CHAPTER ONE

INTRODUCTION

1.1 Introduction

A transportations system can be defined as the combination of elements and their interactions, which produce the demand for travel within a given area and the supply of transportation services to satisfy this demand. Transportation system is one of the most fundamental components of the socio-economic and physical structure of an urban settlement. A well-planned and developed transportation system not only provides opportunities for mobility of the people, but also influences the growth pattern and the level of economic activity of a city (Meyer and Miller, 1984). Traffic management is the planning, monitoring and control or influencing of traffic. It aims to: maximize the effectiveness of the use of existing infrastructure; ensure reliable and safe operation of transport; address environmental goals; and ensure fair allocation of infrastructure space (road space, rail slots, etc.) among competing users (European Communities, 2009). Traffic Management maximizes the use of existing road space, using traffic operations enforcement, materials and equipment to achieve safe and efficient movements.

Bangladesh gained independence in 1971 and then, the transportation sector grew rapidly and transportation medium on land and rivers began to develop. Air travel came into existence later. Though Bangladesh has greatly evolved in the transportation sector, it still, unfortunately, has many flaws which hamper the development of other economic and social sectors. The transportation has evolved in mostly with land vehicles but it still needs improvement with safety standards which endangers the life of civilians. In Bangladesh, among the various modes of transport, road transport system has been playing a significant role in transporting passengers and goods. The Roads and Highway Department (RHD) manage several categories of road. RHD has total length of 20,948 km. road under its control. RHD also control a total number of 4,659 bridges and 6,122 culverts. RHD are currently operating about 161 ferry boats in 81 crossings on its road network throughout the country (Bangladesh Economic Zone Authority).

1.2 Background

Chittagong is the second largest city in Bangladesh as well as the second largest metropolitan in Bangladesh after Dhaka. Chittagong, also known as the second capital city of Bangladesh is the least motorized mega city but the second most densely populated city after Dhaka with a current population of almost 10 million at annual growth rate of 5% per annum (STP, 2006). The population of Chittagong Metropolitan area is presently estimated to be 8.5 million people (STP, 2006), a number that is expected to double by 2025. For such a large city and huge travel demand, mass transit is a prerequisite for its transportation system. Present contribution of mass transit is only 29% of the passenger trips where mass transit should share 75% of the total trips to provide an efficient transportation system (STP, 2006). Chittagong is the city of its size without a well-organized, properly scheduled bus system or any type of mass rapid transit system. The transport modes in metropolitan Chittagong are classified in three major groups on the base of type of operation and usage. These groups are private transport, Para transit and mass transit. Para transit and mass transit together are also termed as urban public transport. Trends showed that growth rate for the low occupancy travel modes such as cars and cycle rickshaws, were much higher than that for high occupancy travel modes such as buses and mini buses. Rickshaw, which is an outdated mode of transport for a populous and fast growing metropolitan area, comprised about 43.5 percent of total vehicles. Whereas bus which is the major travel mode in most of the developing countries, composed only of 2.7 percent (STP, 2006). As a result, major share of road space remains occupied by the small capacity vehicles. Road spaces are also occupied by other than traffic such as dustbins, construction materials, hawkers, etc. and reduce the effective width of roadway. There are no priority measures for bus or tempo on the road but bus and tempo is the only mass transit option in Chittagong city. This transport situation consequently has increased traffic congestion, travel delay, and accident and deteriorating the accessibility, comfort, safety, operational efficiency and environment. The existing traffic congestion is largely caused by inadequate road usage due to a lack of traffic management. An appropriate systematic traffic management system is essential for safety and smooth traffic flows on roads, making a maximum usage of road facilities to enlarge the current road capacities. The management of the existing road space is badly conceived. There is virtually no control over which vehicles use which roads. Lane discipline does not exist and there is haphazard parking and stopping on the running lanes. There is lack of development coordination between the concerned agencies including Chittagong Development Authority (CDA), Chittagong Metropolitan Police (CMP), and Chittagong City Corporation (CCC). Together, this breakdown in communications and operational service has caused a substantial loss in available capacity. At present there are 40,000 registered and about 2 lakh non-registered rickshaws, CNG’S & buses (Architect Ashiq Imran). To make everything operational they need to run under a system, which required a planning department. The planning department would do all the panning regarding traffic, fixing stoppage for vehicles and creating parking spaces, controlling number of public transports and so on to resolve the chaotic situation in Chittagong port city. The Chittagong Metropolitan Police (CMP) has a huge task in taking control of the violations which take place constantly.

1.3 Objectives of the study

This study is simply aimed at understanding briefly the transportation management on the Chittagong metropolitan selected area.

Therefore in summing up the major objectives of this thesis are:

- To measure the maximum rate of flow of traffic for determining the saturation flow of the selected intersection.

- To determine the existing vehicular flow and capacity of the selected intersection.
- To observe the road marking condition, road surface quality, signs, signals etc.

1.4 Future scope of the study

It poses enormous potentials to be further studied and recommendation best option for selected intersection. The capacity of roadway under uninterrupted condition can be obtained by modifying the capacity of the roadway ideal conditions and develop public awareness also. Speed-flow studies are useful to evaluate the more parameters in transportation engineering. There is a scope on speed flow study on urban road links for future work.

1.5 Limitations of the Study

- Study period was short.
- Traffic polices were not co-operative in many cases.
- People were reluctant to provide information.
- In some cases, weather was a limiting factor.

1.6 Organization of the thesis Work

The thesis has been arranged in the following order also including bibliography of publications and references of websites used for the study.

- Chapter One: This includes the general introduction, the objectives of the study and the limitations of the study.
- Chapter Two: Includes Literature of the various road signs, signals and marking manual are used in the world and in Bangladesh as well as the various types of signs, marking and signals and its figure. This chapter also covers some definitions & parameters.
- Chapter Three: Includes the methodology of the study.
- Chapter Four: Includes the data collection & analysis on traffic signal.
- Chapter Five: Includes conclusions & suggestion to possible changes.

1.7 Summary

From this chapter, it is pointed out that a well-planned and developed transportation system is much required for the Port City Chittagong. Urbanization in Chittagong is essentially a process of migration from rural and smaller towns. The study is dedicated to analyzing present traffic capacity in the selected major transport axis of Chittagong city. The main objective of the study is to measure the maximum rate of flow of traffic for determining the saturation flow as well as the capacity of the selected intersection. Limitations and scope of the study also included in this chapter. Organization of the entire thesis work is also organized briefly in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Chittagong, known as the Port City of Bangladesh, is a major coastal city and financial center in southeastern Bangladesh. Chittagong plays a vital role in the Bangladesh economy. The port of Chittagong, one of the world's oldest port, whose coast appeared on Ptolemy's world map, is the principal maritime gateway to the country. The city is located on the banks of the Karnaphuli River between the Chittagong Hill Tracts and the Bay of Bengal. Modern Chittagong is Bangladesh's second most significant urban center after Dhaka. Urbanization in Chittagong is essentially a process of migration from rural and smaller towns. After the liberation of Bangladesh in 1971, the development processes of Chittagong City rapidly increased. Chittagong City has also been witnessing a tremendous growth in population and physical expansion. The city has now been turned into 83rd most populous city of the world and 49th most populous city in the Asia as well as the 2nd most populous city in Bangladesh after Dhaka (World Statistical Data). The population of Chittagong has grown from only 2 lakhs in 1951 to 5 million in 2020 –a growth of 4.8 million in 70 years (World Population Prospects). As per future prediction, this population will further grow to about 6.3 million by the year 2030 and to 7.1 million by 2035 (World Statistical Data). The city experiences the proliferation of scattered development without appropriate guidance which resulted in huge urban system difficulties. Even, the fringe areas of the city are progressing without any guidance, control and regulation yet which will be one of the main integral parts of the city in the near future. Sporadic residential, commercial and other socio-economic infrastructures like super markets, high-rise buildings or apartments/complexes, garments factories etc. are being constructed at various parts of the city without appropriate consideration of planning principles, resulting indiscipline trip generation. Unplanned mixed land use pattern, presence of Chittagong Port, Cantonment, Navy, CPEZ Point, airport within the core area of the city, heavily centralized government frame structure are directly and indirectly affecting the entire transportation system of the Chittagong city. Inefficient and malfunctioning traffic management is also one of the major problems of Chittagong city transportation system, which is highly responsible for making the existing system more unproductive. Indeed, for the causes of unplanned and nonintegrated road network development, there have very limited scope to apply traditional low cost but very cost-effective traffic management measures. Crisis in the transportation system has considerably affecting the physical form and functional performance of the city. It is progressively deteriorating the entire social and physical environment causing suffering and inconveniences to the people. With ever growing increasing travel demand resulting from phenomenal growth of urban population as well as high densities land use pattern, it is a great concern and required urgent attention to prepare Chittagong city as a sustainable mega city. But for the misunderstanding of the factual and root causes of the problems of Chittagong city, every uncoordinated approach whichever is taken for improving the condition is pushing the city in worse condition gradually.

Most of the improvement initiatives are undertaking considering mainly the short term need without any long term vision, which often becomes an extra burden or constraint to the city's overall transport infrastructure development potential. However, there is a need for undertaking comprehensive study to realize or identify the root causes of the problems and inherent weaknesses of the city relating to the land use and transportation system. In view of the above, a comprehensive study has been carried out by the authors in order to identify the inherent weaknesses as well as the forthcoming challenges for sustainable development of the city by analyzing most of the interrelated fields of urban land use and transport system.

2.2 Review of Literature

Chittagong is one of the great port city of Asia. Today Chittagong is a fairly large metropolitan area with a population of about 8.5 million as well as the second most densely populated city after Dhaka. Over the last few years the transportation problem of Chittagong city has visibly been deteriorating gradually. Urbanization in Chittagong is essentially a process of migration from rural and smaller towns. Inefficient and malfunctioning traffic management is also one of the major problems of Chittagong city transportation system, which is highly responsible for making the existing system more unproductive. This is the only country where one road is used by rickshaw, bus, truck, CNG, truck and trailer as well as bicycle. Reaching one’s respective destination in time is dream that is only warning. Bus rapid transit is necessary for the port city and the city corporation need to take this initiative to introduce this service, which can ease the severity constrain faced by the customers on a daily basis. A well-planned and developed transportation system is much required for the Port City.

The study is dedicated to analyzing present traffic capacity in the selected major transport axis of Chittagong city. The traffic study has been conducted on one of the most important intersection named Tigerpass intersection by taking into consideration its commercial value and the movement of traffic. Observation of operational conditions indicates that the road continuously suffers from unrestrained movements of pedestrians, motorized and non-motorized vehicles.

The topic, that is selected for this study is, “Saturation Flow & Capacity Analysis at Selected Intersection of Chittagong City”. Saturation flow, lost time, Capacity and Passenger Car Unit (PCU) are the significant parameters in the planning, design and control of signalized intersection. The accurate estimation of saturation flow values is prime importance when determining the capacity of signalized intersection. Saturation flow is important for estimating signal green time. The design, the capacity and operation of a signalized intersection critically depend on passenger car unit (PCU) and saturation flow. Saturation flow describes the number of passenger car unit (PCU) in a dense flow of traffic for a specific intersection lane group. To find out the capacity we need to know about the saturation flow which further helps to time the traffic signals. However, it is revealed that traditional methods which are mainly developed using the average value of observed queue discharge headways to estimate the saturation headway might lead to underestimate saturation flow rate.

This study attempts to review of literature on the saturation flow and capacity analysis of signalized intersection. A saturation flow and the proportion of mix traffic, which suggest that mix traffic flow have significant impact and should be considered in the capacity analysis of signalized intersection. In this research paper, the effort was made to analyze the results by developing the dynamic PCU for the candidate signalized intersection catering to mixed traffic condition in Chittagong city. In this study methodology was developed to calculate the PCU, saturation flow and capacity in according for the enumerated traffic conditions.

2.3 Traffic signs

Traffic signs are mainly used to

- Inform drive
- Adjust their lane position and speed
- Guide them to reach their points of interest

2.4 Classification

Functional classes of traffic signs are:

- Mandatory Signs(shall follows)
    - inform users of traffic laws or regulations
    - the violation of these signs is legal offence
    - these are usually circular in shape with red border, white background

- Examples
    - Regulatory
        - Slow/stop
        - Keep right
        - Restriction on speed, size, weight
        - One way traffic etc.
    - Prohibitory
        - No right/left/U turn
        - No entry for vehicle types
        - No overtaking
        - No horn
        - No waiting/parking etc.

    - Special mandatory signs for priority typed intersection

  - Stop
  - Used when vision is obstructed
  - USA/UK are practice-octagonal, red-background, white border
  - Yield/Give way
  - Used when vision is not obstructed and stop is needed only when necessary
  - USA/UK practice-triangular pointing downward
- Warning or Cautionary Signs(should follow)
- These are known as safety signs
- Not always an offense if not complied with
- Usually equilateral triangle or diamond in shape
- These signs convey message to warm about potentiality hazardous conditions ahead and where caution/attention is required. For examples:
  - Side road
  - Junctions
  - Level crossing
  - Zigzag/slippery road
  - Sharp bend
  - Road bump
  - Narrow bridge
  - School, hospital, cinema hall etc.

➢ Informatory or Guide Signs(may follow)
- These signs show the direction of important places of interests and are used to guide road users along to make the travel convenient, safe and comfortable.
- Used at a location where the motorist would be in doubt.
- Informatory signs do not lose their effectiveness by over-use and as such it is desirable to use them as frequent as in necessary.
- Usually rectangular in shape.
- Examples
  - Route direction
  - Points of interests
  - Mile stone/distance

2.5 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
- ✓ 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

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.

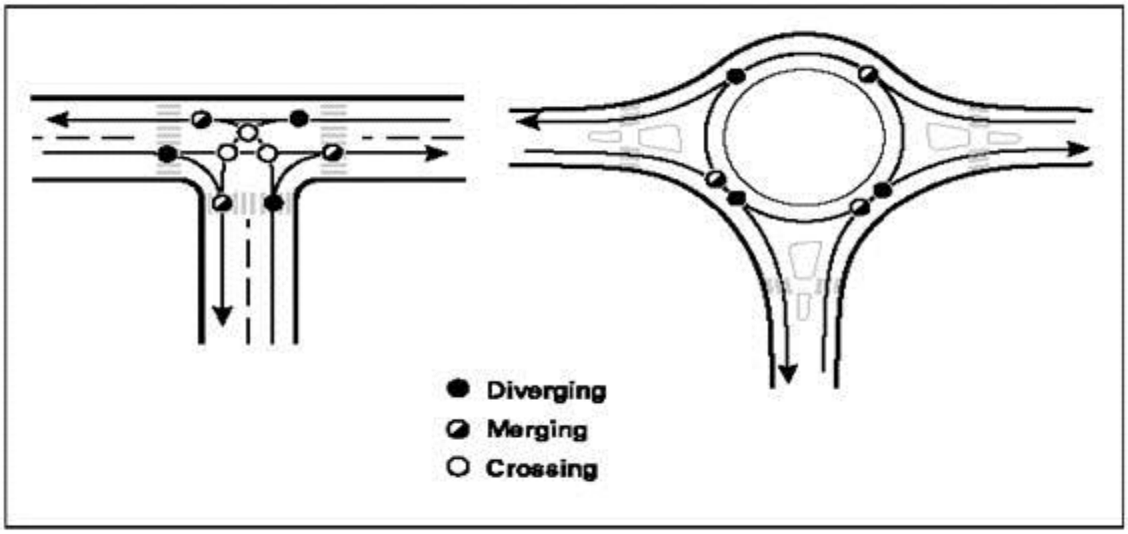


Figure 2.1: Birds-eye photograph of a channelized t-intersection and typical three-leg or T-intersection.

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.

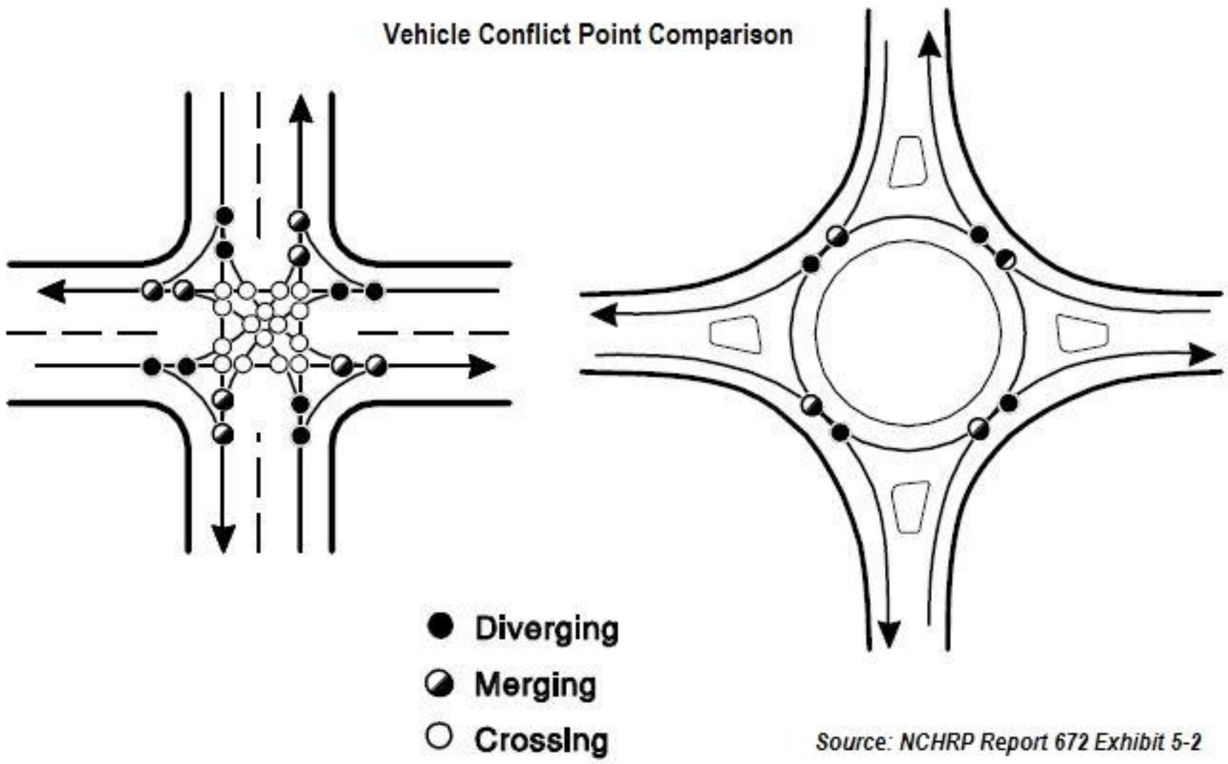


Figure 2.2: Birds-eye photograph of a channelized Four-leg intersection and typical Four-leg or cross intersection.

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.

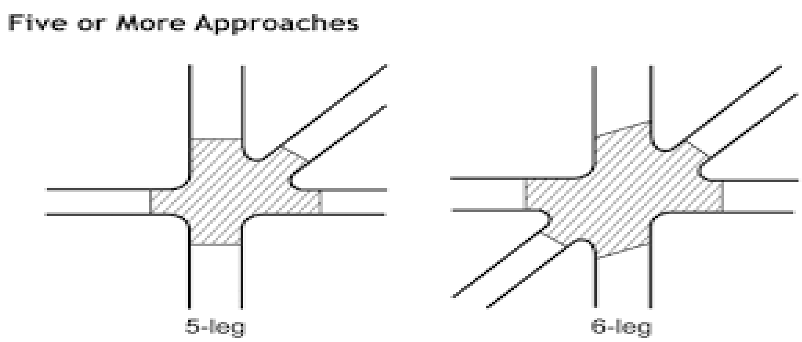


Figure 2.3: Birds-eye photograph of a channelized Multi-leg intersection and typical Multi-leg intersection.

2.6 Definition of volume

Traffic volume is an important parameter in most transportation planning applications. Low volume roads make up about 69% of road miles in the United States. Estimating traffic on the low volume roads is a cost-effective alternative to taking traffic counts.

2.6.1 Definitions & useful parameters

- **Average Daily Traffic (ADT)-**
  The average 24 hour volume, being the total volume during a stated period divided by the number of days in that period. Normally, this would be periodic daily traffic volumes over several days, not adjusted for days of the week or seasons of the year.

- **Average Annual Daily Traffic (AADT)-**
  The total volume of traffic passing a point or segment of a highway facility in both directions for one year divided by the number of days in the year. Normally, periodic daily traffic volumes are adjusted for hours of the day counted, days of the week, and seasons of the year to arrive at average annual daily traffic.

- **Passenger Car Equivalent (PCE)-**
  Passenger Car Equivalent is essentially the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car.

- **Passenger Car Unit(PCU)-**
  It is a vehicle unit used for expressing highway capacity unit. The traffic operations at a signalized intersection would be very much easier and simplified if all vehicles in the traffic stream were of an identical size and travelled straight ahead only. In practice, however, the operations are complicated because the traffic stream normally consists of an inseparable mixture of different types of vehicles performing different maneuvers at the traffic junction. The time taken by a vehicle to depart from the stop line varies considerably from vehicle to vehicle, because of the variations in their length, weight, power and driver behavior. Also the time used by a vehicle to perform a turning movement, at an intersection, depends on its type.

  In respect of its road-capacity requirements each type of vehicle is equivalent to a number of passenger cars and this is called the 'passenger car unit' (PCU) equivalent. Scruggs defined PCU factor as: under saturated conditions if a particular type 'of vehicle requires 'X' times as much time at an intersection as is required by an average passenger car, then that type is equivalent to X PCU. It is needed to remove the effects of traffic composition from saturation flow calculations.

  As saturation flows at intersection are affected by the proportion and type of vehicles in the traffic stream, attempts have been made to bring all vehicle types making different maneuvers to a homogeneous unit so that flows can be converted to 8 common base. Thus all Vehicles can be classified according to the number of standard passenger cars to which they are equivalent. A great deal of research has been carried out to measure this equivalent factor for different types of vehicles.

Vehicle Type	PCU Value
Truck	3
Bus	3
Mini-Bus	2
Passenger Car	1
Utility	1
CNG, Tempo	0.75
Motorcycle	0.5
Bicycle	0.5
Rickshaw	2

Table 2.1: PCU values of different types of vehicles

2.7 Define flow

We define flow rate as the number of vehicles passing a point in a given time period usually expressed as an hourly flow rate. "Flow" or "flow rate" has gradually replaced the term "volume" over the years. Because flow rate varies over time, not only do we need to define it, but also the time period over which it was measured. For example, assume that you observed a 15-minute rate of 1000 vehicles per hour. This means that you counted 250 vehicles during a 15 minute interval and expressed the flow rate as an hourly rate.

There are four important flow measurement applications: existing traffic demand, service volume, capacity, and saturation flow rate. Existing traffic demand is a unique flow rate value that plays an important role when analyzing an oversaturated (congested) situation. It represents the flow rate at which vehicles would like to be serviced. The existing traffic demand is numerically equal to the measured flow rate if there is no oversaturation upstream of the site in question. If, however, the road is oversaturated, the flow rate is indicative only of the flow rate level that can be handled and is not an indication of the existing traffic demand.

We define service volume as the maximum flow at which vehicles can expect to traverse a point given a time period (usually, 15 minutes), prevailing conditions, and maintaining a designated level of service (LOS). LOS is a measure of the quality of flow and takes into account such factors as speed, freedom to maneuver, traffic interruptions, and comfort. By prevailing conditions, we mean prevailing roadway, traffic, and control conditions.

2.8 Speed

The second fundamental traffic flow characteristic is speed. There are two ways to measure speed:

1) Time-mean-speed (TMS) and
2) Space-mean-speed (SMS).

TMS is calculated from the individual speed recorded for vehicles passing a point over a selected time period. We calculate SMS by dividing the average travel time by the measured distance.

Speed and travel time are fundamental measurements of a highway's traffic performance and speed is a key variable in the design of roadway facilities.

Engineers also use it in LOS determination, accident analysis, economic studies, and most traffic engineering studies.

Given the design, demand, and control along a highway system, most analytical models of traffic use speed and travel time as the measure of system performance.

Some models use speed or travel time as an input for the estimation of fuel consumption, vehicle emissions, and traffic noise.

2.9 Delay

Delays are often used to measure the performance of traffic flow at intersections. Travel time may be defined as the total elapsed time of travel, including stop and delay, necessary for vehicle to travel from one point to another point over a specified route under existing traffic condition.

2.9.1 Types of Delay

The most common measure of operational quality is delay, although queue length is often used as a secondary measure.

While it is possible to measure delay in the field, it is a difficult process, and different observers may make judgments that could yield different results.

For many purposes, it is, therefore, convenient to have a predictive model for the estimate of delay. Delay, however, can be quantified in many different ways.

The most frequently used forms of delay are defined as follows:

- Stopped time Delay
- Approach Delay
- Travel time Delay
- Time-in-queue Delay
- Control Delay

2.9.2 Stopped time Delay

Stopped-time delay is defined as the time a vehicle is stopped in queue while waiting to pass through the intersection. It begins when the vehicle is fully stopped and ends when the vehicle begins to accelerate. Average stopped-time delay is the average for all vehicles during a specified time period.

2.9.3 Approach Delay

Approach delay includes stopped-time delay but adds the time loss due to deceleration from the approach speed to a stop and the time loss due to re-acceleration back to the desired speed. It is found by extending the velocity slope of the approaching vehicle as if no signal existed. Approach delay is the horizontal (time) difference between the hypothetical extension of the approaching velocity slope and the departure slope after full acceleration is achieved. Average approach delay is the average for all vehicles during a specified time period.

2.9.4 Travel time Delay

It is the difference between the driver's expected travel time through the intersection (or any roadway segment) and the actual time taken. To find the desired travel time to traverse an intersection is very difficult. So this delay concept is rarely used except in some planning studies.

2.9.5 Time-in-queue Delay

Time-in-queue delay is the total time from a vehicle joining an intersection queue to its discharge across the STOP line on departure. Average time-in-queue delay is the average for all vehicles during a specified time period. Time-in-queue delay cannot be effectively shown using one vehicle, as it involves joining and departing a queue of several vehicles.

2.9.6 Control Delay

Control delay is the delay caused by a control device, either a traffic signal or a STOP-sign. It is approximately equal to time-in-queue delay plus the acceleration-deceleration delay component. Delay measures can be stated for a single vehicle, as an average for all vehicles over a specified time period, or as an aggregate total value for all vehicles over a specified time period. Aggregate delay is measured in total vehicle-seconds, vehicle-minutes, or vehicle-hours for all vehicles in the specified time interval. Average individual delay is generally stated in terms of seconds per vehicle for a specified time interval.

2.10 Travel time

Travel time, or the time required to traverse a route between any two points of interest, is a fundamental measure in transportation. Travel time is a simple concept understood and communicated by a wide variety of applications for transportation engineers and planners.

Introduction Travel time study determines the amount of time required to travel from one point to another on a given route. In conducting such studies information on locations, durations, and causes of delay maybe be collected. When this is done the study is known as a travel time and delay study. The data obtained give a good indication of the level of service on the study section the data also aid traffic engineers in identifying problem locations which may require special attention in order to improve the overall flow of traffic on the route.

2.10.1 Application of travel time & delay data

The data obtained in these studies can be used in any one of the following traffic engineering tasks:

- Determination of the efficiency of a route with respect to its ability to carry traffic.
- Identification of locations with high delays and the cause of those delays.
- Determination of relative efficiency of a route by developing sufficiency ratings or congestion indices.
- Determination of travel times on specific links for use in trip assignment models.
- Establish appropriate travel time unit cost values (cents per minute or dollars per hour) for each trip category.
- Calculate the total value of travel time savings for the project.
- Performance of before and after studies to evaluate the effectiveness of traffic operation improvements.
- Performance of economic studies in the evaluation of traffic operation alternatives that reduce travel time.

2.11 Saturation Flow

Saturation flow is a very important road traffic performance measure of the maximum rate of flow of traffic. It is used extensively in signalized intersection control and design. Saturation flow describes the number of passenger car units (PCU) in a dense flow of traffic for a specific intersection lane group.

Every direction of traffic flow will have to wait for signal to green from red. The slow movement is to be maintained upon the display of yellow light. The continuous display of green signal in any one direction means giving uninterrupted priority to through traffic.

This will test the capacity of intersection to allow the vehicular flow. Flow rate that happens through the signal in this uninterrupted green phase of signal is called saturation rate of vehicular flow. Vehicles move with the saturation rate during the green phase displayed as part of cycle length timing.

2.11.1 Factors affecting the Saturation Flow

The actual saturation flow rate might vary due to the following factors:

- Number of lanes.
- Effect of parking lanes.
- Grade near the road approaching the intersection.
- Proportion of left turning vehicles present among the vehicles moving in lane group.

2.11.2 Lost Time

Lost time is the time during which no vehicles able to pass through an intersection despite the traffic signal displaying a green signal. Lost time is always measured in seconds. The total lost time is the sum of the following two separate elements:

- Initial lost time or Start-up lost time
- Final lost time or Clearance lost time

Initial or start-up lost time happens when a traffic signal changes from red to green and the first queued vehicle moving through the intersection.

Final or clearance lost time is the lost time to stopping a line of vehicles at the end of a green phase.

2.11.3 Effective green time

Effective green time is the time during which a given traffic movement or set of movements may proceed at saturation flow rate. It is equal the cycle length minus the effective red time. Stated another way it is g=G+A-Lost Time, where lost time includes start-up or initial delay and a portion of the yellow or amber time.

2.12 Capacity

Capacity is defined as the maximum number of vehicles, passengers, or the like, per unit time, which can be accommodated under given conditions with a reasonable expectation of occurrence. It speaks about the physical amount of vehicles and passengers a road can afford.

Traffic capacity and traffic volume has same units, difference between the two is that traffic volume represents the actual rate of flow of the traffic and responds to the variation in the traffic demand, while capacity indicates a capability or maximum rate of flow with a certain level of service characteristics that can be carried by the road. Traffic capacity of a roadway depends upon a number of prevailing roadway and traffic composition.

In addition, the capacity analysis depends on the environmental conditions too. Capacity is a probabilistic measure and it varies with respect to time and position. Hence it is not always possible to completely derive analytically the capacity. In most cases it is obtained, through field observations.

2.12.1 Basic capacity

Basic capacity is the maximum number of vehicles that can pass a given point on a lane or a roadway during one hour, under the ideal roadway and traffic conditions that can possibly be attained.

2.12.2 Possible capacity

Possible capacity is the maximum number of vehicles that can pass a given point on a lane or roadway during one hour, under the prevailing roadway and traffic conditions.

2.12.3 Practical capacity

Practical capacity is the maximum number of vehicles that can pass a given point in a lane or roadway during one hour, when traffic density is not so great as to cause unreasonable delay, hazard or restriction to the driver’s freedom to maneuver under prevailing roadway and traffic conditions. This is usually considered to be the ‘design capacity’.

2.12.4 Capacity under uninterrupted condition

The capacity of roadway under interrupted flow condition can be modifying the capacity of the roadway under ideal conditions.

Table 2.2 shows capacity of highway under ideal conditions according to Highway Capacity Manual (HCM)-1994 (USA).

These ideal conditions comprise:

- uninterrupted flow, with no interference by side traffic or obstructions,
- a vehicle stream composed solely of passenger vehicles,
- 12ft wide traffic lane,
- should be capable of providing operation at 70 mph,
- With no restriction of passing sight distance.

Roadway Type	Capacity (passenger Vehicle/hr.)
Multi-lane Free Flow	2000 per lane
Two lane, two way	2000 total both direction
Three lane , two way	4000 total both direction

Table 2.2: Capacity of roadway as per HCM-1994

2.13 Level of service (LOS)

In the 1965 Highway Capacity Manual levels of service at signalized intersection were related to load factor. Load factor presented some problem such problem as its insensitivity to low service volume, absence of any rational; basis for defining break points, and difficulty in identifying loaded cycle. Sutra and Haynes (1977) used road user opinion survey that involves depicting and rating different traffic situation at carefully selected single signalized intersection. Over 300 drivers' rated randomly arranged film sequences of two types – a driver view (micro view) and an overall view (macro view) of an intersection –and evaluated these films, segment by segment, in terms of appropriate level of service. Statistical analyses indicated that average individual delay correlated better with level of service. The hypothesis that Load Factor is better predictor of Level of Service was tested and was rejected.

Chandra et al (1996) studied the parameter to define level of service for mixed traffic at signalized intersection. Due to many problems associated with the measurement and interpretation of delay at signalized intersection LOS parameter were redefined. Degree of saturation and percent of vehicle stopping in the approach were considered the appropriate parameters. Data collected at eight signalized intersection in Delhi were analyzed and breakpoints for various level of service were determined. They developed the graphical relationship incorporating the average stopped delay, saturation green ratio and the Degree of Saturation (DOS). Break points in the range of DOS for different LOS have been determined based on these parameters. DOS was also related to the percent stopping to define six LOS for mixed traffic flow at signalized intersection.

2.13.1 Signalized intersections level of service

The average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. LOS is directly related to the control delay value. The criteria are listed in the following table.

Level of Service	Control Delay per Vehicle (Sec./Veh)
A	≤10
B	>10-20
C	>20-35
D	>35-55
E	>55-80
F	>80

Table 2.3: Level of service criteria for signalized intersection

2.13.2 Un-signalized intersections level of service

Level of service (LOS) for a TWSC intersection is determined by the computed or measure control delay and is defined for each minor movement. LOS is not defined for the intersection as a whole. LOS criteria are shown in the following table.

Level of Service	**Control Delay per Vehicle (Sec. /Veh.)**
A	0-10
B	>10-15
C	>15-25
D	>25-35
E	>35-50
F	>50

Table 2.4: Level of service criteria for un-signalized intersection

Level of service A

Describes operation with very low control delay. This level of service occurs when progression is extremely favorable and most vehicles arrive during green phase. Many vehicles do not stop at all.

Level of service B

This level generally occurs with good progression, short cycle length, or both. More vehicles stop than LOS-A causing higher level of delay.

Level of service C

The higher delays may result from only fair progression, longer cycle length, or both. Individual cycle failures may begin to appear at this level. The number of vehicles stopping is significant.

Level of service D

At this level the influence of congestion becomes more noticeable longer delays may result from some combination of unfavorable progression, long cycle lengths, or high v/c ratios. Many vehicles stop and individual cycle failures are noticeable.

Level of service E

At LOS E delays will be high indicating poor progression, long cycle length, and high v/c ratios. Individual cycle failures are frequent.

Level of service F

This level is considered to be unacceptable to most drivers often occurs with over saturation, i.e. when arrival flow rate exceeds the capacity of lane groups. It may also occur at high v/c ratios with many individual cycle failures. Poor progression and long cycle lengths May also be major contributing causes to such delay levels.

Level of Service	Traffic Flow Condition		Passing Sight Distance (%) >1500 ft.	Basic Limiting Value for AHS* Of 70 mph.	Maximum Service Value Under Ideal Condition
	Description	Operating Speed (mph)			
A	Free Flow	≥60	100 80 60 40 20 0	0.20 0.18 0.15 0.12 0.08 0.04	400
B	Stable	≥50	100 80 60 40 20 0	0.45 0.42 0.38 0.34 0.30 0.24	900
C	Approaching Unstable Flow	≥40	100 80 60 40 20 0	0.70 0.68 0.65 0.62 0.59 0.54	1400

D	Approaching Unstable Flow	≥35	100 80 60 40 20 0	0.85 0.84 0.83 0.82 0.81 0.80	1700
E	Unstable Flow	30	Not Applicable	<=<1	2000
F	Forced Flow	<30	Not Applicable	Not Meaningful	Widely Variable (0 to capacity)

Where,

AHS= Average Highway Speed

2.13.3 Factors affecting level of service

The level of service can be derived from a road under different operating characteristics and traffic volumes.

The factors affecting level of service (LOS) can be listed as follows:

- Speed and travel time
- Traffic interruptions/restrictions
- Freedom to travel with desired speed
- Driver comfort and convenience
- Operating cost.

2.14 Summary

From the through literature review, it is found that there are many factors that affect the urban road intersection capacity. Moreover, it is revealed that though traffic control measures are being used in abroad, but a few of them applied in local traffic control measure to optimize the intersection capacity. Considering our city traffic condition, composition of traffic stream and road users' application of traffic rules and regulation, traffic management, intersection etc. Level of service of selected intersections were found out under this study.

It is also revealed that though many researches have undertaken in abroad, a very little study had so far been carried out to improve the intersection capacity and quantify the intersection performance evaluation in the context of local traffic conditions. It is to be noted here that not the link capacity but the intersection capacity that dictate the whole transport network capacity. Therefore, how to identify the junction related problems as well as to evaluate and to determine level of service and eventually the different ways of augmenting the intersection capacity and thereby to enhance the network productivity are described in the next chapter.

CHAPTER THREE
METHODOLOGY

3.1 General

The study has been broadly divided into main two themes, firstly investigation of the project and secondly collection and analysis of the traffic data at specific route. Based on the information and the data collected from the field survey.

3.2 Site Selection

We selected one intersection of Tigerpass intersection for our thesis purpose.

Maps of site:

- ❖ Tigerpass Intersection

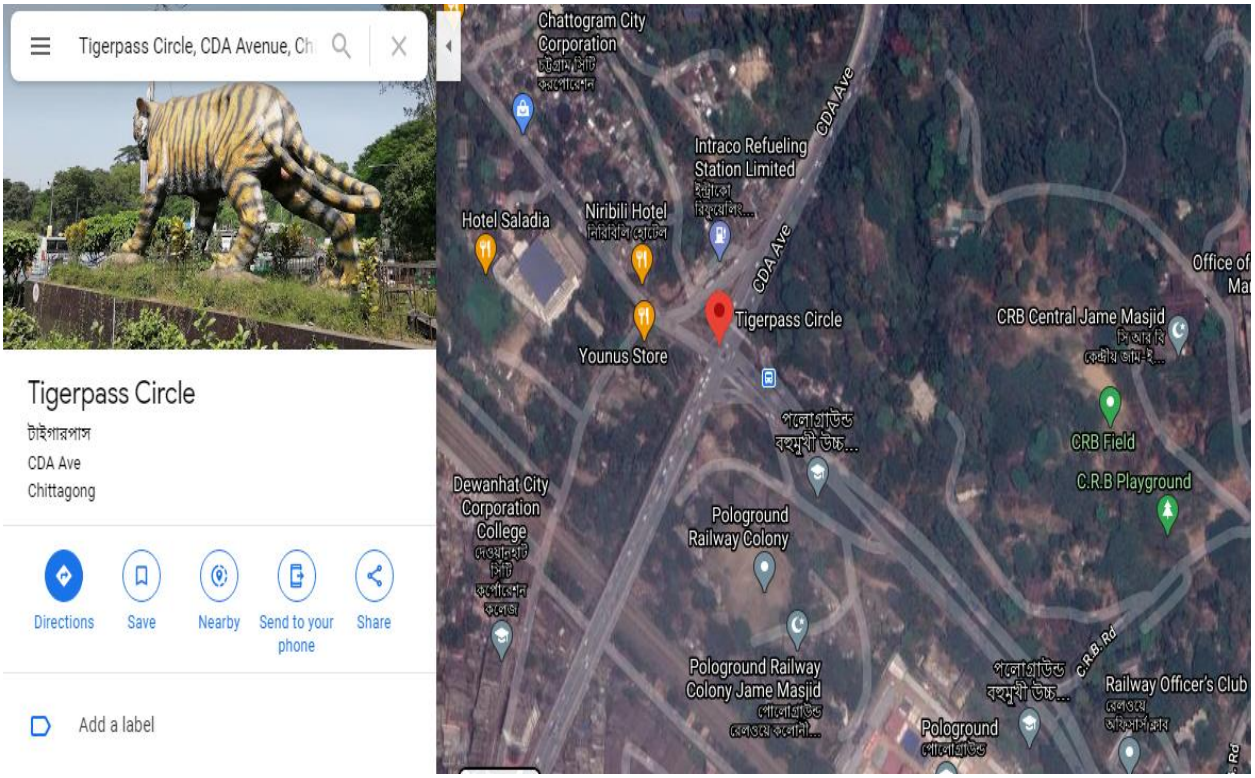


Photo 3.1: Map & Photography of Tigerpass Intersection.

3.3 Work Procedure

- Topic selection

- Preliminary survey

  - Select location for survey
  - Complete the pre-survey document

- Field survey

  - Record data
  - Evaluate the data
  - Calculate the saturation flow and capacity analysis of roadway

- Data analysis

  - Complete all calculation report
  - Finalize the report
  - File the report

- Completion

3.4 Flow Chart

3.5 Statement of Flow Chart

Topic selection

The topic, that is selected for this study is, "Saturation Flow & Capacity Analysis at Selected Intersection of Chittagong City". Saturation flow, lost time, Capacity and Passenger Car Unit (PCU) are the significant parameters in the planning, design and control of signalized intersection. The accurate estimation of saturation flow values is prime importance when determining the capacity of signalized intersection. Saturation flow is important for estimating signal green time.

Preliminary survey

The study is dedicated to analyzing present traffic capacity in the selected major transport axis of Chittagong city. The traffic study has been conducted on one of the most important intersection named Tigerpass intersection by taking into consideration its commercial value and the movement of traffic. Observation of operational conditions indicates that the road continuously suffers from unrestrained movements of pedestrians, motorized and non-motorized vehicles.

Field survey

Two methods are used in the study. They are field survey and photographic survey. A video of traffic flow of Tigerpass intersection is recorded firstly for the study work. All data are collected from the video records and then some calculations are done. Saturation flow, capacity and operating speed of vehicles were calculated for the intersection. Two histograms are also created for Tigerpass to Dewanhat intersection and Tigerpass to Lalkhan Bazar intersection to calculate the saturation flow.

Data analysis

This study attempts to review on the saturation flow and capacity analysis of signalized intersection. A saturation flow and the proportion of mix traffic, which suggest that mix traffic flow have significant impact and should be considered in the capacity analysis of signalized intersection. The road surface quality, road marking and signal system are observed from this intersection. Overall it is pointed out from the study that, the traffic flow condition at Tigerpass intersection is an unstable flow.

Completion

The present study is focused mainly on traffic volume capacity analysis only. The study is also related to the capacity of a roadway and its ability to accommodate traffic. Speed-flow studies are useful to evaluate the more parameters in transportation engineering. There is a scope on speed flow study on urban road links for future work.

3.6 Field survey (Tigerpass Intersection):

- Volume (Total PCU) in intersection of 5 cycles at flow time.
- Volume (Total PCU) in intersection at peak hour.

3.7 Photographic survey (Tigerpass Intersection):

- Water logging on road side of Tigerpass intersection.
- Low sufficient drainage facility of Tigerpass intersection.
- Lack of utility service space in road side of Tigerpass intersection.
- Poor drainage surface with wastages of Tigerpass intersection.
- Zebra crossing marking quality poor of Tigerpass intersection.
- Observations of road marking condition, signs, signals etc.

3.8 Summary

In summary, the chapter covers the research approach and the methodology adopted on this research. Further explanation is provided on the survey design and sampling of data collection. Work procedure is presented by flow chart. Field survey and photographic survey are also included in this chapter. Photographic survey contains the observations of road marking condition, road surface quality, drainage facility, signs, signals etc. The selected intersection shown by map at the beginning of the chapter.

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.1 General

In this chapter the result of the analysis and various things are presented equally the calculations is being done by the Microsoft Word Software. The aim of this study was to observe and identify mixed traffic situation, this behavior, traffic signal, traffic control time loss, highest queue delay, Phase delay, intersection delay and overall the saturation flow as well as road capacity analysis of an individual lane.

To analyze the existing situation of capacity on the selected intersection in the Chittagong city. In this there are three major works have to be done. The first one is the recording video in the selected intersection by using manual method. The second one is to counting number of approach wise directional vehicle from the video. The third and final one is to calculate the PCU value by these counted vehicles and the rest is to calculate the saturation flow and capacity analysis. In the following section the details description of these three steps of works are given along with relevant equations whenever necessary.

4.2 Traffic count and data analysis for Saturation Flow calculation of Tigerpass to Dewanhat Intersection

No. of Vehicle per 6sec. Interval		1	2	3	4	5	No. of Vehicles in total 5 Cycle	PCU Factor	Converted PCU in total 5 Cycle	Total PCU	Sample	Average
0sec.	CNG/Tempo	5	1	2	4	3	15	0.75	11.25	43.75	5	8.75
	Car	3	2	2	2	3	12	1	12			
	Bus	0	1	0	0	1	2	3	6			
	Truck	0	0	1	0	0	1	3	3			
	Motor-cycle	1	3	1	2	2	9	0.5	4.5			

	Mini-Bus/Truck	0	0	0	0	0	0	2	0			
	Rickshaw	1	0	0	1	0	2	2	4			
	Utility	2	0	0	0	1	3	1	3			
6sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
6sec.	CNG/Tempo	4	6	7	3	3	23	0.75	17.25	53.75	5	10.75
	Car	1	2	3	1	2	9	1	9			
	Bus	2	0	0	2	0	4	3	12			
	Truck	0	1	0	0	0	1	3	3			
	Motor-cycle	1	3	0	1	3	8	0.5	4			
	Mini-Bus/Truck	0	0	0	0	1	1	2	2			
	Rickshaw	1	0	1	0	1	3	2	6			
	Utility	0	0	0	0	0	0	1	0			
12sec.	Bi-cycle	0	0	0	1	0	1	0.5	0.5			
12sec.	CNG/Tempo	3	0	1	2	1	7	0.75	5.25	38.25	5	7.65
	Car	2	1	2	2	1	8	1	8			
	Bus	0	2	0	0	0	2	3	6			
	Truck	1	0	0	0	2	3	3	9			
	Motor-cycle	1	0	0	3	0	4	0.5	2			
	Mini-Bus/Truck	0	0	0	0	1	1	2	2			
	Rickshaw	0	0	0	1	2	3	2	6			
	Utility	0	0	0	0	0	0	1	0			
18sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			

18sec.	CNG/Tempo	4	3	3	3	4	17	0.75	12.75	43.25	5	8.65
	Car	1	0	2	4	1	8	1	8			
	Bus	0	0	2	0	1	3	3	9			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	0	2	0	1	1	4	0.5	2			
	Mini-Bus/Truck	1	0	0	1	0	2	2	4			
	Rickshaw	0	0	1	0	2	3	2	6			
	Utility	0	0	0	0	1	1	1	1			
24sec.	Bi-cycle	0	0	0	1	0	1	0.5	0.5			
24sec.	CNG/Tempo	2	0	4	2	5	13	0.75	9.75	42.75	5	8.55
	Car	2	2	1	3	2	10	1	10			
	Bus	0	1	0	1	1	3	3	9			
	Truck	1	0	0	0	0	1	3	3			
	Motor-cycle	0	3	2	1	4	10	0.5	5			
	Mini-Bus/Truck	0	0	1	0	0	1	2	2			
	Rickshaw	0	0	1	0	0	1	2	2			
	Utility	0	0	0	1	0	1	1	1			
30sec.	Bi-cycle	1	0	0	0	1	2	0.5	1			
30sec.	CNG/Tempo	4	2	1	5	1	13	0.75	9.75			
	Car	1	0	3	2	3	9	1	9			
	Bus	0	0	1	0	0	1	3	3			
	Truck	0	0	0	1	0	1	3	3			

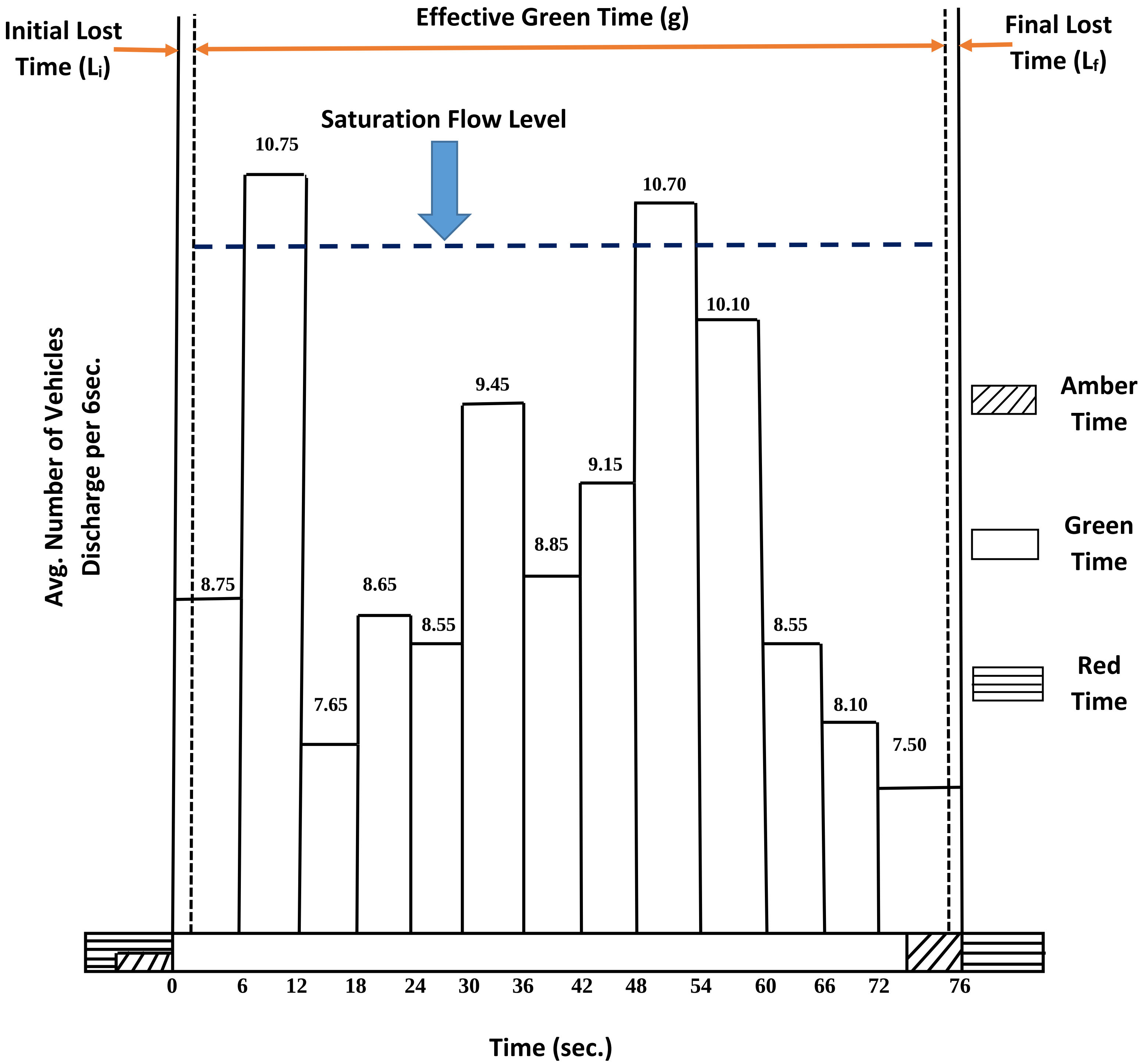
	Motor-cycle	2	2	1	3	2	10	0.5	5	47.25	5	9.45
	Mini-Bus/Truck	1	0	0	1	1	3	2	6			
	Rickshaw	0	0	1	2	1	4	2	8			
	Utility	1	0	0	0	1	2	1	2			
36sec.	Bi-cycle	0	1	2	0	0	3	0.5	1.5			
36sec.	CNG/Tempo	0	3	2	0	4	9	0.75	6.75			
	Car	1	0	0	2	3	6	1	6			
	Bus	0	1	1	1	0	3	3	9			
	Truck	0	0	0	2	0	2	3	6			
	Motor-cycle	3	0	2	0	2	7	0.5	3.5	44.25	5	8.85
	Mini-Bus/Truck	0	0	0	0	1	1	2	2			
	Rickshaw	0	0	1	1	1	3	2	6			
	Utility	0	2	1	0	1	4	1	4			
42sec.	Bi-cycle	0	0	0	0	2	2	0.5	1			
42sec.	CNG/Tempo	4	2	2	3	2	13	0.75	9.75			
	Car	3	1	2	1	2	9	1	9			
	Bus	0	1	1	0	0	2	3	6			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	0	1	1	2	4	8	0.5	4	45.75	5	9.15
	Mini-Bus/Truck	0	0	0	0	2	2	2	4			
	Rickshaw	0	0	1	1	3	5	2	10			

	Utility	0	1	0	1	0	2	1	2			
48sec.	Bi-cycle	0	1	0	0	1	2	0.5	1			
48sec.	CNG/Tempo	2	6	5	1	0	14	0.75	10.5	53.5	5	10.7
	Car	1	5	1	4	3	14	1	14			
	Bus	0	0	0	0	2	2	3	6			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	0	1	0	1	2	4	0.5	2			
	Mini-Bus/Truck	1	1	1	0	1	4	2	8			
	Rickshaw	0	1	0	3	1	5	2	10			
	Utility	1	0	1	1	0	3	1	3			
54sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
54sec.	CNG/Tempo	2	3	6	3	4	18	0.75	13.5	50.5	5	10.1
	Car	3	3	1	2	1	10	1	10			
	Bus	0	0	2	0	1	3	3	9			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	1	2	2	1	1	7	0.5	3.5			
	Mini-Bus/Truck	0	0	0	2	0	2	2	4			
	Rickshaw	0	0	0	1	3	4	2	8			
	Utility	1	0	0	0	1	2	1	2			
60sec.	Bi-cycle	0	0	0	1	0	1	0.5	0.5			
60sec.	CNG/Tempo	2	5	3	2	3	15	0.75	11.25			
	Car	2	0	2	1	3	8	1	8			

	Bus	0	0	0	2	0	2	3	6	42.75	5	8.55
	Truck	0	0	1	0	1	2	3	6			
	Motor-cycle	0	1	0	2	0	3	0.5	1.5			
	Mini-Bus/Truck	0	0	1	0	1	2	2	4			
	Rickshaw	0	0	0	1	0	1	2	2			
	Utility	0	2	1	0	1	4	1	4			
66sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
66sec.	CNG/Tempo	3	1	4	4	2	14	0.75	10.5	40.5	5	8.1
	Car	0	2	0	0	2	4	1	4			
	Bus	0	0	1	0	0	1	3	3			
	Truck	1	0	1	0	0	2	3	6			
	Motor-cycle	0	2	2	1	3	8	0.5	4			
	Mini-Bus/Truck	0	1	0	1	1	3	2	6			
	Rickshaw	0	0	1	0	2	3	2	6			
	Utility	0	0	0	1	0	1	1	1			
72sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
72sec.	CNG/Tempo	3	1	4	6	2	16	0.75	12	37.5	5	7.5
	Car	3	0	1	0	3	7	1	7			
	Bus	0	0	0	0	1	1	3	3			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	0	2	2	2	0	6	0.5	3			

76sec.	Mini-Bus/Truck	0	1	1	0	0	2	2	4			
	Rickshaw	0	0	1	1	0	2	2	4			
	Utility	0	1	0	1	1	3	1	3			
	Bi-cycle	1	0	0	1	1	3	0.5	1.5			

4.3 Histogram of Saturation Flow for Tigerpass to Dewanhat Intersection



4.4 Saturation Flow Calculation 0f Tigerpass to Dewanhat Intersection

- **Calculate Lost Time**

Initial lost time, $L_i = t - (n/s) = 6 - \frac{43.75}{10.5} = 1.83$ sec. ≈ 2 sec.

Where,

t = duration of initial interval = 6 sec.

s = saturation flow = 10.5 PCU/sec. [from histogram]

n = No. of vehicles discharge in initial interval = 43.75 PCU

Final lost time, $L_f = t - (n/s) = 4 - \frac{37.5}{10.5} = 0.43$ sec. ≈ o.5 sec.

Where,

t = duration of final interval = 4 sec.

s = saturation flow = 10.5 PCU/sec. [from histogram]

n = No. of vehicles discharge in final interval = 37.5 PCU

- **Calculate Effective Green Time**

Effective green time, $g = G + A - (L_i + L_f) = 66 + 10 - (2 + 0.5) = 73.5$ sec.

Where,

G = observed green period = 66 sec.

A = observed amber/yellow period = 10 sec.

L_I = initial lost time = 2 sec.

L_f = final lost time = 0.5 sec.

- **Approach Capacity**

Approach capacity = $\frac{g}{c} \times s = \frac{73.5}{76} \times 10.5 = 10.1$ PCU/sec. ≈ 10 PCU/sec.

Where,

g = effective green time

c = cycle time = 76 sec.

s = saturation flow = 10.5 PCU/sec. [from histogram]

4.5 Traffic count and data analysis for Saturation Flow calculation of Tigerpass to Lalkhan Bazar Intersection

No. of Vehicle per 6sec. Interval		1	2	3	4	5	No. of Vehicles in total 5 Cycle	PCU Factor	Converted PCU in total 5 Cycle	Total PCU	Sample	Average
0sec. - 6sec.	CNG/Tempo	6	4	4	3	5	22	0.75	16.5	48	5	9.6
	Car	2	3	1	0	1	7	1	7			
	Bus	1	0	0	1	1	3	3	9			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	2	2	3	3	2	12	0.5	6			
	Mini-Bus/Truck	0	0	1	0	0	1	2	2			
	Rickshaw	0	2	0	1	0	3	2	6			
	Utility	1	0	0	0	0	1	1	1			
	Bi-cycle	0	0	1	0	0	1	0.5	0.5			
6sec.	CNG/Tempo	4	7	4	3	4	22	0.75	16.5	56.5	5	11.3
	Car	2	1	0	3	1	7	1	7			
	Bus	1	0	1	0	1	3	3	9			
	Truck	0	0	0	0	2	2	3	6			
	Motor-cycle	3	1	1	3	0	8	0.5	4			
	Mini-Bus/Truck	0	0	0	1	0	1	2	2			
	Rickshaw	0	1	1	2	1	5	2	10			

	Utility	0	0	2	0	0	2	1	2			
12sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
12sec.	CNG/Tempo	5	2	3	4	1	15	0.75	11.25	47.25	5	9.45
	Car	1	1	1	2	3	8	1	8			
	Bus	2	1	0	1	0	4	3	12			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	2	2	2	1	4	11	0.5	5.5			
	Mini-Bus/Truck	0	0	1	0	1	2	2	4			
	Rickshaw	1	0	0	1	0	2	2	4			
	Utility	0	0	1	1	0	2	1	2			
18sec.	Bi-cycle	0	1	0	0	0	1	0.5	0.5			
18sec.	CNG/Tempo	2	0	3	4	4	13	0.75	9.75	47.75	5	9.55
	Car	3	3	0	1	0	7	1	7			
	Bus	0	1	1	0	0	2	3	6			
	Truck	0	0	1	0	0	1	3	3			
	Motor-cycle	2	2	2	3	2	11	0.5	5.5			
	Mini-Bus/Truck	1	1	0	1	1	4	2	8			
	Rickshaw	1	0	1	1	0	3	2	6			
	Utility	0	0	0	0	2	2	1	2			

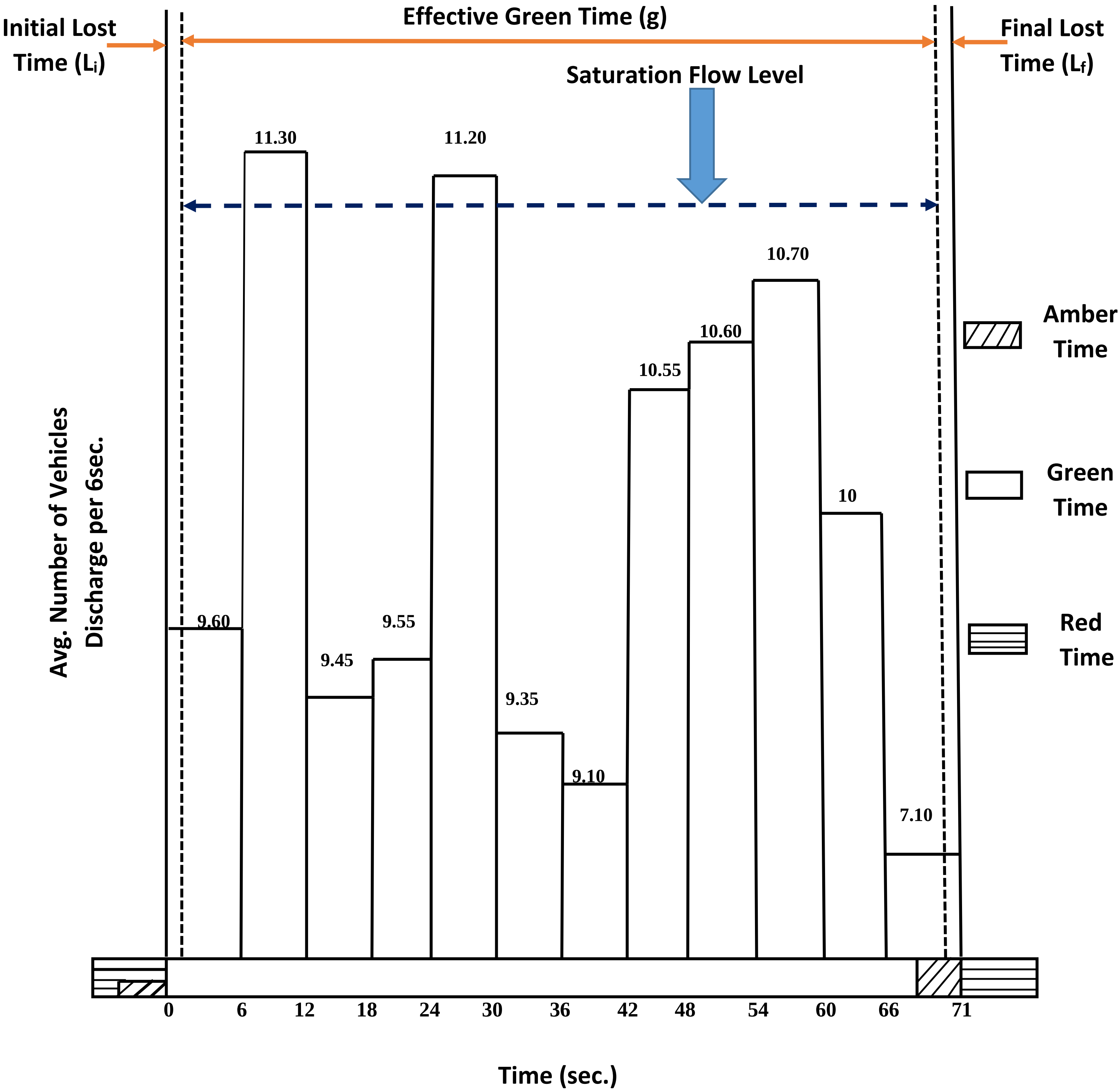
24sec.	Bi-cycle	1	0	0	0	0	1	0.5	0.5			
24sec.	CNG/Tempo	3	2	0	3	4	12	0.75	9			
	Car	1	1	2	1	2	7	1	7			
	Bus	0	1	1	0	1	3	3	9			
	Truck	1	0	0	0	0	1	3	1			
	Motor-cycle	2	0	4	0	3	9	0.5	4.5	56	5	11.2
	Mini-Bus/Truck	0	0	0	0	0	0	2	0			
	Rickshaw	1	2	2	2	2	9	2	18			
	Utility	1	1	2	1	0	5	1	5			
30sec.	Bi-cycle	0	0	0	0	1	1	0.5	0.5			
30sec.	CNG/Tempo	4	4	3	1	3	15	0.75	11.25			
	Car	2	1	2	1	3	9	1	9			
	Bus	0	0	0	0	1	1	3	3			
	Truck	0	2	0	1	0	3	3	9			
	Motor-cycle	1	2	1	0	1	5	0.5	2.5	46.75	5	9.35
	Mini-Bus/Truck	2	0	1	0	0	3	2	6			
	Rickshaw	0	1	0	0	1	2	2	4			
	Utility	0	0	0	1	0	1	1	1			
36sec.	Bi-cycle	1	0	1	0	0	2	0.5	1			

36sec.	CNG/Tempo	4	3	6	4	3	20	0.75	15	45.5	5	9.1
	Car	3	2	0	1	3	9	1	9			
	Bus	0	0	0	0	1	1	3	3			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	3	1	3	1	0	8	0.5	4			
	Mini-Bus/Truck	0	0	1	2	0	3	2	6			
	Rickshaw	0	2	0	0	1	3	2	6			
	Utility	0	1	1	0	0	2	1	2			
42sec.	Bi-cycle	0	0	0	1	0	1	0.5	0.5			
42sec.	CNG/Tempo	3	5	4	3	4	19	0.75	14.25	52.75	5	10.55
	Car	1	3	1	2	1	8	1	8			
	Bus	2	0	0	1	0	3	3	9			
	Truck	0	0	0	0	1	1	3	3			
	Motor-cycle	0	0	4	2	3	9	0.5	4.5			
	Mini-Bus/Truck	1	0	0	0	0	1	2	2			
	Rickshaw	2	1	1	1	0	5	2	10			
	Utility	0	0	0	1	1	2	1	2			
48sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
48sec.	CNG/Tempo	2	4	1	3	2	12	0.75	9			

	Car	2	0	3	1	0	6	1	6			
	Bus	0	0	2	1	0	3	3	9			
	Truck	1	0	0	1	0	2	3	6			
	Motor-cycle	2	3	1	3	1	10	0.5	5	53	5	10.6
	Mini-Bus/Truck	1	2	1	1	0	5	2	10			
	Rickshaw	1	0	0	0	2	3	2	6			
	Utility	0	0	0	0	2	2	1	2			
54sec.	Bi-cycle	0	0	0	0	0	0	0.5	0			
54sec.	CNG/Tempo	6	3	4	3	4	20	0.75	15			
	Car	0	3	1	2	0	6	1	6			
	Bus	0	1	1	0	0	2	3	6			
	Truck	0	0	0	1	1	2	3	6			
	Motor-cycle	3	0	2	0	3	8	0.5	4	53.5	5	10.7
	Mini-Bus/Truck	2	1	0	1	1	5	2	10			
	Rickshaw	1	0	1	1	0	3	2	6			
	Utility	0	0	0	0	0	0	1	0			
60sec.	Bi-cycle	0	0	0	0	1	1	0.5	0.5			
60sec.	CNG/Tempo	4	1	3	0	4	12	0.75	9			
	Car	0	4	0	2	1	7	1	7			

66sec.	Bus	0	1	2	0	1	4	3	12	50	5	10
	Truck	0	0	0	1	0	1	3	3			
	Motor-cycle	4	2	3	2	0	11	0.5	5.5			
	Mini-Bus/Truck	0	0	0	0	1	1	2	2			
	Rickshaw	2	2	1	0	0	5	2	10			
	Utility	0	0	0	1	0	1	1	1			
	Bi-cycle	0	0	1	0	0	1	0.5	0.5			
66sec. 71sec.	CNG/Tempo	1	4	2	3	4	14	0.75	10.5	35.5	5	7.1
	Car	1	1	0	0	3	5	1	5			
	Bus	1	0	1	0	1	3	3	9			
	Truck	0	0	0	0	0	0	3	0			
	Motor-cycle	1	3	2	3	2	11	0.5	5.5			
	Mini-Bus/Truck	0	1	0	0	0	1	2	2			
	Rickshaw	0	0	0	0	1	1	2	2			
	Utility	0	0	1	0	0	1	1	1			
	Bi-cycle	0	0	0	1	0	1	0.5	0.5			

4.6 Histogram of Saturation Flow for Tigerpass to Lalkhan Bazar Intersection



4.7 Saturation Flow Calculation of Tigerpass to Lalkhan Bazar Intersection

- **Calculate Lost Time**

Initial lost time, L_i = t – (n/s) = 6 – $\frac{48}{11.07}$ = 1.7 sec. ≈ 2 sec.

Where,

t = duration of initial interval = 6 sec.

s = saturation flow = 11.07 PCU/sec. [from histogram]

n = No. of vehicles discharge in initial interval = 48 PCU

Final lost tome, L_f = t – (n/s) = 5 – $\frac{35.5}{11.07}$ = 1.8 sec. ≈ 2 sec.

Where,

t = duration of final interval = 5 sec.

s = saturation flow = 11.07 PCU/sec. [from histogram]

n = No. of vehicles discharge in final interval = 35.5 PCU

- **Calculate Effective Green Time**

Effective green time, g = G + A – (L_i + L_f) = 61 + 10 – (2 + 2) = 67 sec.

Where,

G =observed green period = 61 sec.

A = observed amber/yellow period = 10 sec.

L_i = initial lost time = 2 sec.

L_f = final lost time = 2 sec.

- **Calculate Approach Capacity**

Approach capacity = $\frac{g}{c}$ × s = $\frac{67}{71}$ × 11.07 = 10.45 PCU/sec. ≈ 10.5 PCU/sec.

Where,

g = effective green time = 67.5 sec.

c = cycle time = 71 sec.

s = saturation flow = 11.07 PCU/sec. [from histogram]

4.8 Traffic Count for Operating Speed Analysis

Tigerpass to Dewanhat

Vehicle Type	**Number (Veh. /hr.)**
CNG/Tempo	224
Car	188
Bus/Mini-Bus	36
Truck	28
Motor-cycle	168
Utility	32

Total = 676 veh. /hr.

4.9 Data Analysis for Operating Speed Calculation

Vehicle Type	No. of Vehicles	Distance (ft.)	Time (sec.)	Velocity (Fps.)	Average Velocity (Fps.)	Operating Speed (mph.)
CNG/Tempo	5	100	3	33.33	30.64	29.65
		100	4.5	22.22		
		100	2.1	47.62		
		100	3.9	25.64		
		100	4.1	24.39		
Car	5	100	3.7	27.03	28.099	
		100	3.2	31.25		
		100	4	25		
		100	4.4	22.73		
		100	2.9	34.48		
Bus/Mini-Bus	5	100	6.1	16.39	18.07	
		100	5	20		
		100	5.5	18.18		
		100	6.7	14.93		
		100	4.8	20.83		
Truck	5	100	4	25	25.95	
		100	4.2	23.81		
		100	4.7	21.28		

		100	3	33.33		
		100	3.8	26.32		
Motor-cycle	5	100	2.9	34.48	37.71	
		100	2	50		
		100	2.6	38.46		
		100	3.1	32.26		
		100	3	33.33		
Utility	5	100	4.1	24.39	37.41	
		100	3.8	26.32		
		100	3	33.33		
		100	3.5	28.57		
		100	2.7	37.04		

4.10 Operating Speed Calculation (Tigerpass Intersection)

$$\frac{\sum(Number\ of\ individual\ motorized\ vehicles\ \times\ Average\ speed)}{Total\ number\ of\ motorized\ xehicles}$$

$$= \frac{224\times30.64+188\times28.099+36\times18.07+28\times25.95+168\times37.71+32\times37.41}{676}$$

= 31.15 mph. ≈ 35 mph.

4.11 Roadway Capacity Calculation

Roadway pattern: Two lane two way

Lane width: 12 ft.

Shoulder condition: 2 ft. on both side of roadway

% of passing sight distance: 60 %

Operating speed: 35 mph.

Level of service: D

Now,

Capacity of two lane two way = 2000 × 0.83 = 1660 veh/hr.

Capacity reduction factor for 12 ft. lane width = 1

Capacity reduction factor for 2 ft. shoulder = 0.83

So, actual roadway capacity = 1660 × 1 × 0.83

= 1378 veh/hr. total in both direction.

4.12 Observation from photographic survey:

Below the photographic survey collect from Tigerpass intersection. In this photographic survey, we observe Road Marking condition, road sign, surface condition and information sign.

Photo 4.1: Poor surface quality of Tigerpass intersection.

Photo 4.2: Damage road surface of Tigerpass intersection

Photo 4.3: Water logged on road side of Tigerpass intersection

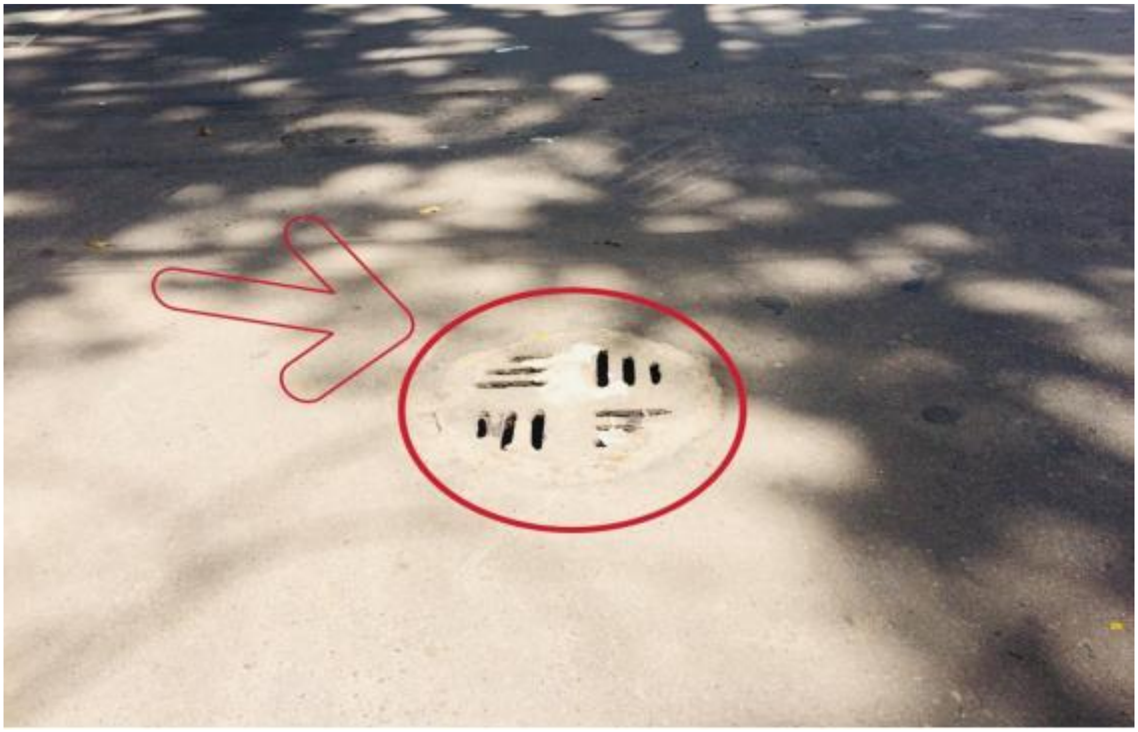


Photo 4.4: Manhole place in wrong position of Tigerpass intersection.

Photo 4.5: Poor drainage surface with waste of Tigerpass intersection

Photo 4.6: Poor zebra crossing marking quality of Tigerpass intersection.

Photo 4.7: Vehicles stand on zebra crossing of Tigerpass intersection.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 General

The main focus of this research is the performance evaluation of selected road intersection of Chittagong City, which will help the City Authority and Government for evaluating the present situation of road network of Chittagong City, and also help them for finding out the appropriate evaluation of the present ill operated condition and giving a conceptual idea of economic loss due to present operation of intersection. Lastly, it will help for finding out ranking system of road intersection inside Chittagong City area (Tigerpass intersection). For this, manual methods of data collection were applied in this article. Data was analyzed both qualitatively and quantitatively. Based on these, the summary of findings of this study, conclusions and understandings of the factors of efficiency of this intersection, and future vision of development is going to be presented in following articles.

5.2 Findings

Findings of qualitative observations general findings of these studies, which have been gathered during manual field survey in different intersections of Chittagong City, findings are summarized below:

- Queue is built up based on the optimum road space utilization criterion; when a vehicle join with the queue, main stimulus is the front gap irrespective of the lane in which it is available. As a result, it has been observed that straight ahead vehicles through traffic, regardless of the type whether motorized or not, occupy any position across the road based on the available space. Another feature of the queue formation is that the smaller sized vehicles such as bi cycles and motor cycles use inter vehicular space to come in front of the queue. Sometimes the smaller vehicles do not try to follow the traffic signal.

- For the smooth operation of a junction, it is not possible to make it delay free. Because the delay is associated in the operation of intersection, both manual and automatic signal system. This delay is increasing with the progress of time of the day. As a result, queue is increasing in every approach of these junctions, which affect the performance of those intersections of Chittagong City and reduces the level of service (LOS).

- Another striking observation is the pedestrian crossing, though every intersections of Chittagong city have some crossing facilities, such as grade separated facility: over bridge, underpass, etc. at grade facility zebra crossing, pedestrian refuge, pedestrian signal, etc. But pedestrian cross through this intersection through road interrupting the traffic flow. Illegal encroachment of footpath and road side, illegal parking, bus stoppage, rickshaw stoppage, etc. increase the side friction, that delayed the traffic flow, decreases the performance of intersection and LOS.

5.3 Recommendation

The following are some recommendations provided considering holistic thinking to facilitate safe pedestrian and future transportation policy making:

- Traffic factors (such as many trucks, buses in the traffic stream and variation of flow) affect the capacity and service columns of a road way.
- Demand here is very low depending on the street capacity.
- Onstage, the flow due to unstable flow is not in demand. If it were to free flow, the demand would have been even greater if power was not available.
- All of those intersections are not properly maintain the signal system.
- Due to the abundance of non-motorized vehicle traffic in selected intersections, as a result cannot get demand due to capacities.
- Illegal parking near the cross marks which obstacles pedestrian crossing and should be stopped.

5.4 Limitations

- Such a study requires financial and human resource to conduct extensive study. But due to resource and time constraint it limits to conduct more compressive study.
- The study does not cover deep analysis on capacity and saturation flow as well as traffic management system for the studied area.
- It had not possible to conduct land use and traffic interaction for more analysis on the selectivity of the intersection.

5.5 Summary

The study observed the process of calculating the saturation flow and capacity of a selected road intersection of Chittagong city. The study will help the City Authority and Government for evaluating the present situation of road network of Chittagong City. General findings of the study are pointed out in this chapter. Recommendation and limitations of the study are also included in this chapter.

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APPENDICES

Table-1: Operating characteristics for various levels of service on 2 lane highways and general level of service criteria during uninterrupted flow conditions as per HCM-1994

Level of Service	Traffic Flow Condition		Passing Sight Distance (%) >1500 ft.	Basic Limiting Value for AHS* Of 70 mph.	Maximum Service Value Under Ideal Condition
	Description	Operating Speed (mph.)			
A	Free Flow	≥60	100 80 60 40 20 0	0.20 0.18 0.15 0.12 0.08 0.04	400
B	Stable	≥50	100 80 60 40 20 0	0.45 0.42 0.38 0.34 0.30 0.24	900
C	Approaching Unstable Flow	≥40	100 80 60 40 20 0	0.70 0.68 0.65 0.62 0.59 0.54	1400
D	Approaching Unstable Flow	≥35	100 80 60 40 20 0	0.85 0.84 0.83 0.82 0.81 0.80	1700

E	Unstable Flow	30	Not Applicable	<=<1	2000
F	Forced Flow	<30	Not Applicable	Not Meaningful	Widely Variable (0 to capacity)

Table-2: PCU values of different types of vehicles

Vehicle Type	PCU Value
Truck	3
Bus	3
Mini-Bus	2
Passenger Car	1
Utility	1
CNG, Tempo	0.75
Motorcycle	0.5
Bicycle	0.5
Rickshaw	2

Table-3: Capacity of roadway as per HCM-1994

Roadway Type	Capacity (passenger Vehicle/hr.)
Multi-lane Free Flow	2000 per lane
Two lane, two way	2000 total both direction
Three lane , two way	4000 total both direction

Table-4: Effect of lane width on capacity for uninterrupted flow conditions as per HCM-1994

Lane Width (ft.)	Capacity (%)	
	Two-Lane Roadways	**Multi-Lane Roadways**
12	100	100
11	88	97
10	81	91
09	76	81

Table-5: Effective roadway width due to restricted lateral clearance under uninterrupted flow as per HCM-1994

Clearance from Pavement to Observation, Both Sides (ft.)	**Effective Width of Two 12-ft. Lane (ft.)**	**Capacity of Two 12-ft. Lanes (ft.)**
6	24	100
4	22	92
2	20	83
0	17	72