

# **Traffic Speed-Flow Characteristics of a Busy Dhaka Metropolitan Area Corridor**

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## **Declaration**

I declare that this report was composed by myself, that the work contained herein is my own works & efforts, except where explicitly stated otherwise in the text, and that this work has not been submitted anywhere for any awards. The entirety of contents included here is totally based on my own labor along with my groupmates assigned for the completion of the Traffic Speed Study. Necessary references have been included for further study, along with all the sources of information.

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## **Abstract**

The Present Vehicle Spot Speed Study concentrates on measuring the speed characteristics at predetermined area under the natural conditions. The present spot speed studies are coordinated to assess the movement of rates of vehicles in a surge of activity at a particular region on a roadway. The proposed look into work goes from breaking down the modular speed of vehicles, highway outline component, upper and lower speed restrain for regulation, planning and analysis, traffic operation, control and direction. The range, time and conditions of the study may be coordinated by its objective and expansion. In this report, we conducted a speed study on the road between Panthapath Signal and Russell square. Manual method was used due to lack of funds and simplicity of operation. For travel speed, matching registration plate method was used.

Maximum vehicle speed was found to vary between 15-20 kmph in Russell Square to Panthapath direction and 30-35 kmph in Panthapath to Russell Square. 50% of the observed vehicles were light vehicles. Various spot speed measures were obtained, which showed that free flow condition was not present on the corridor. The frequency distribution curves in each direction were nearly symmetric along axis. Space mean speed was found to be less than Time mean speed. The Wardrop relationship was established and evaluated. Level of Service was found to be LOS F.

Yearly cost in delay was found to be 33385971 BDT, which is a loss incurred on the country's budget. Thus, a lane expansion project was evaluated to be beneficial for a 20-year design period. Furthermore, various other protective and control measures were recommended for betterment of the speed characteristics of the vehicles on the road.

Limitations of the studies were present; however, future studies are recommended to use high resource means for more accurate results.

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# **Chapter One**

## **Introduction**

### **1.1 Background**

Speed data is needed for a variety of traffic analyses, leading to understanding the speed trends on a particular corridor and establishing traffic operation and control. Furthermore, various design elements rely heavily on speed parameters along with heavy leaning on safety parameters. On the contrary, speed is also reliant on such parameters. Speeds vary with the type of road and traffic volume. It is higher along freeways and highways and lower along collector and local streets. Speed is affected by factors such as lane width and sight distance. Speed decreases with an increase in traffic volumes. Traffic volume is defined as the number of vehicles that pass a point along a roadway or traffic lane per unit time. This study aims at identifying various such parameters, points of interests regarding analyses of such and corresponding implications. Furthermore, the delay of traffic is also analyzed in terms of monetary values for better understanding of losses incurred.

### **1.2 Objectives**

For the entirety of this study, there will be three speed analyses that will be conducted and thus the specific objective of each analysis is provided below.

- 1) Spot Speed
- 2) Travel Speed
- 3) Speed-Flow

The specific objectives for Spot Speed are:

- A) Calculate spot speeds
- B) Present data in a tabular form for statistical analysis

- C) Plot Histogram, Frequency Curve and Cumulative frequency curve
- D) Determine weighted average speed, Pace, modal speed, speed limits, design speed
- E) Check the speed distribution pattern by fitting a normal distribution curve

For travel speed:

- A) Find Time-mean speed ( $V_t$ ).
- B) Find Space-mean speed ( $V_s$ ).
- C) Prove that: The Space-mean speed is lower than the time mean speed ( $V_s < V_t$ )
- D) Prove that: The Wardrop relationship between time-mean speed and space mean speed is valid for the data  

$$\bar{V}_t = \bar{V}_s + \delta s^2 / V_s; \delta s \rightarrow \text{standard deviation of } \bar{V}$$
- E) Delay for each type of vehicle (assuming free flow spot-speed as the travel speed)
- F) Find the cost of delay based on preset users' value of travel time (VOT), vehicle occupancy rate and vehicles operating cost (VOC)

For Speed-Flow

- A) Draw speed (space-mean)-flow curve based on the observed data
- B) Superimpose typical speed-flow relationship diagram (qualitative)
- C) Show different level of services (LOS)
- D) Find LOS of study corridor

### 1.3 Scopes

The scopes of the study are not relevantly limited to just speed analyses, as it has further implications on the planning and maintenance of the road as whole, while establishing control and management. Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway and are used for:

- A) Establishing the effectiveness of new or existing speed limits and/or enforcement practices
- B) Establishing trends to assess the effectiveness of national policy on speed limits and enforcement
- C) Specific design applications (like sight distance, breaking distance, passing distance etc.)
- D) Specific control applications (yellow/all red timing – the size of dilemma zone depends on speed)
- E) Investigation of high-accident locations at which speed is suspected to be a causative factor

Travel speed study determines the amount of time required to travel from one point to another on a given route. Often, information may also be collected on the locations, durations, and causes of delays. Travel speed is used for:

- A) Efficiency check
- B) Collection of rating data
- C) Model calibration
- D) Collect data for economic analysis (user costs)
- E) Evaluation of performance before and after improvement
- F) Problem zone identification

Delay studies can be used to determine speed variations along a route at different times; number, location, cause, frequency, and duration of delays, and overall speed and travel time along a route, and consists of the following scopes:

- A) A speed-delay study shows overall speed and moving speeds between specified locations.

- B) It shows delay times, locations, and total delay times. It can show cause, frequency, and location of delay.
- C) A study made during peak hours and nonpeak hours is good for a comparison study.
- D) A flow map of speeds can be made. The speeds on different routes can be shown by color code or proportional width of bands
- E) The study locates points of congestion and insufficient road capacity.
- F) An evaluation can be made of traffic control devices and the adequacy of posted speed limits.
- G) The study assists in determining priorities for traffic control and road construction programs.
- H) Studies of emergency vehicles at different times of day, with and without emergency lights and siren indicate if they are useful or save substantial time.

# **Chapter Two**

## **Literature Review**

Traffic information are vital for traffic planning and management. That's why Traffic Engineers and policy makers need traffic information. To design a roadway there are specific road elements that must be determined. Some of these are the number of lanes, lane width, median type and width, length of acceleration and deceleration lanes for on and off ramps, need for truck climbing lanes for roadways with steep grades, curve radii required for vehicle turning, and the roadway alignment required to provide adequate stopping and passing sight distance (Mannering and Kilareski 1998).

### **2.1 Previous Studies**

In the recent past, researchers have tested a wide array of technologies in an attempt to find improved methods of monitoring traffic conditions. This research in traffic surveillance has ranged from studies of traditional loop detection methods to the use of anti-submarine warfare technology. A brief survey of technologies explored during the past decade and a half is given below to provide an understanding of the level of research interest in traffic surveillance technologies.

Bohnke and Pfannerstill acknowledged a need for more reliable traffic data acquisition than localized data collection generated by traditional loop detectors (1986). The pair introduced a pattern recognition algorithm which could utilize unique vehicle presence signatures generated by successive series of inductance loop detectors.

Rilett and Park used spectral basis neural networks (SNN) to forecast multiple-periods freeway corridor travel times based on the data from the US 290 in Houston, Texas. In the result, the mean absolute percent error (MAPE) ranges from 5.9 percent to 15.3 percent from

5 minutes to 25 minutes. They also find that the higher the time period, the higher errors will be when using SNN to predict the travel time on freeway.

Ju and Maze performed simulations on incident detection strategies using the FREQ8PE simulation model (1989). Their research evaluated a comparison of incident detection strategies using police patrol versus the use of motorist call boxes at 1 km spacing. The motorist call boxes formed the backbone of the modelled freeway surveillance and control system (FSCS). This FSCS yielded a benefit-to-cost ratio of 2.69 as it generated benefits from travel-time reduction and reduced fuel consumption. These benefits were brought about by reduced incident detection time afforded by the motorist call boxes.

Prior to the installation of an AVI system in Houston, a cellular phone demonstration project was performed (Levine and McCasland, 1994). Researchers recruited 200 volunteers to participate in the program, which required them to call a traffic information office when they passed specific freeway locations during their morning and evening commutes. The lessons learned from the cell phone project aided in the development of the data analysis, processing and dissemination techniques used for the AVI system that was later constructed.

In a similar scenario, prior to installing a large-scale AVI system in the Puget Sound area, a small-scale test of AVI was performed (Butterfield et. al., 1994). In this test, AVI was “piggy-backed” with existing loop detectors. Results yielded an AVI detection rate of about 80% for a fleet of tag-equipped buses.

Abdulhai, Porwal and Recker used an advanced Time Delay Neural Network (TDNN) model combined with Genetic Algorithm (GA) to predict the traffic flow and density. The travel time can be computed based on the predicted traffic flow and density. Similar to the study from Rilett and Park, the TDNN works well for short periods of times but to a lesser extent for higher periods of time.

Ishak, S., and C. Alecsandrus used multiple topologies of dynamic neural network to optimize the short-term travel time prediction. They also tested and compared four different neural network architectures under different settings and traffic conditions. The four different neural networks are a) Multi-Layer Perceptron Network (MLP). b) Modular network. c) Hybrid principal component analysis (PCA) network and d) Co-Active Neuro-Fuzzy Inference System (CANFIS).

## 2.2 Relevant Definitions

**Speed:** In simple words, speed is defined as the distance travelled in a unit time. Speed is expressed in m/s, fps, and mph etc. units.

**Spot speed:** Spot speed is the instantaneous speed of a vehicle as it passes a specified point along a road. Spot speeds may be determined by manually measuring (with use of electronic or electromechanical devices like pneumatic tube detectors or radars) the time required for a vehicle to traverse a relatively short, specified distance.

**Free flow speed:** The desired speed of drivers in low volume conditions and in the absence of traffic control devices. In other words, the mean speed of passenger cars that can be maintained in low to moderate flow rates on a uniform freeway segment prevailing roadway and traffic conditions.

**Travel speed:** Travel 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 travel 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

more than the running speed. Uniformity between travel and running speeds denotes comfortable travel conditions

**Design speed:** Design speed is defined as the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern (ITE 1999). This definition implies that the design speed should be selected based on drivers' expectations, the type of highway and terrain and topography.

**Running Speed:** Running speed is determined by dividing the total distance by the total running time for the route. That is, all stop time delays are excluded. Overall Speed and Running Speed studies are conducted over a specified route for determining quality of service between alternate routes. The main purpose of all speed studies is to obtain speed distributions, identify hazardous areas (excess speed), accident analyses, traffic control planning, and check geometric design. For speed studies, off-peak hours are used for conducting surveys on open stretches of straight roads away from the influence of stop signs, construction and signals.

**Average Speed:** Average speed is the arithmetic mean of all observed vehicle speeds (which is the sum of all spot speeds divided by the number of recorded speeds).

**Median Speed:** It is the speed at the middle value in a series of spot speeds that are arranged in ascending order. 50 percent of the speed values will be greater than the median; 50 percent will be less than the median.

**Modal Speed:** It is the speed value that occurs most frequently in a sample of spot speeds.

**The *i*th-percentile:** The *i*th-percentile Spot Speed which is the spot speed value below which *i* percent of the vehicles travel; for example, 85th-percentile spot speed is the speed below which 85 percent of the vehicles travel and above which 15 percent of the vehicles travel.

**Pace Speed:** It is the highest speed within a specific range of speeds that represents more vehicles than in any other like range of speed. The range of speeds typically used is 10 km/h or 10 mph.

**Space-Mean-Speed (SMS):** Space-Mean-Speed is the average of vehicle speeds weighted according to how long they remain on the section of road. Mathematically it is harmonic mean of the observed speeds.

**Time-Mean-Speed (TMS):** The time mean speed is the arithmetic mean of spot speeds of all vehicles passing a point during a specified interval of time.

**Delay Studies:** Delay is defined as an extra time spent by drivers against their expectation. Delay can have many forms depending on different locations. A study made to provide information concerning the amount, cause, location, duration, and frequency of delay as well as travel time and similar value. The time lost by traffic due to traffic friction and traffic control device is called delay.

**Histogram:** A histogram is a graphical representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous variable (quantitative variable) and was first introduced by Karl Pearson. To construct a histogram, the first step is to "bin" the range of values—that is, divide the entire range of values into a series of intervals—and then count how many values fall into each interval. The bins are usually specified as consecutive, non-overlapping intervals of a variable. The bins (intervals) must be adjacent, and are often (but are not required to be) of equal size

**Frequency Curve and Cumulative Frequency Curve:** A smooth curve which corresponds to the limiting case of a histogram computed for a frequency distribution of a continuous distribution as the number of data points becomes very large. Cumulative frequency is the

running total of the frequencies. On a graph, it can be represented by a cumulative frequency polygon, where straight lines join up the points, or a cumulative frequency curve.

**Delay (D):** The elapsed time (in seconds) spent driving at a speed less than 5 mph.

**Operational delay:** There can be delays caused by the interaction of various factors such as congestion, inadequacy of carriageway widths, mixed traffic conditions, parked cars and heavy pedestrian flow. This kind of delay is called congestion delay or operational delay and is rather difficult to measure precisely. One method of measuring congestion delay is to determine the average running speed when the traffic conditions are free-moving and vehicles are free to move without hindrance. The difference between this speed and the actual speed under congested conditions gives an idea of the congestion delay.

**Stopped-time delay:** That part of the delay during which the vehicle is at rest. These are delays that can be measured and occur at intersections and railway crossings and stop signs.

**Fixed delay:** That part of the delay caused by control devices such as traffic signals

**Vehicle operating costs, VOC:** refer to costs that vary with vehicle usage, including fuel, tires, maintenance, repairs, and mileage-dependent depreciation costs.

**Value of time, VOT:** In transport economics, the value of time is the opportunity cost of the time that a traveler spends on his/her journey. In essence, this makes it the amount that a traveler would be willing to pay to save time, or the amount they would accept as compensation for lost time.

## **2.3 Methods of Various Studies**

### **2.3.1 Methods of Spot Speed Study**

Methods of Conducting Spot Speed Studies are divided into two main categories:

1. Manual

## 2. Automatic

### I. Road Detectors

### II. Doppler-Principle Meters

### III. Electronic-Principle Detectors Manual Method

**Stopwatch method:** The stopwatch method can be used to successfully complete a spot speed study using a small sample size taken over a relatively short period of time. The stopwatch method is a quick and inexpensive method for collecting speed data. However, it is the least accurate of the methods.



Figure 1: Digital Stopwatch

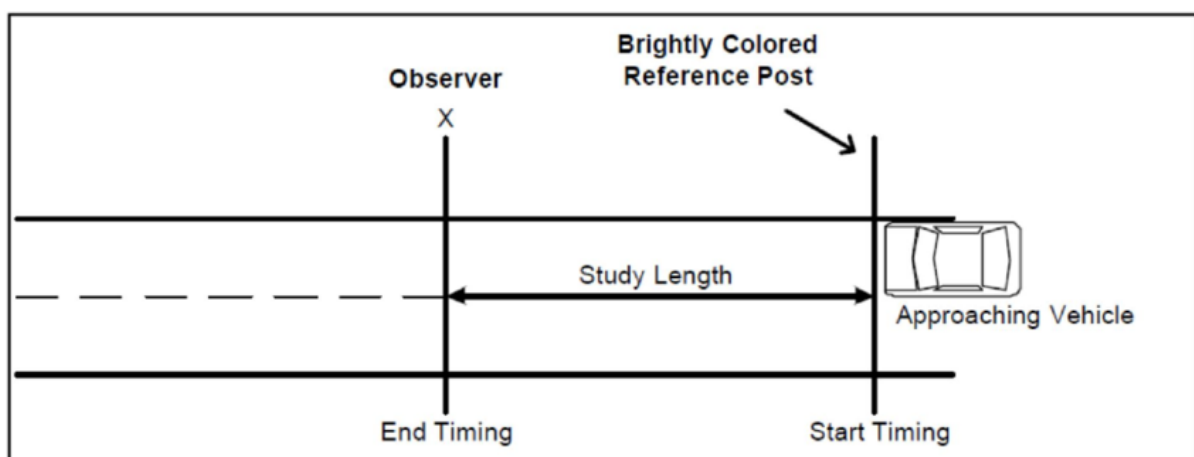


Figure 2: Layout of Stopwatch Stop Speed Study

**Key Steps to a Stopwatch Spot Speed Study:** A stopwatch spot speed study includes five key steps:

1. Obtain appropriate study length.
2. Select proper location and layout.
3. Record observations on stopwatch spot speed study data form.
4. Calculate vehicle speeds.
5. Generate frequency distribution table and determine speed percentiles.

1. **Obtain Appropriate Study Length:** The study length is important because it is used in the calculation of vehicle speeds. Table 1 provides recommended study lengths, which are based on the average speed of the traffic stream. Using these recommended study lengths makes speed calculations straightforward and less confusing. If these lengths are not appropriate, another length can be used assuming it is long enough for reliable observer reaction times.

**Table 1:** Recommended Spot Speed Study Lengths

<b>Traffic Stream Average Speed</b>	<b>Recommended Study Length(feet)</b>
Below 25 mph	88
25–40 mph	176
Above 40 mph	264

2. **Select Proper Location and Layout:** Figure 2 illustrates a typical layout for conducting a spot speed study using a stopwatch. When selecting a location and layout, care must be exercised so that the observer can clearly see any vertical reference posts. The observer should be positioned higher than the study area and be

looking down. The position could be on a bridge or a roadway back slope. The observer should use reference points to aid in collecting the elapsed time it takes a vehicle to travel through the study area. The reference point to start timing may be a brightly colored vertical post. The reference point to end timing may be a tree or a signpost in the observer's sight line. An accurate sketch of the site should be documented, including number of lanes, position of observer, and description of reference points.

- 3. Record Observations on Stopwatch Spot Speed Data Form:** On the stopwatch spot speed data form the observer records the date, location, posted speed limit, weather conditions, start time, end time, and down time. As the front wheels of a vehicle (or only the lead vehicle in a group) crosses a mark or pavement crack at the beginning of the predetermined study length, the observer starts the stopwatch. The watch is stopped when the vehicle's front wheels pass a reference line in front of the observer. A slash is recorded on the data form corresponding to the elapsed time observed.
- 4. Calculate Vehicle Speeds:** To calculate vehicle speed, use the predetermined study length and the elapsed time it took the vehicle to move through the course (as recorded on the stopwatch data form) in the following formula:

$$v = \frac{D}{1.47T}$$

where V = spot speed (mph),

D = length (feet),

and T = elapsed time (seconds).

In the equation, 1.47 is a constant that converts units of feet per second into miles per hour. For example, if the spot speed study length is 150 feet and the motorist's elapsed time is 4.23 seconds, the motorist is travelling at  $150 \div 1.47 \times 4.23$  feet = mph.

### **Road Detectors (Automatic)**

Pneumatic Road Tubes or Induction Loops are used in this method, which can be used to collect data on speeds at the same time as volume data are being collected. The advantage of the detectors is that human errors are considerably reduced. The disadvantages are that they



Figure 3: Pneumatic Road Tubes

are expensive and may affect the driver behavior. Pneumatic Road Tubes are laid across the lane in which data are to be collected.

### **Doppler-Principle Meters (Automatic)**

This radar meters are frequently used for measurement of spot speed. It measures speed directly by measuring the difference in the frequency between the emitted and reflected radar wave emitted on an oncoming vehicle. It is radar meter, which is targeted to a vehicle, so the wave, the frequency between the emitted and reflected wave that the difference is used to calculate the speed. This is normally referred as Doppler Effect. Dynamometer actually works based on the principle of Doppler Effect, which justifies the difference in frequency is proportional to the speed of oncoming vehicle. Using this principle, the instrument is programmed to calculate the speed of the vehicle.



Figure 4: Radar Meter

This is recent advancement in speed studies; it automatically records speed and employs a radar transmitter-receiver unit. The apparatus transmits high frequency electromagnetic waves as a narrow beam towards the moving vehicle, the beam changes its frequency depending up on the vehicle's speed and is returned to the receiver unit. Upon calibration spot speed of the vehicle is obtained.

Though these meters are widely used by engineers, traffic polices and others these have certain practical limitations. They are:

- A) In some situations, there is a possibility of recording wrong input like when a test sample is obstructed by other vehicles, the triggered radar beam bounds back by hitting the obstacle but not the test sample.
- B) Accurate measurements from radar meter are obtained only when the radar wave is reflected directly along the axis of the movement. But in some cases, it is practically difficult.

### **Electronic-Principle Detectors (Automatic)**

The presence of vehicles is detected through electronic means, and information on these vehicles is obtained, from which traffic characteristics such as speed, volume, queues, and headways are computed. The most promising technology using electronics is video image

processing, sometimes referred to as a machine-vision system. The main advantage of method is that it gives a permanent record with 100% sample obtained. This method is quite expensive and generally adopted in a situation where evidence is required. Even video recorder can be used which give more accurate result.

### **2.3.2 Methods for Travel Speed Study**

The following methods are intensively used for travel speed and delay studies

1. Matching Registration Plate or License Plate Method.
2. Floating Car Method- by using test vehicle.
3. Elevated Observer Method.

### **2.3.3 Methods Applied and Reason**

For Spot Speed study, stopwatch method was adopted for ease of use and limitation of resources. Furthermore, as the corridor had mostly free-flowing traffic, it negates all the shortcomings of the methods with respect to humane errors.

For Travel Speed Study, we have used “Matching Registration Plate Method”. This method was used because:

- A) Able to obtain travel times from a large sample of motorists, which is useful in understanding variability of travel times among vehicles within the traffic stream;
- B) Provides a continuum of travel times during the data collection period and ability to analyze short time periods (e.g., 15-minute averages for continuous data);
- C) Data collection equipment relatively portable between observation sites.

### **2.3.4 Determination of Sample Size**

The data collected in volume study used to determine sample size of various vehicles. 1st we collected volume data of various type of vehicles for 15 minutes, then calculated the

percentage of various type of vehicles with respect to total volume. Then we selected the sample size of various type of vehicles in accordance with the percentage.

### 2.3.5 Estimating Cost of Delay Based on VOC, VOR & VOT

There is a relationship between VOC and cost of delay. The extra cost consumed by delay can be estimated by using VOC per unit time. VOC related to delay are crew cost, fuel cost and lubricant cost given below:

**Table 2: RHD Manual Report to Estimate VOC**

Item Cost	Unit	Medium Truck	Small Truck	Large Bus	Mini Bus	Micro Bus	Utility	Car	CNG	Motor Cycle
Crew Cost	Tk. per hour	24	15	35	25	19	12	20	13	-
Maintenance Labor Cost	Tk. per hour	56	56	56	56	56	56	56	56	56
Annual hrs. driven	Hrs. per annum	2036	1748	2864	2131	1171	863	1276	1695	588

Using the above table and assuming that internal rate of return is 6%, VOC per delay is calculated. Moreover, combination of annual hrs. driven and cost per hr. gives VOC per delay. Thus, following chart has been updated.

**Table 3: Modified VOC for Vehicle Classes as per RHD**

Item Cost	Unit	Bus	Micro Bus	Utility	Car	CNG	Motor Cycle
VOC (2016)	Tk./delay(hr. /vehicle/ year)	38.5	20.2	13.5	22.3	26.9	7.6

### 2.3.6 Measurement of Delay

Measurement of delay is done through the time difference between free flow speed and the travel speed obtained from the survey. For this study the free flow speed can be assumed to be the spot mean speed.

VOR is another factor which is used to estimate cost of delay. VOT is the monetary value of time which indicates that how much money one person is willing to pay for unit duration of delay. VOR for different vehicle classes are shown below:

**Table 4: VOR for Vehicle Classes**

Vehicle Types	Bus	Micro Bus	Utility	Car	CNG	Motor Cycle
VOR(person/vehicle)	30	2	2	1.5	1	1

The equation for estimating cost of delay is given by:

$$\text{Cost of delay} = \text{VOC} (\text{Tk./delay}(\text{hr./vehicle/year})) * \text{delay}(\text{hrs./vehicle/year}) \\ + \text{VOT}(\text{Tk./person/hr.}) * \text{VOR}(\text{person/vehicle}) * \text{delay}(\text{hrs./vehicle/year})$$

The VOT of passenger's in Bangladesh is considered to be 25 Tk./person/hr.

# **Chapter Three**

## **Methodology**

### **3.1 Introduction**

This chapter outlines the techniques for the collection of data and the procedures applied to accomplish / carry out the study. Its methodology expresses a systematic way through which any study can be done in fruitful way. This chapter delineates the overall design of the study and research methodologies that have been followed to achieve the objectives set out in Chapter 1. It also describes data collection procedures and techniques. Eventually, the difficulties or problems faced during data collection process and limitation of the study has been illustrated.

### **3.2 Reconnaissance Survey**

Before carrying out the speed study, we need to do a reconnaissance survey.

#### **Purpose**

The main objective of reconnaissance survey is of examining the general character of the area for the purpose of determining the most feasible routes, or routes, for furthermore detailed investigations. Data collected should be adequate to examine the feasibility of all the different routes in question, as also to furnish the Engineer-in-charge with approximate estimates of quantities of costs, to enable him to decide on the most suitable alternative or alternatives.

The survey should also help in determining any deviations necessary in the basic geometric standards to be adopted for the highway facility.

## **Survey Method**

The reconnaissance survey may be conducted in the following sequence

- A) Study of topographical survey sheets, agricultural, soil, geological and meteorological maps, and aerial photographs, if available.
- B) Aerial reconnaissance (where necessary and feasible)
- C) Ground reconnaissance (including another round of aerial reconnaissance for inaccessible and difficult stretches, where called for).

### **Aerial Reconnaissance**

An aerial reconnaissance will provide a bird's eye view of the alignments under consideration along with the surrounding area. It will help to identify factors which call for rejection or modification of any of the alignment. Final decision about the alignments to be studied in detail on the ground could be taken on the basis of the aerial reconnaissance.

### **Ground Reconnaissance**

The various alternative routes located as a result of the map study are further examined in the field by ground reconnaissance. As such, this part of the survey is an important link in the chain of activities leading to selection of the final route. Ground reconnaissance consists of general examination of the ground walking or riding along the probable route and collecting all available information necessary for evaluating the same. In the case of hill sections, it may sometime be advantageous to start the reconnaissance from the obligatory point situated close to the top.

### **3.3 Spot Speed Study Steps**

- A) Organize Study Plan

- B) Select Data Collection Method
- C) Select Appropriate Site
- D) Collect Field Data
- E) Reduce and Analyze Data
- F) Interpret Data
- G) Report Findings

### **Step 1 - Organize Study Plan Good**

Planning prior to data collection can enhance the accuracy of measurements. Essential to this initial step is to identify the reason for conducting the study and nature of the problem to be evaluated. Other considerations for the study plan are the date(s) and time(s) during which the study should be completed, and the number of vehicles that should be observed as part of the study.

Traffic speeds tend to fluctuate during various times of day. For example, congestion during peak time periods may significantly reduce the overall vehicular speed of a facility. To obtain a thorough overall understanding of the traffic patterns, samples should include several pertinent time periods throughout the day. Speed limits are based on free flow operations therefore, speed measurements for speed zoning purposes should be conducted during daytime periods when traffic conditions are the closest to free or uninterrupted flow.

Other factors that might affect the spot speed study should also be taken into account in the plan and includes the following:

Roadside Development: The type of development along a roadside can have significant influence on traffic speeds. A dense development that is in close lateral proximity to the roadway will tend to increase driver's perception of a potential conflict. As such perception intensifies, the traffic stream will tend to reduce its speed. As you can see in the picture, there

are high rise buildings just by the side of the road and also in close proximity. These are huge traffic generators and causes obstruction to flow. Therefore, the traffic stream will have a lower spot speed.

Roadway Geometry: Roadway geometry indicates roadway width, intersection spacing, median type etc. which can affect traffic flow and its relative speed profile.

Parking Activity: On street-parking availability along a roadway will affect the speed profile of the roadway's traffic stream. The on-street parking density influences a driver's perception of roadway width. During the survey, rickshaws, motorcycles, cars were seen parked not only on the street but also in an undisciplined manner.

Pedestrian Activity: The denser the pedestrian activity and the closer its relative lateral location to the traveled way, the greater a driver's perception of potential conflict becomes. Since there are hospitals (Square Hospital, Somorita Hospital etc.), mosques, high rise residential towers and Bashundhara city complex in close proximity, pedestrian activity is extremely high. So, vehicles tend to have a reduced speed.

## **Step 2: Selecting Data Collection Method**

The stopwatch method is chosen as the data collection method. Because stopwatches are easily available, inexpensive and gives quick results. Since each group collected data for a short period of time (20-25min), the use of stopwatch is justified. But stopwatches only give us the time taken by each vehicle to cross a certain measured distance and not the speed. The spot speed needs to be determined later on. The use of radar guns could have easily solved the issue, which give direct values for speeds. Due to financial limitations and with only 1 or 2 radar guns in the stock, we had to resort to the stopwatch method. There were 8 groups positioned along the Panthapath Road Segment between Russell Square and Green road-Panthapath intersection.

Methodology: For group 4, a suitable section in the roadway was selected where free flow occurs or there are unobstructed conditions. Sample speeds were measured and since the speeds were less than 25mph, a section of 88 feet was chosen. Group 1 collected a total sample of 91 vehicles. The number of each type of vehicles was chosen based on the ratio of the classified vehicles obtained in the traffic volume study for that roadway. For the first 50 vehicles, two observers were located at two positions - one at the beginning and one at the end. The first observer raised hand when a vehicle crossed the start mark and the second observer started the stopwatch. When the same vehicle crossed the finish mark, the second observer stopped the time and the time taken was noted down along with the type of vehicle. However, there were certain disadvantages to this method. Using a radar gun would have directly give us the speed. But in stopwatch method, there are human reaction errors. For example, raising the hand and for the second observer to take note of that and starting the stopwatch consumes some time. However, this could be compensated if the second observer delays to stop the watch when the vehicle crosses the finish mark. On the other hand, if the first observer is early and the second observer delays in taking the reading, the errors will be additive and hence a give a lower spot speed.

To reduce the human reaction error, an alternative method was chosen for the next 41 vehicles and its validity was also checked.

Four reference points were chosen of which two can be visible by each observer. Two reference points at the start and two in the end. Each observer had a stopwatch and time taken for each vehicle to cross the reference points was noted. When the signal was green, there was a huge density of vehicles. In the previous method, the second observer often was in doubt which vehicle the first observer was pointing to. In this method, each vehicle was fixed by each observer and their respective speed was measured. So, no error occurred. To verify whether this method is accurate or not, the time taken for the same vehicle to cross two

reference points were noted by each observer. There was only slight difference in the time recorded.

### **Step 3 & 4: Location Selection and Collect Field Data**

The specific location of a study should be chosen carefully so that recorded speeds reflect how vehicles typically travel along unimpeded sections of the road under free flow conditions.

A location was selected some distance away from the Panthapath Signal, where the flow was uniform. The study was conducted on a Wednesday and started at 4:00 p.m. The time was selected to correspond to the period when peak flow occurs. The study continued for 30min and a sample size of 91 vehicles was measured.

### **3.6 Study Area Description**

The corridor under study is a segment from Bir Uttam Kazi Nuruzzaman Road, which is a link road connecting Mirpur Road with Kazi Nazrul Islam Avenue, with one node being in Russel Square and the other at SAARC Fountain, Kawran Bazar. As it was designed to be a link road, the route is expected to carry high-speed traffic with no non-motorized vehicle allowed. The road has 3 intersections in total, while our study includes the corridor from Russel Square to Panthapath intersection, which is in 1 kilometer of length. The road has multiple side roads acting as access roads to residential built-up areas nearby. Despite being considered a link road; the road consists of various commercial spaces on the roadside which creates various impedance for the flow. Various hospitals are also located in this road, leading to loading and unloading of vehicles with various parking facilities, legal or else. The path also consists of various shopping complex, especially one of the largest of Dhaka City, the Bashundhara City Shopping Complex, which generates much of the incoming traffic.

However, no short route public buses are available for the route, leading to traffic comprising of mostly personal vehicles and motorcycle. The availability of various restaurants and commercial spaces lead to some traffic generation which creates impedance for passing traffic, leading to the road not being utilized as a link road whatsoever and rather a typical business district road of Dhaka City.

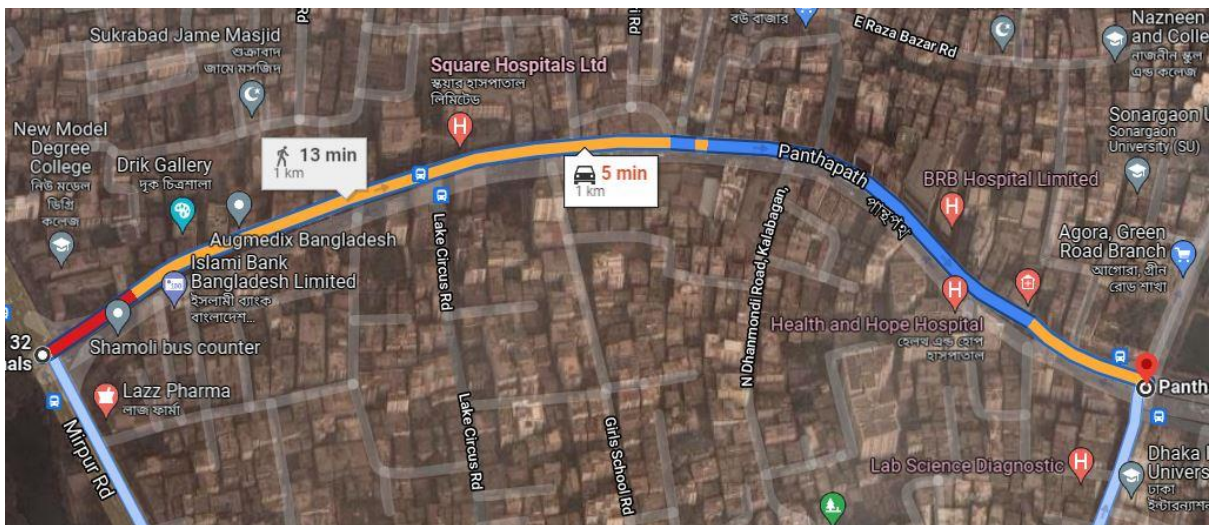


Figure 5: Bir Uttam Kazi Nuruzzaman Road

## **Chapter Four**

### **Data Collection & Analysis**

Collected Data has been presented and correspondingly analyzed in this chapter with respect to objectives stated in chapter one.

#### **4.1 Data Collection**

- Location: Panthapath-Rusell Square Road (about 20 feet way from Panthapath Mor intersection)
- Method – Matching registration plate, Stopwatch method. • Equipment – Tape, Stopwatch etc.
- Date: 23/12/21
- Day: Thursday
- Status: Working Day
- Time Schedule: 8am to 12pm
- Weather condition: Sunny.
- Temperature: 25 degrees Celsius
- Duration – 4 hrs (short count)
- Number of Enumerator – 05

#### **4.2 Data Analysis**

##### **4.2.1 Spot Speeds**

###### **Group 1**

For Group 1, time taken to travel a strip of 88 feet and their corresponding spot speeds are given below. The average speed of each type of vehicle is also shown.

**Table 5: Group 1 Spot Speed Data**

<b>Name of Vehicle</b>	<b>Light Vehicle</b>	<b>Motorbike</b>	<b>AutoRickshaw</b>	<b>Bus</b>
$V_{avg}$ (kmph)	39.7	35.0	30.6	38.0

Detailed calculations are provided in Appendix Table 1

- From the data of Group 1, it is evident that light vehicles, especially cars have the highest speed (39.7 kmph). Light vehicles are the dominating form of vehicle on the road.
- Bus has the relatively high speed (38.0 kmph) because only one or two buses could be recorded and thus result is skewed.
- Motorcycle also has a relatively high speed as it has a tendency to interweave between traffic and can maintain high speeds even in less-than-ideal conditions.
- Cars the dominating type of vehicles with an average speed of 39.7 kmph.

## **Group 2**

For group 2 another suitable 88 feet section was chosen.

Speed analysis is given below

**Table 6: Group 2 Spot Speed Data**

<b>Name of Vehicle</b>	<b>Light Vehicle</b>	<b>Motorbike</b>	<b>AutoRickshaw</b>	<b>Bus</b>
$V_{avg}$ (kmph)	24.7	30.4	23.6	24.0

Detailed calculations are provided in Appendix Table 2

- From the data of Group 2, it is evident that motorcycle has the highest speed (30.4 kmph). Just when the signal goes green, most of the motorcycles being at the front accelerated and since there was no obstruction to the flow, they reached a higher speed and hence the average speed was higher compared to other classified vehicles.
- Bus has a relatively high speed (24.0 kmph) as bus speed is skewed due to small sample size.
- When comparing to Group-6, all values of Group-2 are generally lower. This is because this is mid-road and Group-6 is road start point. At mid-road vehicle speed is reduced due to side friction and entry of vehicles from sideroads.

### Group 3

**Table 7: Group 2 Spot Speed Data**

Name of Vehicle	Light Vehicle	Motorbike	AutoRickshaw	Bus
$V_{avg}$ (kmph)	31.8	37.5	28.7	18.4

Detailed calculations are provided in Appendix Table 3

- From the data of Group 3, it is evident that motorcycle has the highest speed (37.5 kmph). Just when the signal goes green, most of the motorcycles being at the front accelerated and since there was no obstruction to the flow, they reached a higher speed and hence the average speed was higher compared to other classified vehicles.
- Bus has the lowest speed (18.4 kmph).
- This is mainly the side friction associated with their size and nature of service (i.e., bus has a tendency to stop and go for recruiting). Especially in our country this tendency is quite common.
- Cars the dominating type of vehicles with an average speed of 31.8 kmph.

- When compared with Group-5(mid-road), Group-3(road start) has higher speed values as vehicles

are just entering road and not obstructed by side friction or vehicular movement from sideroads.

#### Group 4

**Table 8: Group 4 Spot Speed Data**

Name of Vehicle	Light Vehicle	Motorbike	AutoRickshaw
$V_{avg}$ (kmph)	25.5	31.8	29.8

Detailed calculations are provided in Appendix Table 4

- From the data of Group 4, we see that motorcycle has the highest speed (31.8 kmph).
- Cars the dominating type of vehicles with an average speed of 25.5 kmph.
- We see speed values are very close to and higher than those of Group-2(mid-road) as Group-4(road-end) have just come from mid-road and accelerated a little bit.

#### Group 5

**Table 9: Group 5 Spot Speed Data**

Name of Vehicle	Light Vehicle	Motorbike	AutoRickshaw	Bus
$V_{avg}$ (kmph)	19.27	30.28	20.39	22.46

Detailed calculations are provided in Appendix Table 5

- From the data of Group 5, it is evident that motorcycle has the highest speed (30.28 kmph).
- Car has the lowest speed (18.4 kmph).

- When compared with Group-3(road start), Group-5(mid-road) has lower speed values as vehicles are just in mid-road and obstructed by side friction or vehicular movement from sideroads.
- We can also observe that motorcycle speed is relatively high and close to Group-3 value as motorcycle can interweave between vehicles and maintain high speed despite obstructions.

## Group 6

**Table 10: Group 6 Spot Speed Data**

Name of Vehicle	Light Vehicle	Motorbike	AutoRickshaw	Bus
$V_{avg}$ (kmph)	29.67	29.43	26.83	23.91

Detailed calculations are provided in Appendix Table 6

- From the data of Group 6, it is evident that car has the highest speed (29.67 kmph).
- Bus has the lowest speed (23.91 kmph).
- When compared with Group-2(mid-road), Group-6(road start), has higher speed values as vehicles are just entering the road and not obstructed by side friction or vehicular movement from side-roads.

### 4.2.2 Statistical Analysis Table (Panthapath to Russel Square Direction)

The speed data can be presented by:

1. Frequency Distribution Table, and
2. Frequency and Cumulative Frequency Distribution Curves

The individual speeds of vehicles collected from the field are used to prepare the frequency distribution table. The spot speed data collected along the Panthapath to Russell Square direction were grouped into some speed ranges and the frequency in each class were counted. The frequency distribution table shows the total number of vehicles observed in each speed group. The percentage frequency was obtained by dividing the frequency in each class by the total frequency.

**Table 11: Spot Speed Data for Panthapath to Russel Square**

Spot Speed Data for Panthapath to Russel Square				
Speed Range (mile per hr.)	Mid Speed V (mile per hr.)	Number of Vehicles Observed (f)	% Frequency	Cumulative % frequency
0-5	2.5	0	0.00	0.00
5-10	7.5	1	0.67	0.67
10-15	12.5	10	6.67	7.34
15-20	17.5	23	15.33	22.67
20-25	22.5	21	14.00	36.67
25-30	27.5	20	13.33	50.00
30-35	32.5	34	22.67	72.67
35-40	37.5	18	12.00	84.67
40-45	42.5	8	5.33	90.00
45-50	47.5	12	8.00	98.00
50-55	52.5	0	0.00	98.00
55-60	57.5	0	0.00	98.00
60-65	62.5	3	2.00	100.00
Total		150	100	

The weighted average speed was obtained by dividing the summation of the product of speed and frequency by the summation of frequency. For the Panthapath to Russell Square section, **the weighted average speed is 29.57 kmph.**

## Flow Histogram

It will show % frequency vs speed range data. From here we can understand at which speed maximum percent of vehicle are prone to travel. The histogram is shown below:

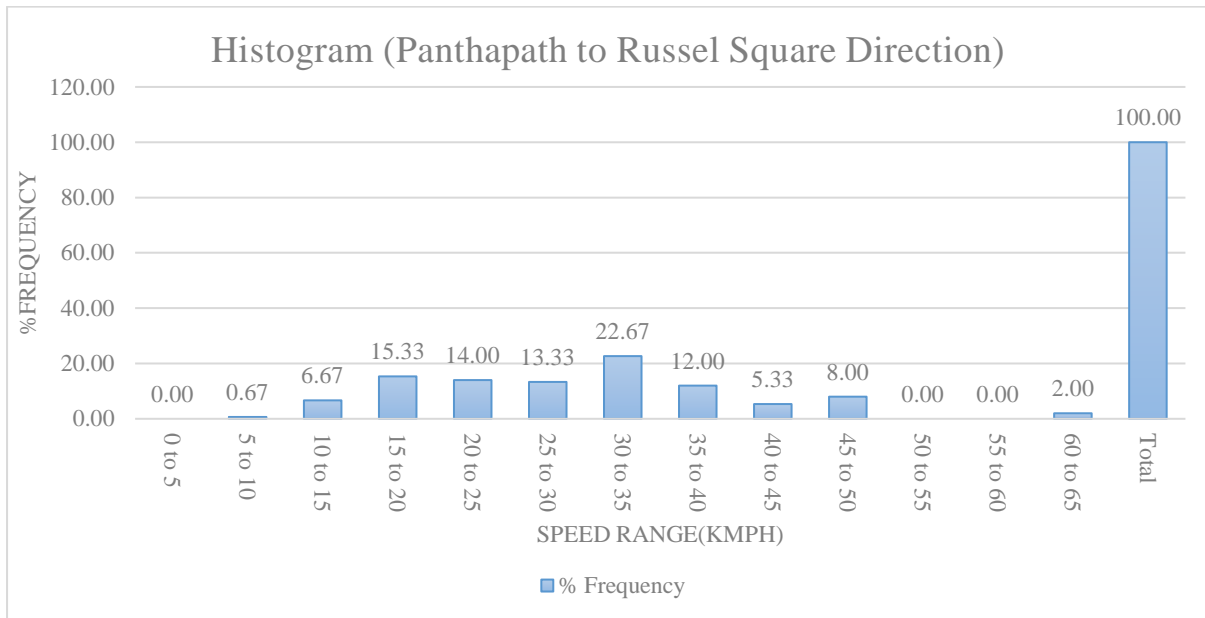


Figure 6: Histogram (Panthapath to Russel Square Direction)

- From the histogram it can be observed that most vehicles have speed range between 30-35 kmph. This is around 23%. Vehicles having speed in the 25-30 kmph range was also significant with a percentage frequency of around 13%.
- Velocity less than 20 kmph is very rare. The velocity of vehicles within the 15-20 kmph is mostly due to non-motorized vehicles like rickshaw.
- From speed data we can say there is no free flow nor “stop and go” situation
- Very few vehicles have speed greater than 50 kmph and indicates only a mere 2%.

## Frequency Curve

This curve plots %frequency vs spot speed. From here we can obtain the following:

- Modal speed
- Pace of traffic stream
- Average speed
- Upper and lower speed limit regulation
- Design speed

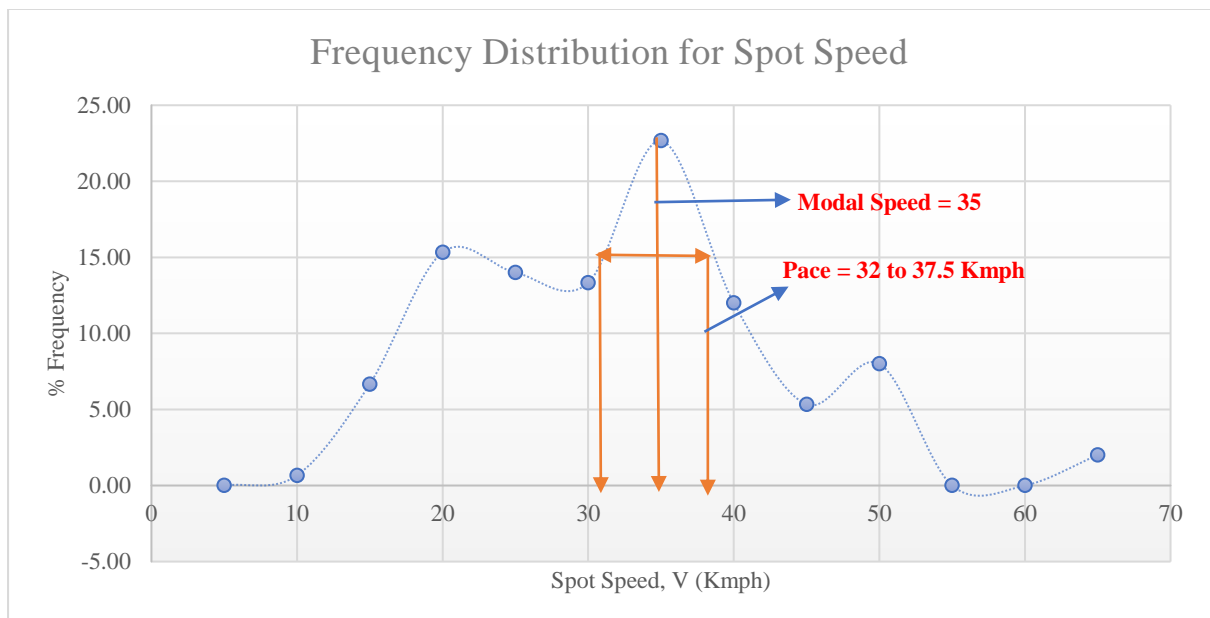


Figure 7: Frequency Distribution of Spot Speed (Panthapath to Russel Square Direction)

Hence, we can conclude:

- Modal speed is 35 kmph for this road and traffic condition. This is the speed which has the highest frequency and therefore indicates the optimum speed which drivers want to maintain in the roadway under concern.
- Pace is in between 32 kmph and 37.5 kmph. That is most drivers are seen driving with a 15-mph difference, and in between these speeds.

- As the curve is nearly symmetric, the median speed should be close to 35 kmph.

### Cumulative Frequency Distribution

It provides with the following variables:

- Design speed
- Safe speed
- Speed limits
- Median speed

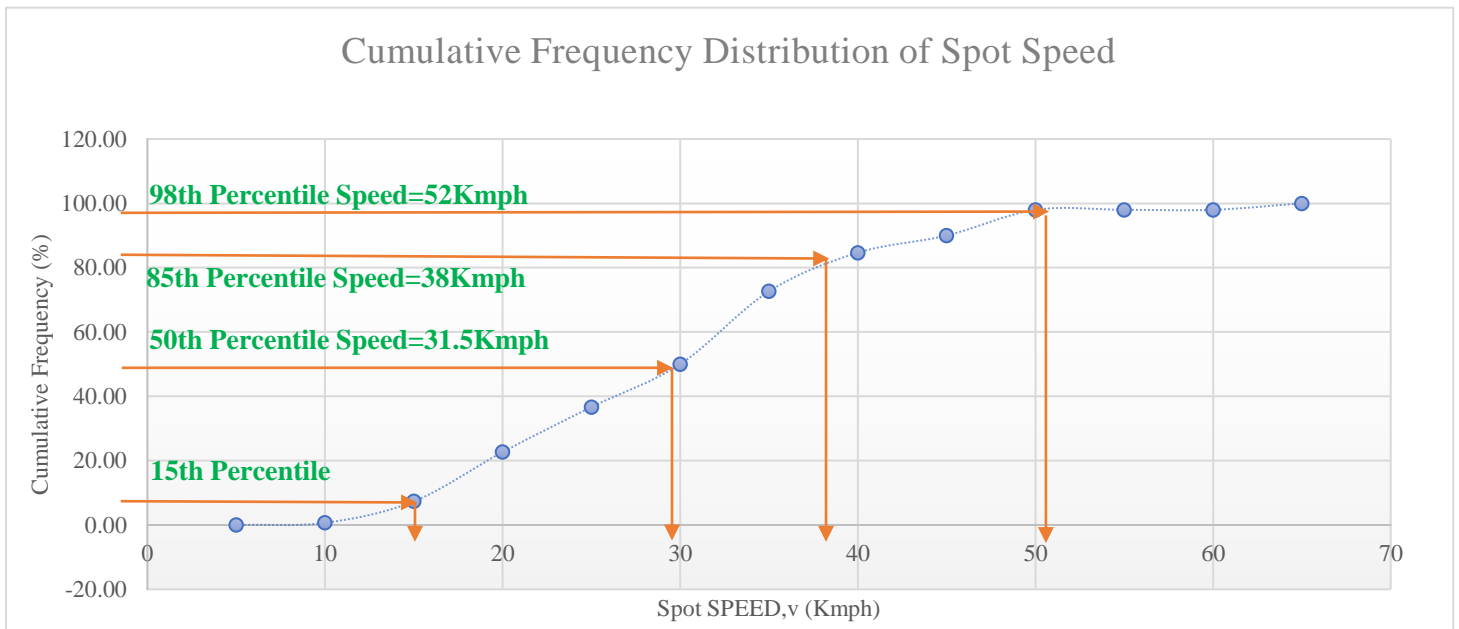


Figure 8: Cumulative Frequency Distribution of Spot Speed (Panthapath to Russel Square Direction)

- From the cumulative frequency graph, the 98th percentile correspond to the design speed. So, the design speed for this road from Panthapath to Russell Square section is 51 kmph.

- The median speed is the speed corresponding to 50th percentile. From the graph we can see the median speed is 34kmph.
- The 15th percentile speed is 27 kmph and the 85th percentile speed is 47 kmph. These are the lower and upper speed limits. The speed range is therefore 27 kmph- 47 kmph.

#### 4.2.3 Statistical analysis table (Russell Square to Panthapath Direction)

**Table 12: Spot Speed Data for Russel Square to Panthapath Direction**

Spot Speed Data for Russel Square to Panthapath Direction				
Speed Range (mile per hr.)	Mid Speed V (mile per hr.)	Number of Vehicles Observed (f)	% Frequency	Cumulative % frequency
0-5	2.5	0	0	0
5-10	7.5	4	2.484	2.484
10-15	12.5	46	28.571	31.055
15-20	17.5	75	46.584	77.639
20-25	22.5	31	19.255	96.894
25-30	27.5	4	2.484	99.378
30-35	32.5	1	0.621	100
35-40	37.5	0	0	100
Total		161	100	

For the Russell Square section to Panthapath direction, the **weighted average speed** is found to be **17.12 kmph**

## Flow Histogram

It will show % frequency vs speed range data. From here we can understand at which speed maximum percent of vehicle are prone to travel.

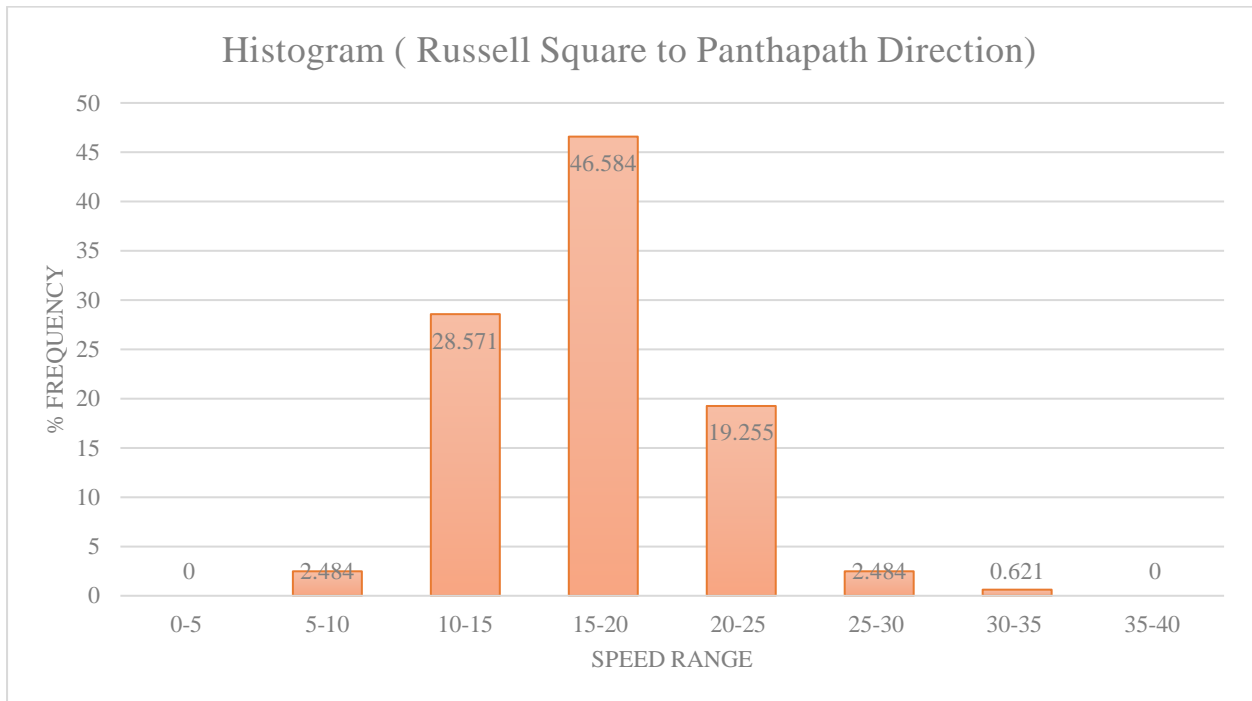


Figure 9: Histogram (Russel Square to Panthapath Direction)

- From the histogram it can be observed that most vehicles have speed range between 15-20 kmph. This is around 47%. Vehicles having speed range 10-15kmph and 20-25kmph were also significant with percentages of around 29% and 19%.
- Velocity less than 5kmph is very rare. The velocity of vehicles within the 5-10mph are mostly due to non-motorized vehicles like rickshaw. There were no vehicles with velocities less than 5mph.
- From speed data we can say there is no free flow nor “stop and go” situation. As a result of side frictions, free flow was not possible.

- Very few vehicles are within speed greater than 30mph. There are no vehicles in the 35-40mph range although vehicles with such speeds were seen in Panthapath to Russell Square Section.

## Frequency Curve

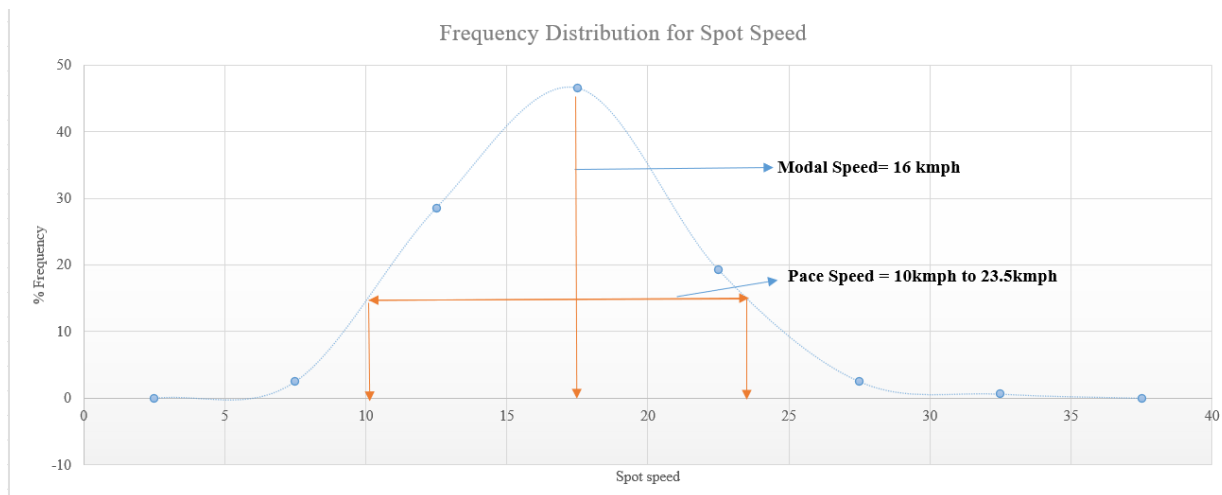


Figure 10: Frequency Distribution of Spot Speed (Russel Square to Panthapath Direction)

From the frequency curve we can obtain the following information –

- Modal speed is 16 kmph for this road and traffic condition. This is the optimum speed which most vehicles want to maintain.
- Pace is in between 10 kmph and 23.5 kmph. That is most drivers are seen driving, with a 15 kmph difference, in between these speeds
- As the curve is nearly symmetric, so median speed should be close to 16 kmph.

## Cumulative Frequency Distribution

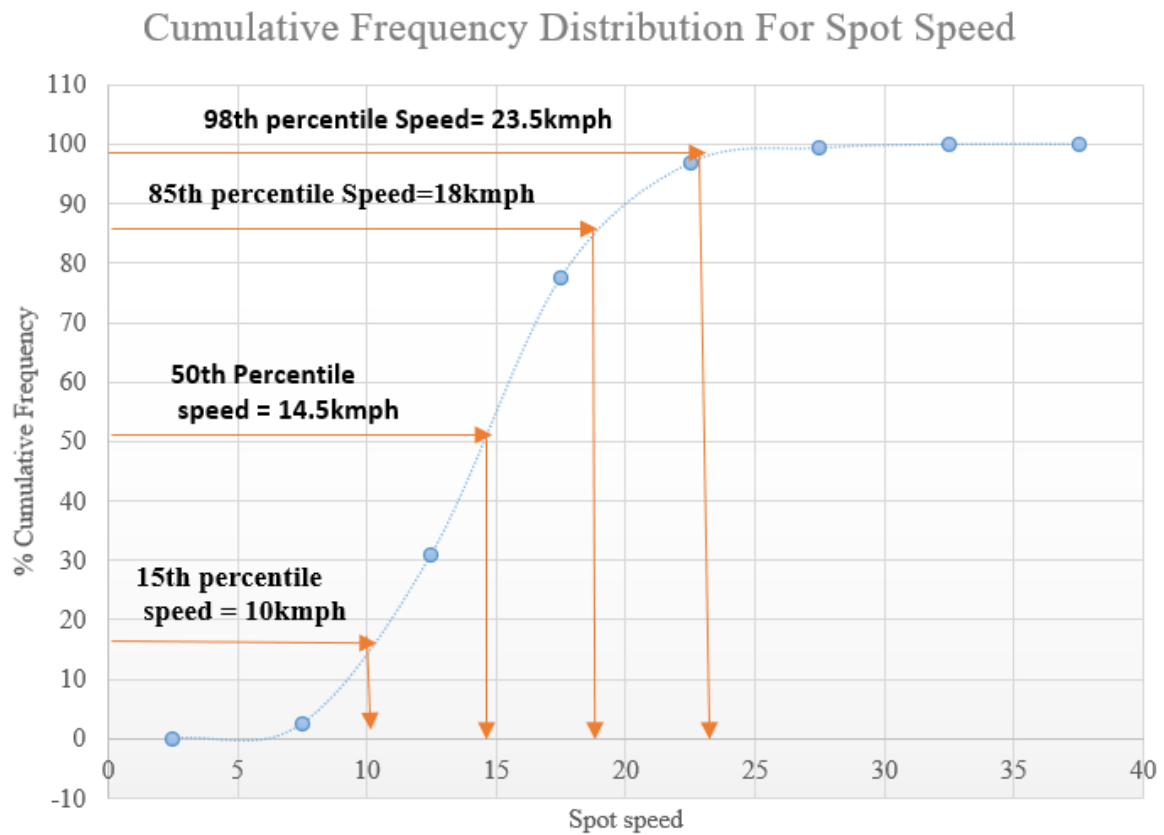


Figure 11: Cumulative Frequency Distribution of Spot Speed (Russel Square to Panthapath Direction)

- From the cumulative frequency graph, the 98th percentile correspond to the design speed. So, the design speed for this road from Russell Square to Panthapath section is 23.5 kmph.
- The median speed is the speed corresponding to 50th percentile. From the graph we can see the median speed is 14.5 kmph.
- The 15th percentile speed is 10 kmph and the 85th percentile speed is 18 kmph. These are the lower and upper speed limits. The speed range is therefore 10 kmph-18 kmph.

#### 4.2.4 Fitting Normal Distribution Curve

##### Standard Deviation for Light Vehicle

In order to fit a normal distribution curve, firstly we need to know the mean and standard deviation of the speed for the particular vehicle. Standard deviation is a measure of the dispersion of a set of data from its mean. If the data points are further from the mean, there is higher deviation within the data set. Standard deviation is calculated as the square root of variance by determining the variation between each data point relative to the mean. The following table shows the calculation of mean and standard deviation for Light Vehicle.

**Table 13: Calculation of Mean and Standard Deviation for Light Vehicles**

Speed Range (kmph)	Mid-Point (xi) (kmph)	No. of Vehicles Observed (fi)	fixi	Mean ( $\bar{x}$ )	yi = xi - $\bar{x}$	fiyi	fiyi <sup>2</sup>	Standard Deviation (sd)
0-5	2.5	0	0	28.483	-25.983	0	0	9.918619643
5-10	7.5	2	15		-20.983	-41.966	880.572578	
10-15	12.5	6	75		-15.983	-95.898	1532.737734	
15-20	17.5	11	192.5		-10.983	-120.813	1326.889179	
20-25	22.5	24	540		-5.983	-143.592	859.110936	
25-30	27.5	28	770		-0.983	-27.524	27.056092	
30-35	32.5	25	812.5		4.017	100.425	403.407225	
35-40	37.5	10	375		9.017	90.17	813.06289	
40-45	42.5	0	0		14.017	0	0	
45-50	47.5	9	427.5		19.017	171.153	3254.816601	
50-55	52.5	0	0		24.017	0	0	
55-60	57.5	0	0		29.017	0	0	
60-65	62.5	2	125		34.017	68.034	2314.312578	
Total =		117	3332.5			-0.011	11411.9658	

Here, mean and standard deviation was estimated using following formulas.

$$\text{Mean, } \mu = 3332.5 / 117 = 28.483$$

$$\text{Standard deviation, } \sigma = \sqrt{(11411.9658 / (117-1))} = 9.92$$

## Chi( $\chi^2$ ) Test for Light Vehicle

A chi-squared test, also written as  $\chi^2$  test, is any statistical hypothesis test where in the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true. The chi-squared test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories. For normal distribution curve fitting a statistical chart is shown in the table:

**Table 14: Chi( $\chi^2$ ) Value Calculation**

Speed Range (kmp)	Upper Speed Class Limit (xi) (kmph)	xi - $\bar{x}$	u = (xi - $\bar{x}$ )/sd	Cumulative Probability P(= $\leq$ u)	Probability of Speed lying between successive values of xi (DP)	Observed Frequency (O)	Theoretical Frequency E = ( $\sum$ O)(DP)	Chi-square Value $c^2 = (O - E)^2/E$
0-5	5	-23.483	-2.37	0.0089	0.0089	0	1.04	1.04
5-10	10	-18.483	-1.86	0.0314	0.0225	2	2.63	0.15
10-15	15	-13.483	-1.36	0.0869	0.0555	6	6.49	0.04
15-20	20	-8.483	-0.86	0.1949	0.1080	11	12.64	0.21
20-25	25	-3.483	-0.35	0.3632	0.1683	24	19.69	0.94
25-30	30	1.517	0.15	0.5596	0.1964	28	22.98	1.10
30-35	35	6.517	0.66	0.7454	0.1858	25	21.74	0.49
35-40	40	11.517	1.16	0.8770	0.1316	10	15.40	1.89
40-45	45	16.517	1.67	0.9525	0.0755	0	8.83	8.83
45-50	50	21.517	2.17	0.9850	0.0325	9	3.80	7.10
50-55	55	26.517	2.67	0.9962	0.0112	0	1.31	1.31
55-60	60	31.517	3.18	0.9993	0.0031	0	0.36	0.36
60-65	65	36.517	3.68	0.9998	0.0005	2	0.06	59.37
65-70	70	41.517	4.19	.9999	0.0001	0	0.01	0.01
<b>Total =</b>						117	117	82.85

Here the cumulative probability for each class was obtained with the use of normal distribution function chart values and their individual probability from the difference. The theoretical frequency obtained was used for drawing the theoretical normal distribution curve as shown in figure below. Chi square value for each class was also obtained.

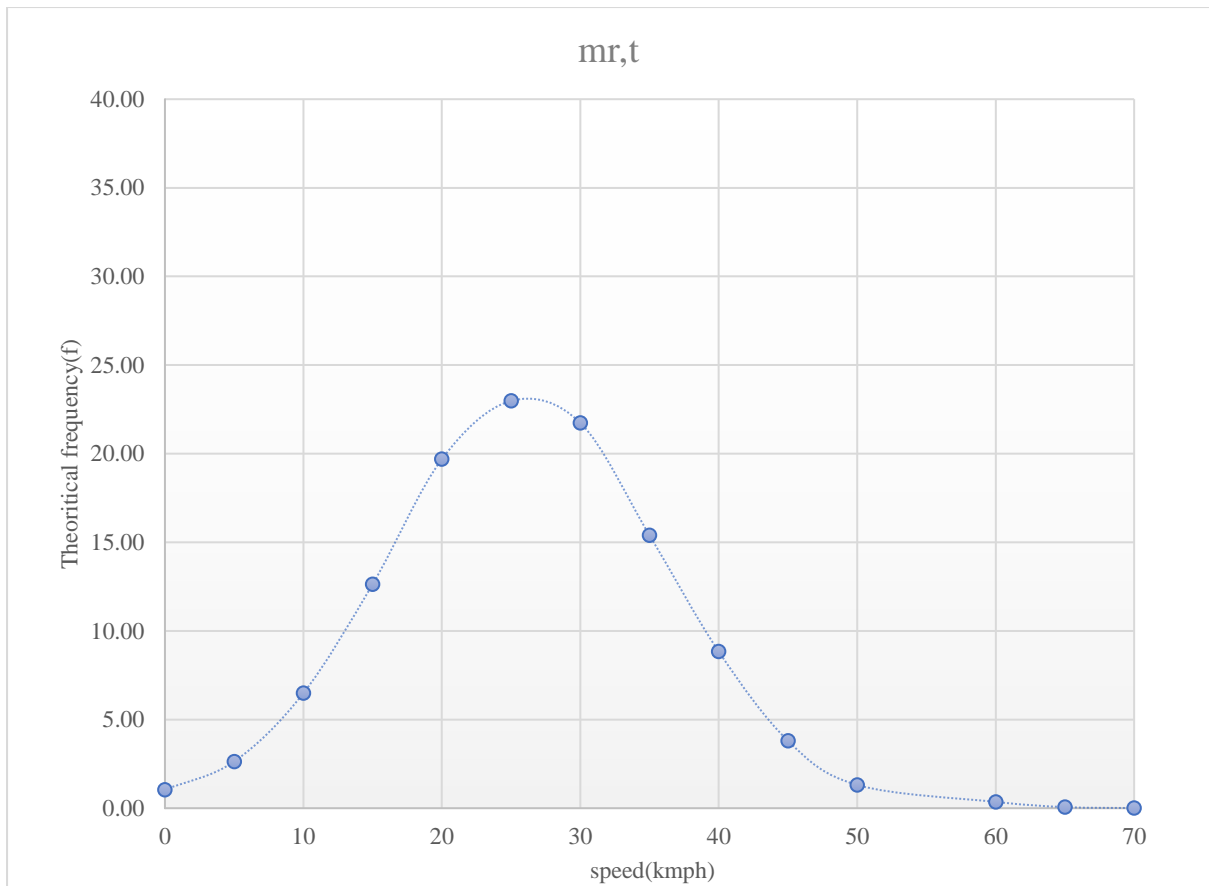


Figure 12: Theoretical Normal Distribution Curve

Thus, goodness of the fit was checked by superimposing the observed normal distribution curve upon the theoretical curve as shown in the figure 12.

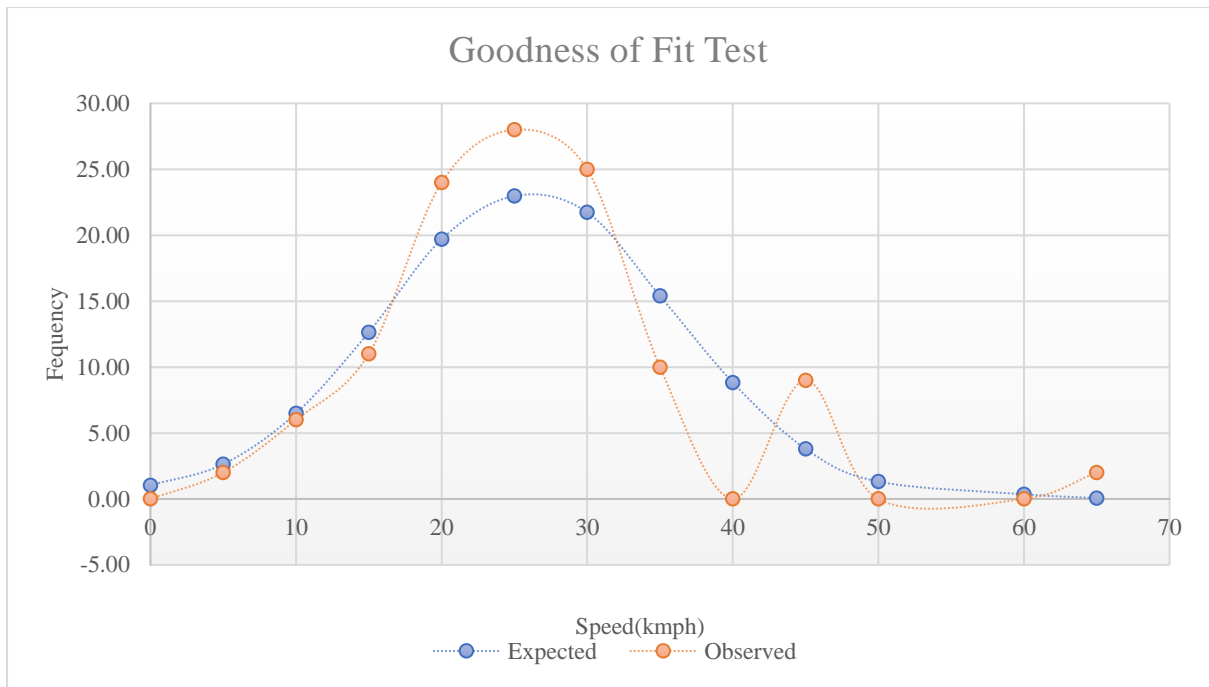


Figure 13: Goodness of the Fit Comparison with theoretical and actual

For the following range of speed 0-5,5-10, 50-55,55-60,60-65,65-70 kmph, the observed frequency is less than 5. So, the corresponding values were added with the next data. As a result, chi square values were corrected as shown in table below.

**Table 15: Corrected Chi( $\chi^2$ ) Value Calculation**

Speed Range (kmp)	Upper Speed Class Limit (xi) (kmph)	u = (xi - $\bar{x}$ )/sd	Cumulative Probability P(= < u)	Probability of Speed lying between successive values of xi (DP)	Observed Frequency (O)	Theoretical Frequency E = ( $\sum O$ )(DP)	Chi-square Value $c^2 = (O - E)^2/E$
0-5	5	-2.75	0.0030	0.0030	0.35	0	0.35
5-10	10	-2.16	0.0158	0.0128	1.50	0	1.50
10-15	15	-1.58	0.0571	0.0413	4.83	8	2.07
15-20	20	-0.99	0.1631	0.1060	12.40	11	0.16
20-25	25	-0.41	0.3409	0.1778	20.80	24	0.49
25-30	30	0.18	0.5714	0.2305	26.97	28	0.04
30-35	35	0.76	0.7764	0.2050	23.99	25	0.04
35-40	40	1.35	0.9115	0.1351	15.81	10	2.13
40-45	45	1.93	0.9732	0.0617	7.22	6	0.21
45-50	50	2.52	0.9941	0.0209	2.45	5	2.66
50-55	55	3.10	0.9990	0.0049	0.57	0	0.57
55-60	60	3.69	0.9999	0.0008	0.10	0	0.10
60-65	65	4.28	0.9999	0.0000	0.00	0	0.00
65-70	70	4.86	0.9999	0.0000	0.00	0	0.00
<b>Total =</b>					117	117	10.32

Chi-square value observed=10.32

Now, no. of observations (class range) = 5

No. of independent parameters= 2

Degree of freedom = 5-2-1=2

For DOF=2 & 95% Level of Significance, Critical Chi-square value from table = 0.103

So, Chi-square observed > Chi-square critical

So, for 95% Level of significance, the observed data show a bad fit with expected normal distribution as evident in figure below



Figure 14: Goodness of the Fit Comparison with theoretical and corrected observed value

#### 4.2.5 Travel Speed Study

If we analyze the data, we can find the vehicle matching and the percentage of matching:

**Table 16: Percentage of matching vehicles in License Plate Method**

Vehicle Types	Vehicles Counted	Matched	% Matched	% Total Matched
LV	157	35	22.29	18.52
CNG	143	19	13.29	
Bike	50	10	20	
Bus	1	1	100	

So most matched vehicle is Light Vehicle with 22% and least matched vehicle is Auto-rickshaw with 13.29%. Bus is not considered as only 1 vehicle was present.

#### Calculation of Time-mean and Space –mean Speed and Proof of $V_s < V_t$

##### Time-Mean Speed:

The speed obtained when the sum of all values is divided by the number of observations. It gives arithmetic mean of the spot speeds vehicles passing a point. Useful for traffic regulation purposes.

##### Space-Mean Speed:

Space mean speed is defined as the harmonic mean of speeds passing a point during a period of time. It also equals the average speeds over a length of roadway.

**Summary** (Detail in Appendix)

#### (Russell Square to Panthapath)

From the above table we find that,

n= Number of observations = 38

$\sum v =$  Sum of individual speeds = 238.29 mph

$s =$  space distance = .59 mile

$t =$  mean travel time = 14700 sec = 4.08 hrs.

So, time-mean speed,  $V_t = \sum v/n = 238.29/38 = 6.27$  mph

and space-mean speed,  $V_s = (n*s)/t = (38*.59)/4.08 = 5.50$  mph

### **(Panthapath to Russell Square)**

From the above table we find that,  $n =$  Number of observations = 27

$\sum v =$  Sum of individual speeds = 326.02 mph

$s =$  space distance = .59 mile

$t =$  mean travel time = 5340 sec = 1.48 hrs.

So, time-mean speed,  $V_t = \sum v/n = 326.02/27 = 12.07$  mph

and space-mean speed,  $V_s = (n*s)/t = (27*.59)/1.48 = 10.76$  mph

So, for the both cases we can see that space-mean speed is lower than time-mean speed ( $V_s < V_t$ ).

Hence, it is proven that the Space-mean speed is lower than the time mean speed ( $V_s < V_t$ )

### **4.2.6 Wardrop Relationship**

It is obvious that the space-mean speed is lower than the time-mean speed (usually  $\bar{v}_s < \bar{v}_t$ ).

Beyond this there exists a relationship between space-mean speed and time-mean speed with standard deviation and variance. It is called Wardrop relationship, which is given by

$$\bar{v}_t = \bar{v}_s + \frac{\delta S^2}{\bar{v}_s}$$

Here,

$\bar{v}_t$  = Time mean speed

$\bar{v}_s$  = Space mean speed

$\delta s$  = Standard Deviation

$\delta s^2$  = Variance

$\bar{x}$  = Weighted average speed

$x_i$  = Mid-point speed of i-th range

**Table 17: Wardrop Relationship (Panthapath to Russel Square)**

<b>Standard Deviation, <math>\delta s</math></b>	Variance, $\delta s^2$	Space Mean Speed, $V_s$	Time Mean Speed, $V_t$ (Wardrop)
<b>3.93</b>	15.43	10.76	12.19

Summary:

Here, Standard deviation,  $\delta s = 3.93$

Variance,  $\delta s^2 = 15.43$

So, from equation  $V_t$  (Wardrop) = 12.19 mph

**Table 18: Wardrop Relationship (Russel Square to Panthapath)**

<b>Standard Deviation, <math>\delta s</math></b>	Variance, $\delta s^2$	Space Mean Speed, $V_s$	Time Mean Speed, $V_t$ (Wardrop)
<b>2.41</b>	5.80	5.5	6.55

Summary:

Here, Standard deviation,  $\delta s = 2.41$

Variance,  $\hat{\sigma}^2 = 5.80$

So, from equation  $V_t$  (Wardrop) = 6.55 mph

In both cases, the calculated value is close to observed, so, Wardrop Relationship is verified.

#### 4.2.7 Calculation of Delay

To estimate the delay in each direction, we need the number of vehicles passing through the section in 4 hours according to our duration of survey. The following table shows the number of vehicles of each type flowing in each direction in a specific time travel:

**Table 19: Number of Vehicles Flowing in each direction**

Vehicle Class	East to West		West to East	
	Vehicles/hr	Vehicles/4hr	Vehicles/hr	Vehicles/4hr
Bus (B)	7	28	8	32
Truck (T)	0	0	3	12
Light Vehicle (LV)	347	1388	532	2128
Auto Rickshaw (AR)	158	632	168	672
SPT	0	0	0	0
Motorcycle (MC)	150	600	379	1516

**Table 20: Delay from East to West**

Vehicle Type	Obs. No.	Duration (sec.)	Distance (mile)	Free Flow Duration	Delay (sec)		Avg Delay (hr/vehicle)	Total Vehicle in 4hr	Total Delay (hr/vehicle/4hr)	DEF (Thursday)	Estimated 7 days Volume (vehicle)	Avg 24 hr volume, ADT (vehicle)	Total Delay (hr/vehicle/day)	MEF (December)	AADT	Total Delay (hr/vehicle/day)
LV	1	180	0.59	120	60	0.0147	1388	20.41	7.012	58396	8342	122.7	1.355	11304	60675	
	2	180	0.59	120	60											
	3	120	0.59	120	0											
	4	120	0.59	120	0											
	5	240	0.59	120	120											
	6	120	0.59	120	0											
	7	180	0.59	120	60											
	8	180	0.59	120	60											
	9	120	0.59	120	0											
	10	180	0.59	120	60											
	11	180	0.59	120	60											
	12	180	0.59	120	60											
	13	360	0.59	120	240											
	14	180	0.59	120	60											
	15	180	0.59	120	60											
	16	120	0.59	120	0											
	17	120	0.59	120	0											
AR	18	420	0.59	180	240	0.0262	632	16.55	7.012	26590	3799	99.48	1.355	5147	49203	
	19	240	0.59	180	60											
	20	180	0.59	180	0											
	21	300	0.59	180	120											
	22	240	0.59	180	60											
	23	240	0.59	180	60											
	24	300	0.59	180	120											
MC	25	120	0.59	120	0	0.0111	600	6.667	7.012	25243	3606	40.07	1.355	4886	19817	
	26	180	0.59	120	60											
	27	180	0.59	120	60											

**Table 21: Delay from West to East**

Vehicle Type	Obs. No.	Duration (sec.)	Distance (mile)	Free Flow Duration	Delay (sec)	Avg Delay (hr/vehicle)	Total Vehicle in 4hr	Total Delay (hr/vehicle/4hr)	DEF (Thursday)	Estimated 7 days Volume (vehicle)	Avg 24 hr volume, ADT (vehicle)	Total Delay (hr/vehicle/day)	MEF (December)	AADT	Total Delay (hr/vehicle/year)
<b>AR</b>	1	480	0.59	300	180	0.0569	672	38.27	7.012	28272	4039	230.0	1.355	5473	113749
	2	540	0.59	300	240										
	3	540	0.59	300	240										
	4	480	0.59	300	180										
	5	600	0.59	300	300										
	6	480	0.59	300	180										
	7	540	0.59	300	240										
	8	600	0.59	300	300										
	9	300	0.59	300	0										
	10	540	0.59	300	240										
	11	540	0.59	300	240										
	12	420	0.59	300	120										
<b>LV</b>	13	240	0.59	180	60	0.0343	2128	72.90	7.012	89529	12790	438.2	1.355	17330	216709
	14	240	0.59	180	60										
	15	420	0.59	180	240										
	16	300	0.59	180	120										
	17	300	0.59	180	120										
	18	240	0.59	180	60										
	19	300	0.59	180	120										
	20	540	0.59	180	360										
	21	240	0.59	180	60										
	22	300	0.59	180	120										
	23	300	0.59	180	120										
	24	300	0.59	180	120										
	25	360	0.59	180	180										
	26	300	0.59	180	120										
	27	360	0.59	180	180										
	28	180	0.59	180	0										
	29	180	0.59	180	0										
	30	360	0.59	180	180										
<b>MC</b>	31	420	0.59	180	240	0.0524	1516	79.41	7.012	63781	9112	477.3	1.355	12346	236048
	32	540	0.59	180	360										
	33	300	0.59	180	120										
	34	240	0.59	180	60										
	35	600	0.59	180	420										
	36	300	0.59	180	120										
	37	180	0.59	180	0										

## Cost of Delay

**Table 22: Cost of Delay Calculation**

Vehicle Class	VOC (2016) (Tk/hr/vehicle/yea	VOR (person/vehicle)	VOT (Tk/person/hr)	Total Delay (hr/vehicle/year) (East to West)	Total Delay (hr/vehicle/year) (West to East)	Cost of Delay (Tk/year) (East to West)	Cost of Delay (Tk/year) (West to East)	Total cost of Delay (Tk)
Light Vehicle (LV)	22.3	1.5	25	60675	216709	3628365	12959198	33385971
Auto Rickshaw (AR)	26.9	1	25	49203	113749	2553636	5903573	
Motor Cycle (MC)	7.6	1	25	19817	236048	646034	7695165	

### Cost of delay over 20 years

Considering an internal rate of return of 6%

Delay Cost over 20 years =  $33385971(1+0.06)^{20}$  = Tk 107,073,331

Cost of a new one lane 1 km urban road =Tk 55,00,000

Benefit-Cost ratio =  $107,073,331/(3*2*55,00,000)$  = 3.24 > 1

So, this project is economically feasible

#### 4.2.8 Speed (space-mean) Flow Curve

The relationship between speed and flow has been a topic of intense research in traffic flow theory. If traffic conditions on a given road segment are stationary and that drivers behave the same way, on average, under the same average conditions, a relationship between speed and flow exists.

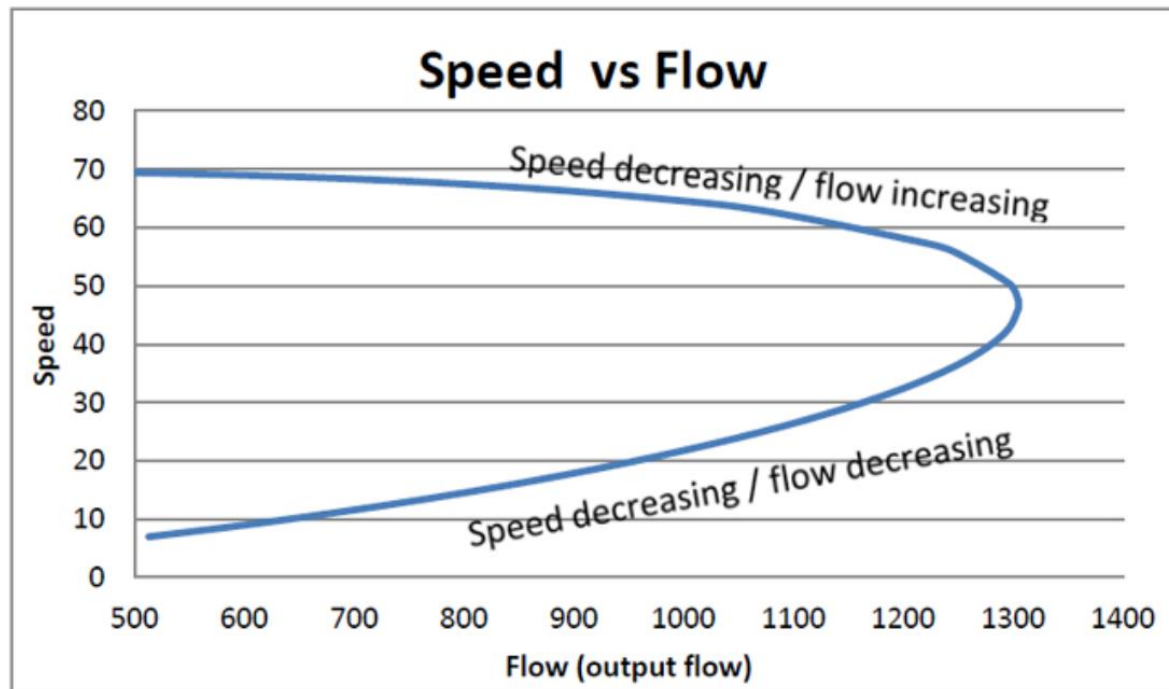


Figure 15: An Ideal Speed (Space-mean)-Flow Curve

#### Determination of Level of Service

Highway Capacity Manual (HCM) used travel speed and volume by capacity ratio ( $v/c$  ratio) to distinguish between various levels of service. The value of  $v/c$  ratio can vary between 0 and 1. Depending upon the travel speed and  $v/c$  ratio, HCM has defined six levels of service, level A to level F based on a graph between operating speed and  $v/c$  ratio as shown in the figure.

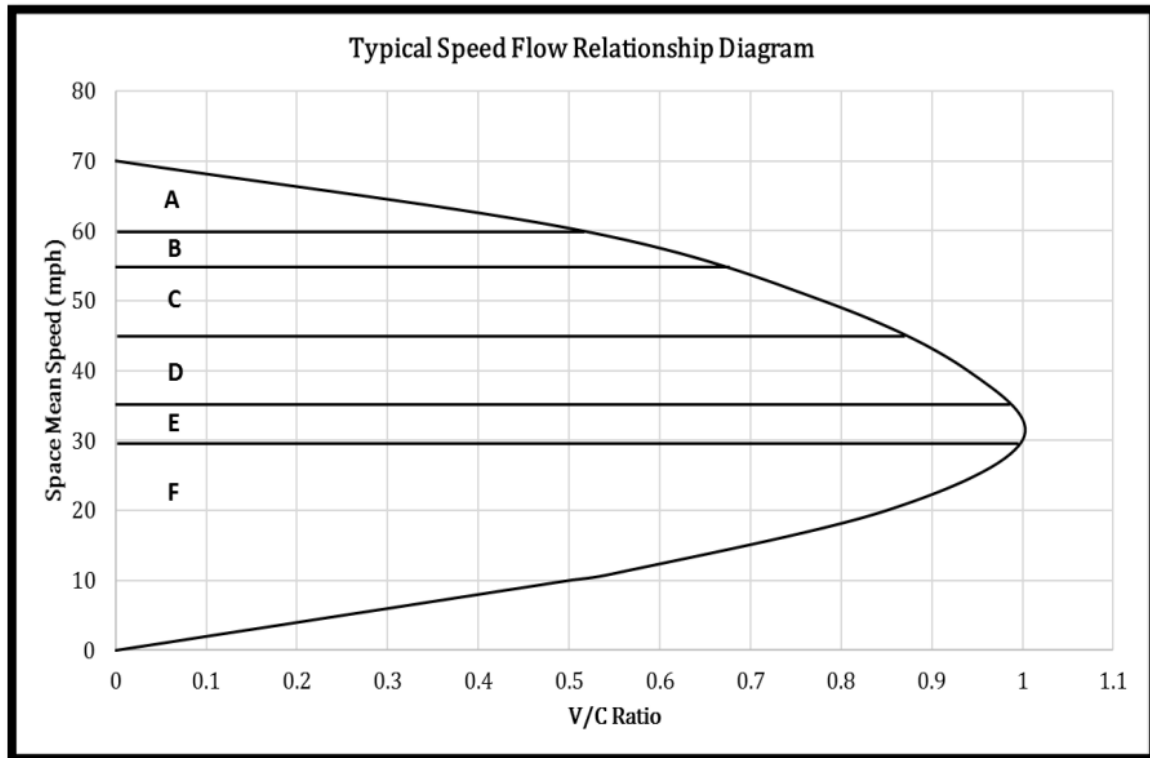


Figure 15: Level of Service Determination from Speed Flow Relationship Diagram

Level of service A represents the zone of free flow. Here the traffic volume will be less, traffic will be experiencing free flow also. The drivers will be having the complete freedom to choose their desired speed. Level of service B represents zone of reasonably free flow. Free flow speeds are still maintained at this level of service. The drivers' freedom to choose their desired speed is only slightly restricted. At level of service C, the presence of other vehicles begins to restrict the maneuverability within the traffic stream. Average speeds remain at or near the free flow speed level, but significant increase in driver vigilance is required at this level. At level of service D, the average speeds begin to decline with increasing flows. Freedom to maneuver within the traffic stream is noticeably restricted. At this level, density deteriorates more quickly with flow. Level of service E define operation at capacity. At this level, the stream reaches its maximum density limit. There will be no usable gaps in the stream and even slight disruptions will cause a breakdown, with queues forming rapidly behind the disruption. Level of service F describes conditions in a queue that has formed

behind a point of breakdown or disruption. As vehicles shuffle through the queue, there may be periods when they move quickly, and others when they are stopped completely. Thus, this level of service is used to describe the point of breakdown as well, even though operations downstream of such a breakdown may appear good. Level of service F represents the region of forced flow, having low speed and complete breakdown of the system. For determining level of service of the roadway,

Volume Capacity ratio of the roadway was determined with the use of following table

**Table 23: Volume/Capacity Ratio**

Direction	Time	Volume	Avg Volm	V/C ratio	Space-mean
		PCU/Hr	PCU/hr		Speed
<b>Panthapath to</b>	8:00-8:30	859.5	1051.67	0.26	10.76
<b>Russel Square</b>	9:00-9:30	1184			
	10:00-10:30	1111.5			
<b>Russel Sq to</b>	11:00-11:30	1682	1841.83	0.46	5.5
<b>Panthapath</b>	12:00-12:30	1928.5			
	1:00-1:30	1915			

Here capacity was estimated in the following manner:

$$\text{Capacity} = \text{Peak Factor}(k) \times \text{ADT} = 0.15 \times 26623.5 = 3993.525$$

Here, peak factor (k) was considered 15% of Average ADT.

Average ADT was estimated from the ADT obtained for each direction in the volume study of the corresponding survey location as shown in the table 24

**Table 23: Estimation of Average ADT for the Roadway**

Direction	ADT	Average ADT	Capacity
Panthapath to Russel Square	20112	26623.5	3993.525
Russel Sq to Panthapath	33135		

As shown in table 23, for Panthapath signal to Russell square direction a point (V/C ratio = 0.26, space mean speed = 10.76 mph) was obtained and was superimposed over the ideal theoretical LOS graph as shown in figure 16.

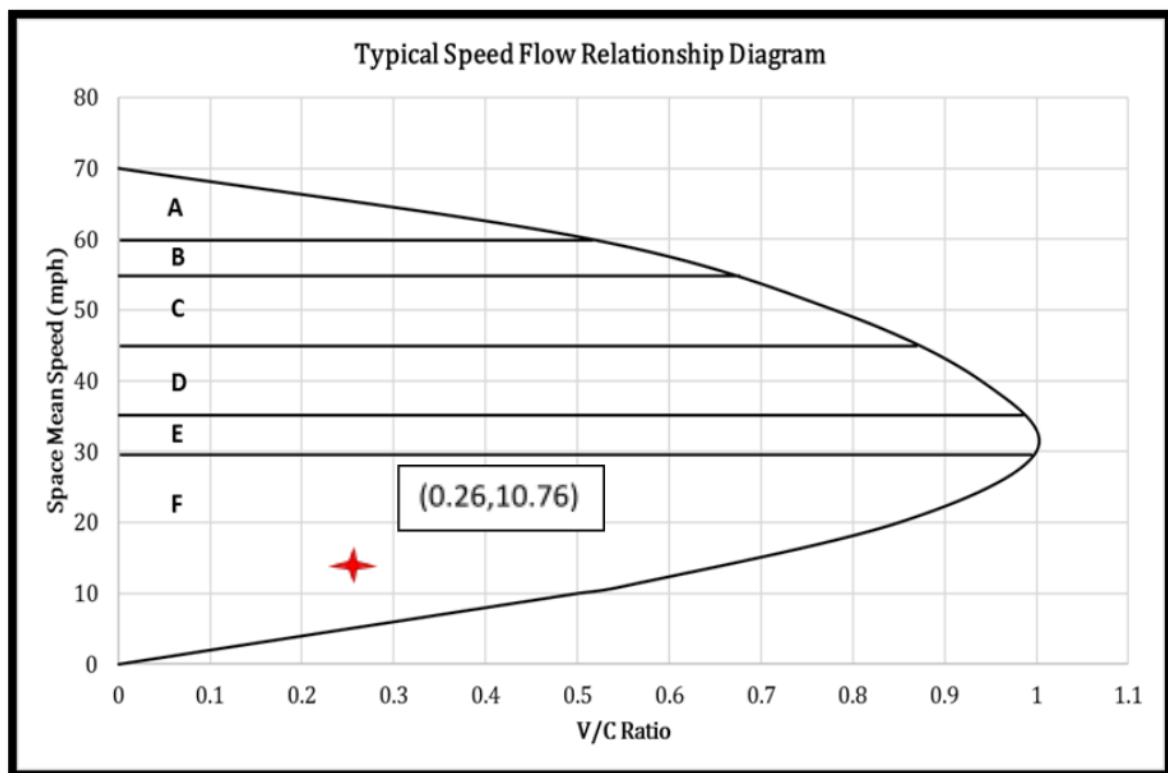


Figure 16: Level of Service for Panthapath to Russel Square Direction

From the figure, it can be determined that the level of service = F

As shown in table 23, for Russell square to Panthapath direction a point (V/C ratio = 0.46, space mean speed = 5.5 mph) was obtained and was superimposed over the ideal theoretical LOS graph as shown in figure 16.

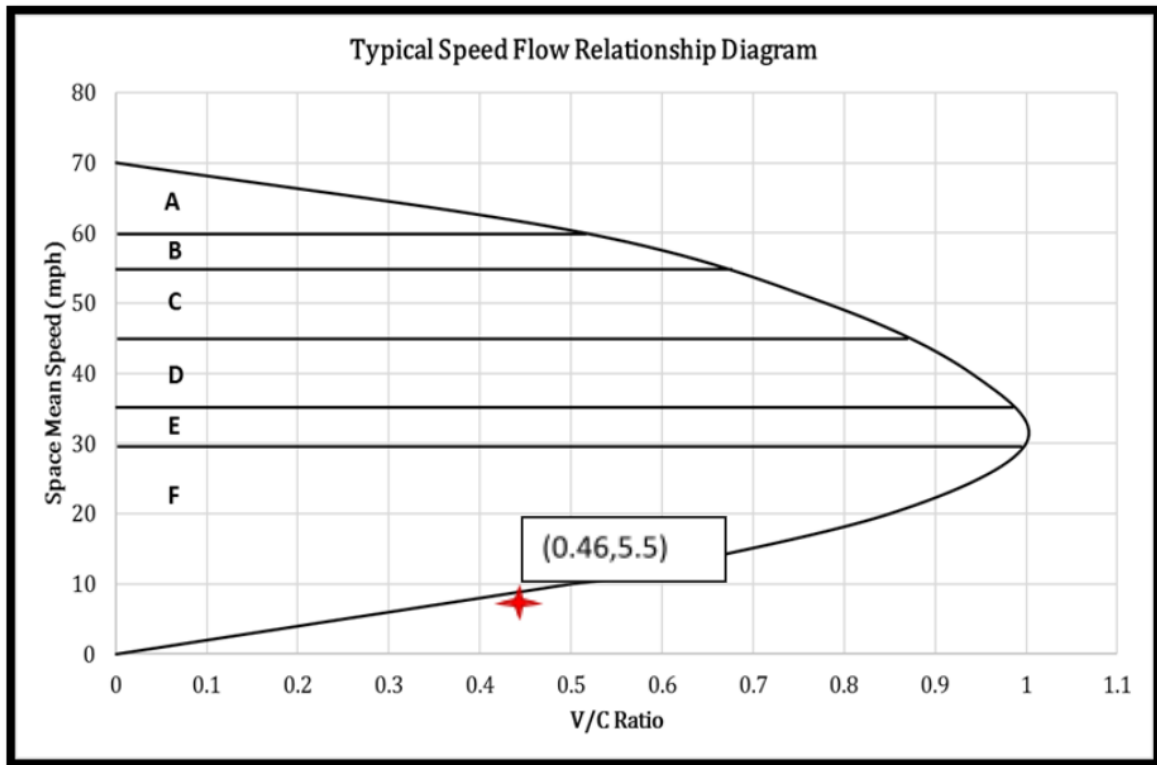


Figure 17: Level of Service for Russel Square to Panthapath Direction

From the Graph in figure 3, no level of service can be determined as the superimposed point is outside of the theoretical speed flow curve.

# Chapter Five

## Conclusion & Recommendations

### 5.1 Introduction

In this chapter, observations and insights made in the previous chapter are presented in a summarized form. These leads to some recommendation for the improvement of this roadway. Though the study is done with proper attention, there is always a scope for better study. Recommendation for both the improvement of roadway and for further study is under the scope of this chapter

### 5.2 Results

#### 5.2.1 Spot Speed

##### **Panthapath to Russell Square Direction**

- Weighted average speed is 29.57 kmph.
- Modal speed 35 kmph
- Pace is in between 32 kmph and 37.5 kmph.
- Design speed for this road from Panthapath to Russell Square section is 51 kmph.
- Median speed is 34 kmph.
- The speed limits are therefore 27 kmph- 47 kmph.

##### **Russell Square to Panthapath Direction**

- Weighted average speed is 17.12 kmph.
- Modal speed is 16 kmph
- Pace is in between 10 kmph and 23.5 kmph.
- Design speed for this road from Russell Square to Panthapath section is 23.5 kmph.
- The median speed is 14.5 kmph.

- The speed limits are therefore 10 kmph-18 kmph

**From speed data we can say there is no free flow situation.**

Although the distribution of speed seemed to have a normal distribution but after checking with the chi-squared test, there was a significant difference between the expected frequencies and the observed frequencies. This may or may not be true since we didn't have sufficient data. At 95% level of confidence, the observed data showed a bad fit with expected normal distribution.

### **5.2.2 Travel Speed**

#### **Panthapath to Russel Square Direction**

- Time-mean speed,  $V_t = 12.07$  mph
- Space-mean speed,  $V_s = 10.76$  mph

#### **Russell Square to Panthapath Direction**

- Time-mean speed,  $V_t = 6.27$  mph
- Space-mean speed,  $V_s = 5.50$  mph

**For both cases,  $V_s$  was found to be less than  $V_t$  as hypothesized, and the results were coherent with the Wardrop Relationship**

### **5.2.3 Cost of Delay**

Total Yearly Cost of Delay was found to be 33385971 BDT

In 20 years, it is forecasted to rise to 107,073,331 BDT in cost.

Expansion of the 1km road by one lane in urban setting was estimated to cost 55,00,000 BDT.

Converting the cost of delay to incumbent benefit from expansion of road, leads to the project having a benefit-cost ratio of 3.24 which is far greater than 1, implying that expanding the road by one lane is an economically viable project.

#### **5.2.4 Speed-Flow Characteristics**

For Panthapath to Russel Square Direction Level of Service was determined as F.

For Russel Square to Panthapath direction, Level of Service could not be determined.

#### **5.3 Recommending Improvement Measures**

- A) As speed decreases near the two intersections, channelization on Panthapath side and its implication should be introduced.
- B) It was found that speed decreased due to loss of width which is the result of unauthorized parking. So, improvement can be done here.
- C) Traffic control systems need to improve to allow for smooth flow.
- D) NMV should be restricted from intermingling with higher speed vehicles.
- E) Public Transport should be increased
- F) Width expansion of the road seems to be a viable project, and should be investigated further
- G) Side friction should be reduced by ejecting dustbins, vendors, rickshaws parked in the road.
- H) Separate lanes for non-motorized vehicles.
- I) Improve road quality by repairing cracks, potholes.
- J) High rise buildings should have separate frontal roads so that the traffic generated does not hinder the through traffic of main road
- K) Pedestrians should not be allowed casually jaywalk

#### **5.4 Limitations**

- A) The number of individuals was limited along with usage of manual method. If more data can be collected, it would give us a more representative data. Then, the weighted average speed, modal speed and other speeds calculated would be more accurate and representative
- B) Data for only one day was collected due to time constraints. However, it is necessary to collect data for all days except the holidays (when number of vehicles are very few and leads to unacceptable results).
- C) At 95% Level of significance, the observed data show a bad fit with expected normal distribution. We should have collected more data to see if this is actually true. The limited amount of speed data might have led to unusual results.

#### **5.5 Recommendation for Future Studies**

- A) Proper reconnaissance and table-top analysis must be done before start of piloting
- B) Higher resource and manpower need to be ensured
- C) Automatic methods should be used for getting more accurate results
- D) Larger sample should be collected for getting more satisfactory results.

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# Appendix

Group-1 Spot Speeds								
No.	Car		CNG		MotorCycle		Bus	
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)
1	4	24.14	3.84	25.15	3.2	30.18	2.5	38.62
2	4.5	21.46	3.77	25.61	2.5	38.62	2.58	37.43
3	3	32.19	2.4	40.23	3.45	27.99		
4	3.5	27.59	3.05	31.66	4.33	22.30		
5	3	32.19	2.27	42.54	3.13	30.85		
6	2	48.28	3.11	31.05	3.5	27.59		
7	2	48.28	3.64	26.53	4.39	22.00		
8	1.5	64.37	3.37	28.65	1.49	64.81		
9	1.5	64.37	3.05	31.66	2.25	42.92		
10	2	48.28	4.23	22.83	2.58	37.43		
11	2.5	38.62			3.11	31.05		
12	2	48.28			2.18	44.29		
13	3	32.19			2.8	34.49		
14	3	32.19						
15	3	32.19						
16	2.5	38.62						
17	3	32.19						
18	2	48.28						

Table 1

Group-2 Spot Speeds									
No.	Car		CNG		MotorCycle		Bus		
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	
1	3.44	28.07	4.26	22.67	3.69	26.17	4.03	23.96	
2	2.83	34.12	3.52	27.43	3.83	25.21			
3	3.08	31.35	4.83	19.99	2.42	39.90			
4	4.07	23.72	6.63	14.56	2.53	38.17			
5	3.76	25.68	4.55	21.22	3.44	28.07			
6	3.22	29.99	3.23	29.89	3.31	29.17			
7	3.44	28.07	3.59	26.90	3.49	27.67			
8	6.04	15.99	3.67	26.31	4.42	21.85			
9	4.79	20.16			2.72	35.50			
10	4.05	23.84			3.28	29.44			
11	4.18	23.10			3.36	28.74			
12	4.31	22.40			1.97	49.02			
13	3.06	31.56			2.75	35.11			
14	4.6	20.99			3.98	24.26			
15	4.2	22.99			4.57	21.13			
16	5.03	19.20			3.71	26.03			
17	6.76	14.28			3.1	31.15			
18	5.91	16.34							
19	4.69	20.59							
20	3.8	25.41							
21	3.64	26.53							
22	3.72	25.96							
23	2.77	34.86							
24	3.46	27.91							

Table 2

Group-3 Spot Speeds								
No.	Car		CNG		MotorCycle		Bus	
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)
1	2.46	39.25	2.9	33.30	2.6	37.14	6.29	15.35
2	2.63	36.72	4	24.14	2.81	34.36	4.5	21.46
3	2.49	38.78	4.8	20.12	2.46	39.25		
4	3.53	27.35	3.68	26.24	2.45	39.41		
5	3.84	25.15	3.9	24.76	2.25	42.92		
6	2.91	33.18	2.13	45.33	2.23	43.30		
7	2.03	47.57	3.48	27.75	2.83	34.12		
8	3.02	31.97	3.18	30.36	2.36	40.92		
9	5.3	18.22	3.23	29.89	2.25	42.92		
10	4.43	21.80	4.36	22.15	2.63	36.72		
11	3.44	28.07	4.1	23.55	2.71	35.63		
12	2.83	34.12	2.66	36.30	4	24.14		
13	2.72	35.50			2.61	37.00		
14	2.87	33.64			2.3	41.98		
15	2.08	46.42			3	32.19		
16	2.5	38.62						
17	2.54	38.02						
18	2.93	32.96						
19	2.09	46.20						
20	3.92	24.63						
21	4.71	20.50						
22	4.9	19.71						

Table 3

Group-4 Spot Speeds						
No.	Car		CNG		MotorCycle	
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)
1	3.07	31.45	3.1	31.15	2.85	33.88
2	3.14	30.75	2.72	35.50	2.17	44.50
3	3.64	26.53	4.04	23.90	2.91	33.18
4	3.31	29.17	4.36	22.15	2.91	33.18
5	3.31	29.17	2.75	35.11	5.33	18.12
6	3.16	30.56	4.12	23.44	2.19	44.09
7	4.11	23.49	4.2	22.99	3.21	30.08
8	3.31	29.17	3.89	24.82	3.42	28.23
9	4.36	22.15	2.58	37.43	3.38	28.57
10	6.63	14.56	3.15	30.65	2.8	34.49
11	3.9	24.76	2.5	38.62	2.99	32.29
12	4.12	23.44	2.99	32.29	3.74	25.82
13	4.76	20.29			3.25	29.71
14	4.69	20.59			3.31	29.17
15	3.72	25.96			4.77	20.24
16	5.65	17.09			2.66	36.30
17	4.28	22.56			2.9	33.30
18	2.5	38.62			2.1	45.98
19	3.63	26.60			3	32.19
20	4.2	22.99			4.43	21.80

Table 4

Group-5 Spot Speeds								
No.	Car		CNG		MotorCycle		Bus	
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)
1	9.75	9.90	8	12.07	3.85	25.08	4.3	22.46
2	5.37	17.98	6	16.09	2.47	39.09		
3	6.2	15.57	5	19.31	2.91	33.18		
4	3.6	26.82	5	19.31	3	32.19		
5	3.59	26.90	8	12.07	4.5	21.46		
6	6.81	14.18	4	24.14	2.2	43.89		
7	3	32.19	3	32.19	3.31	29.17		
8	5.64	17.12	4	24.14	3.52	27.43		
9	3.05	31.66	4	24.14	3.38	28.57		
10	4.85	19.91			4.43	21.80		
11	8.08	11.95			2.88	33.53		
12	7.85	12.30			3.64	26.53		
13	9.47	10.20			4	24.14		
14	3.81	25.34			3.21	30.08		
15	4.58	21.08			2.9	33.30		
16	4.8	20.12			2.75	35.11		
17	6.75	14.31						

Table 5

Group-6 Spot Speeds									
No.	Car		CNG		MotorCycle		Bus		
	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	Time(s)	Speed(kmph)	
1	5.84	16.53	3.72	25.96	3.52	27.43	4.1	23.55	
2	2.1	45.98	3.22	29.99	3.49	27.67	3.98	24.26	
3	3.01	32.08	3.51	27.51	2.41	40.07			
4	3.4	28.40	4.22	22.88	3.84	25.15			
5	3.67	26.31	4.25	22.72	3.37	28.65			
6	3.53	27.35	3.81	25.34	2.71	35.63			
7	2.88	33.53	2.96	32.62	4.12	23.44			
8	2.87	33.64	3.5	27.59	4.19	23.05			
9	3.21	30.08			3.18	30.36			
10	3.6	26.82			2.94	32.84			
11	3.6	26.82							
12	3.66	26.38							
13	4.58	21.08							
14	2.61	37.00							
15	3.28	29.44							
16	3.27	29.53							
17	2.89	33.41							

Table 6

Russel Square to Panthapath									
Vehicle Type	Reg. No.	Entry Time	Exit Time	Section Length (mile)	Travel Time, t (sec)	Speed,vi (mph)	Mean Speed,(v)	vi-v	(vi-v)^2
CNG	4807	12.09	12.17	0.59	480	4.43	6.27	-1.85	3.41
	0252	12.09	12.18		540	3.93		-2.34	5.46
	0383	12.08	12.17		540	3.93		-2.34	5.46
	0620	12.1	12.18		480	4.43		-1.85	3.41
	0280	12.08	12.18		600	3.54		-2.73	7.46
	0431	12.08	12.16		480	4.43		-1.85	3.41
	4440	12.08	12.17		540	3.93		-2.34	5.46
	0383	12.08	12.18		600	3.54		-2.73	7.46
	4713	12.11	12.16		300	7.08		0.81	0.65
	1785	12.08	12.17		540	3.93		-2.34	5.46
	3022	12.09	12.18		540	3.93		-2.34	5.46
	9390	12.1	12.17		420	5.06		-1.21	1.47
LV	5052	12.13	12.17	240	8.85	2.58	6.65		
	8023	12.14	12.18	240	8.85	2.58	6.65		
	1726	12.1	12.17	420	5.06	-1.21	1.47		
	8911	12.13	12.18	300	7.08	0.81	0.65		
	9462	12.13	12.18	300	7.08	0.81	0.65		
	3122	12.12	12.16	240	8.85	2.58	6.65		
	1900	12.12	12.17	300	7.08	0.81	0.65		
	5052	12.09	12.18	540	3.93	-2.34	5.46		
	9000	12.12	12.16	240	8.85	2.58	6.65		
	3352	12.12	12.17	300	7.08	0.81	0.65		
	975	12.13	12.18	300	7.08	0.81	0.65		
	9663	12.12	12.17	300	7.08	0.81	0.65		
	6264	12.1	12.16	360	5.90	-0.37	0.14		
	1659	12.13	12.18	300	7.08	0.81	0.65		
	3978	12.1	12.16	360	5.90	-0.37	0.14		

	6332	12.13	12.16		180	11.80		5.53	30.57
	7670	12.14	12.17		180	11.80		5.53	30.57
	4183	12.12	12.18		360	5.90		-	0.14
	8146	12.08	12.15		420	5.06		-	1.47
	9297	12.08	12.17		540	3.93		-	5.46
	5035	12.09	12.14		300	7.08		0.81	0.65
	7384	12.14	12.18		240	8.85		2.58	6.65
	2336	12.06	12.16		600	3.54		-	7.46
	6069	12.09	12.14		300	7.08		0.81	0.65
	4013	12.14	12.17		180	11.80		5.53	30.57
Bus	3405	12.08	12.18		600	3.54		-	7.46
				SUM=	14700	238.29			214.65

Table 7

Panthapath to Russel Square									
Vehicle Type	Reg. No.	Entry Time	Exit Time	Section Length (mile)	Travel Time, t (sec)	Speed,vi (mph)	Mean Speed,(v)	vi-v	(vi-v)^2
LV	1971	12.13	12.16	0.59	180	11.8	12.07	-0.27	0.08
	1067	12.09	12.12		180	11.8		-0.27	0.08
	6409	12.08	12.1		120	17.7		5.63	31.64
	9662	12.15	12.17		120	17.7		5.63	31.64
	2729	12.08	12.12		240	8.9		-3.22	10.40
	7344	12.1	12.12		120	17.7		5.63	31.64
	2363	12.12	12.15		180	11.8		-0.27	0.08
	725	12.08	12.11		180	11.8		-0.27	0.08
	2374	12.13	12.15		120	17.7		5.63	31.64
	2977	12.08	12.11		180	11.8		-0.27	0.08
	8745	12.15	12.18		180	11.8		-0.27	0.08
	7670	12.1	12.13		180	11.8		-0.27	0.08
	4183	12.12	12.18		360	5.9		-6.17	38.13
	7225	12.08	12.11		180	11.8		-0.27	0.08
	3628	12.09	12.12		180	11.8		-0.27	0.08
	6794	12.15	12.17		120	17.7		5.63	31.64
2670	12.13	12.15	120	17.7	5.63	31.64			
CNG	6300	12.08	12.15	420	5.1	-7.02	49.25		
	8726	12.11	12.15	240	8.8	-3.22	10.40		
	4340	12.15	12.18	180	11.8	-0.27	0.08		
	2060	12.1	12.15	300	7.1	-4.99	24.95		
	6300	12.14	12.18	240	8.9	-3.22	10.40		
	8441	12.1	12.14	240	8.8	-3.22	10.40		
	4340	12.08	12.13	300	7.1	-4.99	24.95		

Bike	4934	12.16	12.18		120	17.7		5.63	31.64
	8814	12.12	12.15		180	11.8		- 0.27	0.08
	2602	12.11	12.14		180	11.8		- 0.27	0.08
				SUM=	5340	326.02			401.28

Table 8