INVESTIGATION OF ROAD INTERSECTION OPERATION USING MICRO-SIMULATION TECHNIQUE

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by

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Dedicated to

My Family Members

The thesis titled "Investigation of Road Intersection Operation Using Micro-Simulation Technique'" submitted by Tahmina Rahman Chowdhury, Roll No: 100604414 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering on 25th March, 2019.

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Abstract

In developing countries, the traffic composes of both motorized vehicles and non-motorized vehicles using the same road way, hence the resulting traffic system is non-lane based and heterogeneous. The motorized or fast-moving vehicles are mainly bus, cars, CNG driven auto rickshaws, trucks whereas the slow-moving vehicles referred as non-motorized vehicles (NMV) consists of rickshaws and bi-cycle, which is different in driving behavior and shows lack of lane discipline in particular. Even though the proportion of NMV varies from 10-80 percent, it has a major impact on the traffic characteristics and operations at the signalized intersections. NMV not only reduces the roadway capacity and speed of motorized vehicle but also induces congestion at signalized intersections while discharging stream and affects the queue length and delay time.

A review of literature has shown that many simulation model development works had been done on the lane based homogeneous traffic system consisting of motorized vehicles. This paper mainly deals investigation of road intersection operation on signalized intersection through a microscopic simulation modeling approach. In order to calibrate, there are certain parameters that need to be adjusted in order to get results that are close to field data.

A wide range of data had been collected to develop and calibrate the model of the study area. Data related to geometry of the road were collected directly from the field. Two segmented videos of 30 minutes time interval each, total of one hour were recorded to closely observe the current traffic condition and behavior of vehicles and its impact on others. In addition to that, all the dynamic features of the road such as volume, speed, traffic composition, relative flow of traffic in each direction were extracted from the video. After modeling the network and calibrating it, some network performances parameter such as travel time, and delay time for certain travel sections, had been extracted for 600 second simulation run time, from the model, to observe the effect on network performances due to forced behavior of NMV to MV.

This research may be used as a good reference to visualize the forced behavior that NMV induces on MV in a road network with the help of Simulation tools VISSIM.

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Chapter 1
INTRODUCTION

1.1 Background

Dhaka is the most important city in Bangladesh. With a population of about 15 million and an approximate area 270 sq. km. It is one of the mega cities in Bangladesh and all of the divisional offices, education facilities, many business and shopping centers, temples, stadium, etc. are located in and around Dhaka city. The city plays a major role in controlling the economic development of not only Dhaka city but also whole country. As a result of which traffic and transportation problems are increasing day by day. The intensity of the traffic and pedestrians crossing has increased significantly and there is requirement of augmentation of capacity for safe and efficient means to cross over roads especially at junctions in multiple directions. These problems are manifesting in the form of increased traffic congestion, right angle crashes, delays, and several other problems like noise and air pollution.

Signalized intersections are key elements in the urban transportation network and they carry heavy movement of motorized vehicles and pedestrians, which in turn generate many conflicts among crossing, turning and merging maneuvers. For a variety of reasons such as population, economic and auto ownership growth, increasing traffic demand can exceed the carrying capacity of the intersection during peak periods. As a consequence, traffic condition deteriorates and safety problems increases. So, the improvement of urban transportation system for DMA has become a pressing issue to improve its traffic situation and urban environment.

1.2 Present State of the Problem

In a road traffic system, intersections are one of the prominent bottlenecks, which interrupt smooth flow of traffic and thereby cause delays. To avoid unnecessary delay or to get an efficient traffic flow movement, these intersections need to be designed properly and carefully. Along with appropriate road geometry, the necessary traffic control devices also need to be applied wisely. In the developed countries like USA, UK, Australia to obtain orderly movement of vehicles through junctions they have strict traffic control rules, regulations and well-established planning & designing methodology for geometric design of road intersection and as well as standard guide lines for the application of traffic control devices. Because of these practices, clear pattern in queue formation and discharging can be seen from road junctions of these countries. Day by day they have been adopting latest traffic engineering tools to provide better performance of the junction which is a vital part of road network.

The road traffic system in Bangladesh is going through the worst phase since its independence. All the major signalized intersections within the urban areas have got severe traffic congestion which produce long delay and insurmountable sufferings to the road users. This is happening mainly because of faulty layout of junctions, illegal parking/bus stoppage near exit, faulty placement of signals, arbitrary setting of signal time/phase, poor pedestrian crossing facilities, most importantly poor policing activities and many other factors.

However, from the field observation it has been identified that most of the total problems which cause traffic congestion in our intersections mainly because of the faulty placement of signals and as well as poor policing. So, it is necessary to improve geometrical condition of roadway and explore the better placement to improve the performance of existing junctions in Dhaka city. This study thus attempts to investigate the geometrical faults and proper position of the signal and to observe the contribution of traffic police in particular relation to performance of junctions.

1.3 Objectives of the Study

The study is aimed at investigating two main scopes for improving junction capacity viz. proper placement of signal and optimization of cycle time. The specific objectives of the study are:

- To identify the traffic operational problems within the junction area associated with the faulty geometrical conditions and the lack of enforcement.
- To assess the effect of geometric parameters and enforcement on junction's traffic handling capacity using micro simulation technique.
- To determine junction delay and explore appropriate traffic movement phasing.
- To recommended better junction operation technique.

It is expected that detailed analysis of field data would provide the following useful results:

- Identifications of the factors associated with the performance of an intersection so that capacity of the intersections can be improved.
- Quantification of junction improvement potential.

1.4 Scope of the Study

The scope of the study is as follows:

- The simulation model is calibrated using usual parameters value.
- Effect of NMV on other vehicles were visualized.

1.5 Thesis Outline

This thesis comprises of six chapters illustrating the necessary steps taken to achieve the above-mentioned objectives. The thesis is organized as follows:

A brief review of the traffic characteristics prevailing in Bangladesh is presented in the first Chapter with special emphasis placed on the objectives of this study. The chronological development of the model is also outlined.

Chapter 2 incorporates a brief description of the main methods of measuring and calculating the key parameters for traffic flow. Factors influencing these parameters are also described in this chapter. The choice of measurement techniques for this research work is added at the end of the chapter.

Chapter 3 deals with the review of literature that has been developed in the field. Here the site selection criteria and methods of the study and the challenges of simulating heterogenous traffic system has been discussed in this chapter.

In Chapter 4 details of data collection has been provided. Field data required for modelling and data required for analyzing the existing conditions have been provided in this chapter.

Chapter 5 describes the method of field study and estimation of different mixed traffic descriptive parameters for non-lane-based model development and validation. Findings from critical observations of different aspects of mixed traffic behavior are also incorporated.

Chapter 6 Presents the conclusion of the entire study and provides suggestions and recommendations for further development of the work.

Chapter 2
LITERATURE REVIEW

2.1 Introduction

Traffic micro simulation models has now become a standard and in most cases an efficient tool for evaluating and developing road traffic management and control systems worldwide. The scenario that is difficult to create or data that is difficult to collect from the field can now be easily be simulated using micro simulation model by calibrating the model properly. This chapter focuses on how the micro simulation software are developed throughout the years to characterize the real time scenario in the network both in homogeneous and heterogeneous traffic condition and point out their scope of work and how this research will be extended with the help of previous work done.

2.2 Intersection

In a road traffic system, intersections are one of the prominent bottlenecks that interrupt smooth flow of traffic and thereby cause delays. Vehicle speed would have been much higher and journey time much lesser without these junctions. But where there is crossing, at grade intersections have to be provided as a natural solution. So, these junctions are becoming sensitive part with respect to the overall network. That is the reason the management of these junctions has to be done carefully rather than the link design. The overall performance and the capacity of the network will obviously be reduced due to faulty intersections in spite of having a very well-designed link. To avoid unnecessary delay or to get an efficient traffic flow movement, these

intersections need to be designed properly and carefully. Along with appropriate road geometry, the necessary traffic control devices are also needed to be applied properly.

2.2.1 Basic design considerations of signalized intersection

In a road traffic system, intersections are one of the prominent bottlenecks that interrupt smooth flow of traffic and thereby cause delays. Vehicle speed would have been much higher and journey time much lesser without these junctions. But where there is crossing, at grade intersections have to be provided as a natural solution. So, these junctions are becoming sensitive part with respect to the overall network. That is the reason the management of these junctions has to be done carefully rather than the link design. The overall performance and the capacity of the network will obviously be reduced due to faulty intersections in spite of having a very well-designed link. To avoid unnecessary delay or to get an efficient traffic flow movement, these intersections need to be designed properly and carefully. Along with appropriate road geometry, the necessary traffic control devices are also needed to be applied properly.

A lot of research works have been carried out for better traffic control and management at intersections in the countries like USA, UK and Australia. All the latest traffic engineering tools are being applied to achieve maximum efficiency in these junctions. At the same time due to their enormous resource availability they are going for grade separation that gives them hundred percent efficiency.

Whereas in Bangladesh very limited studies had been undertaken, as we are not at the position to adopt this grade separation solution due to our severe resource constraints, we have to seek for other optimization methods of managing intersections. We have to apply proper management technique at the intersections to achieve maximum efficiency.

Intersection may be signalized for number of reasons, most of which relate to the safety and effective movement of conflicting vehicular and pedestrian flows through intersection. Two concepts are of important in understanding signalized intersection design and operation. These are:

- The time allocation of the 3600 seconds in an hour to conflicting movements and to "lost times" in the cycle.
- The effect of right-turning vehicles on the operation of the intersection.

Basic elements to consider in intersection design are discussed in the *AASHTO* documents. Along with other factors Human factors, Traffic considerations, Physical elements and Economic factors are significant in intersection design. These factors are pointed below:

Human Factors:

- Driving habits,
- Ability of drivers, pedestrians, and bicyclists to make decisions,
- Driver, pedestrian, and bicyclist expectancy,
- Decision and reaction time of various users,
- Conformance to natural paths of movement,
- Pedestrian use, ability, and habits, and
- Bicyclist use, ability, and habits;

Traffic Considerations:

- Design and actual capacities,
- Design-hour turning movements,
- Size and operating characteristics of vehicles,
- Variety of movements (diverging, merging, weaving, turning, and crossing),
- Vehicle speeds,

- Crossing distance,
- Signal complexity,
- Transit involvement,
- Light rail operations,
- Freight rail operations,
- Crash experience,
- Bicycle movements, and
- Pedestrian movements.

Physical Elements:

- Character and use of abutting property,
- Vertical alignments at the intersection,
- Sight distance,
- Angle of the intersection,
- Conflict area,
- Speed-change lanes,
- Geometric design features,
- Traffic control devices,
- Lighting equipment,
- Utilities,
- Drainage features,
- Safety features,
- Environmental factors,
- Pedestrian facilities (sidewalk, curb ramps, crosswalks), and

- Medians and islands;

Economic Factors:

- Cost of improvements,
- Effects of controlling or limiting rights of way (ROWs) on abutting residential or commercial properties where channelization restricts or prohibits vehicular movements,
- Energy consumption,
- Vehicular delay cost,
- Pedestrian delay,
- Air quality cost,
- Functional intersection area,
- Right of way available,
- Number of approach lanes, and
- Number of legs.

2.2.2 Intersection development process

The development of intersections typically follows a path that includes planning, design, construction, and operations. The development process also is influenced by feedback from other projects and research findings. The process must be able to reflect changes in goals and objectives, travel patterns, safety emphasis, geometric restrictions, and capacity needs. Recent emphasis in society is on the better accommodation of pedestrians and bicycles in the transportation network. All phases of the roadway development process must be able to integrate the changes needed to reflect this evolving society goal.

Additionally, laws require design and construction that are usable by pedestrians who have disabilities. Improvements (curb ramps, limited grade and slope, etc.) important to those with mobility impairments are well known. However, treatments that are effective in providing information to pedestrians with vision impairment are less understood.

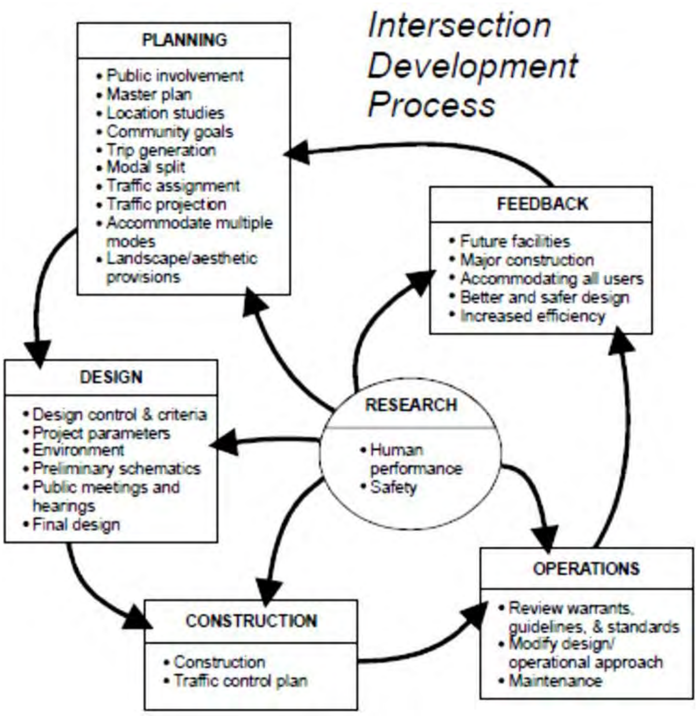


Figure 2.1: Intersection Development Process

Planning is conducted in conjunction with an overall regional plan and with public involvement that reflects the community goals. At this stage the facilities are classified and basic corridor requirements are identified. Consideration of all modes should occur, including transit, bicycle, and pedestrian facilities. Understanding the constraints presented by intersections can assist in developing a network that meets the basic needs of all modes. If the intersection is identified as being in a historic district or if there are historic buildings near the intersection, contact the District Environmental Coordinator for information.

Design involves the development of the project plans while considering the design control and criteria applicable to the setting. The intersection type, lane configuration, basic geometric form, pedestrian improvements, and right-of-way requirements are all developed during design. Due to public interest in the development of transportation projects, the design stage routinely includes public participation in some form.

Construction involves the building of all parts of the intersection as designed. An element of construction is the consideration of how to accommodate the safe movement of vehicles, pedestrians, and other users during the work.

Operations of the intersection include consideration of all users when selecting the traffic control devices and evaluating how the devices are functioning. During operations, the traffic control plan can be reviewed to determine if changes are desired. These changes could result in revisions to the operational approach or in changes to the design of the intersection.

Feedback from existing intersections can improve the planning, design, and operations process. Feedback can come in many forms such as volumes, operating speed, and complaints/comments from users. Crash records can be a valuable source of additional information on the performance of a site.

Research can also provide valuable information on how to better plan, design, or operate an intersection. It is an integral part of the process as it provides information on the various users of the system, what techniques have worked in other areas, and how to improve the system.

2.3 Types of Intersections

There are many types of intersections. At each particular location, selecting an intersection type is influenced by:

- Functional class of intersecting streets,
- Design level of traffic,

- Number of intersecting legs,
- Topography,
- Access requirements,
- Traffic volumes, patterns, and speeds,
- All modes to be accommodated,
- Availability of right of way, and
- Desired type of operation.

Although many of the intersection design examples are located in urban areas, the principals involved apply equally to design in rural areas. Some minor design variations occur with different kinds of traffic control, but all of the intersection types lend themselves to the following types of control:

- Cautionary or non-stop control,
- Stop control for minor approaches,
- Four-way stop control, and
- Both fixed-time and traffic-actuated signal control.

When two or more roads intersect, there is potential for conflict between vehicles and between various modes of travel. A priority in the design of at-grade intersections is to reduce the potential severity of conflicts and at the same time, assure the convenience and ease of all users in making the necessary maneuvers.

The basic types of intersections are:

- T-intersection (with variations in the angle of approach),
- Four-leg intersection,
- Multi-leg intersection, and
- Roundabouts.

A brief discussion of these intersection types follows. The basic intersection types vary greatly in scope, shape, and degree of channelization.

Three-Leg or T-Intersections: The normal pavement widths of both highways should be maintained at T-intersections except for the paved returns or where widening is needed to accommodate the selected design vehicle.

Four-Leg or Cross Intersections**:** Four-leg intersections vary from a simple 90-degree intersection of two lightly traveled local roads to a complex intersection of two main highways. The overall design principles, island arrangements, use of auxiliary lanes, and many other aspects of three-leg intersection design also apply to four-leg intersections.

Multi-leg Intersections: Multi-leg intersections are seldom used and should be avoided where possible. Most often they are found in urban areas where volumes are light and stop control is used. At other than minor intersections, safety and efficiency are improved by rearrangements that remove some conflicting movements from the major intersection.

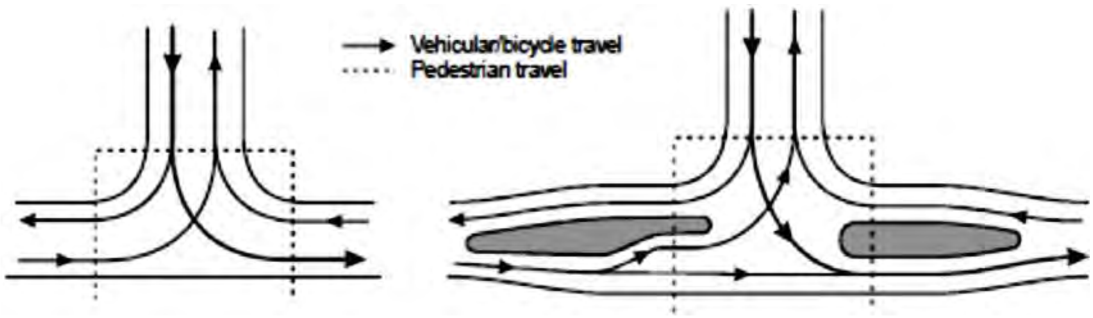


Figure 2.2: Typical Three-leg Intersection

Figure 2.3: Aerial Photograph of a Channelized T-Intersection

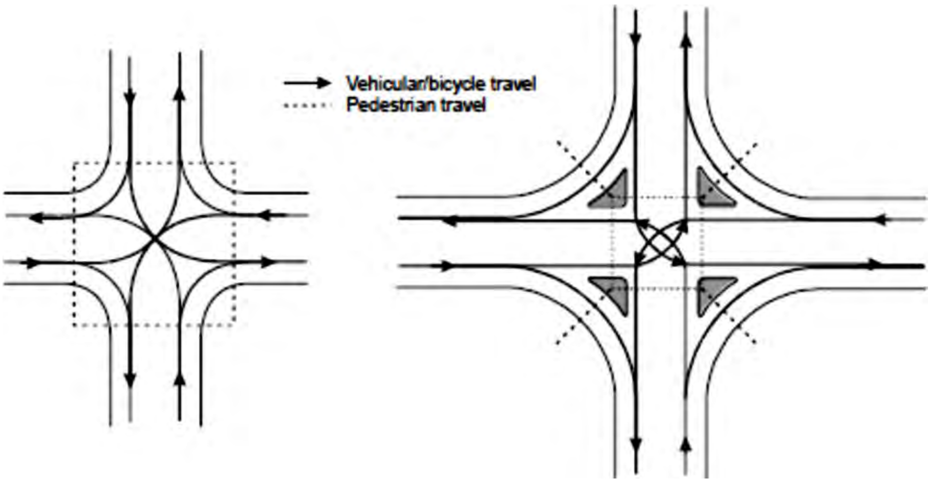


Figure 2.4: Typical Four-leg Intersection

Figure 2.5: Aerial Photograph of Four-leg Intersections

Two basic operational and design principles define modern roundabouts:

- Yield-at-entry where entering vehicles must yield to crossing pedestrians and to vehicles on the circulatory roadway of the roundabout and

- Deflection of entering traffic where entering traffic is deflected to the right by a central island on each approach to the roundabout.

2.4 Fundamental Parameters of Traffic Flow

Traffic engineering pertains to the analysis of the behavior of traffic and to design the facilities for a smooth, safe and economical operation of traffic. Traffic flow, like the flow of water, has several parameters associated with it. The traffic stream parameters provide information regarding the nature of traffic flow, which helps the analyst in detecting any variation in flow characteristics. Understanding traffic behavior requires a thorough knowledge of traffic stream parameters and their mutual relationships. In this chapter the basic concepts of traffic flow is presented.

2.4.1 Traffic stream parameters

The traffic stream includes a combination of driver and vehicle behavior. The driver or human behavior being non-uniform, traffic stream is also non-uniform in nature. It is influenced not only by the individual characteristics of both vehicle and human but also by the way a group of such units interacts with each other. Thus a flow of traffic through a street of defined characteristics will vary both by location and time corresponding to the changes in the human behavior. The traffic engineer, but for the purpose of planning and design, assumes that these changes are within certain ranges which can be predicted. For example, if the maximum permissible speed of a highway is 60 kmph, the whole traffic stream can be assumed to move on an average speed of 40 kmph rather than 100 or 20 kmph.

Thus, the traffic stream itself is having some parameters on which the characteristics can be predicted. The parameters can be mainly classified as : measurements of quantity, which includes density and flow of traffic and measurements of quality which includes speed. The traffic stream parameters can be macroscopic which characterizes the traffic as a whole or microscopic which study the behavior of individual vehicle in the stream.

As far as the macroscopic characteristics are concerned, they can be grouped as measurement of quantity or quality as described above, i.e. flow, density, and speed. While the microscopic characteristics include the measures of separation, i.e. the headway or separation between vehicles which can be either time or space headway. The fundamental stream characteristics are speed, flow, and density and are discussed below.

2.4.2 Speed

Speed is considered as a quality measurement of travel as the drivers and passengers will be concerned more about the speed of the journey than the design aspects of the traffic. It is defined as the rate of motion in distance per unit of time. Mathematically speed or velocity v is given by, $v = d/t$

where, v is the speed of the vehicle in m/s, d is distance traveled in m in time t seconds. Speed of different vehicles will vary with respect to time and space. To represent these variations, several types of speed can be defined. Important among them are spot speed, running speed, journey speed, time mean speed and space mean speed. These are discussed below.

2.4.2.1 Spot speed

Spot speed is the instantaneous speed of a vehicle at a specified location. Spot speed can be used to design the geometry of road like horizontal and vertical curves, super elevation etc. Location and size of signs, design of signals, safe speed, and speed zone determination, require the spot speed data. Accident analysis, road maintenance, and congestion are the modern fields of traffic engineer, which uses spot speed data as the basic input. Spot speed can be measured using an endoscope, pressure contact tubes or direct timing procedure or radar speedometer or by time-lapse photographic methods. It can be determined by speeds extracted from video images by recording the distance travelling by all vehicles between a particular pair of frames.

2.4.2.2 Running speed

Running speed is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion. i.e. this speed doesn’t consider the time during which the vehicle is brought to a stop, or has to wait till it has a clear road ahead. The running speed will always be more than or equal to the journey speed, as delays are not considered in calculating the running speed.

2.4.2.3 Journey speed

Journey speed is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time. If the journey speed is less than running speed, it indicates that the journey follows a stop-go condition with enforced acceleration and deceleration. The spot speed here may vary from zero to some maximum in excess of the running speed. A uniformity between journey and running speeds denotes comfortable travel conditions.

2.3.2.4 Time mean speed and space mean speed

Time mean speed is defined as the average speed of all the vehicles passing a point on a highway over some specified time period. Space mean speed is defined as the average speed of all the vehicles occupying a given section of a highway over some specified time period. Both mean speeds will always be different from each other except in the unlikely event that all vehicles are traveling at the same speed. Time mean speed is a point measurement while space mean speed is a measure relating to length of highway or lane, i.e. the mean speed of vehicles over a period of time at a point in space is time mean speed and the mean speed over a space at a given instant is the space mean speed.

2.4.3 Flow

There are practically two ways of counting the number of vehicles on a road. One is flow or volume, which is defined as the number of vehicles that pass a point on a highway or a given lane or direction of a highway during a specific time interval.

2.4.4 Variations of volume

The variation of volume with time, i.e. month to month, day to day, hour to hour and within an hour is also as important as volume calculation. Volume variations can also be observed from season to season. Volume will be above average in a pleasant motoring month of summer, but will be more pronounced in rural than in urban area. But this is the most consistent of all the variations and affects the traffic stream characteristics the least.

Weekdays, Saturdays and Sundays will also face difference in pattern. But comparing day with day, patterns for routes of a similar nature often show a marked similarity, which is useful in enabling predictions to be made.

The most significant variation is from hour to hour. The peak hour observed during morning and evening of weekdays, which is usually 8 to 10 per cent of total daily flow or 2 to 3 times the average hourly volume. These trips are mainly the work trips, which are relatively stable with time and more or less constant from day to day.

2.4.5 Types of volume measurements

Since there is considerable variation in the volume of traffic, several types of measurements of volume are commonly adopted which will average these variations into a single volume count to be used in many design purposes.

1. Average Annual Daily Traffic (AADT): The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.

2. Average Annual Weekday Traffic (AAWT) : The average 24-hour traffic volume occurring on weekdays over a full year. It is computed by dividing the total weekday traffic volume for the year by 260.

3. Average Daily Traffic (ADT): An average 24-hour traffic volume at a given location for some period of time less than a year. It may be measured for six months, a season, a month, a week, or as little as two days. An ADT is a valid number only for the period over which it was measured.

4. Average Weekday Traffic (AWT): An average 24-hour traffic volume occurring on weekdays for some period of time less than one year, such as for a month or a season.

The relationship between AAWT and AWT is analogous to that between AADT and ADT. Volume in general is measured using different ways like manual counting, detector/sensor counting, moving-car observer method, etc. Mainly the volume study establishes the importance of a particular route with respect to the other routes, the distribution of traffic on road, and the fluctuations in flow. All which eventually determines the design of a highway and the related facilities. Thus, volume is treated as the most important of all the parameters of traffic stream.

2.4.6 Density

Density is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km. One can photograph a length of road x, count the number of vehicles, nx, in one lane of the road at that point of time and derive the density k as,

$k = nx/x$

2.4.7 Derived characteristics

From the fundamental traffic flow characteristics like flow, density, and speed, a few other parameters of traffic flow can be derived. Significant among them are the time headway, space headway etc.

2.4.8 Travel time

Travel time is defined as the time taken to complete a journey. As the speed increases, travel time required to reach the destination also decreases and vice-versa. Thus, travel time is inverse distance headway and travel time. They are discussed one by one below.

2.4.8.1 Time headway

The microscopic character related to volume is the time headway or simply headway. Time headway is defined as the time difference between any two successive vehicles when they cross a given point. Practically, it involves the measurement of time between the passage of one rear bumper and the next past a given point.

2.4.8.2 Distance headway

Another related parameter is the distance headway. It is defined as the distance between corresponding points of two successive vehicles at any given time. It involves the measurement from a photograph, the distance from rear bumper of lead vehicle to rear bumper of following vehicle at a point of time.

2.5 Microscopic Traffic Simulation

The microscopic traffic simulation models are based on the reproduction of the traffic flows simulating the behavior of the individual vehicles, this not only enables them to capture the full dynamics of time dependent traffic phenomena, but also to deal with behavioral models accounting for drivers' reactions. The underlying hypothesis is that the dynamics of a stream of traffic is the result of a series of drivers' attempts to regulate their speed and acceleration accordingly with information received. The driver's actions resulting from the interpretation of the information received will consist on the control of the acceleration (braking and accelerating), the control of heading (steering) and the decision of overtaking the precedent vehicle either to increase the speed or to position themselves in the right lane to perform a maneuver (i.e. a turning).

The origins of microscopic traffic simulation can be traced back to the early stages of digital computers. Although the basic principles were set up many years ago, with the seminal work of, among others, Robert Hermann and the General Motors Group in the early fifties, the computing requirements made them impractical until hardware and software developments made them affordable even on today's laptop computers.

Most of the currently existing microscopic traffic simulators are based on the family of car- following, lane changing and gap acceptance models to model the vehicle's behavior. Car following models are a form of stimulus-response model, where the response is the reaction of the driver (follower) to the motion of the vehicle immediately preceding him (the leader) in the traffic stream. The response of the follower is to accelerate or decelerate in proportion to the magnitude of the stimulus at time t after a reaction time T. The generic form of the conceptual model is:
response (t +T) = sensitivity * stimulus (t)

Among the most used models are:

- Helly' s model implemented in SITRA-B+,
- Herman's model or its improved version by Wicks implemented in MITSIM,
- The psycho-physical model of Wiedemann used in VISSIM,
- The ad- hoc version of Gipps used in AIMSUN2,
- Other microscopic simulators such as INTEGRATION, and
- PARAMICS.

When used as a microscopic simulator, Trans Modeler simulates the behavior of each vehicle every one-tenth of a second. Vehicles can vary in terms of their physical and performance characteristics, and can be custom defined by users. Acceleration, deceleration, car-following, lane-changing, merging/yielding, and movements at intersections are simulated in detail and are affected by driver aggressiveness, vehicle characteristics, and road geometry. While default settings are provided for important behavioral models.

2.5.1 Requirements for calibration

The recent emphasis on utilizing advanced technologies to make more efficient use of existing transportation infrastructure, coupled with the continuing advances in desktop computing technologies, has created an environment in which traffic simulation models have the potential to provide a cost-effective, objective, and flexible approach for assessing design and management alternatives. However, the models must be demonstrated to be valid, and they must be adequately calibrated for local conditions (Hellinga, op. cit).

The proposed calibration in this paper consists of three main phases and eight component steps. These steps are as follows:

Phase 1: It comprises those tasks and activities that are conducted prior to the commencement of any modelling.

Phase 2: This phase consists of the initial calibration of model parameter values on the basis of available field data. Typically, these parameters required calibration include network coding, including the specification of the location of zones and nodes; link characteristics such as macroscopic speed-flow-density relationships; driver behavior characteristics such as routing strategies and gap acceptance requirements; and origin-destination traffic demands.

Phase 3: The results from the model are compared to field conditions and tested against the previously established criteria. If these criteria are met, then the model is considered to be adequately calibrated and the model can be used for evaluating non-base case scenarios.

2.5.2 Microscopic simulation model calibration and validation

Microscopic traffic simulation models are widely used in the transportation engineering field. Because of their cost-effectiveness, risk-free nature, and high-speed benefits, areas of use include transportation system design, traffic operations, and management alternatives evaluation. Despite their popularity and value, the credibility of simulation models falls short due to the use of default parameters without careful consideration. Improper model parameters prevent simulation models from accurately mimicking field conditions. (B Park, J Won, MA Perfecter) A procedure was proposed for microscopic simulation model calibration and validation, in this paper, prepared by Park and Schneeberger (Park op. cit).

2.5.2.1 Identification of calibration parameters

Before calibration identification of the calibration parameters are necessary. In this section, the parameters that are needed to be adjusted are put focus on. These parameters are needed to be tuned to create a well calibrated model so that the simulation can give a reliable output which will be close to the real world. These parameters are

- The emergency stopping distance,
- Lane-change distance,
- Desired speed,
- Number of observed preceding vehicles,
- Average standstill distance, additive part of desired safety distance,
- Waiting time before diffusion, and
- Minimum headway.

2.5.2.2 Development of calibration of microsimulation model

The software's used for micro simulation modelling are generally designed for lane based homogeneous traffic system. But not all the cases in the real world consist of homogeneous traffic stream. A uniform flow of stream makes many calculations much simpler because vehicles' size, speed, and following distances can be held constant. This allows for changes in other variables without the worry of confounding. Heterogeneous traffic mixes do not provide this luxury, with a variety of vehicles interacting within the traffic stream (Katz,2009). As there are many complexities in mixed traffic, it is very much difficult to collect and analyze real world data.

Also, procedures to calibrate simulation models are not well defined. Even though it is a challenge to understand driver behavior in heterogeneous traffic and calibrate the micro simulators accordingly, a few works are done on this field of calibrating a model to create heterogeneous traffic system so that it can be closely simulate the real time condition of the field.

The heterogeneous traffic is characterized by a mix of vehicles having diverse static (length, width, etc.) and dynamic (acceleration/deceleration, speed, etc.) properties. These vehicles include non-conventional motorized as well as non-motorized vehicles, and their composition is highly transient. Another distinguishing aspect of such traffic is the absence of lane marking and lane discipline resulting in complex movement of vehicles especially at intersections. Often, the lane widths are not uniform (Manjunaha et al.,2013). Characteristics and modelling issues of such traffic are well documented in the literature (Arasan Koshy, 2005).

A number of papers had been published on calibration of micro simulators that are restricted to homogeneous traffic system. Earlier than often researcher used default parameters for developing model. This tends to give erroneous outputs. Taking this in to account, Hellinga (Hellinga, 1998), Cohen (Cohen, 2004), Dowling et al., (Dowling, Skabardonis & Alexiadis, 2004), Zhang et al., (Zhang & Owen, 2004) and others suggested general methodologies and techniques for calibration. Along with a set of guidelines Milam et al., (Milam & Choa, 2000) implemented the calibration methodology in CORSIM. Toledo et al. (Toledo et. al, 2003) used O-D flow data to calibrate MITSIM Lab. (Manjunatha op. cit).

Among the studies on calibration of VISSIM, in particular, a discussion of the car following and driver behavior logic that is incorporated in the VISSIM is well presented in Fellendorfand Vortisch (Fellendorf & Vortisch, 2001) with a detailed analysis of the Wiedemann driver behavior model implemented in the VISSIM. Later Park and Schneeberger (Park & Schneeberger, 2003) used Latin Hypercube sampling along with a linear regression model to generate scenarios and solve to match the travel times in field and simulation.

Parameter optimization is one of the important calibration techniques, and various algorithms have been applied for solving this problem by obtaining the optimal values for the parameter sets used in calibration. (Manjunatha op. cit). A sensitivity analysis is to be conducted to select parameters and their ranges. An optimization formulation should be introduced to find a solution parameter set so as to minimize the intersection delay. Most of the earlier calibration studies use a single measure of performance for the sake of simplicity. Recently, multi criteria approaches were adopted by Duong et al., (Duong, Saccomanno & Hellinga, 2010) in VISSIM and Park and Kwak (Park & Kwak, 2011) in TRANSIMS respectively. Traffic representation is considered important and hence a visual check is generally suggested after the calibration process. The present study focuses on dynamic work done on calibrating the micro simulation model in VISSIM.

2.5.2.3 Validation of simulation model

The use of microscopic simulation models to assess the likely effects of new traffic management applications and changes in vehicle technology is becoming increasingly popular. However the validity of the models is a topic of increasing concern, as the quality of the presentation often exceeds the models ability to predict what is likely to happen.

Traditionally, model validity has been ascertained through comparing outputs aggregated at a macroscopic level such as speed flow and lane use, against real data. Little microscopic comparison is generally possible and, where this is done there is often no separation of the calibration and validation process. However, microscopic validation may be undertaken when suitable data is available. For this case , time series data collected by an instrumented vehicle, and its use in the validation of the car following performance of a fuzzy logic based car following model. Good agreement has been attained between the simulated model and observed data, primarily using a root mean square error indicator. (J. Wu, M. Brackstone, M. McDonald, 2003).

2.5.3 Microsimulation over static model

The deployment of Intelligent Traffic Systems (ITS) requires support of complementary studies clearly showing the feasibility of the systems and what benefits should be expected from their operation. The large investments required have to be justified in a robust way.

That means feasibility studies that validate the proposed systems, assess their expected impacts and provide the basis for sound cost benefit analyses. Microscopic traffic simulation has proven to be a useful tool to achieve these objectives. This is not only due to its ability to capture the full dynamics of time dependent traffic phenomena, but also being capable of dealing with behavioral models accounting for drivers' reactions when exposed to ITS systems.

The advent of ITS has created new objectives and requirements for micro-simulation models. Quoting from Deliverable D3 of the European Commission Project SMARTEST "The objective of micro-simulation models is essentially, from the model designers' point of view, to quantify the benefits of Intelligent Transportation Systems (ITS), primarily Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS). Micro-simulation is used for evaluation prior to or in parallel with on-street operation. This covers many objectives such as the study of dynamic traffic control, incident management schemes, real-time route guidance strategies, adaptive intersection signal controls, ramp and mainline metering, etc. Further-more some models try to assess the impact and sensitivity of alternative design parameters". The analysis of traffic systems and namely ITS systems, is beyond the capabilities of traditional static transport planning models. Microscopic simulation is then the suitable analysis tool to achieve the required objectives. (U. Klein ; T. Schulze ; S. Strassburger, 1998).

2.6 Microsimulation Model VISSIM

VISSIM is a microscopic, time step and behavior-based simulation model developed to model urban traffic and public transport operations and flows of pedestrians. VISSIM is software that can simulate traffic for multi-modal microscopic, public transport and pedestrians, developed by PTV (planning transport verkehr) AG in Karlsruhe, germane. VISSIM is the most advanced tools available to stimulate traffic flows multi-modes, including auto, transportation of goods, buses, heavy rail, tram, LRT, motorcycles, rickshaws, bicycles, pedestrians. Simulation of multi-modal describes the ability to stimulate more than one type of traffic. All of these can interact with each other. In VISSIM the type of traffic that can be stimulated including vehicles (cars, buses, trucks) public transport (auto-rickshaws, buses) cycles (bicycles, motorcycles) pedestrians and rickshaws. Users of this software can simulate all types of geometric configurations or road user behavior that occurs in the transportation system.

VISSIM is used in many simulations needs of traffic and public transport, such as the scheme of slowing traffic, the study of the light Rail/Bus rapid transit, estimates of use of intelligent transport system as appropriate, signalized intersections and signalized complex and so on. VISSIM is based on intensive research over the years, and since its introduction in 1992 has been used by many people around the world and proved to be the most superior software for microscopic traffic simulation. Microscopic simulation. Microscopic simulation meaning each unit (cars, trains, people) to be simulated, simulated individually.

VISSIM has been used to analyze networks of all kinds of sizes within individual intersections up to the entire metropolitan area. In the following transportation networks. Additionally, VISSIM can also simulate the geometric and the unique operating conditions contained in the transportation system. The data analyzed do want to put on as the user desires. The calculations of effectiveness can very enter on VISSIM software; generally, include delay, speed, queues, travel time and stops.

The program can analyze private and public transport operations under constraints such as lane configuration, vehicle composition, traffic signals, PT stops, etc., thus making it a useful tool for the evaluation of various alternatives based on transportation engineering and planning measures of effectiveness. Accordingly, also pedestrian flows can be modelled, either exclusively or combined with private traffic and/or public transport. VISSIM can be applied as a useful tool in a variety of transportation problem settings.

The following list provides a selective overview of previous applications of VISSIM:

- Development, evaluation and fine-tuning of signal priority logic: VISSIM can use various types of signal control logic. In addition to the built-in fixed-time functionality there are several vehicle-actuated signal controls identical to signal control software packages installed in the field. In VISSIM some of them are built-in, some can be docked using add-ons and others can be simulated through the external signal state generator (VAP) that allows the design of user-defined signal control logic. Thus, virtually every signal control (incl. SCATS, SCOOT) can be modeled and simulated within VISSIM if either the controller details are available or there is a direct VISSIM interface available (e.g. VS-PLUS).
- Evaluation and optimization (interface to Signal 97) of traffic operations in a combined network of coordinated and actuated traffic signals.
- Feasibility and traffic impact studies of integrating light rail into urban street networks.
- Analysis of slow speed weaving and merging areas.
- Easy comparison of design alternatives including signalized and stop sign controlled intersections, roundabouts and grade separated interchanges.
- Capacity and operations analyses of complex station layouts for light rail and bus systems have been analyzed with VISSIM.

- Preferential treatment solutions for buses (e.g. queue jumps, curb extensions, bus-only lanes) have been evaluated with VISSIM.
- With its built-in Dynamic Assignment model, VISSIM can answer route choice dependent questions such as the impacts of variable message signs or the potential for traffic diversion into neighborhoods for networks up to the size of medium sized cities.
- Modeling and simulating flows of pedestrians in streets and buildings -allow for a wide range of new applications. VISSIM can also simulate and visualize the interactions between road traffic and pedestrians.

2.6.1 VISSIM features

VISSIM can model all modes

- Almost all types of Vehicles,
- Tram/Train/PT Lines,
- Pedestrians, and
- Interaction between different modes.

Detail Analysis of vehicle network performance

- Service Time & Delay Analysis,
- Queue Lengths,
- Travel Times,
- Level of Service,
- Retrieval Time, and
- Number of Toll booths required.

2.6.2 Reasons for using VISSIM micro-simulator

- Better representation of real-life traffic
- Better representation of real-life traffic
- Visual representation of performance in 3D
- Flexible geometry
- Better communication to Stakeholders
- Ability to examine efficiency of control systems
- Upstream /downstream queuing
- Testing of ITS strategies
- Variable message signs
- Ramp metering Ramp metering
- Transit Signal Priority
- Signal preemption
- Signal control testing
- Corridor alternatives analysis
- Ability to analyze control techniques that have not been implemented / studied in detail elsewhere.

2.6.3 Typical applications of VISSIM

VISSIM can be applied to model a variety of operations including the following:

- Model the development, evaluation, and fine-tuning of transit signal priority logic,
- Model various types of signal control logic,

- Model, evaluate or optimize traffic operations in a combined network of coordinated and actuated traffic signals,
- Model and evaluate the feasibility and impact of integrating light rail into urban street networks,
- Model weaving and merging areas,
- Model design alternatives including signalized and stop sign controlled intersections, roundabouts, and grade separated interchanges,
- Model capacity and operations analyses of complex station layouts for light rail and bus systems,
- Model preferential treatment solutions for buses (e.g. queue jumps, curb extensions, bus-only lanes),
- Model ramp metering,
- Model traffic calming measures, pedestrian and cyclists,
- Model and evaluate lane restrictions (HOV lane, trucks),
- Comparison of junctions with regard of design alternatives (roundabouts, un- signalized and signal controlled; grade separated interchanges),
- Design, test and evaluation of vehicle-actuated signal control operations, and
- Capacity analysis and testing of transit priority schemes.

Feasibility analysis of large networks (e.g., motorways) with alternative route choice using dynamic assignment

- Impact analysis of Intelligent Transport Systems (ITS), e.g., variable message sign systems, ramp metering, incident diversion, special lanes, route guidance systems.

- Wide range of highly specialized traffic engineering tasks, such as capacity analysis of railroad block section operation and of toll plaza or border control facilities.
- Besides the modeling of larger networks also more local studies can be performed, e.g. a comparison of two signal control methods for a complex junction. For studies of this kind, the model of traffic demand is not used. Instead, the user provides an origin-destination-matrix for the modeled network to the traffic flow model.
- Due to the microscopic modeling of traffic flow the impacts of traffic control measures can be analyzed on a very detailed level.

2.6.4 Review of some study using VISSIM

Model	Methodology	Factors affecting decision making	Study
Lane changing model	Capturing mandatory (MLC) and discretionary (DLC) situations ; introduction of CORSIM	Vehicle type (heavy vehicle or not), speed (potential speed), headway, traffic density, nearside or offside, presence of heavy vehicles regulations, distance (or time) to the intended turn, space/scope	Roberch (1999); Ahmed et al (1996); Yang and Koutsopoulos (1996); Hidas and Behbahanizadeh (1998); Ahmed (1999); Choudhury (2005); Choudhury (2008)

Gap acceptance model	Assumption of exponential distribution of critical gaps, introduction of impatience functions, comparing the gaps with critical gaps	Lead gap, lag gap, relative speed, presence of heavy vehicles	Hernan and Weiss (1961); Drew et al (1967) Miller (1972); Mahmassani and Sheffi (1981); Toledo (2003); Choudhury (2008)
Car following model (GM model, collision avoidance model and psychophysical model)	Introduction of sensitivity-stimulus framework, fabrication of perception threshold	Relative velocity, regulations, driver psychology (e.g. tailgating behavior), headway (time or speed), reaction time of the following vehicle	Reuschel (1950); Pipes (1953); Chandler et al. (1958); Gazis et al. (1959); Kometani and Sasaki (1959); Gazis et al. (1961); Michaels (1963); Weidmann(1974); Gipps (1981); Leutzbach(1988); Brackstone and McDonald (1999); Toledo (2003); Lee (2007);
General acceleration model	Considering speed and headway to be the prime determinant in case of applying maximum acceleration	Driving regimes based on time headway and space headway (e.g.emergency, car following, free flow)	Pipe (1953); Gazis et al. (1959); Gipps (1981); Benekohal and Treiterar (1988); Yang and Koutsopoulos (1996); Ludmann et al. (1997); Zhang et al. (1998)

Even though there are many micro simulation tools, several studies had been done on choosing and identifying the correct tools for using to solve and simulate particular traffic scenario. One of such study was done by Frad Chao et. al. (F. Chao et. al,2004) focusing on the comparisons of three major traffic simulation software CORSIM, PARAMICS and VISSIM.

In addition to that a number of researches had also been conducted using the micro simulation tools VISSIM. Most of the studies are on simulating and foreseen the traffic characteristics that will occur upon the construction of a traffic development plan both in road management and control system and on the sensitivity analysis of the parameters used in that particular software. Computer simulation proves to be a very powerful tool for analyzing complex dynamical problems such as traffic congestions. (G. Papageorgiou et al,2008).

Besides studying on the effect of traffic congestion, also the effect of proposed alternative, Bus Rapid Transit, to alleviate traffic congestion was also foreseen using VISSIM simulator is discussed in this paper. As a general-purpose computer-based traffic simulation system VISSIM models links, junctions and “small” networks at a high level of detail (M. Fellendorf,1994). However, this paper concentrates on the abilities of VISSIM as a simulation tool for evaluating actuated signal control including bus priority. But all the research discussed earlier in this section are done on countries where lane based heterogeneous traffic operation system exists, which is not in the case in other countries like Bangladesh. So, calibration of parameters and validation is must.

VISSIM utilizes psychophysical car-following models that rely on ten user-defined parameters to represent freeway driving behavior. Several VISSIM driver behavior parameters have been shown to have a significant impact on roadway capacity (N. E. Lownes and R. B. Machemehl, 2006). This paper is intended to provide insight useful for manual calibration of VISSIM micro simulation or the development of calibration algorithms.

2.7 Adaptation of VISSIM

Al-Ahmadi (1985) performed a study on Khobar downtown area, Saudi Arabia in his thesis dissertation entitled “evaluating policy changes using a network simulation model”. In his study he compared several available network simulation models such as SIGOP III, TRANSYT, and NETSIM and came out with a conclusion that NETSIM is a potential simulation model that can effectively be used to evaluate traffic policy changes for road networks in downtown areas.

Ratrout (1989) in his Ph.D. dissertation “Assessment of the applicability of “TRANSY-7F” optimization model to the traffic conditions in the cities of Al-Khobar and Dammam, Saudi Arabia” reviewed all available network optimization models to select the best model for optimizing traffic in Saudi Arabia. The models that were reviewed by him are TRANSYT, SSTOP, SIGOP III, SIGRID, COMBINATION, PRIFRE, PASSER II, SOAP, PASSER III, SUB, and NETSIM. It was concluded that TRANSYT-7F model is the most appropriate model in this regard based on its ability to handle many special traffic conditions, such as more than four phases in a cycle and sign controlled intersections. This ability makes the model applicable to almost every network configuration in Saudi Arabia.

Al-Ofi (1994) conducted a study on urban intersections in Dammam and Khobar cities to investigate the effect of signal coordination on intersection safety. In his study he considered TRANSYT, SIGOP, PASSER, and MAXBAND models and found TRANSYT model as the suitable model for this study based on its attractive features over other models and it was already subjected to calibration and validation studies in several countries including Saudi Arabia (Ratrout, 1989). It was concluded that the signal coordination reduces intersection accidents and he suggested a methodology to incorporate safety into an inbuilt optimization algorithm of TRANSYT-7F model.

A traffic micro-simulation model consists of sub-models that describe human driver behavior. Important behavior models include; gap-acceptance, speed adaptation, lane-changing, ramp merging, overtakes, and car-following (Olstam and Tapani, 2004). The gap-acceptance model determines minimum acceptable distance to surrounding vehicles in the context of intersections and merging situations. Speed adaptation refers to the adaptation to the road design speed at a vehicle’s current position in the network. Lane- changing models describe drivers’ behavior when deciding whether to change lane or not on a multi-lane road link, e.g. when traveling on a motorway. Analogously, on two-lane rural roads the overtake model controls drivers’ overtaking behavior. Finally, there is the car-following model, which describes the interactions with preceding vehicles in the same lane. Most previous research on driving behavior modeling has been focused on car- following. Numerous papers have been written on this topic. However, very few qualitative comparisons and descriptions of car-following models have been made.

Previous comparisons of micro-simulation programs have been conducted by ITS University of Leeds (2000), Brockfeld et al. (2003) and Bloomberg et al. (2003**)** used different traffic simulation programs to model and simulate a test region. The outcome of their comparison was an evaluation of the simulation programs ability to fit real traffic data from the test area. They found that none of the tested models produced better or worse results than the other. Moreover, all models generated results consistent with the methodologies used in the Highway Capacity Manual (Transportation Research Board, 1997). Brockfeld et al. (2003) used nonlinear optimization in order to calibrate parameters of different simulation models to traffic data from a test region. They found that the average error between simulated and real data was about 16 %. The cause behind the difference between models and measured traffic data has however not yet been fully investigated.

During 1997 and 1998, Parsons Transportation Group (PTG) conducted a study for the Long Island Rail Railroad in New York City which included a detailed evaluation of VISSIM, CORSIM, WATSIM, and TRANSIM. As a result, VISSIM was selected for that project based on its overall ability to model transit, automobile traffic, complex traffic and transit geometries, and complex user defined traffic control strategies such as preemption and priority (Brian et al. 2000). The VISSIM model has been validated for various real-world situations and is increasingly being used by transportation professionals (Fellendorf & Vortisch, 2001).

Brian et al (2000) described the procedure and results of a comparison of the VISSIM simulation model to the more well-known CORSIM and TRANSYT-7F models. These comparisons were made while modeling the existing traffic conditions for the roadway network surrounding the transitway mall in downtown Dallas. Based on the results of the existing conditions analysis and calibration procedure, it is concluded that both CORSIM and VISSIM were able to adequately model the existing conditions for automobile traffic within the Dallas CBD. Furthermore, the analysis and calibration procedure indicated that VISSIM could adequately model LRT operations within the transitway mall. As a result, the overall study concluded that VISSIM should be used to determine the effects of the future light rail expansion within the transitway mall.

Under ideal conditions (Fred et al 2002**),** the calibration of individual components of a simulation model will improve the simulation model's ability to replicate traffic flow results that match field conditions within an acceptable range of error. Typical traffic flow characteristics that can be used in validation include traffic volumes, average travel time, average travel speed, queue lengths, and density. Unfortunately, professional guidelines that define the acceptable range of error for these characteristics have not been developed. Instead, transportation professionals have either ignored the need for validation or developed their own guidelines. Although these guidelines are a starting point for discussing guidelines for the transportation profession, they lack statistical justification to determine if they provide an acceptable range of error (Fred et al 2002).

Table 2.1 shows the parameters, description and criteria required for validation of VISSIM software. For validation volume, average travel time, average travel speed, freeway density, maximum and average queue length are important or need to be considered. Observed values and standard deviation are validation criterion for validation. Variation of observed values ranges from 80% to 110% depending on different parameters.

Table 2.1: Validation Guidelines

Validation Guidelines		
Parameters	**Description**	**Validation Criteria**
Volume Served	Percent difference between input volume and the simulation model output or assigned volume	95 to 105 % of observed value
Average Travel Time	Standard Deviation between floating car average travel times and simulated average travel time for a series of links	1 Standard Deviation
Average Travel Speed	Standard Deviation between floating car average travel speed and simulated average travel speed for individual links	1 Standard Deviation
Freeway Density	Percent difference between observed freeway density (from volume counts and floating car travel speed) and simulated density	90 to 110 % of observed value

Average and Maximum Vehicle Queue Length	Percent difference between observed queue lengths and simulated queue lengths	80 to 120 % of observed value

Fred et al (2002) conducted a comparison of the three major traffic simulation models (CORSIM, PARAMICS, and VISSIM) in use today for a specific project involving a typical freeway interchange study and concluded that the PARAMICS and VISSIM generated simulation results that better matched field observed conditions, traffic engineering principles, and expectation/perception of reviewing agencies including California Department of Transportation (Caltrans) (Fred et al 2002).

Gomes et al (2004) presented a procedure for constructing and calibrating a detailed model of a freeway using VISSIM and applied it to a 15-mile stretch of I-210 West in Pasadena, California. This test site provides several challenges for microscopic modeling: an HOV lane with an intermittent barrier, a heavy freeway connector, 20 metered onramps with and without HOV bypass lanes, and three interacting bottlenecks. All of these features were included in the VISSIM model. Field data used as input to the model was compiled from two separate sources: loop-detectors on the onramps and mainline (PeMS), and a manual survey of onramps and off ramps. Gaps in both sources made it necessary to use a composite data set, constructed from several typical days. FREQ was used as an intermediate tool to generate a set of OD matrices from the assembled boundary flows. The model construction procedure consists of: 1) identification of important geometric features, 2) collection and processing of traffic data, 3) analysis of the mainline data to identify recurring bottlenecks, 4) VISSIM coding, and 5) calibration based on observations from 3). A qualitative set of goals was established for the calibration. These were met with relatively few modifications to VISSIM's driver behavior parameters (CC-parameters).

Analysis of the supply and demand characteristics of the freeway lead to the conclusion that two of these bottlenecks were geometry-induced, while another was caused by weaving. A successful calibration of the VISSIM model was carried out based on this observation. As a conclusion (Gomes et al 2004), this study has shown that the VISSIM simulation environment is well-suited for such freeway studies involving complex interactions. With few and well-reasoned modifications to its driver behavior parameters, the simulation model is capable of reproducing the field-measured response on the onramps, HOV lanes, and mixed-flow lanes.

Cate and Urbanik (2004), offers another view of truck lane restriction on high- speed, limited access facilities. As highway volumes increase (especially those of large trucks), states across the country have sought new ways to increase driver comfort, operating efficiency, and traffic safety. More agencies are turning to the "managed lanes" concept rather than utilizing physical expansion of roadways. The managed lanes concept involves the assignment of special operating conditions to specific lanes of a roadway in order to improve the efficiency and/or safety of the roadway as a whole. This strategy typically involves restricting the use of one or more lanes on the basis of vehicle type or occupancy and may or may not vary by time of day. One such managed-lane concept utilized by many local and state agencies is truck lane-use restrictions.

While drivers of smaller vehicles are typically pleased with these lane restrictions, the previous research efforts in this area have revealed mixed results in the areas of safety and efficiency. They presented the results of an evaluation of truck lane restrictions using the VISSIM microscopic traffic simulation software package as an analysis tool. The objective of this application is to study truck lane restrictions at a very detailed level not previously available in general-purpose traffic simulation models. The suitability of VISSIM as a means of testing lane restrictions is confirmed and the necessary model adjustments are completed to determine the operational impacts of lane restrictions.

Eddie et al (2001) says selecting VISSIM, microscopic traffic simulation software, to model the bus deck and ramp operations at the Transbay Terminal was perhaps the most important decision made during the comprehensive analysis of the Terminal. The Transbay Terminal is an elevated terminal located in San Francisco, California, and has served as San Francisco's hub of bus transit services for over 50 years. They concluded this statement based on the following analysis.

Accurate modeling of bus operations and visual/graphical presentation of the bus operations were the primary features being evaluated during the selection process of the most appropriate traffic simulation software (Eddie et al 2001). Four microscopic traffic simulation software packages were considered: CORSIM, VISSIM, Paramics, and SIMTRAFFIC. SIMTRAFFIC was discarded early in their evaluation and was not considered further because it does not model bus routes. Proper modeling of bus staging operations requires the capability to code buses that pull out to the left instead of the right. Although CORSIM, VISSIM, and Paramics all model bus routes, only VISSIM models bus staging/stopping on the left-hand side of the road.

Proper modeling of bus interaction (i.e. yielding, stopping, queuing, etc.) within the Terminal was necessary to determine bus blockages and scheduling conflicts. CORSIM models bus interaction fairly well through a series of algorithms built into the software. However, VISSIM and Paramics permit the user to designate the right-of-way for conflicting movements through the use of “priority rules.” Through “priority rules,” the user can define the yielding and stopping locations on any link to accurately model the interaction between vehicles (Eddie et al 2001). These users defined “priority rules” make the bus interactions within the Terminal more realistic and accurate. Although the arrival of the buses to the bus stops for passenger pick-up is random the departures are based on a set schedule. All buses are set to leave the Terminal at a specific time (5:00 PM, 5:15 PM, etc.) to maintain their schedule regardless of when they arrived at the Terminal.

Therefore, it was necessary to model specific departure times and not a random dwell time at the bus stop. Random dwell times at bus stops are entered for both CORSIM and Paramics. Only VISSIM permits the user to enter a specific departure time regardless of when the bus arrived at the bus stop.

Graphically, CORSIM and Paramics were not able to duplicate the smooth curves and transitions provided in the Transbay Terminal designs. CORSIM and Paramics allow some customization of curb lines; however, they primarily rely on straight lines. Proper modeling of the offsite staging/storage facility to determine bus staging/storage constraints in the facility cannot be adequately performed in CORSIM because of its limitations on link lengths and node spacing (Eddie et al 2001). Paramics has no limitation on node spacing; however, it will give a warning for closely spaced nodes and very short links (<25 feet) will improperly simulate vehicles along links and through nodes due to the nature of the geometry and way in which

Paramics simulates. Table 2.2 summarizes the simulation software comparison as it relates to bus operations and graphics.

Table 2.2: Simulation Software Comparison

Simulation Tool	Models Bus Routes	Left-Side Bus Stops	Accurate Bus Interaction	Bus Schedule Flexibility	Models Short Links(< 50 feet)	Import Aerials and Autocad	3D Simulation
CORSIM	YES	NO	LIMITED	LIMITED	NO	NO	NO
VISSIM	YES	YES	YES	YES	YES	YES	YES
Paramics	YES	NO	YES	LIMITED	LIMITED	YES	LIMITED
SIMTRAFFIC	NO	NO	NO	NO	LIMITED	NO	NO

Based on the above criteria (Eddie et al 2001), it was determined that VISSIM was the most appropriate simulation software to use for the evaluation of the Transbay Terminal alternatives. VISSIM offered excellent modeling of complicated bus routes and superior graphics.

Arroyo and Torma (2000) discussed the case study in which VISSIM software package was used. A micro-simulation model of the Old Town Transit Station was created using the VISSIM program. This transit station is in the heart of Historic San Diego. It provides public access to Old Town, a major tourist attraction sitting at the foot of one of the first Spanish settlements in California. The Old Town Transit Station includes bus access, a light-rail station and the Coaster Line (a passenger and freight rail line that connects San Diego to Los Angeles with daily service). The model is able to develop a simulation of the effects of ramp metering on local streets and the complex effect of signal timing, pedestrian volumes, train preemption, and traffic congestion. This real-time simulation can present actual Coaster, San Diego Trolley and bus line arrival and departure times in conjunction with the actual signal controller logic used for the neighboring signals.

Arroyo and Torma (2000) also discussed the case study in which VISSIM software package was used. A micro-simulation model of a proposed traffic signal near the intersection of San Marcos Boulevard and Rancho Santa Fe Road was created using the VISSIM program. San Marcos is a small city in north San Diego County. Rancho Santa Fe Road is a major north-south running arterial that intersects with San Marcos Boulevard which connects the coastal communities with the inland cities. This is a particularly congested intersection that City staff wanted to model for in depth review. The traffic signal would allow access to the Lucky's directly from San Marcos Boulevard. The city is concerned that traffic, which now queues in the two eastbound-to-northbound left turn lanes and two eastbound through lanes, requires greater storage than would be available between the proposed intersection and Rancho Santa Fe Road. Using aerial photos, field data and timing plans obtained from the City of San Marcos Engineering department they were able to model conditions in the PM peak hour. Using the simulation, they were able to determine feasible alternatives including the widening of San Marcos Boulevard from two lanes to three from the proposed signal to Rancho Santa Fe Road in order to increase the storage capacity. The model shows that by coordinating the timing plans for the two signals they can coexist without causing gridlock or significant increases in delay while improving circulation for Lucky's grocery store.

VISSIM has the power and flexibility that it can offer analyzing even roundabouts. HDR recently used VISSIM to analyze traffic operations for two very different roundabout projects (Trueblood M. and Dale J., 2003). The first project included the analysis of six proposed two-lane roundabouts along Missouri Avenue in St. Robert, Missouri, while the other project included the analysis of a proposed "dumbbell" arrangement along Missouri Route 367 just outside the City of St. Louis, Missouri. VISSIM was used on both projects due to its excellent graphical capabilities and its ability to model roundabouts through user-defined parameters.

Rouphail and Chae (2002) conducted a study to explore the feasibility of modeling pedestrian behavior in the context of present and proposed intersection treatment designs and operations using available computer models. Their research explored the functionality of two currently available computer models (VISSIM and Paramics). An operational roundabout scenario for low vision/blind and sighted pedestrian was constructed using measures of latency time obtained in a field setting. The effects of pedestrian gap acceptance and traffic volume were analyzed in terms of their impact on pedestrian delay and vehicle delay. These results showed that VISSIM could handle the interaction between vehicles and pedestrians or between vehicles, and could provide helpful information for any alternative intersection design or crossing arrangement under the associated traffic operation.

VS-PLUS (Fellendorf, M., 1994) is a control strategy which is currently applied in Switzerland, Austria and Germany. VS-PLUS is taken as an example for VISSIM because of some of its remarkable features:

- Runs on controllers of different manufacturers because it is a separate capsulated C- program.
- Whole flow chart of the control strategy is entered by parameter values within tables.
- Once the engineer has learned the complete set of parameters he can easily design and more importantly adjust existing VS-PLUS plans.
- Vehicle activation is based on vehicle streams which are controlled by signal groups (phases) instead of preset stages.
- Group of parameters is reserved for detection and prisonization of public transport vehicles (i.e. several detection points along a link including continuous comparison of present and expected arrival times by time table; rules of priority for conflicting public transport lines).

Fellendorf, M. (1994) applied VISSIM to successfully evaluate VS-PLUS. A rather complex example is chosen to present a typical application of VISSIM. Examples of this kind can be seen in most cities of Middle Europe as the priorisation programs for the public transport have been one of the major tasks in traffic engineering since the late 80´s. A 2.5 km long arterial road with seven junctions had to be signalized with some contradictory restrictions. No bus or tram should wait at a traffic light unless they stopped at a stop light in front of a traffic light anyway. There are tram lines which cross each other. Overall arterial co-ordination for the car-traffic should be implemented. Each vehicle stream is controlled separately. Compatible movements are not assembled to preset stages since this might reduce the flexibility of the timings. The intergreen times differ considerably.

In spite of its recent market-introduction, VISSIM already has been applied for a variety of complex traffic tasks (Fellendorf, M. 1994). Some of the typical ones are:

- VISSIM calls vehicle actuated signal control strategies which are identical to the implementations in the controller. Besides testing with generated traffic flow one can test by manually initiating detectors. The triggering of the detectors is reported in macro files which can be used for running identical test situation with altered signal control parameters.
- VISSIM has been used with a variety of control systems (Fellendorf, M. 1994) like SDM, TRENDS/TRELAN, VS-PLUS and a general stage-based control strategy documented in the German guidelines.
- VISSIM has also been applied to fixed time-controlled networks when the assessment of queuing was a major problem. Time-space diagrams or macroscopic programs like TRANSYT have difficulties when the staging is rather complex and times of fully compatible and semi-compatible movements overlap.
- VISSIM models all kinds of different junction layout and control like signalized and non-signalized roundabouts and junctions.
- Because of the detailed modeling of public transport VISSIM was used to evaluate different stop layouts.
- VISSIM has been used to development, evaluation and fine-tuning of transit signal priority logic.
- VISSIM has been used to evaluate and optimize (interface to Signal97/TEAPAC) traffic operations in a combined network of coordinated and actuated traffic signals.

- VISSIM has been used to evaluate the feasibility and impact of integrating light rail into urban street networks.
- VISSIM has been applied to the analysis of slow speed weaving and merging areas.
- VISSIM allows for an easy comparison of design alternatives including signalized and stop sign controlled intersections, roundabouts and grade separated interchanges.
- Capacity and operations analyses of complex station layouts for light rail and bus systems have been analyzed with VISSIM.
- Preferential treatment solutions for buses (e.g. queue jumps, curb extensions, bus only lanes) have been evaluated with VISSIM.

2.8 Advantages of VISSIM Over Other Widely Used Models

- VISSIM is more capable of modeling the interaction of various modes of transit with automobile traffic. VISSIM can model light rail transit and can model more bus routes and bus stops than other models. In addition, VISSIM is capable of modeling gates at rail crossings as well as complex traffic control strategies such as preemption and priority systems.
- VISSIM network editing is done completely through the use of its Graphical User Interface which runs in various versions of Microsoft Windows. Due to the fact that the interface used to build a VISSIM model is also the same interface used to view the animation, you know exactly what your network structure is going to look like as you are building your model. In addition, VISSIM can also import scaled versions of background bitmap files which can be used to build the model upon.
- VISSIM uses links and connectors. These links and connectors are used to construct both streets and intersections. This permits VISSIM to be very flexible when working with complex geometries. VISSIM can easily

be used to accurately model curvature, variable location of stop lines, and correct turning paths.

- VISSIM's output is contained in several separate output files. VISSIM can produce very detailed results on any time interval defined by the user. This is common need in research applications or when developing new control algorithms.

- VISSIM provides animation capabilities with major enhancements in the 3-D simulation of vehicle types (i.e. from different passenger cars, trucks, transit vehicles, light rail and heavy rail). In addition, movie clips can be recorded within the program, with the ability to dynamically change views and perspectives. Other visual elements, such as trees, building, transit amenities and traffic signs, can be inserted into the 3-D animation.

- VISSIM provides a flexible platform with several user-definable features that allow the user to more realistically model the traffic operations of roundabouts. Unlike the modeling of four-way stop-controlled or signalized intersections, roundabouts are based more on the ability of drivers to accept or deny gaps.

- VISSIM has the ability to control gaps and headways on a lane-by-lane basis to more accurately simulate these types of operations present at roundabouts.

- Another benefit that VISSIM incorporates is that roadway networks consist of a link-connector structure instead of a link-node structure. This enables VISSIM to simulate short links without affecting the behavior of drivers as they proceed through small links. With VISSIM it is possible to model any kind of intersection (or sequence/network of intersections) with a precision down to one millimeter!

2.9 Disadvantages of VISSIM

- In-depth knowledge of traffic engineering techniques required.
- High learning curve due to depth of software features.
- High cost of software.
- VISSIM is complex and requires extensive knowledge of the program and its features.
- The models used within VISSIM must be created with care, for minor inconsistencies between the model and the facility's design can result in major errors in the analysis.
- Due to the number of variables within the VISSIM software, there are many opportunities for adjustment within the model.

2.10 Overview

Thus, chapter introduces basic aspects of the signalized intersection. Some definitions, types of intersections, intersection design criteria, parameters, traffic flow, speed, density, delay, volume, types and variations of volume, capacity analysis of signalized intersection in particular has been discussed in this chapter. Capacity analysis mainly includes the determination of saturation flow and delay. This chapter also focuses on Microsimulation techniques. Detail requirement of calibration and validation of models are discussed here. Later on, discussion has been done on microsimulation software VISSIM. Adaption of VISSIM, works based on VISSIM, comparison between different microsimulation software, advantages and disadvantages of using VISSIM has been discussed in this chapter also. It is therefore, revealed that there is need for a comprehensive study in this respect. Research methodology and data collection have been described in next chapter.

Chapter 3
METHODOLOGY

3.1 Introduction

This chapter includes the technique of data collection and the procedure applied for the execution of the study is described. In this chapter study area selection, the overall research methodologies that have been followed to achieve the objectives, times of data collection, data collection procedures, problems identified, analysis and outlines of the study are described.

The methodology of this research work is divided into five main steps:

- Literature review and acquaintance with VISSIM 5.3,
- Data collection from Field and model developed in VISSIM,
- Modeling, calibrating and validating the model,
- Analysis of collected data from VISSIM, and
- Report writing.

"In 1981, there were only 15 signalized intersections and another 15 were proposed in the Integrated Urban Development Plan. Prior to 1977, RAJUK was responsible for signal installation and control. In the early 1980s, control of signal was transferred to Traffic Police Division with RHD engineers assigned to help. This experiment lasted only a year before signals were reassigned to DCC. Traffic signals have increased over recent years with 12 signals being installed in just the last two years." (PPK consultants Ltd. others, 1994).

DCC is the sole authority for installing and implementing traffic signals within the Dhaka metropolitan area. DCC gets information about the warrant for a signal in a particular priority junction from Dhaka Metropolitan Police (DMP). DMP also determines the signal timings for different intersections. The method of signal timing determination has no scientific basis and involves no engineering practice. They do not conform to any guidelines of traffic signals and solely depends on intuitive judgment.

In the late 1990s, the traffic signal that were installed earlier without any engineering basis, not only started to become out of order very frequently but also deteriorated the congestion situation because of their non-optimum setting and inflexible timing plan. By the end of the decade, the situation became such that virtually all the signalized intersections became traffic police controlled. This led DCC to officially take countermeasures to newly install traffic signals at key intersections of Dhaka city along with supplementary improvements like channelization and provision of road marking.

It was BDT 240 million World Bank project in joint association with Dhaka Urban Transport Project (DUTP) to install traffic signals at 59 intersection of Dhaka city. It also involved geometric improvements like channelization, flaring, removal of unnecessary roundabouts etc. and other improvements like road marking, signing etc. The newly installed traffic signals were designed by hiring the consultants from Australia, who designed the traffic signals according to Australian standard. However, the road traffic situation of Dhaka city is quite different from that Australia. As a result, the timing plan designed by consultants was found to be inadequate. This has led the DCC to frequently change the timing plans on request from traffic police, which has increased the cycle time day by day with subsequent delays and spillback of queue to the upstream intersections.

There are about 98 intersections in DNCC and DSCC area of which 77 intersections are signalized and the remaining 21 ones are not signalized. Although there are 77 locations installed by signalization, non-operated traffic signalized intersections are seen around 26 locations. This is due to no maintenance made since installed. Following tables show the existing conditions of the intersections. (Source: JICA study team).

Table 3.1 and Table 3.2 show type of intersections and number of signalized intersections in Dhaka city. It shows the percentage of three leg intersections are more than that of four leg and roundabout is lower than non-round about.

Table 3.1: Type of Intersections

		Number	Percentage
1	Three Leg Intersection	48	48.98%
	1) Roundabout	5	5.10%
	2) Non roundabout	43	43.88%
2	Four Leg Intersection	46	46.94%
	1) Roundabout	8	8.16%
	2) Non roundabout	38	38.78%
3	More than Four Leg	4	4.08%
	1) Roundabout	2	2.04%
	2) Non roundabout	2	2.04%
Total		98	100%
	1) Roundabout	15	15.31%
	2) Non roundabout	83	84.69%

Source: JICA Study Team

Table 3.2: Number of Signalized Intersections

		Number	Percentage
1	Signalized	77	78.57%
	1) Operated	51	52.04%
	2) Not operated	26	26.53%
2	Non-Signalized	21	21.43%
Total		98	100%

Source: JICA Study Team

Figure 3.1 shows the different intersections location in Dhaka City Corporation area.

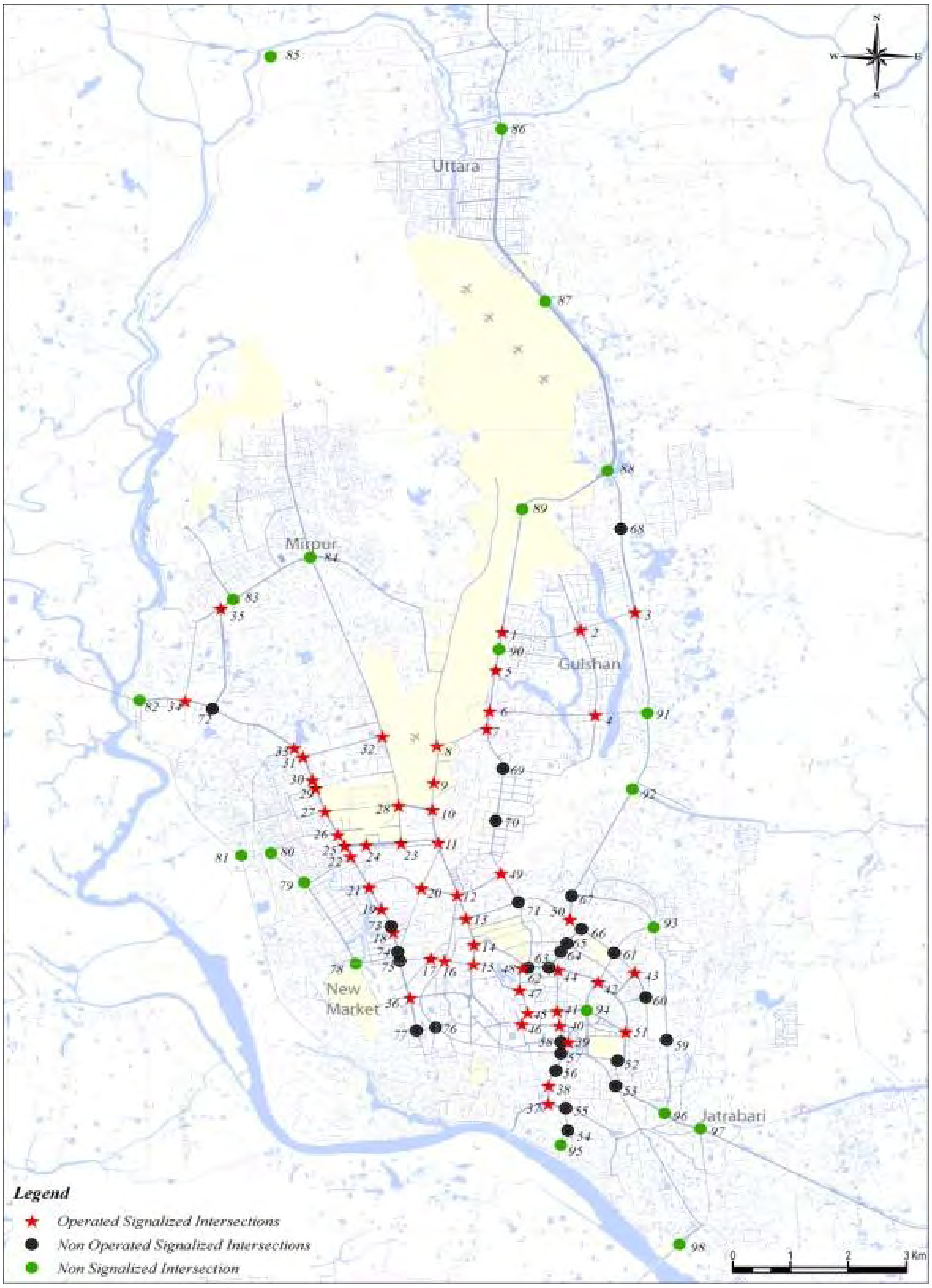


Figure 3.1: Location of Intersections

3.2 Literature Review

The review of literature of this research work was an important task. At first literature on simulation modeling were searched both in home and abroad. A wide range of study, regarding this topic is done on developed country as they are easy to applicable there due to lane-based homogeneous traffic system. In order to obtain information, a comprehensive literature was undertaken and information was collected from various sources viz. research studies, theses, journals, project documents in home and abroad. Review of documents was also carried out regarding the traffic simulation. Both primary and secondary data have been collected and compiled with a view to achieve the objectives.

As in Bangladesh, the traffic system is non lane based heterogeneous, there needs to be calibrating parameters. So, to simulate such condition some study regarding the procedure for calibration and validation were studied. As for simulation software VISSIM 5.30, whole user manual was read to understand it's all function properly and look over papers that used VISSIM as a simulation tool. In this work, study of basic modeling concepts, different types of car following rules, the process of calibration and validation was done and finally the manual of VISSIM was followed and practiced in VISSIM in order to get familiar with the software.

3.3 Site Selection Criteria

Due to subsequent increase in traffic volume, change of travel pattern, existence of heterogeneous transport in Dhaka city the traffic signals obsolete, less functioning incompatible with the present demand and concentration of traffic volume. Long queues are observed in almost all intersections delaying travel time beyond tolerable time, which result an adverse impact on national economy as well as on health.

Considering the facts, two intersections were selected for analysis. The main criteria for selection of the sites were:

- To obtain wide variation of vehicles,
- Ability of best point for video recording or manual data collecting, and
- Traffic situations such as with/without non-motorized vehicles.

A large number of sites are observed and two isolated intersections among them were selected for final study. These two selected intersections are:

- Nilkhet Intersection
- Shahbag Intersection

3.3.1 Nilkhet intersection

Nilkhet Intersection is one of the most important intersection or junctions in the Dhaka. Now-a- days it is one of the busiest intersections in Dhaka. In this intersection, both motorized and non-motorized vehicles exist. Here exist facilities of collecting data both manually and automatically. Pedestrian volume is also very high in Nilkhet. The approaches towards Dhaka university, Science lab, Pilkhana, Ajimpur are almost gathered with vehicles and pedestrians. It is one of the important intersections in Dhaka city, as it is close to Dhaka University, BUET and Dhaka Medical College. Figure 3.2 shows Google view of Nilkhet intersection.

Figure 3.2 Google View of Nilkhet Intersection

3.3.2 Shahbag intersection:

Shahbag Intersection is most important intersection or junction in the Dhaka city. It is one of the busy intersections with motorized and non-motorized vehicles. The approaches towards Bangla motor Katabon, TSC, and MotshoVobon. All approaches are involved with very high-volume traffic. Pedestrian movements have been found at all the approaches.Photo 3.2 shows the Google view of Shahbag intersection.

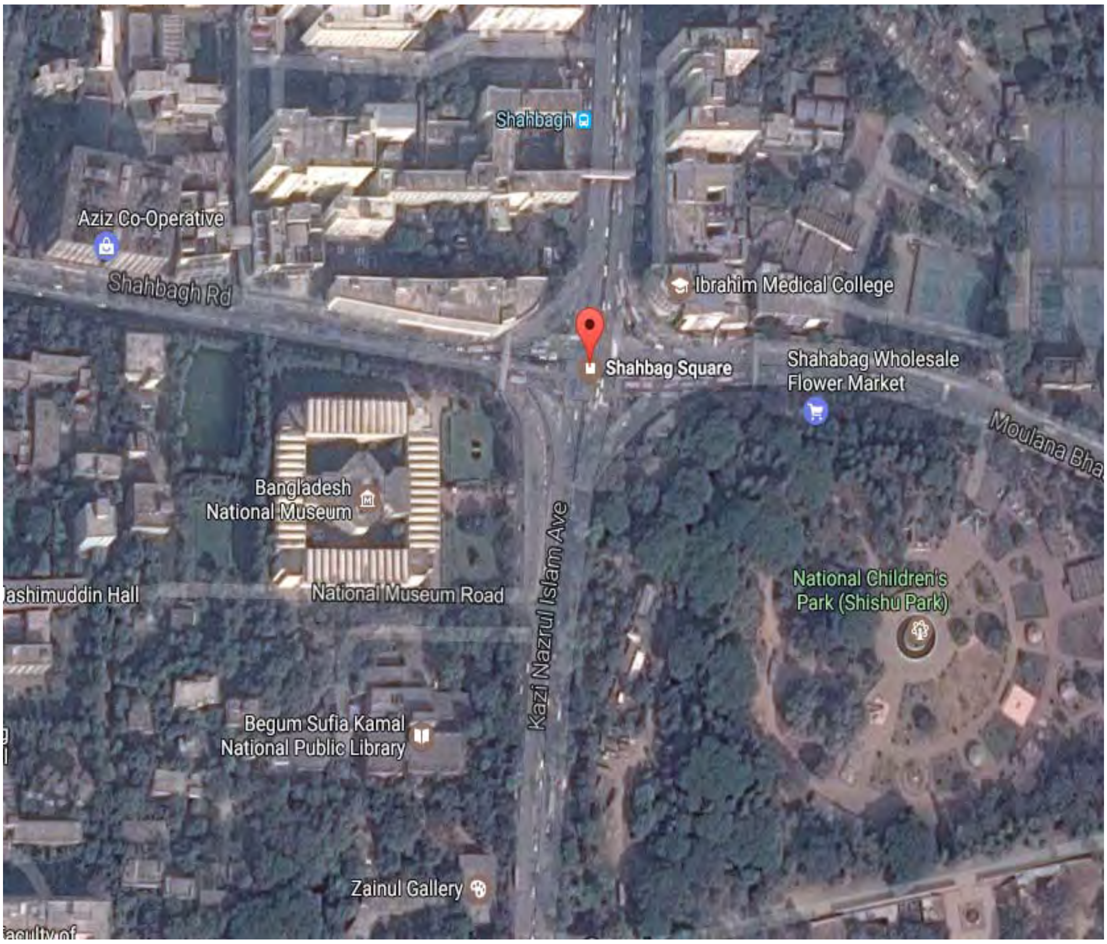


Figure 3.3: Google View of Shahbag Intersection

3.4 Vehicle Classification

Traffic has been classified into two major groups. Vehicle

These are:

- Motorized Vehicles
- Non-motorized Vehicles

Two major groups have also been sub-divided into following classification:

- Bus/Truck
- Car/Micro-bus
- CNG

- Rickshaw
- Motorcycle
- Bicycle
- Laguna

3.5 Outline of the Research Methodology

In order to achieve the objectives some specific steps are necessary to be followed. Following processes/methods were applied for achieving the objectives:

In order to obtain information, a comprehensive literature was undertaken and information was collected from various sources viz. research studies, theses, journals, project documents in home and abroad. Review of documents was also carried out regarding the traffic signal system, traffic signal operation and maintenance, institutional setup etc. in Dhaka city to acquire knowledge about the signal system. Dhaka, the capital city of Bangladesh and the center of its political, cultural and economic life, has been growing at astonishing levels since the independence of the country in 1971. Nilkhet and katabon intersections are two important and busiest intersections. Due to subsequent increase in traffic volume, change of travel pattern, existence of heterogeneous transport in this intersection has made the traffic signal obsolete, less functioning incompatible with the present demand and concentration of traffic volume. Long queues are observed in almost all the approaches delaying travel time beyond tolerable time, which result an adverse impact on national economy as well as on health.

For study the existing signal system it is necessary the information was collected the actual traffic situation, signal system, phasing, geometry etc. For this purpose, survey was conducted. Survey involves the information regarding the system requirements, no of phases, types of signal, arrival traffic flow, types of signal controllers, no of lanes, signal timing control, maximum green time, maximum cycle time, presence of non-motorized vehicle at signalized intersections etc. Investigations on the existing traffic signal condition have to be carried on. These investigations play important roles to propose a new signal design related with minimization of delay in the intersection. Besides calculating optimal signal timing, problems associated with intersection like pedestrian movement, faulty road sign, unauthorized parking, bus stoppage, vendors etc. will also be mentioned with probable solutions of these problems from engineering point of view.

3.6 Objectives of Data Collection

The objectives of the field survey were:

- To obtain a better understanding of the nature of traffic in non-lane based mixed traffic operation.
- To obtain comprehensive data from selected intersection. These include the basic input data such as: geometric layout, signal timing, flow, proportion of motorized and non-motorized vehicles, vehicle mix, proportion of turning vehicles, vehicle arrival pattern and discharge profiles.
- To propose new cycle times for all approaches for minimizing delay.

3.7 Data Collection

Collection of data for this research work was hard and challenging task. Data was collected in two phases. At first phase necessary data was collected from field area in order to develop a model in VISSIM, and at the second phase desired data was extracted from the calibrated model in order to evaluate the effect of NMV on the network.

VISSIM provides a microscopic simulation model which is heavily dependent on the parameters and data input used during the network coding. The basic data set needed for a basic VISSIM network is as follows:

- General Data: Simulation Time
- Network Data:

- Digital images of plan showing the entire study area ,
- Detailed plans for each junction showing lane markings,
- signal heads and detectors, and
- Location of bus stops.

- Traffic Flow Data:
  - For static routing-Turn movements for each junction input flow in vehicles per hour,
  - For Dynamic Assignment- OD Matrix, Location of zones and parking lots,
  - Traffic Composition,
  - Vehicle speed at free flow (Speed limit of the road),
  - Travel time, and
  - Saturation Flows.

- Signal Control Data:
  - Cycle Length Green,
  - Amber and Red times for each signal group.

3.8 General Setting

Following steps were followed to build the model:

- Building a network,
- Drawing / editinh link/ connector,
- Vehicle composition,
- Vehicle input,
- Route decision, and
- Signal control.

3.8.1 Input data for modeling in VISSIM

Field data was collected from Nilkhet and Shahbag intersection from the end of July to September, 2018. A survey team along with some undergraduate students were formed to collect data from the field. Data were collected using video camera method.

The intersections were observed and the traffic movement were recorded with a video camera during the peak times of the day. Suitable height were chosen from where clear view of the intersection can be found. The intersection did not have fixed time signal and signal was controlled by traffic police according to the traffic flow.

The traffic movement was recorder by video camera in the peak time of the day. The speed, dimensions of the vehicle, phase time, occupancy and queue length were measured directly from the field. We measured the geometric layout of the intersection directly from the field by odometer.

Video was recorded in two segments of 30 minutes interval. From the video, traffic characteristics, traffic composition, total volume of vehicle, relative flow of vehicles in each leg was extracted. In addition to that queue length was measured in the field for validation of the model as a measure of performances. All are discussed in Chapter 4 in details.

3.8.2 Output data from model developed in VISSIM

Using the collected data from the field the network was modeled, calibrated and validated discussed in the following section. Output from the software are- i) travel time in a particular section, ii) Delay, iii) Speed at certain point was extracted to check the performance of the network.

3.9 Modeling in VISSIM

After collecting the required data model was made in VISSIM for a fixed signalized intersection using different parameters and a bit map of intersection as a background.

3.9.1 Data input

The main input parameters were vehicle types, vehicle classes, vehicle models, link types, desired speed, traffic compositions, fixed time signal groups, simulation parameters, driving behavior parameter sets and other data were taken as default values in VISSIM.

One of the most focusing data input in the model is that introducing of model of rickshaw and CNG which was drawn in 3D max studio, as this vehicle's model was not introduced in the simulation software. It was done to approximate the effect due to this vehicle types as their size has huge impact on the flow. Both the models are shown in Figure 3.4 and 3.5.

Figure 3.4: 3D Model of Rickshaw

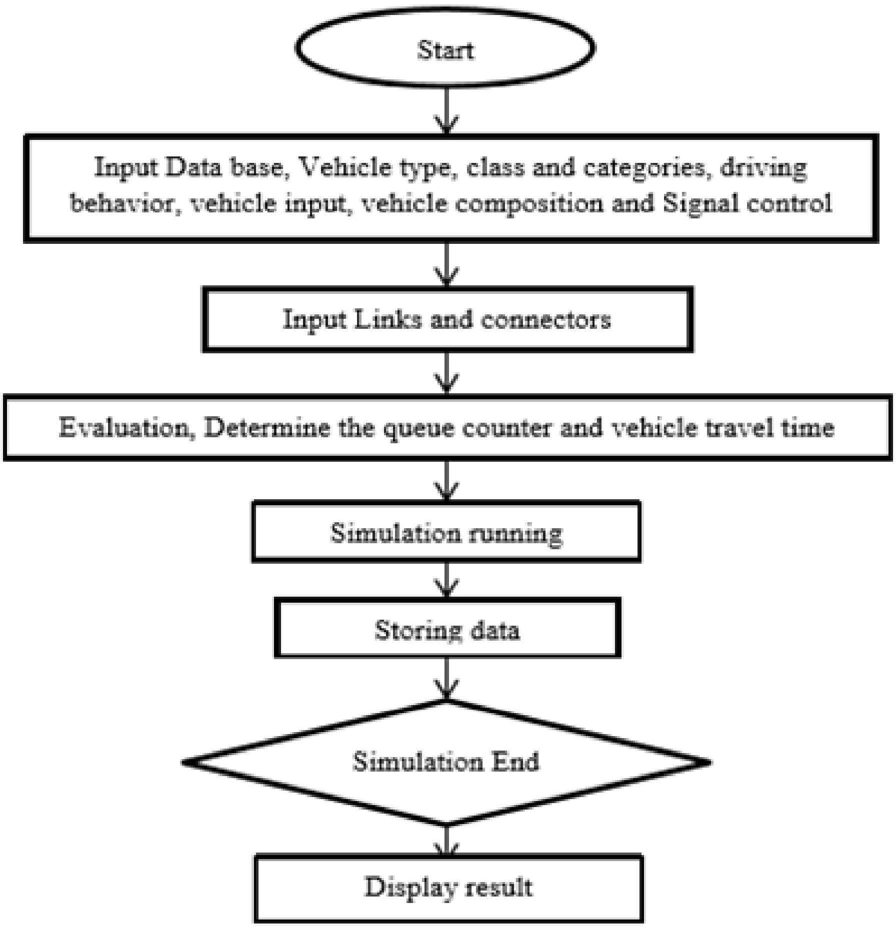
Figure 3.5: 3D Model of CNG

3.9.2 Model calibration

After making model in VISSIM it was calibrated for urban traffic conditions in Dhaka. Calibration is the most difficult and at the same time most important part of any simulation modeling. It is also time consuming. Due to time constraints, the help of a paper was taken by Manjunatha et al (Manjunatha op. cit) in which a set of calibration parameter was set to simulate the heterogeneous traffic system.

As the study area of that paper is a place in India, neighboring country of Bangladesh, where the traffic operation is also non lane based heterogeneous which is somewhat same as in our country.

3.10 Flowchart of the Methodology



Chapter 4
DATA COLLECTION

4.1 Introduction

The methodology process that employed in this study commences with the adaptation of the VISSIM model and calibrating it for the existing traffic conditions until its validation is reached. In this process, the very first step is to select a suitable site, a site that does not cause any difficulty in data collection and model formulation. The next task in this study is to collect the required input data for the VISSIM model and to collect the calibration data to compare with simulated results from the field. Then the study progress by performing the task of network coding, simulating and verifying the coded network and determining the required number of simulations runs. Then the very important task of this study, model calibration is considered.

In running simulation model in VISSIM, a particular field data such as geometric characteristics consisting of road width, shoulder width, width of median if there is one and traffic characteristic that includes traffic volume, vehicle count, types of vehicle needed to be collected. Also, there is a need to select a performance point to be selected with which the model should be calibrated by adjusting some parameters which is integrated in VISSIM software packages so that the results from the model is close to the field data collected. The primary aim of the data collection from the field was to be able to gather information for non-lane based mixed traffic behavior, which will be used in modeling the network in the microscopic traffic flow simulation model VISSIM. Due to the scarceness of data from the mixed traffic behavior and time constrain, it was a great challenge in this research to collect all the acceptable necessary and relevant data for calibration of the microscopic simulation model. After modeling is completed, certain data: travel time, delay time for car at some specified travel section, queue length at counters was collected for quantitative analysis and evaluation of the network performance. This chapter is concerned with the data collection processes of the study. Data from study area were collected during the period of January and February.

Nilkhet and Shahbag is a four-leg intersection. Data were collected based on availability of video and manual point of the intersection for capacity analysis of selected intersection.

There are general four parts, these are

- Volume study,
- Capacity Analysis,
- Speed Analysis, and
- Photographic Survey

4.2 Objectives of Data collection

The objectives of the study were:

- To achieve a better understanding of the scenery of traffic flow.
- To get comprehensive data from selected intersection- against which the microscopic simulation model would be calibrated. These include (a) the basic input data such as: geometric layout of links and background map, signal timing, relative flow, proportion of motorized and non-motorized vehicles, desired speed, vehicle composition, vehicle model distribution, proportion of tuning vehicle and (b) the measure of effectiveness data such as discharge profiles and queue length.
- To observe the behavior of the network.

4.3 Method of Data Collection

The above-mentioned field observation was conducted in five ways:

- Qualitative observation of mixed traffic behavior- for logical implementation of different aspects of the model.
- Direct measurement: - for estimation of different static and dynamic characteristics of vehicles, basic geometric and traffic data and queue length measurements.
- Collection of geometric layouts of intersection and signal time.
- Collection of photographs during estimation of different static and dynamic characteristics of vehicles.
- Video recording- for classifies vehicle counts data during discharge process and estimation of vehicles composition, relative flow and observation of the traffic flow scenario.

4.4 Volume Study

Traffic volume is defined as the number of vehicles passing a point on a highway or lane during a specified period. It is the most basic of all parameters and the one most often used in planning, design and control, operation and management analyses. Since, volume is the most basic of all parameters and is the basis for traffic planning, the observation and analysis of traffic volumes were done with the utmost care and accuracy. Inaccurate volume information will compromise the accuracy and effectiveness of all analyses and improvements developed from it.

Traffic volumes were collected using video camera method for a period of one hour from 01:00pm to 02:00 pm at each intersection for both the networks. All the intersections in the networks have four approaches. At each approach one person was placed to collect traffic volume. Information such as turning movements, pedestrian counts were done manually also.

4.5 Static Parameters

There are some static parameters such as vehicle type, classification, size , height, weight etc. Some of these parameters are discussed as below:

4.5.1 Vehicle type

The behavior of traffic flow in a stream depends on vehicle types and the percentages of the different types of vehicles comprising the traffic stream have an effect on non-lane-based traffic flow. During count of vehicles from video recording mainly two types of vehicles have been found i.e. motorized and non-motorized vehicles.

Traffic behavior varies with the percentages of the different types of vehicles comprising the traffic stream. The relative proportion of vehicles types has significant effects on traffic speeds and other operating characteristics. The influence of vehicle composition on the system effectiveness can, to some extent, be accommodated by vehicle equivalents to express traffic volume in terms of passenger car units rather than in terms of vehicles.

4.5.2 Vehicle classification

To make microscopic simulation models where each vehicle is treated as an entity and when one of the research objectives is to explore the dynamic characteristics for different vehicle types- 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 one of the following classes, so that the composition of the vehicles could be accurately determined. The vehicles that have been found in study area are classified into two major groups i.e. a) motorized and b) non- motorized. These two major groups have also been sub-divided into nine classes considering their dynamic characteristics and are shown as follows:

Motorized:

- Car;

- Bus (Large bus, Micro-bus, Small bus);
- Jeep;
- CNG; and
- Motor cycle (Honda, Vespa) etc.

Non- motorized:

- Bicycle;
- Rickshaw; and
- Thelagari etc.

4.5.3 Vehicle sizes

For input in VISSIM default sizes were used for there each classes, as due to time constrains a wide range was not able to be collected regarding vehicle size. But as the study is focused on to observe the forced behavior of Rickshaw, 3D model of it were made and given as a input of its size shown in Figure 3.2. Also a CNG was modeled, referred in Figure 3.3.

4.6 Dynamic Parameters

Dynamic parameters of vehicles also influence road traffic characteristics. Speed, velocity, queue length are important among them. These are discussed below:

4.6.1 Desired speed distribution

Speed is one of the basic characteristics of a traffic stream. In the simulation model, it is considered that all vehicles enter the system with desired speed. It is, therefore necessary to estimate this parameter from actual traffic data.

During green time vehicles are forces to leave the stop-line and the leading vehicles have to accelerate to get their desired speeds. From the field observations it has been found that when the leading vehicles go to 80 to 85 meter ahead from the stop-line they get their desired speeds and they keep this desired speed until next intersection. It is done by taking a 44 ft strip in the upstream direction of traffic flow in each approach.

But for non-motorized vehicles these desired speeds were measured by taking a fixed 11 ft strip and the required travelling time in a free roadway. This distance was adopted consider the fact that driver behavior would be more homogeneous over a short distance than a longer distance. The desired speed data were collected at different approaches of the intersection and different values were found at different approaches of same vehicle.

4.6.2 Queue length

In response to the light change to amber vehicles near the stop line can decide either to carry on moving or otherwise to stop. Different rules are applied for those who decide to go ahead and to stop. This way, the head of the queue will eventually come to a halt near the stop line and the remaining vehicles will follow the head of the queues until they stop and join the queue. In handling the queue formation during the red period, the model combines the amber and red period in order to represent the process of stopping vehicles, because actually the decision whether to stop or to go ahead during the amber period is made at the instant when the signal turns from green to amber.

During data collection in filed the manual method was used to measure the queue length. Some ranging rods were put into divider of approaches from stop line to up-stream direction every 5 meters interval which was marked by different colored paper to indicate different position. From the just before of the finishing point of each leg the whole approach was divided into 10-meter block. If the queue is within first 10-meter block queue length is calculated as 10-meter, Queue length within 10 meter to 20 meter is represented as 20 meter. This Queue length is used as validation parameter as this parameter is not used as calibration the simulation model in VISSIM.

4.7 Summary of Data Collection

The phase of data collection was a most important task in this study and at the same time it was the most hard-hitting job in the entire study. Microscopic simulation model VISSIM have complicated data input requirement and have many model parameters. To build a VISSIM simulation model for this network and to calibrate it for the local traffic conditions, two types of data are required. The first type is the basic input data used for network coding of the simulation model. The second type is the observation data employed for the calibration of simulation model parameters.

4.7.1 Network coding data

Basic Input Data: Basic input data include data of network geometry, traffic volume data, turning movements, vehicle characteristics, travel demands, vehicle mix, stop signs, traffic control systems, etc.

Data for Model Calibration: The coded VISSIM simulation network needs to be further calibrated to replicate the local traffic conditions. The calibration involves comparing the simulation results against field observed data and adjusting model parameters until the model results fall within an acceptable range of convergence. Data collected for model calibration includes traffic volume data, travel time, maximum queue length, average queue length and average link speed. In collecting all types of data standard procedure were followed.

4.7.2 Data collected from field

Classified vehicles count: In each leg classified vehicles such as Motor/Bi Cycle, Car/Jeep/Micro-bus/Taxi/Tempoo, CNG, Large Bus, Medium Bus, Small Bus, Utility Truck, Rickshaw/Van are counted in 5-minute intervals coming from that leg to another four legs. This counting is continued to an hour. From this classified vehicle counting the vehicle flow per hour in every 5-minute interval can be found. From total vehicles coming the percentage of vehicles diverting to different legs can be found.

Road geometry: Road geometry is important for simulation network coding. Road width, median width, footpath width, gutter width, median and footpath height is determined in the field by odometer and tape. Road width measurement is necessary to determine how many lanes an approach or a exit possess. So, this information is very much necessary for network coding.

Vehicle speed: The speed for each classified vehicle was taken. In each leg of intersection for each type of vehicle ten individual sample speed is determined manually and then taken average of them to find out average speed of each classified vehicle in each leg. Vehicle speed is taken as a calibration parameter.

Table 4.1: A summary of data collected

Major Category	Data Type
Network Data	1. Links with start and end points. 2. Link lengths. 3. Number of lanes. 4. Lane drops and lane gains. 5. Lane storage length for turning movements. 6. Connectors between links to model turning movements. 7. Position of signal heads/stop lines.
Traffic Volume Data	1. Through and turning traffic volume counts. 2. Vehicle composition. 3. Vehicle length. *
Vehicle and Driver Performance Characteristics Data	1. Saturation flow. 2. Average vehicle spacing. 3. Vehicle acceleration and deceleration. *
Speed Data	1. Desired speed. 2. Right turning and left turning movements speed.
Signal Control Data	1. Cycle length. 2. Offsets. 3. Phase direction. 4. Phase duration. 5. Priority rules.
Data for Calibration	1. Section travel time. 2. Average link speed. 3. Average queue length. 4. Maximum queue length.

*Default values were used

4.8 Overview

So, this chapter includes the necessity of data collection with detail objectives and also, includes the procedure of data collection. The types of data required for detail analysis are also included here. Next chapter discuss the analysis of the collected data.

Chapter 5
DATA ANALYSIS

5.1 Introduction

As discussed in the previous chapter, two types of data have been collected. The primary data has been used in modelling in VISSIM. This allows to calibrate and validate the model. Also, this data is analyzed to study the traffic characteristics, composition in the study area. After modelling the secondary data was collected from simulation and they were analyzed to determine different parameters.

5.2 Analysis of Field Data

Collected field data was analyzed to find out the traffic composition of the study area and observe the traffic characteristics, such as speed of the traffics existed in the study area.

5.2.1 Analysis from photographic survey

This was done by observing the recorded clip. To summarize the findings, the following is a list of points describing the behavior of traffic, which would be considered in calibration of the simulation model for non- lane based mixed traffic flow.

- Figure 5.1 shows that; traffic signal is controlled by traffic police by hand as per he thinks fit for that particular moment even though there are traffic signals hand.
- Unauthorized loading -unloading of buses create congestion and reduce capacity of intersections. Moreover, pedestrian crosses the road without using zebra -crossing at Nilkhet. (Figure 5.2)
- No fixed signal time is followed, which creates huge confusion among the road users some time as uniformity of traffic control is not seen. In addition, congestion is created. It was seen that in link with high proportion of NMV, there is high concentration of NMV at the front of queue in irregular manner which disrupts the regular discharge of MV forcing them to slow down the speed. (Figure 5.1). Moreover, in figure 5.3 and figure 5.4 it is observed that, NMV movements are haphazard and, in many cases, parked NMV on roads occupy almost two lanes of road.
- Queue is built up based on the optimum link space utilization criterion. As a result, it has been observed that straight ahead vehicles, regardless of the type whether motorized or not, occupy any position across the link based on the available space. Consequently, the maximum interactions between motorized and non- motorized vehicles are observed during the subsequent discharge process. (Figure 5.1, 5.2 and 5.3)
- During discharge process red signal violation is very common. Some vehicles usually cross the stop line until 1-5 sec after the onset of the red signal.
- At some points road markings and zebra crossings are almost faded. (Figure 5.5)

Figure 5.1 Undisciplined Vehicular Movements at Shahbag Intersection

Figure 5.2 Passenger Loading Unloading Without Lay by at Nilkhet

Figure 5.3 Haphazard NMV Movements at Shahbag Intersection

Figure 5.4 NMV Occupying Almost Two-lanes at Nilkhet

Figure 5.5 Absence of Marking

5.3 Traffic Composition of the Study Area

Public transport in the city provides the basis of the means of movement to perform the residents' business, commercial transactions, education and leisure pursuits. In both areas, there are lots of public transport, private vehicles, para transit and NMVs. Public transport buses are double-decker buses, urban- buses; mini buses, tempo whereas the private transport modes are car, jeep, micro bus and motorcycle. Traffic compositions at Nilkhet is shown at Fig 5.6. It is observed that, % of NMV is dominating in this intersection, which is 49% and Car is second highest. Fig 5.7 shows traffic composition at Shahbag where a maximum of 31% CNG was observed. In this intersection % NMV was 10%.

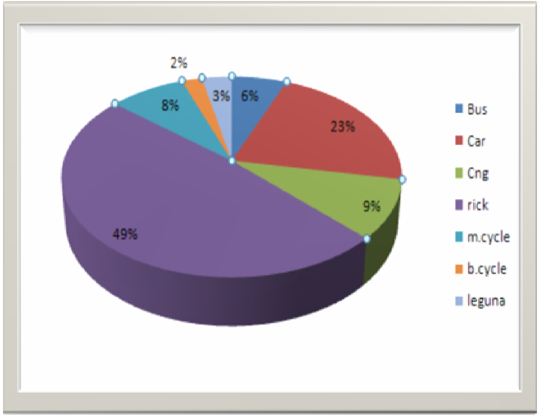


Figure 5.6 Traffic Composition at Nilkhet

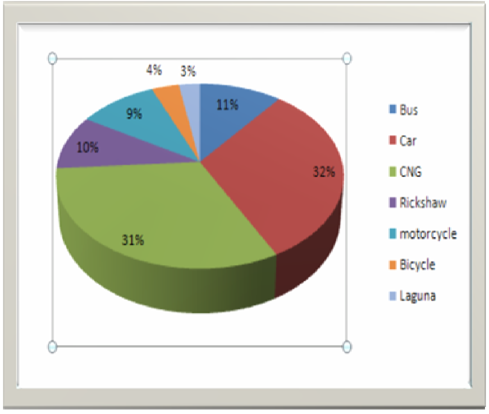
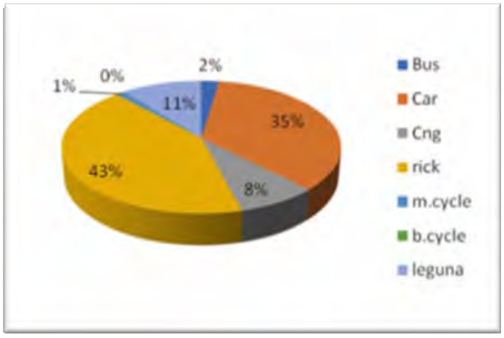


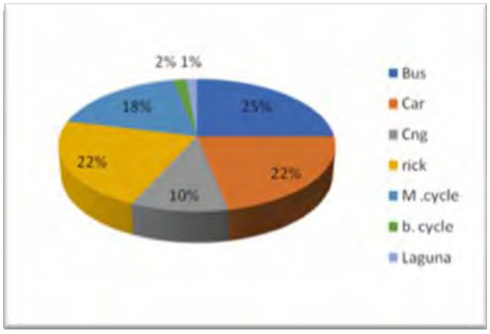
Figure 5.7 Traffic Composition at Shahbag

5.3.1 Traffic composition at each approach of Nilkhet

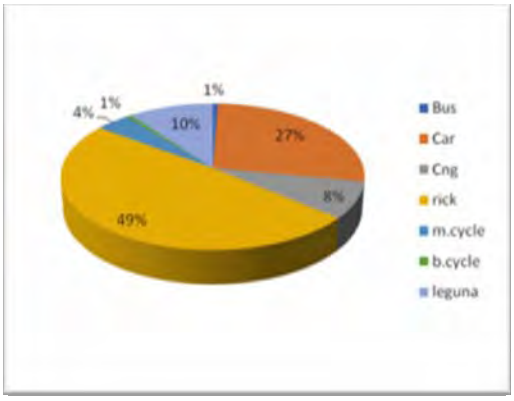
Data collection was done for one hour with 30 minutes intervals. Data was collected at 12th February, 2019 from 1:00-2:00 pm. Fig 5.8 and 5.9 shows vehicular composition at different links of Nilkhet. At each approach NMV is dominant. Even 67%, 64% and 62% was observed at DU, Pilkhana and Mirpur road. In almost all approaches Car was second highest and Bus was third. The least percentage was Bi-cycle and Leguna.



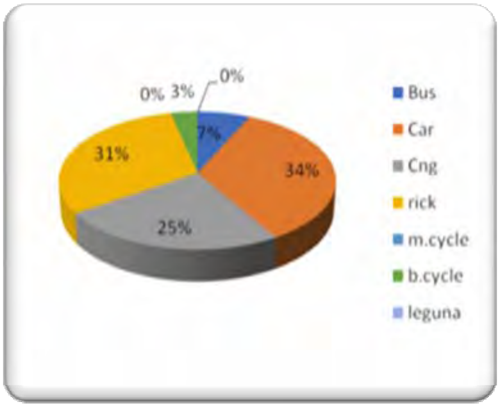
DU to Azimpur



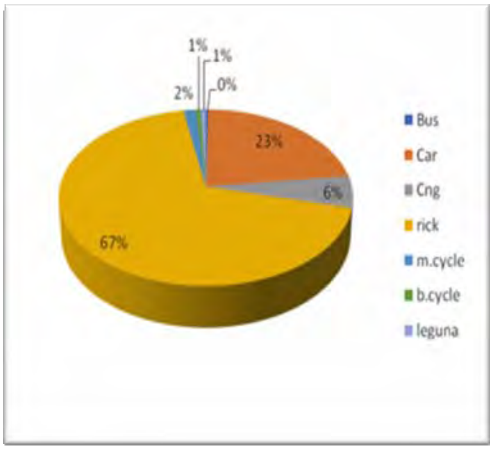
Azimpur to Mirpur



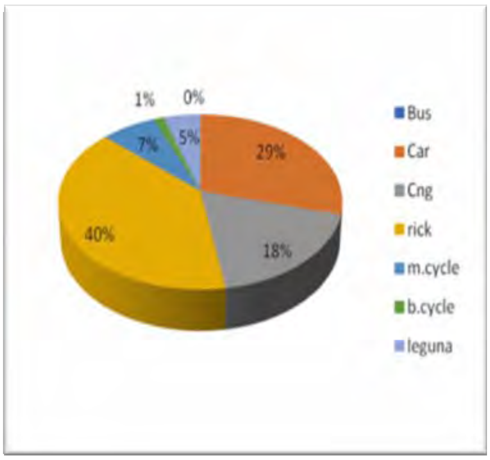
DU to Mirpur



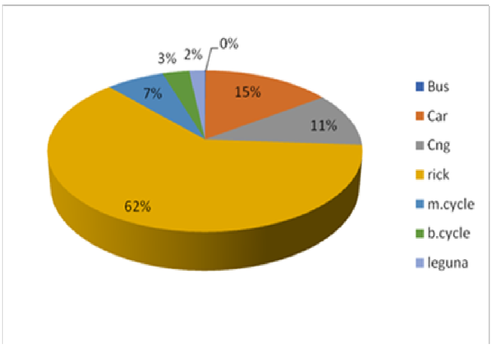
Azimpur to Pilkhana



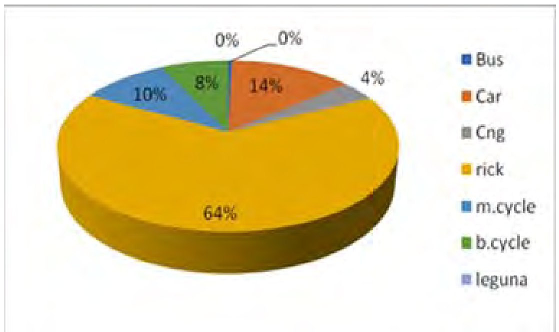
DU to Pilkhana



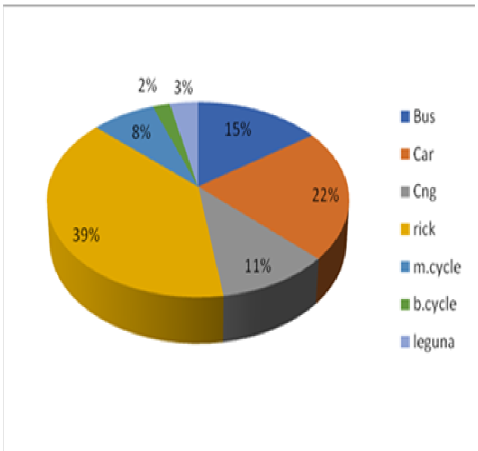
Mirpur to Pilkhana



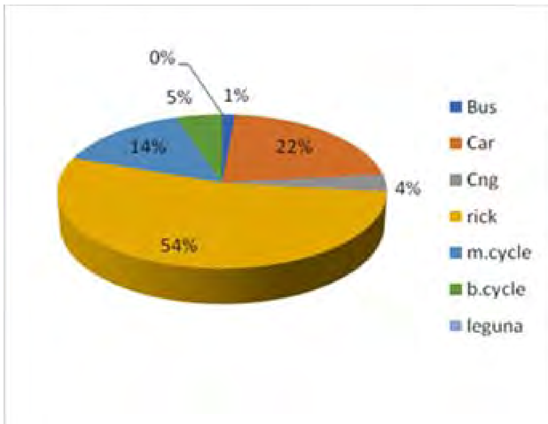
Mirpur to DU



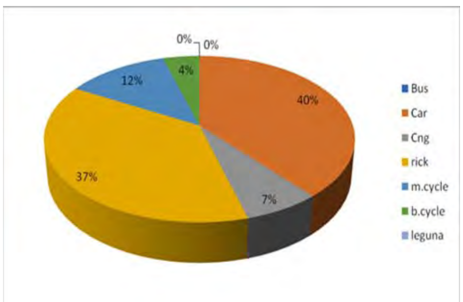
Pilkhana to DU



Mirpur to Azimpur



Pilkhana to Azimpur

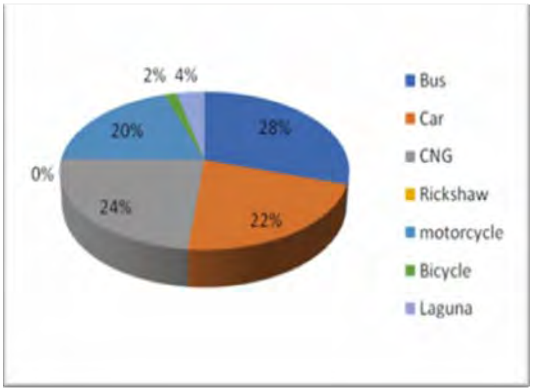


Pilkhana to Mirpur

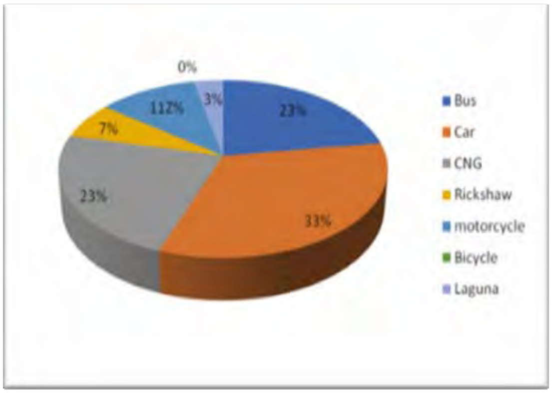
Figure 5.8 Traffic Composition at Different Links of Nilkhet Intersection

5.3.2 Traffic composition at each approach of Shahbag intersection

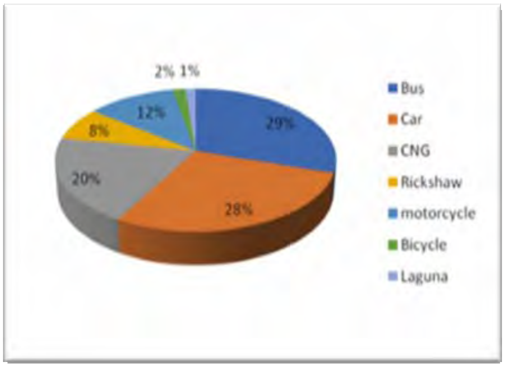
For Shahbagh intersection data collection was done for one hour with 30 minutes intervals. Data was collected at 18th January, 2019 from 1:00-2:00 pm. Fig 5.10 vehicular composition at different links of Shahbagh intersection. Almost each approaches Private car was dominating and CNG volume was second highest. At Katabon to TSC 54% car was maximum among all the approaches. But for Banglamotor to TSC rickshaw volume was high. This may be for that particular hour only.



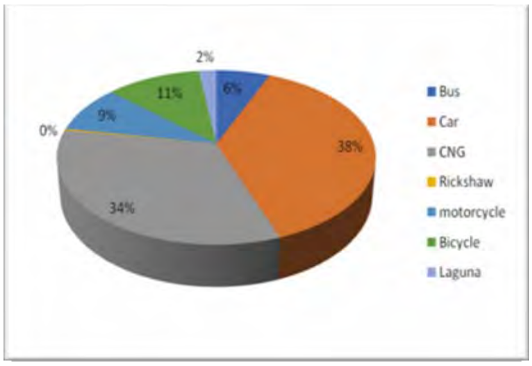
Banglamotor to Motshobhaban



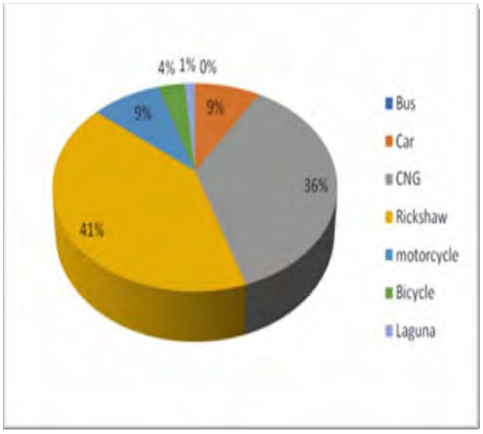
Motshobhaban to Banglamotor

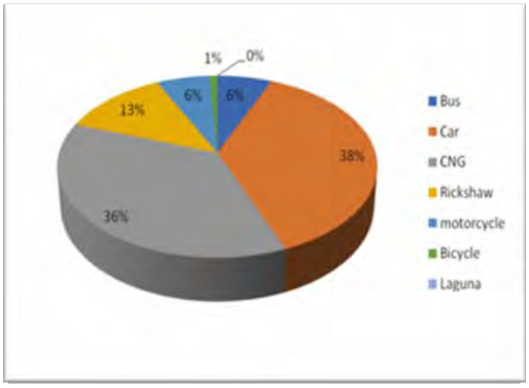


Banglamotor to Motshobhaban



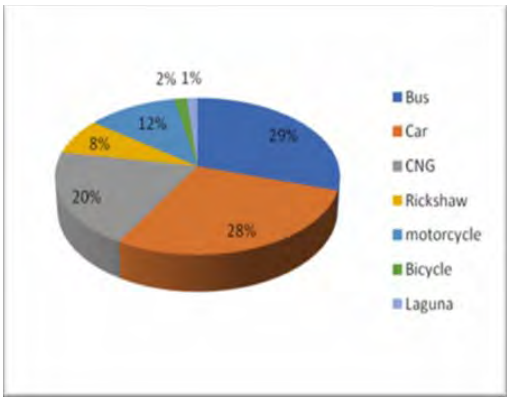
Motshobhaban to Banglamotor

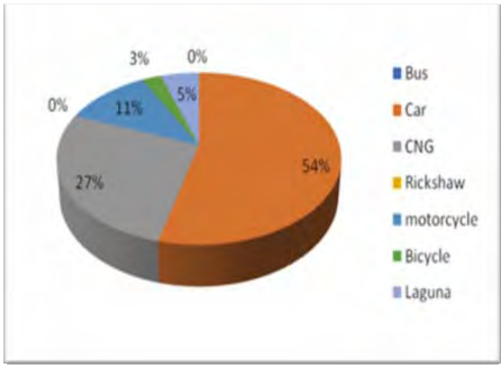




Banglamotor to TSC

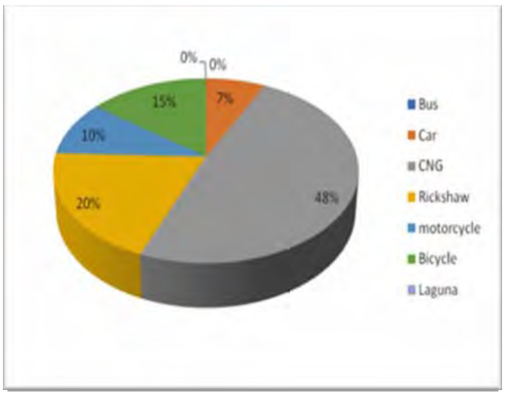
TSC to Banglamotor

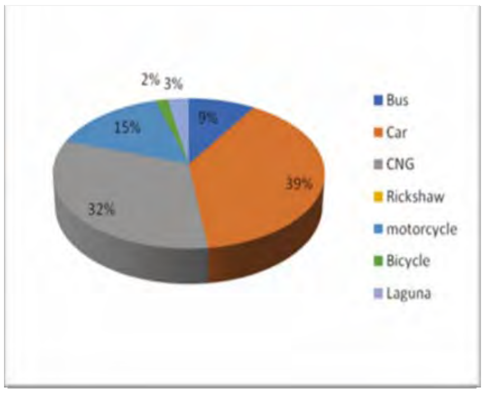




Banglamotor to Kataban

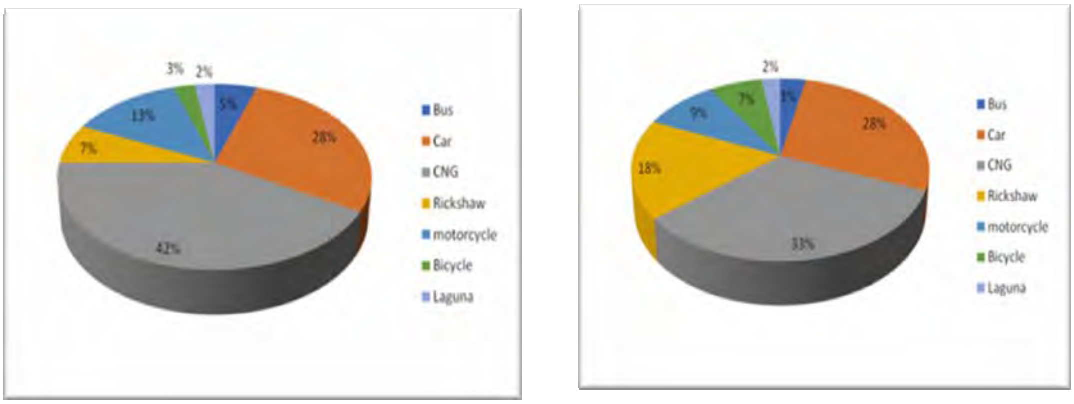
Kataban to Banglamotor





TSC to katabon

Katabon to TSC



Matshabhobon to Katabon Katabon to Matshobhobon

Figure 5.9 Traffic Flow at Different Links of Shahbagh Intersection

5.4 Network Performance

Network Performance Evaluation evaluates several parameters that are aggregated for the whole simulation run and the whole network. Following parameters were selected:

- Average Speed (km/hr),
- Total Travel Time (hr),
- Average Delay Time per Vehicle (s),
- Total Delay Time (hr),
- Average Stopped Delay per Vehicle (s),
- Total Stopped Delay (hr),
- No. of Vehicles in the Network, and
- No. of Vehicles that have left the Network.

5.4.1 Development of simulation model

A well-developed simulation model is very helpful to provide useful statistical information which is difficult to find by manual method. This simulation model development for the intersections are basically done by three major steps

- Simulation network coding,
- Determining calibration and validation parameters, and
- Calibration and validation of simulation model.

5.4.2 Simulation network coding

Simulation network coding is done in five major steps:

Step 1: Importing background map

At first a background map containing intersection and associated legs is imported from Goggle Map. Most importantly the imported map containing scale of goggle map which is required to scale the imported background map in VISSIM.

Step 2: Creating link

For creating link roadway geometry measurement is required which is measured during data collection. Figure 5.10 represents various roadway evolved from Nilkhet intersection and each of which is marked with a number.

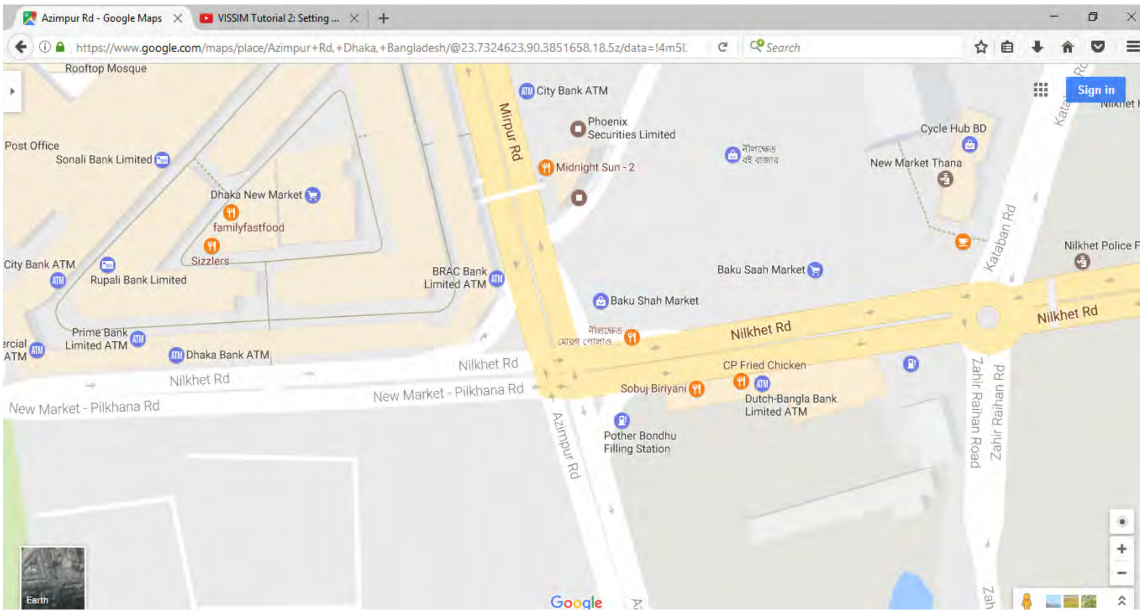


Figure. 5.10 Roadway Evolved from Nilkhet Intersection

Table 5.1 represents the number of lanes are provided during simulation at every approach or exit in the intersection. The width of each lane is considering in between 2.7 to 4.6 m[1]. Roadway numbers are transferred.

Table 5.1: Number of lanes determination in all approaches or exits in Nilkhet intersection

Roadway no	**1**		**2**		**3**		**4**	
Towards	Ajimpur		TSC		Science Lab		Pilkhana	
Road Width(m)	7.6	7.6	8.1	8.3	7.37	7.49	7	7
Lane width (assumed)	3.8	3.8	4	4.2	3.75	3.75	3.5	3.5
No of lanes	2	2	3	3	2	2	2	2

Step 3: Placing connectors

Connector is an important tool which is used during simulation network coding by which one lane from an approach is connected to another. In any approach or exit direction rightmost lane is marked as lane 1 in VISSIM. So connectors are provided accordingly. For matching vehicle movement from one leg to another just like real field, recalculate spline with appropriate number of points is provided.

Step 4: Defining base data for simulation

This step basically concerns with the defining distributions of vehicle type, class and category in each of the five approach and also to four exiting direction from one approach. This is the one of the main steps in simulation. It is discussed below in the same way it is done during simulation network coding.

5.4.3 Vehicle types and classes

VISSIM has some own created vehicles types such as bus, truck, tram, HGV etc. But it does not possess our local vehicles which occupied most vehicles' percentage in intersection. Example of this types of local vehicles is rickshaw, bike and CNG. To import the 3D model of these vehicles, from 'Base Data' tab new v3dm-model is imported from outside to VISSIM. Figure 5.11 represents the window of importing CNG to VISSIM.

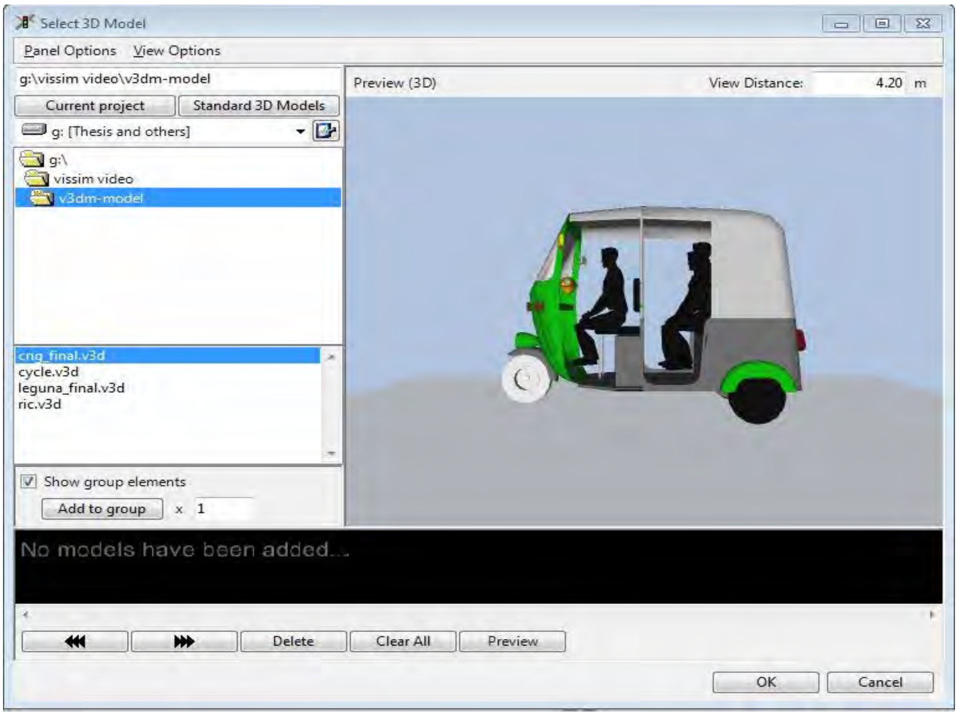


Figure 5.11 Window of Importing CNG to VISSIM.

After importing each vehicle, vehicle types are provided for the corresponding vehicle. In VISSIM vehicle category cannot be changed for a new vehicle model. Figure 5.12 represents the window of the selection of CNG as new vehicle type. It is categorized as car.

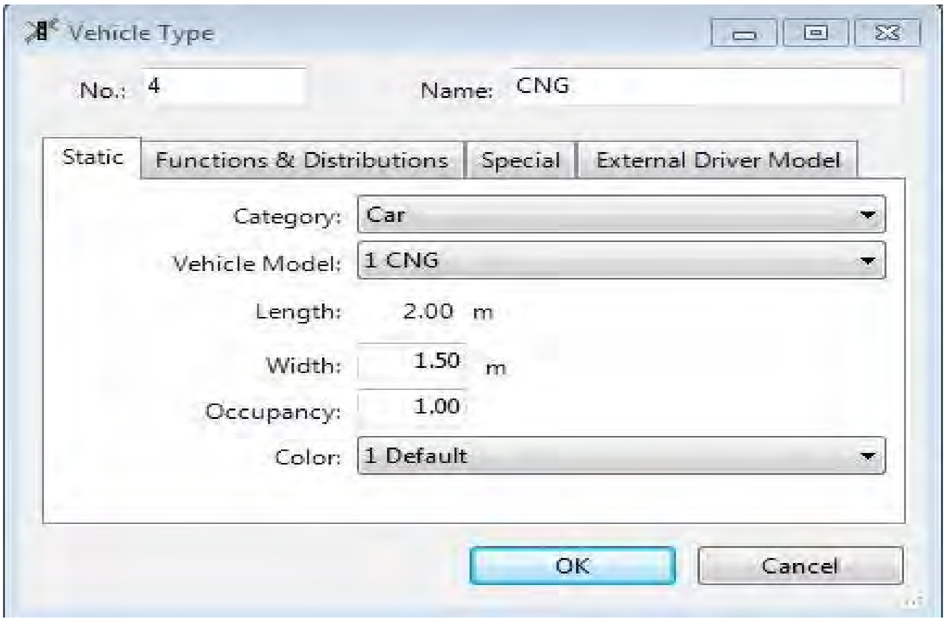


Figure 5.12 Selection of CNG as New Vehicle Type

In this way rickshaw, bike is also selected as new vehicle type. Then inside the vehicle class this new vehicle for example CNG is added. Figure 5.13 represents selection of CNG as a new vehicle class.

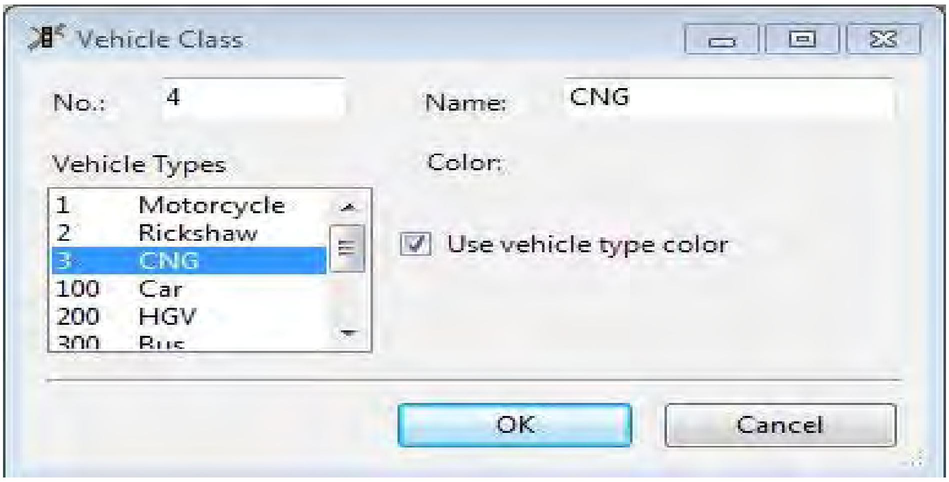


Figure 5.13 Selection of CNG as New Vehicle Class.

Vehicle Inputs

During providing input of vehicles five types of vehicle compositions are created. Figure 5.14 represents the snapshot of this.

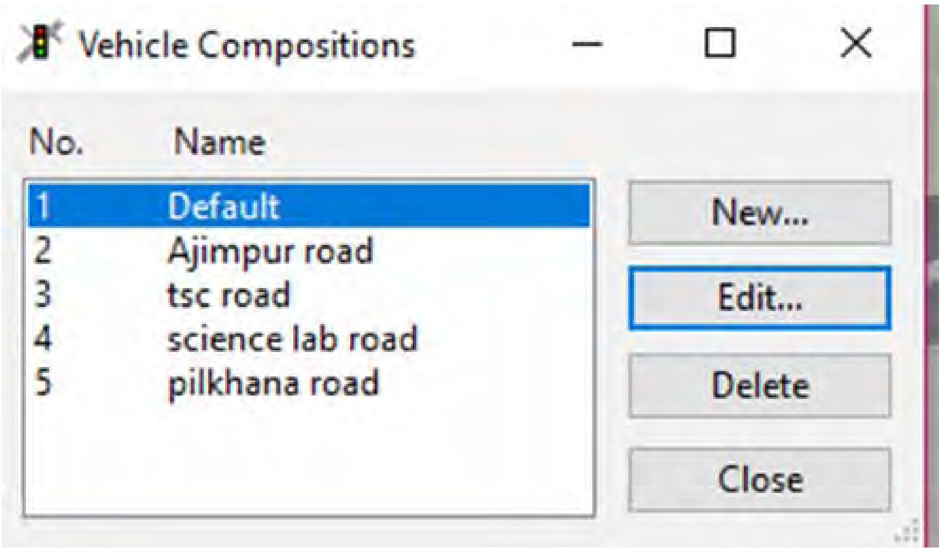


Figure 5.14 Vehicle Compositions Created for Approaches

Inside each vehicle composition relative flow and speed of each type of vehicles are provided. Speed for each type of vehicle measured manually in the field is represented by ‘Des. Speed’.

In the same way vehicle compositions for all approaches are provided. Then in each approach the total number of vehicles is provided in every 5 minutes interval of an hour. In every 5 minutes, total vehicle input is provided in vehicle per hour. Corresponding link number is provided with respective vehicle compositions.

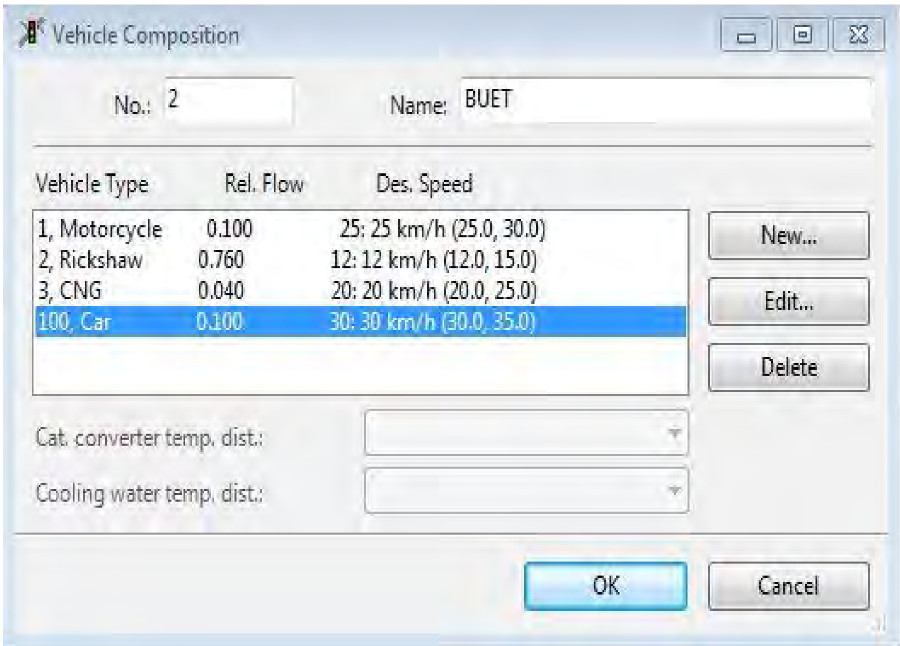


Figure 5.15 Vehicle Compositions Input

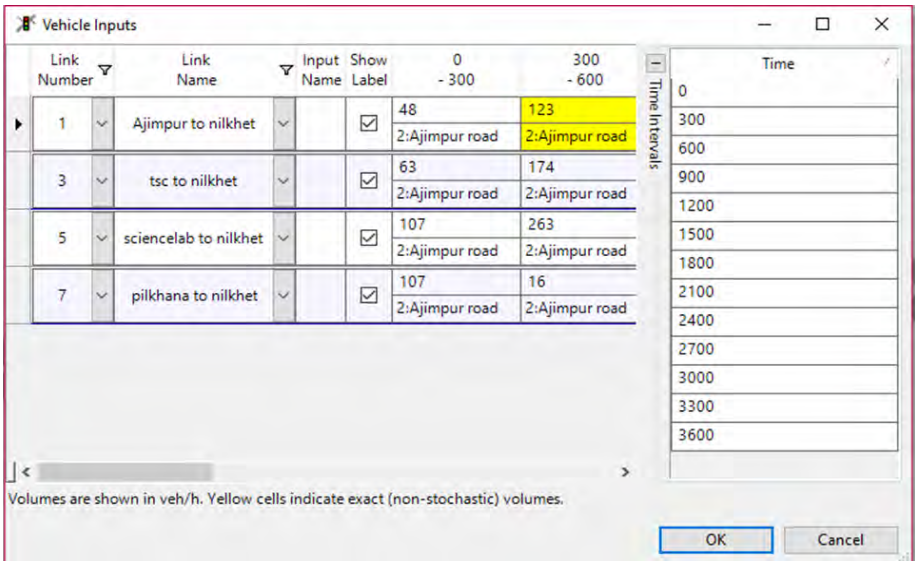


Figure 5.16 Vehicle Input in VISSIM

Routing

From each approach each type of vehicle was assigned with different routes to other approaches. Then after selecting a certain link a particluar vehicle class was selected and the number of that vehicle is assigned in each of those routes. In this figure below it is seen different hourly volume of motorcycles for different routes diverting their journey from Azimpur approach to other four approaches.

Driving behavior

By default, VISSIMs' input is activated as lane-based traffic condition. But in Polashi intersection this study has found non lane based and heterogeneous traffic. So it is needed to change the driving behavior in VISSIM.

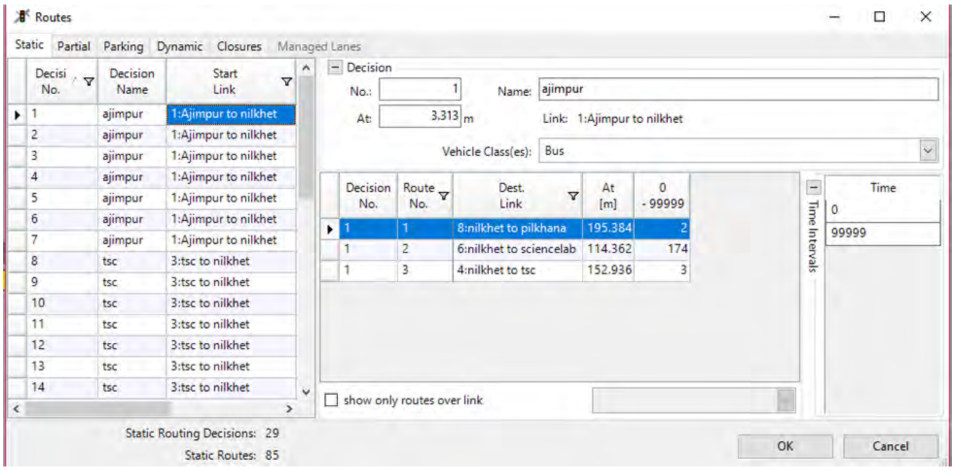


Figure 5.17 Creation of Routes

After creation of Nilkhet traffic inside parameters are changed. Inside 'Following' tab average standstill distance is changed to 0.3 m. Maximum look ahead distance, maximum look back distance is provided 25m both. A duration of 4 sec lack of attention of drivers in the road and probability 30% is provided.

In the next tab 'Lane change' the default parameters are not changed. In lateral tab under 'overtake in both lane' both 'on left' and 'on right' is activated. Under 'minimum lateral distance' distance at 0 kmph is provided 0.2. In the desired position at free flow 'Diamond shaped queuing' is activated by which it is meant that vehicles have to use any lane whichever is convenient for easy travelling. Resulting widow presents in Figure.

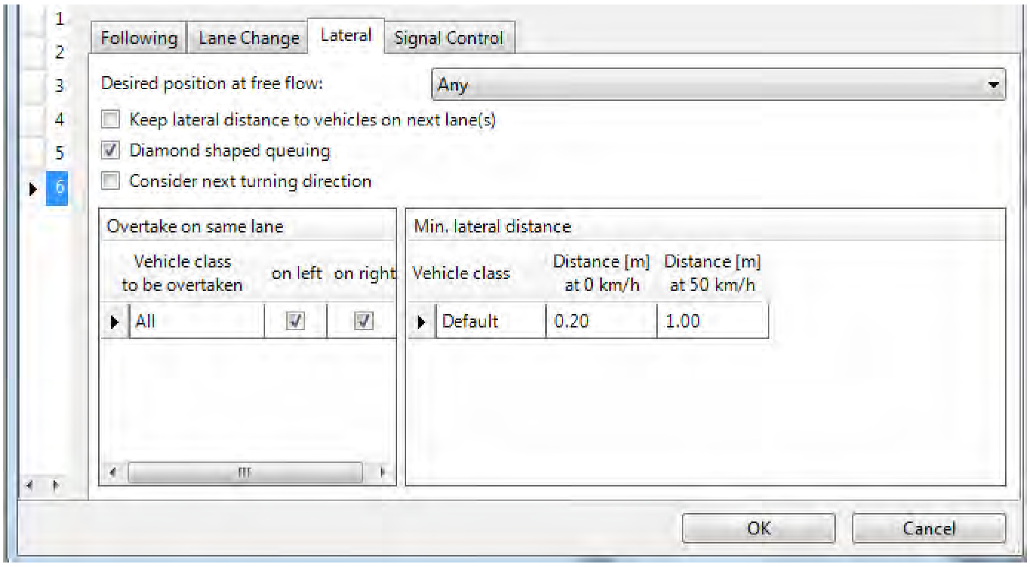


Figure 5.18 Resulting Window for Lateral Option Under 'Driving Behavior'

After modifying the Driving behavior for Nilkhet Intersection, lane behavior is selected.

5.5 Analysis for Nilkhet

After modeling analysis for Nilkhet is done by observing field cycle time. For field cycle time some parameters were investigated. After that, cycle time is changed to investigate the effects. Another purpose of the analysis is to determine the optimum cycle time for the traffic condition. Details is given below.

5.5.1. Change in cycle time

For Nilkhet intersection field cycle time was 392 seconds. Simulation time was 600sec. Using, this cycle time average delay for all types of vehicles, travel time and speed was evaluated. Speed and delay calculation were done manually also. Fig 5.19 shows travel time was 1.395 hr, average delay per vehicle was 44.417 sec and average speed was 1.806 kmph. And then cycle time was changed. Cycle time was decreased by 7 to 15% and increased by 7%. It has been observed that, decrease in cycle time increase the average speed and decrease travel time. Maximum speed was found for cycle time 364 seconds which was 1.954 kmph and average delay was 29.186 sec. (Fig 5.21). In Fig 5.20 an increase in cycle time by 7% shows that, speed was 1.832 kmph. So, the speed increase by 1.44% and consequently delay decreased. In this case, cycle time was 420 sec. By increasing and decreasing the cycle time average delay, speed and travel time for all types of vehicles were found from the software. Results from a decrease in 8% and 15% from field cycle time are shown in Fig 5.23 and 5.24.

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.806;
Total delay time [h], All Vehicle Types	;	0.753;
Average delay time per vehicle [s], All Vehicle Types	;	44.417;
Average speed [km/h], All Vehicle Types	;	1.806;

Figure 5.19 Simulation for Field Cycle Time

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.832;
Total delay time [h], All Vehicle Types	;	0.719;
Average delay time per vehicle [s], All Vehicle Types	;	42.424;
Average speed [km/h], All Vehicle Types	;	1.832;

Figure 5.20 Output from Increasing Cycle Time (7%)

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.954;
Total delay time [h], All Vehicle Types	;	0.495;
Average delay time per vehicle [s], All Vehicle Types	;	29.186;
Average speed [km/h], All Vehicle Types	;	1.954;

Figure 5.21 Output from Decreasing Cycle Time (7%)

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.954;
Total delay time [h], All Vehicle Types	;	0.495;
Average delay time per vehicle [s], All Vehicle Types	;	29.186;
Average speed [km/h], All Vehicle Types	;	1.954;

Figure 5.22 Output from Decreasing Cycle Time (7%)

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                                    ;         Value;
 Average speed [km/h], All Vehicle Types                      ;         1.925;
 Total delay time [h], All Vehicle Types                      ;         0.544;
 Average delay time per vehicle [s], All Vehicle Types        ;        32.078;
 Average speed [km/h], All Vehicle Types                      ;         1.925;
```

Figure 5.23 Output from Decreasing Cycle Time (8%)

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                                    ;         Value;
 Average speed [km/h], All Vehicle Types                      ;         1.938;
 Total delay time [h], All Vehicle Types                      ;         0.520;
 Average delay time per vehicle [s], All Vehicle Types        ;        30.708;
 Average speed [km/h], All Vehicle Types                      ;         1.938;
```

Figure 5.24 Output from Decreasing Cycle Time (15%)

5.5.2 Change in green time

In next step, cycle time was fixed. But for each cycle time, i.e. field cycle time, increased and decreased cycle time; green time was changed to investigate the effect on travel time, speed and delay. The results are shown in Fig. It has been observed that, in all cases a change in green time increase the speed of vehicles.

Fig 5.25 shows, for field cycle time a change in green time increase speed from 1.806 to 1.885. So, there an increase in 4.4% speed. Fig 5.26 shows the results for cycle time 420 sec (7% increase from field). Here also speed increased 1.832 to 1.954 kmph. So, there is 6.7% increase in speed. Fig 5.27 and 5.28 shows the results for cycle time 360 and 332 seconds respectively. Among all cases, maximum speed was found for cycle time 332 sec , which is 2.015 kmph and for this cycle time delay is 22.74.sec.

Fig 5.29 shows the graphical presentation of speed variations for different cycle time. Maximum speed is 2.015kmph and minimum is 1.89 kmph for cycle time 332 sec and 392 sec respectively. Fig 5.30 shows speed analysis from manual and software. It has been found manually that the speed of the intersection was 1.85 kmph and delay was almost 38 sec. (Fig 5.31). Fig 5.26 shows variation of delay for different cycle time and maximum delay was found for field cycle time 392 sec, i.e. 36 sec. per veh.

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.885;
Total delay time [h], All Vehicle Types	;	0.613;
Average delay time per vehicle [s], All Vehicle Types	;	36.194;
Average speed [km/h], All Vehicle Types	;	1.885;

Figure 5.25 Simulation for Field Cycle Time with Increased Green Time

VISSIM: 5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter	;	Value;
Average speed [km/h], All Vehicle Types	;	1.954;
Total delay time [h], All Vehicle Types	;	0.495;
Average delay time per vehicle [s], All Vehicle Types	;	29.186;
Average speed [km/h], All Vehicle Types	;	1.954;

Figure 5.26 Simulation for Cycle Time 420 sec

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter                                              ;        Value;
Average speed [km/h], All Vehicle Types                ;        1.989;
Total delay time [h], All Vehicle Types                ;        0.428;
Average delay time per vehicle [s], All Vehicle Types  ;       25.270;
Average speed [km/h], All Vehicle Types                ;        1.989;
```

Figure 5.27 Simulation for Cycle Time 360 sec

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

Parameter                                              ;        Value;
Average speed [km/h], All Vehicle Types                ;        2.015;
Total delay time [h], All Vehicle Types                ;        0.385;
Average delay time per vehicle [s], All Vehicle Types  ;       22.740;
Average speed [km/h], All Vehicle Types                ;        2.015;
```

Figure 5.28 Simulation for Cycle Time 332 sec

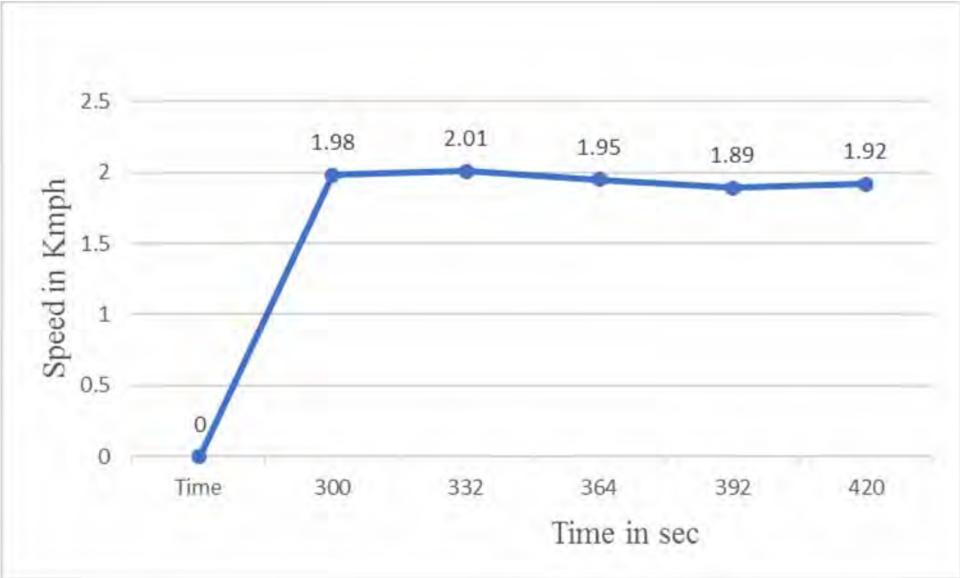


Figure 5.29 Variation of Speed for Different Cycle Time

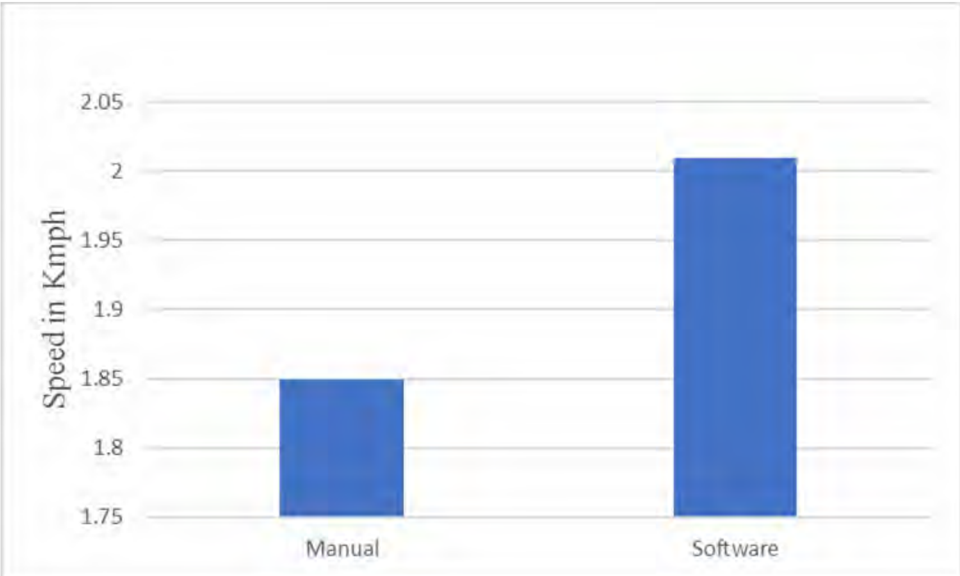


Figure 5.30 Speed Analysis from Manual and Software

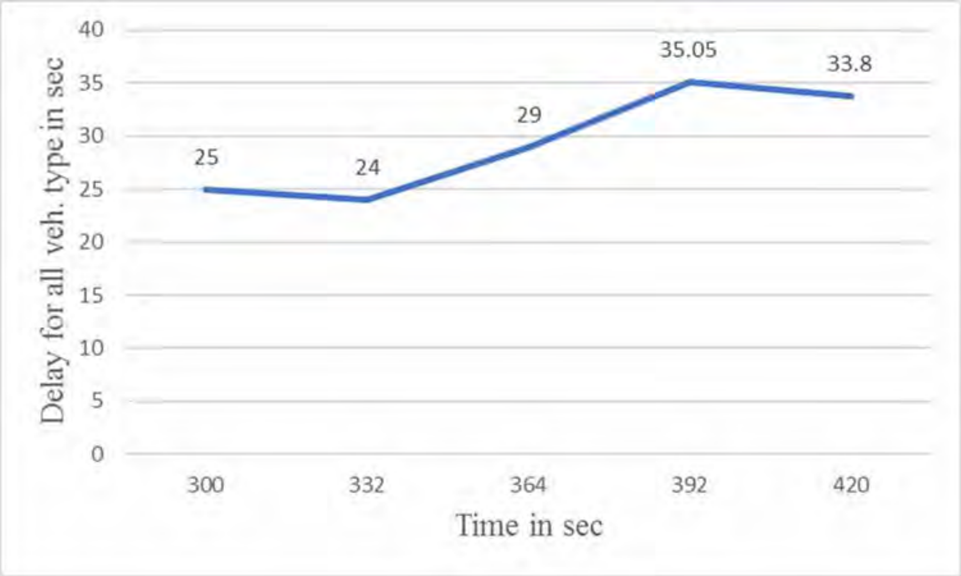


Figure 5.31 Variation of Delay for Different Cycle Time

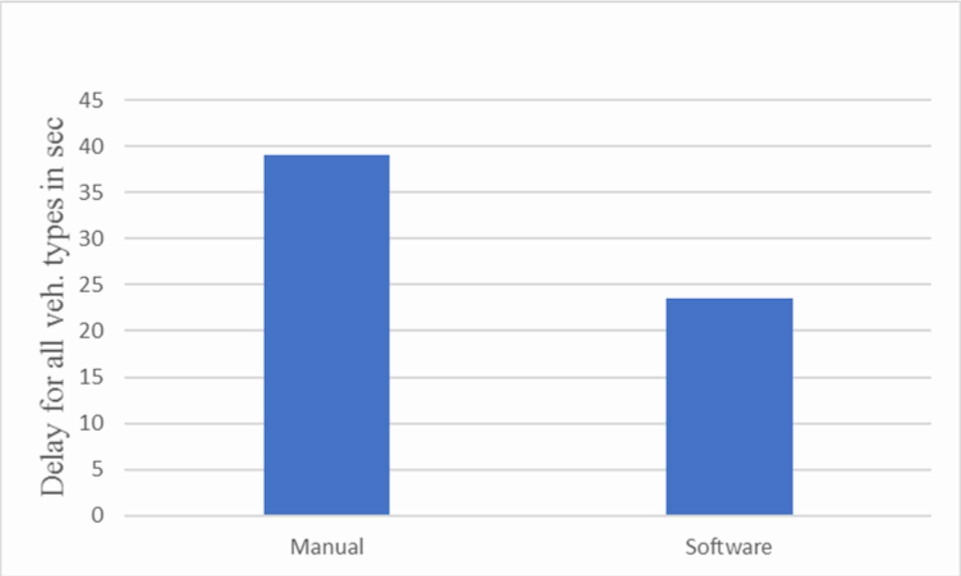


Figure 5.32 Delay Analysis from Manual and Software

5.6 Analysis for Shahbag

For Shahbag analysis is done by observing field cycle time. For field cycle time some parameters were investigated. After that, cycle time is changed to investigate the effects. Another purpose of the analysis is to determine the optimum cycle time for the traffic condition. Details is given below.

5.6.1. Change in cycle time

For Shahbag intersection field cycle time was 240 seconds. Simulation time was 600sec. Using, this cycle time average delay for all types of vehicles, travel time and speed was evaluated. Speed and delay calculation were done manually also. Fig 5.33 shows travel time was 1.1 hr, average delay per vehicle was 34.633 sec per veh. and average speed was 4.224 kmph.

And then cycle time was changed. Here, an increase of 25% cycle time reduces the speed about 10.7% and the speed was found as 3.770 kmph for cycle time 300 sec in Fig 5.34. On the other hand, a reduction in cycle time to 220 sec shown in Fig 5.35 increase 6.1% speed of overall all vehicles. It has been observed that here also that, a decrease in cycle time increase the average speed and decrease travel time.

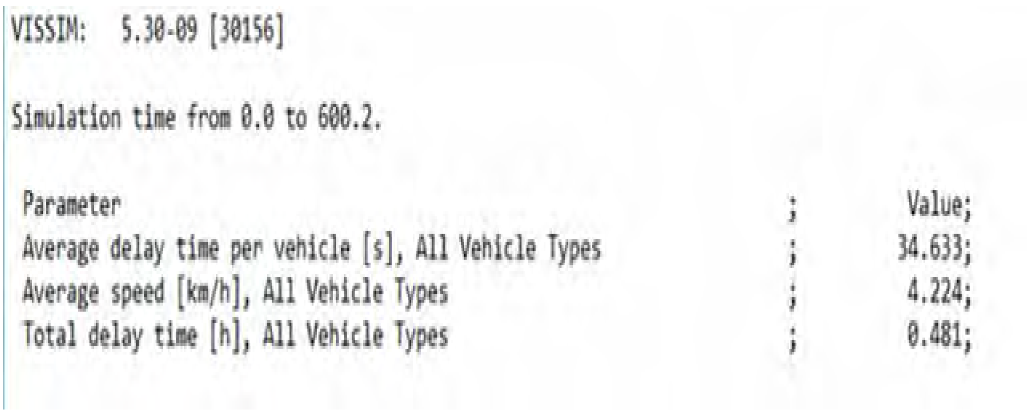


Figure 5.33 Simulation for Field Cycle Time (240 sec)

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                                   ;      Value;
 Average delay time per vehicle [s], All Vehicle Types       ;     51.127;
 Average speed [km/h], All Vehicle Types                     ;      3.770;
 Total delay time [h], All Vehicle Types                     ;      0.710;
```

Figure 5.34 Output from Increasing Cycle Time (25%)

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                                   ;      Value;
 Average delay time per vehicle [s], All Vehicle Types       ;     27.824;
 Average speed [km/h], All Vehicle Types                     ;      4.482;
 Total delay time [h], All Vehicle Types                     ;      0.386;
```

Figure 5.35 Output from Decreasing Cycle Time (220 sec)

5.6.2 Change in green time

In next step, cycle time was fixed. But for each cycle time, i.e field cycle time, increased and decreased cycle time; green time was changed to investigate the effect on travel time, speed and delay. The results are shown in Fig. In case of field cycle time, no change was observed though green time was changed. Fig 5.36 shows, the results for cycle time 300 sec. Here a bit decrease in speed was observed due to change in green time. The speed decreased from 3.77 kmph to 3.70 kmph i.e. 1.85%. Fig 5.37 shows the results 220 sec cycle time but change in green time. Here also a mild decrease in speed was observed. (4.38kmph from 4.48 kmph). Fig 5.33 and 5.34 show speed and delay variation for different cycle time. Fig 5.40 and 5.41 show the variation of speed and delay between manual and software calculation. Manually avg. speed was found to be 3.75 and from software it was 4.38 kmph. Manually, delay was found as 36.4 sec per veh while from software delay was 30.8 kmph. So, results for Shabag intersection varies a lot from that of Nilkhet. A major reason may be the more presence of NMV at Nilkhet.

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                          ;        Value;
 Average delay time per vehicle [s], All Vehicle Types ;     53.852;
 Average speed [km/h], All Vehicle Types            ;        3.701;
 Total delay time [h], All Vehicle Types            ;        0.748;
```

Figure 5.36 Simulation for Cycle Time 300 sec

```
VISSIM:   5.30-09 [30156]

Simulation time from 0.0 to 600.2.

 Parameter                                          ;        Value;
 Average delay time per vehicle [s], All Vehicle Types ;     30.826;
 Average speed [km/h], All Vehicle Types            ;        4.380;
 Total delay time [h], All Vehicle Types            ;        0.428;
```

Figure 5.37 Simulation for Cycle Time 220 sec

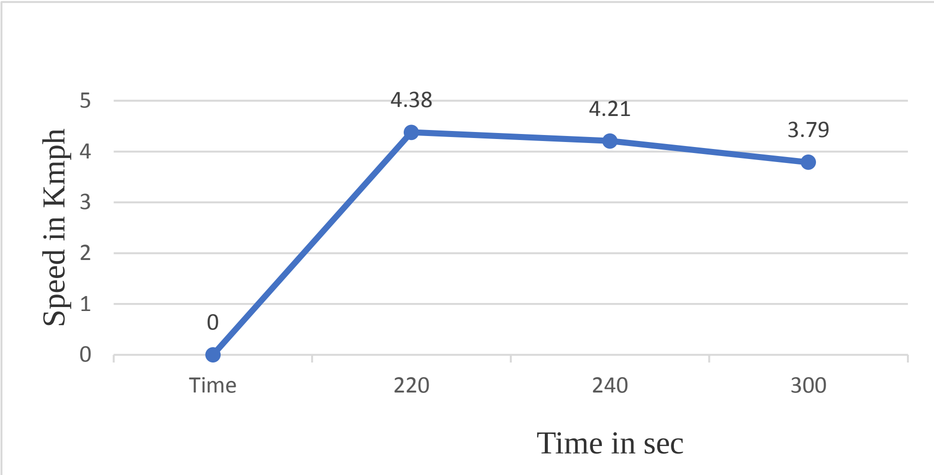


Figure 5.38 Speed Variation for Different Cycle Time

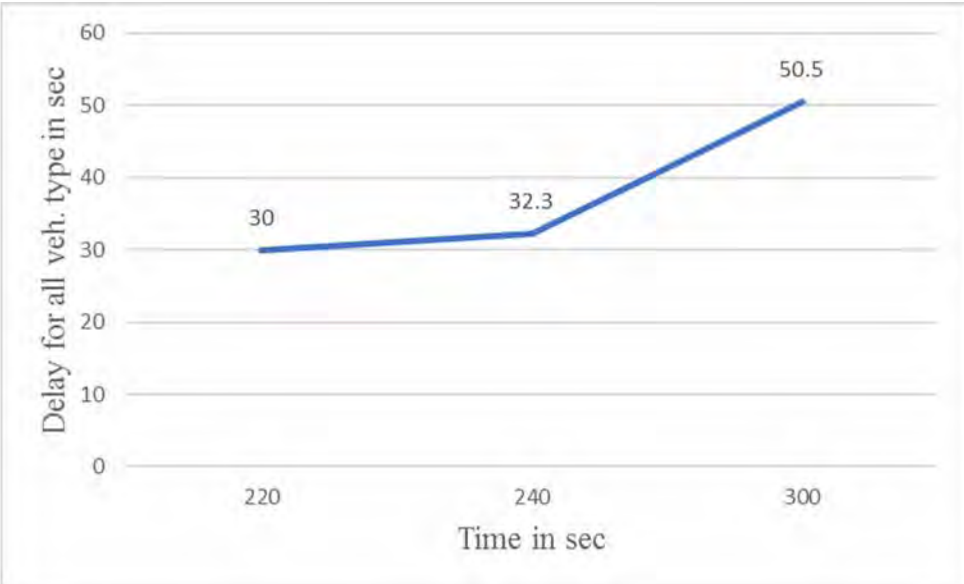


Figure 5.39 Delay Variation for Different Cycle Time

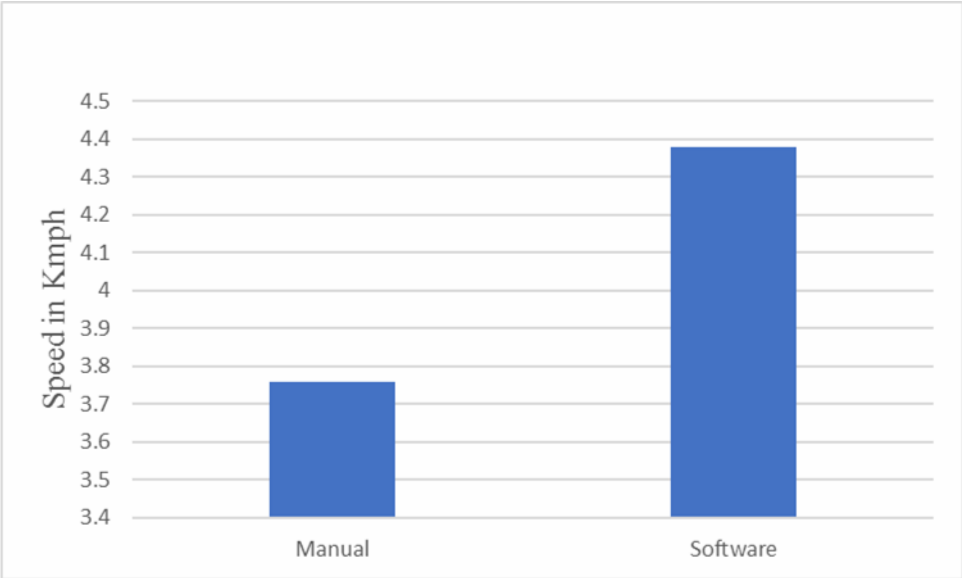


Figure 5.40 Speed Analysis from Manual and Software

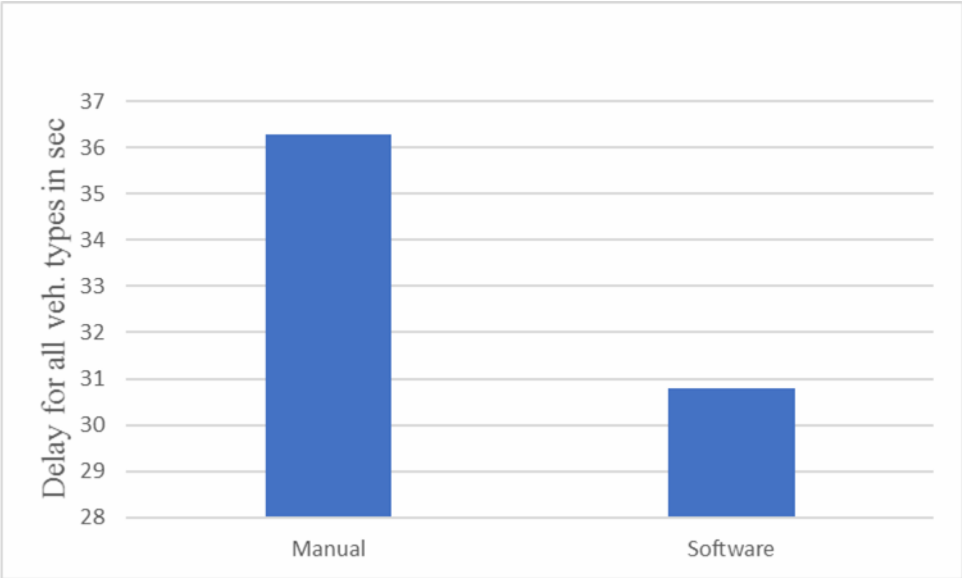


Figure 5.41 Delay Analysis from Manual and Software

5.7 Effect of Forced Behavior Due to NMV

Figure 5.42 shows the discharge profile of vehicles in one hour. Here, it is observed that, NMV proportion is much higher. Second highest vehicle is car and NMV is more than three times higher than car. Lowest category of vehicle discharged during the study period is Bi-cycle. Figure 5.43 shows variation of delay time with and without NMV for different simulation time for Nilkhet intersection. It is observed that, delay time is higher if NMV is present in the network. Fig 5.43 shows highest delay is for simulation time 600 sec and it is 600 sec with NMV and 390 sec without NMV. So, delay is almost 35% higher with NMV at Nilkhet.

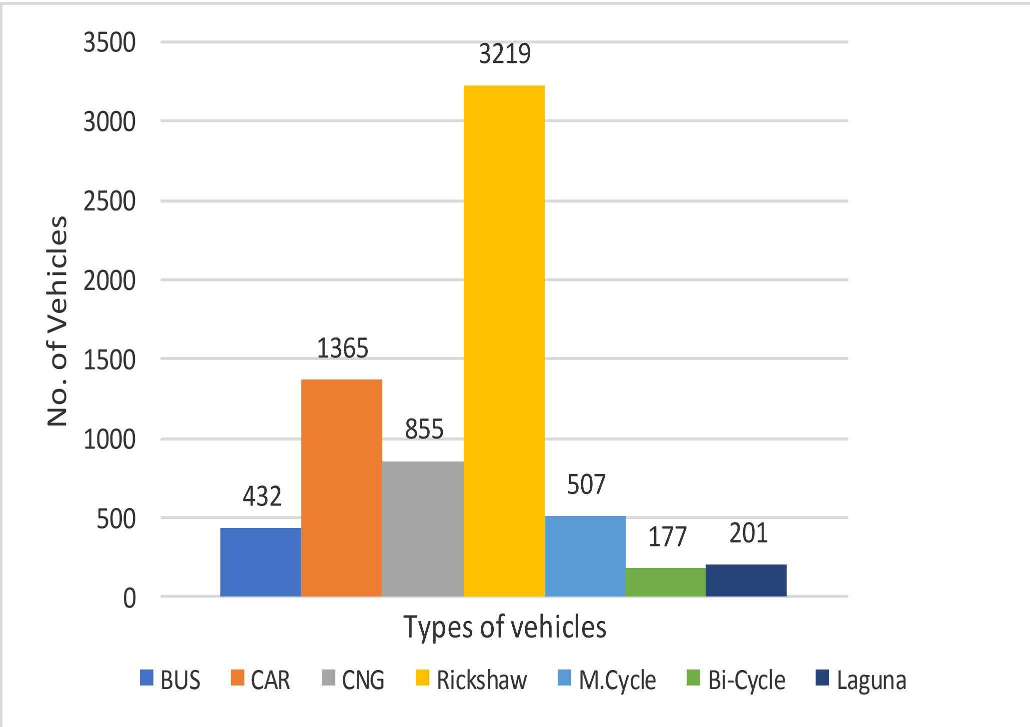


Figure 5.42 Discharge Profile of Vehicles

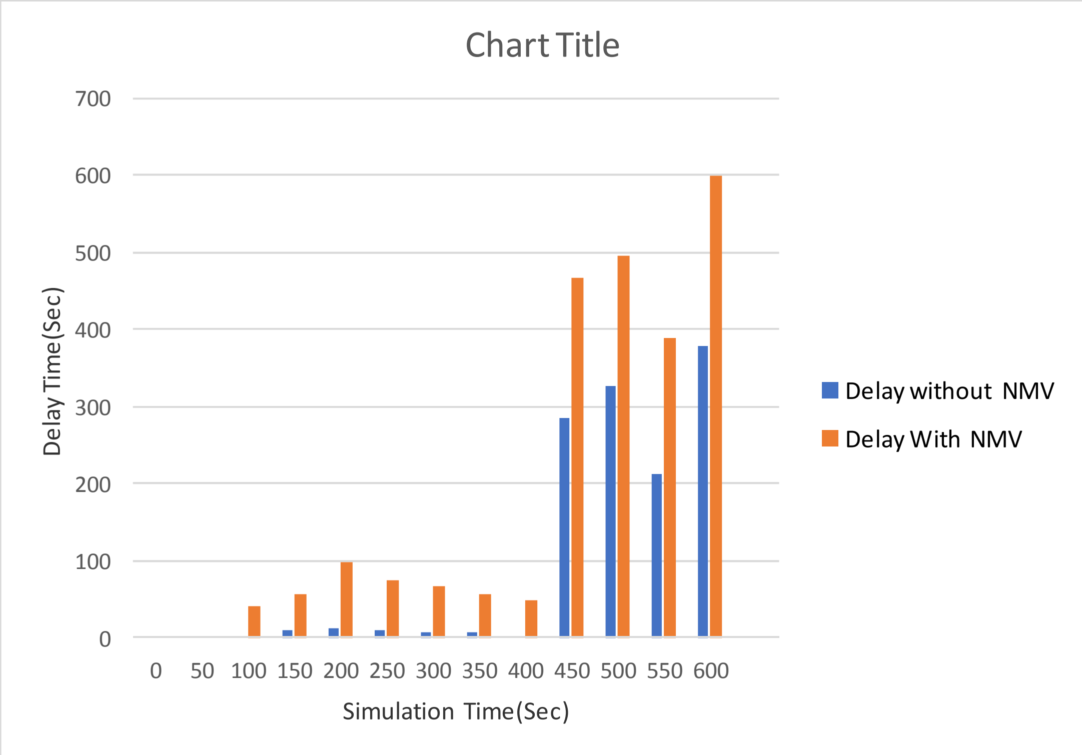


Figure 5.43 Delay Analysis for Nilkhet with and without NMV

5.8 Limitation of Modeling in VISSIM

VISSIM is an excellent microscopic simulation tool. Its prospects are very much higher in transportation fields having intelligent transport system (ITS). But it has some deficiencies, which are as follows:

- It is just a tool for simulating real world scenario. Unless it is provided with an authentic data, it will not give reliable results. It is like a “Black Box”.
- VISSIM is designed for lane based heterogeneous traffic system, which exists predominantly in western region. So for developing or under developed countries the advantage of using this tool becomes restricted.

- Even though there is scope of simulating heterogeneous traffic operation by calibrating some parameters, some real-world scenario is very much difficult; in some cases, it is impossible.
- The full version is not available to all as it is costly, even though student version of it is free with some limited access to certain function. One of them is the simulation period which is restricted to 600s only.

Chapter 6
CONCLUSIONS

6.1 Introduction

This research has focused on the forced behavior of NMV on the road network. To investigate this behavior simulation tool VISSIM 5.30 was used. Required data was collected for modeling the network to develop the model initially and the behavior was observed. The outcomes, limitations of this research and recommendation of further study are discussed in this chapter.

6.2 Conclusions

From the limited study the following conclusions may be drawn:

- The traffic characteristic in Dhaka city has not improved over the years, despite the road users has increased and economical condition of the country boosted.
- NMV in higher volume, forces other traffic to behave not in their desired manner, which is also the same case for larger vehicles in small quantity.
- NMV decreases the overall speed of intersection and increase delay. So, separate lane for non-motorized and motorized vehicles should be provided and strictly regulated.

- It has been observed that here also that, a decrease in cycle time increase the average speed and decrease travel time. It can be mentioned here that, investigation has been done using working model. Discharge is influenced by pedestrian and heterogenous flow which have been minimized here.
- It has been observed that, in all cases increase in green time increase the speed of vehicles.
- Manually speed was found lower than VISSIM and delay was higher also than software. For, Nilkhet it has been found manually that the speed of the intersection was 1.85 kmph and delay was almost 38 sec. For, Shahbag manually avg. speed was found to be 3.75 and from software it was 4.38 kmph. Manually, delay was found as 36.4 sec per veh while from software delay was 30.8 kmph. So, results for Shabag intersection varies a lot from that of Nilkhet. A major reason may be the more presence of NMV at Nilkhet.
- Traffic control should be done by signal system in addition to traffic police.
- Using the VISSIM as a microscopic simulation tools, the effect on certain network parameters can be quantified, yet it is more complex to simulate the heterogeneous non lane-based traffic condition.

6.3 Scope for Further Research

Some of the possible areas for future research are suggested below,

- Calibration and Validation using car following or gap acceptance model could provide better results.
- If extensive data can be collected, more reliable model can be developed to simulate real world scenario.
- Effect of NMV and large vehicles in intersection performance can be evaluated.

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APPENDIX

Nilkhet Intersection

Dhaka University Road:

Date: 12th February, 2019 Time: 1.00pm-2.00pm

Weather condition: Sunny

Table: A.1: Traffic Flow from Dhaka University to Different Direction

Data for 1st 30 minutes

Vehicle Name	0-5		5-10		10-15		15-20		20-25		25-30	
	DU mir	Aji m Pil, K	DU mir	Aji m Pil, K	DU mir	Aji m Pil, K	D U mir	Aji m Pil, K	D U mir	Aji m Pil, K	D U mir	Aji m Pil, K
Bus	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	1	1	-	-	-	-	-	-
Car	-	2	-	6	-	3	-	2	-	5	-	1
	12	5	30	10	25	10	16	5	35	12	25	5
Cng	-	-	-	2	-	1	-	-	-	2	-	-
	2	-	10	-	11	9	4	3	10	-	3	-
Rick	-	-	-	7	-	10	-	-	-	6	-	1
	17	13	56	36	75	35	36	24	40	28	26	15
M.cycl e	-	-	-	-	-	-	-	-	-	-		-
	1	1	-	-	3	-	2	[	15	2	4	1
B.cycle	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	1	-	-	1	-	-	-	-
Laguna	-	-	-	-	-	2	-	-	-	2	-	1
	6	-	17	-	15	-	6	-	9	-	5	-

Table: A.1: Traffic Flow from Dhaka University to Different Direction

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	DU	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**
	Mir.	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**PIL.K**
Bus	-	-	-	-	-	-	-	-	-	-	-	2
	1	-	-	-	-	-	-	-	-	-	-	-
Car	-	4	-	2	-	-	-	1	-	3	-	2
	15	3	10	7	8	5	15	2	14	5	10	5
Cng	-	-	-	-	-	-	-	-	-	2	-	-
	2	3	5	1	7	-	4	1	3	-	3	2
Rick	-	5	-	1	-	1	-	3	-	-	-	2
	35	10	27	15	17	11	22	17	15	11	20	7
M.cycle	-	-	-	1	-	-	-	-	-	-	-	-
	1	-	-	-	2	-	1	-	-	1	3	*
B.cycle	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	2	-	-	-	-	-	-	-	-	1
Leguna	-	-	-	-	-	-	-	1	-	-	-	1
	3	1	4	1	5	1	1	-	5	-	4	-

Ajimpur Road

Date: 12th February, 2019 Time :1.00pm-2.00pm

Weather condition: Sunny day

Table A.2- Traffic Flow from Ajimpur to Different Route

Data for 1st 30 minutes

Vehicle Name	**0-5**		**5-10**		**10-15**		**15-20**		**20-25**		**25-30**	
	DU	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**
	Mir.	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**	**Mir.**	**Pil, K**
Bus	1	-	-	-	-	-	-	-	-	-	-	--
	12	1	13	-	10	-	16	-	21	-	16	-
Car	1	-	-	-	-	-	1	-	1	-	1	-
	16	1	19	-	6	-	-	2	26	2	7	1
CNG	-	-	-	-	-	-	-	-	1	-	-	-
	2	-	12	1	4	-	4	1	5	1	7	2
Rick	-	-	27	1	2	-	1	1	2	3	-	-
	3	-	35	-	10	1	11	-	13	-	-	6
M. cycle	-	-	2	-	-	-	-	-	1	-	-	-
	11	-	13	-	8	-	2	-	12	-	8	-
B. cycle	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	1	-	3	-	1	-	1	-	2	1
Laguna	-	-	-	-	--	-	--	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2- Traffic Flow from Ajimpur to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim
	Mir.	Pil, K	Mir.	Pil, K	Mir.	Pil, K	Mir.	Pil, K	Pil, K	Mir.	Pil, K	Mir.
Bus	-	-	-	-	-	-	1	-	1	-	-	-
	15	-	9	-	25	-	12	1	15	-	10	-
Car	1	-	1	-	1	-	1	-	-	-	-	-
	9	2	16	-	20	1	14	1	19	-	9	-
Cng	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	10		4	1	4	-	10	1	4	-
Rick	-	-	1	-	7	-	-	-	2	-	-	-
	27	-	13	1	10	1	12	-	13	-	10	-
M.cycle	-	-	-	-	-	-	2	1	-	-	1	-
	12	-	15	-	10	-	12	-	8	-	18	1
B.cycle	-	-	-	-	-	-	-	--	-	-	-	-
	1	-	2	-	1	-	-	-	-	-	1	-
Leguna	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	5	-	-	-	-	-	5	-	-	-

Mirpur Road:

Date 12th February2019 Time :1.00pm-2.00pm

Weather condition: Sunny Day

Table A.3 Traffic Flow from Mirpur to Different Route

Data for 1st 30 minutes

Vehicle Name	0-5		5-10		10-15		15-20		20-25		25-30	
	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim
	Mir.	PilK	Mir.	Pil, K	Mir.	Pil, K	Mir.	Pil, K	Mir.	Pil, K	Mir.	Pil, K
Bus	-	10	1	16	-	4	-	26	-	7	-	15
	-	-	-	-	-	-	-	-	-	-	-	-
Car	6	5	18	22	20	18	21	26	9	1	17	22
	-	2	-	17	-	8	-	12	-	3	-	7
CNG	10	5	13	10	11	10	16	8	9	5	5	9
	-	-	-	8	-	4	-	3	-	-	-	1
Rickshaw	46	16	61	34	67	14	65	59	51	11	58	19
	*	4	-	12	-	11	-	13	-	-	-	4
m. cycle	2	-	15	9	8	7	16	11	4	1	2	3
	-	-	-	-	-	3	-	-	-	-	*	2
Bi .Cycle	3	-	7	5	3	1	5	2	1	1	1	3
	-	-	-	-	-	-	-	-	-	-	-	-
Laguna	3	*	7	6	2	1	2	1	1	1	1	2
	-	-	-	3	-	-	-	2	-	-	-	2

Table A.3 Traffic Flow from Mirpur to Different Route

For 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim	DU	Ajim
	Mir.	Pil,K	Mir.	Pil.K	Mir.	Pil.K	Mir.	Pil.K	Mir.	pil.k	Mir.	pil.k
Bus	-	9	-	12	-	18	-	3	-	8	-	15
	-	-	-	-	-	-	-	-	-	-	-	-
Car	19	14	18	16	11	24	6	7	15	19	12	22
	-	2	-	3	-	7	-	4	-	10	-	12
CNG	3	5	3	11	17	9	18	12	6	15	12	9
	*	2	-	7	-	9	-	4	-	9	-	7
Ricks	61	22	54	48	58	34	53	18	62	30	67	48
	-	11	-	8	-	16	-	5	-	12	-	21
m.cyc	2	5	4	9	3	13	2	1	14	9	6	2
	-	3	-	-	-	4	-	2	-	3	-	4
By.Cy	5	2	4	1	2	3	-	1	3	-	2	-
	-	-	-	-	-	2	--	-	-	-	-	2
Legun	1	3	-	2	-	4	3	2	-	4	2	5
	-	-	-	-	-	1	-	2	-	3	-	1

Pilkhana Road:

Date: 12th September Time :1.00pm-2.00pm

Weather condition: Hot day

Table A.4 Traffic Flow from Pilkhana to Different Route

Data for 1st 30 minutes

Vehicle Name	**0-5**		**5-10**		**10-15**		**15-20**		**20-25**		**25-30**	
	DU	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**	**DU**	**Ajim**
	Mir.	**Pil,K**	**Mir.**	**Pil,K**	**Mir.**	**Pil,K**	**Mir.**	**Pil,K**	**Mir.**	**Pil,K**	**Mir.**	**Pil,K**
Bus	-	-	-	-	-	-	-	-	-	-	1	-
	-	-		-	-	--		-	-	-	--	-
Car	5	3	-	-	3	-	2	2	-	-	14	7
	7	0	7	-	-	-	11	-	12	-	13	-
CNG	5	-	-	-	1	-	-	-	-	-	3	2
	1	-	1	-	-	-	-	-	2	-	4	-
Rick	55	7	-	-	34	20	-	-	-	-	60	12
	11		6	-	-	-	8	-	13	-	10	-
M.cycle	5	2	-	-	13	4	*	-	-	-	10	3
	1	-	2	-	-	-	2	-	-	-	6	-
B.cycle	2	1	-	-	-	1	-	-	-	-	5	2
	2	-	-	-	-	-	-	-	-		2	-
leguna	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-

Table A.4 Traffic Flow from Pilkhana to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	DU Mir.	**Ajim Pil,K**	**DU Mir.**	**Ajim Pil,K**	**DU Mir.**	**Ajim Pil,K**	**DU Mir.**	**Ajim Pil.K**	**DU Mir.**	**Ajim pil,k**	**DU Mir.**	**Ajim pil.k**
Bus	*	*	1	*	*	*	*	2	*	*	*	*----
	*	*	*	*	*	*	*	*	*	*	*	*
Car	*	*	15	7	*	*	14	8	*	*	12	3
	6	*	13	2	8	1	11	*	10	*	9	*
CNG	*	*	4	1	*	*	3	2	*	*	2	*
	3	*	2	*	*	*	4	*	2	*	*	*
Rickshaw	*	*	72	12	*	*	57	15	*	*	31	8
	8	3	10	4	9	2	13	8	7	2	11	3
M. cycle	*	*	10	4	*	*	6	4	*	*	2	3
	2	1	3	1	5	*	4	2	2	*	3	1
B. cycle	*	*	4	1	*	*	3	2	*	*	2	*
	*	*	1	*	*	*	3	1	1	*	2	*
Laguna	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	3	*	*	*	*	*	*	*	1	*

Shahbag Intersection:

Banglamotor Road

Date: 18th January 2019 Time 1.00pm-2.00pm

Weather condition :Cold

Table A.5. Traffic Flow from Banglamotor to Different Route

Data for 1st 30 minutes

Vehicle Name	**0-5**		**5-10**		**10-15**		**15-20**		**20-25**		**25-30**	
	Mot.	**K**	**Mot.**	**K**	**Mot.**	**K**	**Mot.**	**K**	**Mot.**	**K**	**Mot.**	**K**
	Ban.m	**TSC**	**Ban.m**	**TSC**	**Ban.m**	**TSC**	**Ban.m**	**TSC**	**Ban.m**	**TSC**	**Ban.m**	**TSC**
Bus	12	-	-	-	8	-	4	-	7	6	1	-
	-	-	-	-	-	1	-	-	*	2	-	1
Car	10	7	3	8	5	7	3	16	3	9	4	14
	-	4	-	15	-	20	-	14	-	25	-	5
Cng	5	3	3	8	8	2	7	11	6	6	2	7
	-	8	-	5	-	12	-	15	-	24	-	20
m.cycle	6	3	4	-	3	-	3	4	7	1	5	-
	-	3	-	9	-	1	-	5	-	7	-	7
Rickshaw	-	-	-	-	-	-	-	-	--	-	-	-
	-	-	-	-	-	-	-	-		-	--	--
Bicycle	-	-	1	-	-	1	-	-	-	2	-	1
	-	-	-	1	-	-	-	-	-	1	-	1
Laguna	2	-	1	1	-	2	1	3	-	1	2	3
	-	1	-	1	-	-	-	-	-	-	-	-

Table A.5. Traffic Flow from Banglamotor to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	K
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	2	-	14	-	8	-	4	-	9	-	11	-
	-	-	-	5	-	1	-	-	-	1	-	1
Car	2	26	4	4	4	35	7	*	2	30	8	14
	-	35	-	4	-	40	*	1	-	12	-	26
Cng	6	6	3	1	5	15	4	-	4	21	7	5
	-	32	-	5		30	-	2	-	25	-	29
m. cycle	6	7	2	-	5	9	3	4	4	3	6	5
	-	2	-	25	-	5	-	3	-	6	-	4
Rickshaw	-	-	-	-	-	-	--	-	-	--	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
Bicycle	1	-	-	-	-	2	1	1	-	1	1	-
	-	-	-	-	-	1	-	-	-	2	-	-
Laguna	-	2	1	-	-	1	-	-	1	2	1	1
	-	1	-	-	-	1	-	-	-	-	-	2

Motshobhoban Road:

Date:18th January 2019 Time:1.00pm-2.00pm

Weather condition: Cold

Table A.6 Traffic Flow from Motshobhobon to Different Route

Data for 1st 30 minutes

Vehicle Name	0-5		5-10		10-15		15-20		20-25		25-30	
	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	-	18	-	20	-	15	-	13	-	12	-	24
	6	-	10	1	7	-	8	-	7	1	14	-
Car	-	7	-	8	-	7	-	16	-	9	-	14
	9	2	10	5	12	3	25	3	20	4	9	4
Cng	-	16	-	5	-	3	-	9	-	3	-	7
	4	6	13	2	4	10	8	11	4	5	8	3
m. cycle	*	9	-	3	-	1	-	6	-	3	-	7
	6	3	5	-	2	-	2	4	6	1	5	-
Rickshaw	-	1	-	4	-	3	-	2	-	4	-	4
	1	4	1	1	3	3	1	3	1	*	1	5
Bicycle	-	--	-	1	-	-	-	-	-	1	-	1
	-	2	-	1	1	-	-	1	-	*	2	1
Laguna	-	2	-	1	-	-	-	-	-	1	-	1
	-	-	1	1	2	2	2	3	3	2	3	2

Table A.6 Traffic Flow from Motshobhobon to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	-	17	-	12	-	10	-	8	-	16	-	14
	12	-	8	--	6	-	4	-	8	-	5	1
Car	-	26	-	5	-	32	-	10	-	25	-	10
	6	2	1	3	26	7	4	3	12	8	6	1
Cng	-	8	-	4	-	7	-	11	-	21	-	24
	10	3	7	5	4	5	9	4	15	9	17	4
m.cycle	-	7	-	2	-	20	-	1	-	4	-	6
	6	7	1	-	8	9	3	4	1	3	1	5
Rickshaw	-	10	-	1	0	10	-	-	-	2	-	4
	1	4	4	6	2	8	4	7	4	5	4	4
Bicycle	-	-	-	-	-	1	-	-	-	1	-	-
	-	2	1	-	-	1	-	-	-	-	-	1
Laguna	-	-	-	1	-	-	-	2	-	-	-	-
	2	-	-	1	1	-	-	-	2	2	1	-

TSC Road:

Date :18th January 2019 Time 1.00pm- 2.00pm

Weather condition: Cold

Table A.7. Traffic Flow from TSC to Different Route

Data for 1st 30 minutes

Vehicle Name	0-5		5-10		10-15		15-20		20-25		25-30	
	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	-	-	1	-	-	-	-	-	2	-	-	-
	1	-	4	-	3	-	2	-	4	--	4	-
Car	7	2	8	5	7	3	9	3	11	4	4	4
	17	*	22	-	17	-	30	-	20	-	8	-
Cng	4	18	13	20	4	15	10	13	4	12	7	29
	12	-	3	-	17	-	21	-	24	-	22	-
m.cycle	3	3	-	12	-	1	4	9	1	3	-	4
	6	-	2	*	10	-	9	-	5	-	3	-
Rickshaw	-	16	2	4	2	23	2	27	3	25	1	35
	-	-	1	-	-	-	-	-	-	-	1	-
Bicycle	1	4	2	1	2	3	1	3	-	-	--	1
	4	-	13	-	4	-	10	-	4	-	7	-
Laguna	-	-	-	1	1	3	-	-	1	-	-	2
	-	-	1	-	2	-	3	-	1	-	3	-

Table A.7. Traffic Flow from TSC to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka	Mot	Ka
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	3	-	-	-	-	-	-	-	-	-	1	-
	10	-	1	-	10	-	-	-	2	-	5	-
Car	26	2	-	3	30	7	-	3	14	8	15	7
	42	-	6	-	46	-	1	-	40	-	26	-
Cng	8	21	5	22	9	14	--	14	13	16	9	22
	35	-	4	-	38	-	4	-	29	-	31	-
m.cycle	7	1	-	2	9	5	4	-	3	9	5	5
	4	-	3	-	4	-	4	-	5	-	9	-
Rickshaw	3	38	1	4	1	29	5	31	4	4	-	22
	-	-	-	-	-	-	--	-	-	-	-	--
Bicycle	1	1	-	1	-	-	-	2	1	4	-	-
	8	-	5	-	4	-	-	-	9	-	13	-
Laguna	3	1	-	-	-	-	2	-	1	1	1	-
	2	-	-	-	1	-	-	-	2	-	1	-

Katabon Road:

Date :18th January 2019 Time 1.00pm- 2.00pm

Weather condition: Cold

Table A.8. Traffic Flow from Katabon to Different Route

Data for 1st 30 minutes

Vehicle Name	0-5		5-10		10-15		15-20		20-25		25-30	
	M	K	M	K	M	K	M	K	M	K	M	K
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	5	0	0	0	7	0	2	0	5	0	6	0
	1	0	0	0	2	0	1	0	2	0	0	0
Car	15	0	20	0	41	0	27	0	18	0	10	0
	1	1	3	2	2	1	1	0	1	7	2	3
Cng	12	0	19	0	34	0	21	0	20	0	4	0
	8	10	12	5	18	7	22	8	7	2	8	5
m. cycle	8	0	7	0	6	0	4	0	7	0	8	0
	2	1	4	3	6	1	3	2	7	1	2	0
Rickshaw	8	0	6	0	2	0	5	0	2	0	3	0
	0	1	0	3	0	2	0	3	0	4	0	2
Bicycle	0	0	0	0	1	0	0	0	1	0	0	0
	0	2	0	1	0	1	0	0	0	2	0	3
Laguna	2	0	3	0	4	0	2	0	3	0	1	0
	0	0	0	0	0	0	0	0	0	0	0	0

Table A.8. Traffic Flow from Katabon to Different Route

Data for 2nd 30 minutes

Vehicle Name	30-35		35-40		40-45		45-50		50-55		55-60	
	M	K	M	K	M	K	M	K	M	K	M	K
	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC	Ban.m	TSC
Bus	2	0	3	0	1	0	4	0	0	0	1	0
	0	0	2	0	1	0	0	0	0	0	0	0
Car	21	0	12	0	8	0	8	0	22	0	9	0
	3	0	4	0	2	1	3	1	1	0	1	0
Cng	7	0	30	0	22	0	11	0	7	0	8	0
	5	4	10	2	15	3	2	7	4	4	4	3
m.cycle	4	0	3	0	8	0	5	0	4	0	6	0
	4	2	2	0	1	0	2	1	1	0	0	1
Rickshaw	2	0	3	0	1	0	3	0	0	0	0	0
	0	1	0	1	0	2	3	3	0	1	0	1
Bicycle	1	0	0	0	0	0	1	0	0	0	1	0
	0	1	0	0	0	2	0	3	0	1	0	2
Laguna	2	0	3	0	0	0	0	0	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0