0	3
6	0	1	0	1	1	1	1
6	1	1	0	0	2	1	3
6	2	1	0	0	3	0	2
6	0	1	0	0	1	1	1
6	1	2	0	1	2	2	2
6	0	0	0	1	3	1	3
6	1	1	0	1	1	0	2
6	1	0	0	1	1	1	1
6	2	1	0	0	2	1	2
Total	44	40	0	29	64	35	81

Table A.11: Katabon E to S Approach

[LOCATION: Katabon, DIRECTION: W to S, WEATHER: Bright sunny day, DATE:30.09.2018, DURATION: 11:00 a.m.-12:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	3	2	0	1	4	0	2
6	3	2	0	0	1	0	1
6	2	1	1	0	2	0	1
6	2	1	1	2	3	0	2
6	2	2	0	2	1	1	3
6	3	2	0	1	2	2	4
6	1	1	2	1	3	0	1
6	1	1	1	0	0	1	1
6	2	1	1	0	1	0	3
6	2	0	2	1	1	0	2
6	3	0	1	1	2	1	1
6	4	2	1	0	1	2	0
6	0	2	0	2	2	1	2
6	1	1	0	1	1	0	1
6	1	1	1	0	0	0	1
6	2	2	1	1	1	1	0
6	2	2	1	2	2	1	0
6	1	1	0	0	0	0	3
6	3	0	0	0	1	1	2
6	1	0	1	1	2	0	1
6	2	2	1	2	0	1	1
6	3	1	1	0	2	1	2
6	1	1	2	0	1	0	3
6	2	2	2	1	0	0	2
6	2	2	1	1	2	0	1
6	1	1	0	0	1	1	1
6	1	0	0	2	0	1	2
6	0	0	1	1	1	2	2
6	0	1	1	0	2	1	1
6	2	1	0	1	0	1	1
6	2	1	0	2	2	0	0
6	1	3	1	0	1	2	2
6	1	2	1	0	0	1	1
6	2	2	2	2	2	1	1
6	3	1	2	1	1	0	2
6	3	0	1	0	0	0	1
6	2	0	1	2	2	2	2
6	1	1	2	1	1	1	0
6	1	2	2	0	0	0	2
6	2	2	1	1	1	0	1
6	2	3	1	2	2	1	1
6	1	2	1	0	3	0	2
6	2	1	0	2	1	1	2
6	2	1	0	1	2	1	1
6	1	2	2	0	2	0	1
6	3	2	1	1	2	2	3
6	1	0	1	2	1	1	0
6	1	0	2	0	2	1	2
6	2	2	2	1	1	0	3
6	2	1	0	0	3	0	3
Total	88	63	46	42	68	33	77

Table A.12: Katabon E to W Approach

[LOCATION: Katabon, DIRECTION: E to W, WEATHER: Bright sunny day, DATE: 30.09.2018, DURATION: 11:00 a.m.-12:00 p.m. (over saturated)]

Time(s)	P.car	Auto Rickshaw	L.bus	S.bus	Utility	NMN	M.cycle
6	1	2	0	0	2	0	1
6	2	1	0	0	1	0	2
6	2	2	0	0	1	0	1
6	1	2	0	0	2	0	1
6	2	2	0	1	2	0	2
6	3	1	0	1	1	0	3
6	3	1	0	0	1	1	3
6	3	3	0	1	1	0	1
6	1	0	0	0	3	0	1
6	1	1	0	2	2	1	2
6	0	1	0	1	1	0	2
6	2	2	0	1	3	1	0
6	1	2	0	0	1	2	1
6	1	1	0	0	2	0	4
6	2	1	0	0	3	0	1
6	2	0	0	0	1	0	2
6	1	2	0	1	3	2	1
6	1	2	0	2	2	1	1
6	0	1	0	1	1	0	2
6	2	1	0	1	2	1	2
6	1	0	0	1	3	1	1
6	1	2	0	0	3	0	1
6	2	2	0	1	2	0	1
6	2	1	0	1	1	1	0
6	1	1	0	0	2	0	2
6	1	3	0	1	3	1	1
6	3	2	0	1	2	1	1
6	3	2	0	0	1	0	4
6	2	3	0	0	1	1	1
6	2	3	0	1	2	0	1
6	1	2	0	2	3	1	2
6	1	2	0	1	0	0	3
6	0	1	0	0	2	1	0
6	3	1	0	0	1	1	1
6	2	1	0	0	0	2	2
6	1	0	0	0	2	1	1
6	2	3	0	1	1	1	1
6	2	2	0	0	1	0	2
6	3	2	0	0	2	1	0
6	3	1	0	1	3	2	2
6	1	1	0	0	2	0	1
6	1	2	0	1	1	0	1
6	0	3	0	1	3	0	1
6	2	3	0	0	0	1	2
6	2	0	0	2	1	0	0
6	1	2	0	1	2	0	2
6	1	2	0	1	1	1	1
6	3	1	0	0	0	0	0
6	2	1	0	1	1	1	0
6	2	3	0	0	2	0	1
Total	82	80	0	30	83	27	69

B. Multiple Linear Regression Analysis Data by SPSS Software

1. Bangla Motor (E to W approach)

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
dimension0 1	M.Cycle, NMV, Auto Rickshaw, Utility, L.bus, S.Bus[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: P.car

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.889	0.495		5.835	0
	Auto Rickshaw	0.114	0.133	0.129	0.859	0.395
	L.bus	-0.56	0.378	-0.223	-1.479	0.146
	S.Bus	-0.035	0.246	-0.023	-0.143	0.887
	Utility	0.099	0.308	0.049	0.322	0.749
	NMV	0.066	0.114	0.095	0.577	0.567
	M.Cycle	-0.087	0.121	-0.106	-0.718	0.477

a. Dependent Variable: P.car

2. Bangla Motor (W to S approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.085	.398		7.760	.000
	Auto Rickshaw	.109	.132	.128	.825	.414
	L.bus	.315	.385	.124	.817	.418
	S.Bus	-.100	.137	-.114	-.736	.466
	Utility	-.024	.305	-.013	-.078	.938
	NMV	.146	.318	.069	.460	.648
	M.Cycle	.006	.101	.009	.060	.953

a. Dependent Variable: P.car

3. Moghbazar (E to W approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.404	.431		5.573	.000
	L.bus	.490	.443	.166	1.108	.274
	S.bus	.156	.116	.199	1.341	.187
	Utility	.254	.265	.149	.960	.342
	NMV	.006	.104	.008	.054	.957
	Motorcycle	-.109	.150	-.105	-.725	.472

a. Dependent Variable: P.car

4. Moghbazar (W to S approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.460	.513		4.795	.000
	L.bus	.485	.448	.164	1.081	.286
	S.bus	.153	.118	.196	1.300	.201
	Utility	.271	.280	.159	.967	.339
	NMV	.016	.116	.021	.135	.893
	M.cycle	-.117	.157	-.112	-.745	.460
	Auto Rickshaw	-.034	.167	-.034	-.205	.838

a. Dependent Variable: P.car

5. Razarbagh (W to S)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.674	.752		3.555	.001
	Auto Rickshaw	-.027	.216	-.021	-.127	.900
	L.bus	-.024	.226	-.017	-.106	.916
	S.Bus	-.069	.160	-.070	-.430	.669
	Utility	.195	.299	.100	.652	.518
	NMV	.077	.164	.075	.468	.642
	M.Cycle	-.105	.146	-.112	-.720	.476

a. Dependent Variable: P.car

6. **Razarbagh (E to W)**

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	4.194	.611		6.867	.000
	Auto Rickshaw	-.023	.138	-.026	-.168	.867
	L.bus	.296	.422	.105	.702	.487
	S.Bus	-.226	.171	-.215	-1.322	.193
	Utility	.056	.337	.027	.166	.869
	NMV	-.191	.148	-.204	-1.290	.204
	M.Cycle	-.063	.113	-.084	-.557	.581

a. Dependent Variable: P.car

7. **Katabon Intersection (E to W approach)**

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
	(Constant)	1.518	0.456		3.327	0.002
	Auto Rickshaw	0.113	0.162	0.105	0.7	0.488
	L.bus	-0.14	0.189	-0.113	-0.739	0.464
1	S.Bus	-0.01	0.177	-0.009	-0.059	0.953
	Utility	0.105	0.142	0.113	0.742	0.462
	NMV	0.06	0.201	0.046	0.299	0.766
	M.Cycle	0.035	0.142	0.038	0.248	0.805

a. Dependent Variable: P.car

8.Katabon Intersection (N to S approach)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.975	.442		4.464	.000
	Auto Rickshaw	.060	.141	.060	.421	.676
	S.Bus	-.171	.200	-.125	-.856	.397
	Utility	-.269	.143	-.275	-1.880	.067
	NMV	.189	.197	.140	.961	.342
	M.Cycle	.012	.136	.013	.090	.928

a. Dependent Variable: P.car

9. Bata Signal Intersection (E to W approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.828	.269		3.081	.004
	Auto Rickshaw	.328	.225	.237	1.458	.152
	L.bus	.068	.239	.044	.286	.776
	S.Bus	.156	.200	.120	.779	.440
	Utility	-.169	.194	-.151	-.872	.388
	NMV	.090	.227	.064	.395	.695
	M.Cycle	-.044	.172	-.043	-.257	.798

a. Dependent Variable: P.car

10. Bata Signal Intersection (E to S approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.888	.385		2.310	.026
	Auto Rickshaw	-.165	.184	-.132	-.896	.375
	S.Bus	-.161	.209	-.116	-.768	.446
	Utility	-.056	.134	-.062	-.417	.679
	NMV	.218	.175	.185	1.245	.220
	M.Cycle	.084	.144	.087	.582	.564

a. Dependent Variable: P.car

11. Science Lab Intersection (W to S approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.299	.715		3.216	.002
	Auto Rickshaw	.071	.190	.060	.374	.710
	L.bus	.000	.414	.000	.001	1.000
	S.Bus	.165	.164	.155	1.008	.319
	Utility	-.097	.429	-.035	-.225	.823
	NMV	.119	.202	.091	.589	.559
	M.Cycle	.176	.199	.135	.888	.379

a. Dependent Variable: P.car

12. Science Lab Intersection (N to S approach)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.935	.620		6.352	.000
	Auto Rickshaw	-.028	.148	-.030	-.192	.849
	L.bus	-.146	.394	-.058	-.370	.713
	S.Bus	-.105	.237	-.069	-.444	.660
	Utility	.298	.496	.094	.600	.552
	NMV	-.070	.182	-.060	-.384	.703
	M.Cycle	.021	.200	.017	.106	.916

a. Dependent Variable: P.car

C. Photographs

Figure A. 1: Bangla Motor Intersection

Figure A. 2: Bangla Motor Intersection

Figure A. 3: Bata Signal Intersection

Figure A. 4: Bata Signal Intersection

Figure A. 5: Bata Signal Intersection

Figure A. 6: Bata Signal Intersection

Figure A. 7: Katabon Intersection

Figure A. 8: Katabon Intersection

Figure A. 9: Katabon Intersection

Figure A. 10: Mogh Bazar Intersection

Figure A. 11: Mogh Bazar Intersection

Figure A. 12: Katabon Intersection

Figure A. 13: Rajar-Bagh Intersection

Figure A. 14: Rajar-Bagh Intersection

Figure A. 15: Rajar-Bagh Intersection

Figure A. 16: Rajar Bagh Intersection

Figure A. 17: Science Lab Intersection

Figure A.18: Science Lab Intersection

Figure A.19: Science Lab Intersection

Figure A.20: Science Lab Intersection