Theoretical Study of Safe Braking Line at Signalized Intersection

by

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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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Approved by,

____
(Ir. Dr. Muslich Hartadi Sutanto)

UNIVERSITI TEKNOLOGI PETRONAS

SERI ISKANDAR, PERAK

SEPTEMBER 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NOR HASLINAYATI BINTI ABDUL GHAFAR

ABSTRACT

Signalized intersection is an area where most of the drivers have a difficulty in deciding either to run through the intersection or decelerate their vehicles and stop before the stop line. The goal of this study was therefore to determine the safe braking line at signalized intersection by using the concept of stopping sight distance. The 377 samples of actual approaching speed of vehicles were collected through the site observation at one signalized intersection in Tronoh, Perak. Statistical analysis showed that the observed 15^{th} and 85^{th} percentile speed at the intersection were 66.2 km/hr and 88.5 km/hr with a mean and standard deviation of 77.5km/h and 9.99km/hr. The Chi-Square goodness-of-fit test was conducted, and the results shows that the distribution of the approaching speed at Tronoh's intersection was normally distribute with a probability of 14.4%. From the study, it shows that the safe braking line from the stopping line at signalized intersection is between 97m for lower speed limit to 152m for the upper speed limit.

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CHAPTER 1
INTRODUCTION

1.1 Background

Intersection is defined as an at-grade crossing of two or more roadways. Signalized road intersection are locations where most of the driver have complicated and difficulty to make a decision-making. This intersection is the most dangerous spot and according to the Principles of Highway Engineering and Traffic Analysis, roadway intersection is one of the major source where many accidents and crashes occur and this issue lead to the great concern to traffic engineer. Figure 1-1 shows illustration of signalized intersection.

Figure 1-1 (a): Illustration signalized intersection (Adapted from Osciumcom, 2014)

However, at some point, this intersection will be install with a traffic signal such as traffic light due to frequent accidents and higher traffic volumes. These traffic signal installation and operation to control conflicting traffic movements at intersection has its advantage and disadvantage (Mannering, Washburn & Kilareski, 2009). Signals that install at the intersection are by no means the perfect solution for delay or accident problems.

1.2 Problem Statement

According to the 2015 accident data from the Royal Malaysian Police (RMP), a total 489,606 accidents occur in Malaysia and 1,000 over accidents happened at signalized control type intersections. These statistics shows an increasing (2.8%) accidents occur in Malaysia compared to year 2014.

Many accidents occur at this spot are closely related to drivers' decisions of running through intersection during yellow light. Every driver that undergoes this phase will eventually question his/herself whether to go or stop during this time. This is a zone that known as dilemma zone or yellow light dilemma zone where the driver neither safely stop before the stop line nor proceed through the intersection during the interval time between yellow light and red light (Lu, Wang, Wu, & Liu, 2015).

The aim of the paper is to measure the safe braking distance from the stop line when vehicle encounter yellow light running at signalized intersection. In this research, theory of stopping sight distance and braking distance will be used in order to achieve the project's objective. Driver's reaction time, vehicle's acceleration and deceleration and vehicle's speed are the parameter that will used during this research.

1.3 Objectives

The objectives of this project are:

1) To investigate the approaching speed of vehicles at observed signalized intersection.
2) To calculate minimum and maximum distance from the stop line at observed signalized intersection by using actual speed in order for vehicle successfully run through the intersection during yellow light interval.
3) To compare the minimum and maximum distance from stop line by using actual and design speed.

1.4 Scope of Study

For this research, the data collected for signalized intersection will be carried out at one of the intersection in Bandar Seri Iskandar, Perak. There are three basic elements that considered in this research which are:

a) Human Factor

   Human behaviour is one of critical component that need to be considered in traffic engineering. This research focus on decision and reaction time which known as perception reaction time (PRT) which is the ability of drivers to make decisions.

b) Traffic Considerations

   Speed of vehicles is the significant parameter that need to be considered since this project concern more towards higher speed compare to lower speed.

c) Physical Elements

   Physical elements such as conflict area, traffic control device and sight distance also were including in the scope of study for this research. This research concern more to stopping sight distance in order to determine the minimum and maximum safe braking line from the observed signalized intersection.

CHAPTER 2
LITERATURE REVIEW

2.1 Dilemma Zone

Dilemma zone can be categorized into two type which Type 1 dilemma zone and Type 2 dilemma zone. According to Zhang et al. (2014), type 1 dilemma zone was discovered by Gazis et al. (1960) which defined dilemma zone is a zone where driver neither successfully pass through the intersection or comfortably stop before the stop line if they within this area which is shown in Figure 2-1 (a).

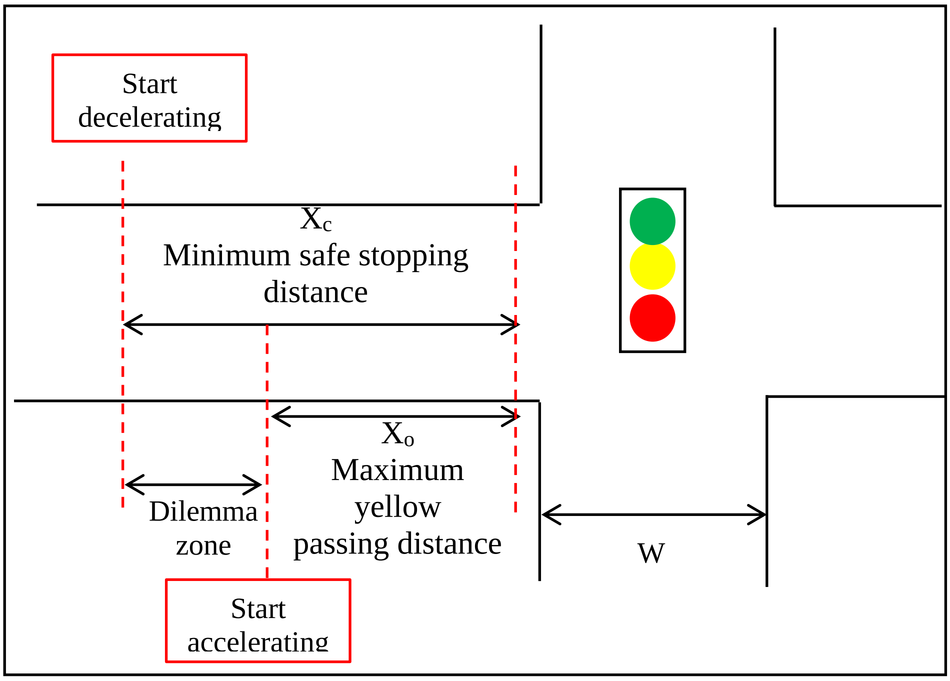


Figure 2-1 (a): Type 1 Dilemma Zone (adopted from Zhang et al. (2014))

Refer to Figure 2-1 (a), X_c is the minimum distance that required by driver so that they can safely stop before the stop line. In other words, this is where the driver need to start decelerating their vehicles. X_o is the maximum distance that the driver can have if they want to run through the intersection without violate red light.

Type 2 dilemma zone can be explained from the studied that was done by Lu et al. (2015). They stated that at the signalized road intersection, every driver will encounter four different zones. These four zones are named as “should-go zone”, “should-stop zone”, “dilemma zone” and “optional zone” as shown in Figure 2-1 (b). Depending on signal timing, approaching vehicle speed and vehicle distance from the stop line every driver need to decide to either pass through the intersection or stop when the light turns to yellow.

Studied by Lu et al. (2015) stated that dilemma zone is an area where the driver neither can pass through the intersection or stop before the stop line without sudden deceleration. Klein et al. (2006) also found that these four zones was used by the Federal Highway Administration under difference term which are “Cannot Stop Zone”, “Cannot Go Zone”, “Dilemma Zone” and “Optional Zone”.

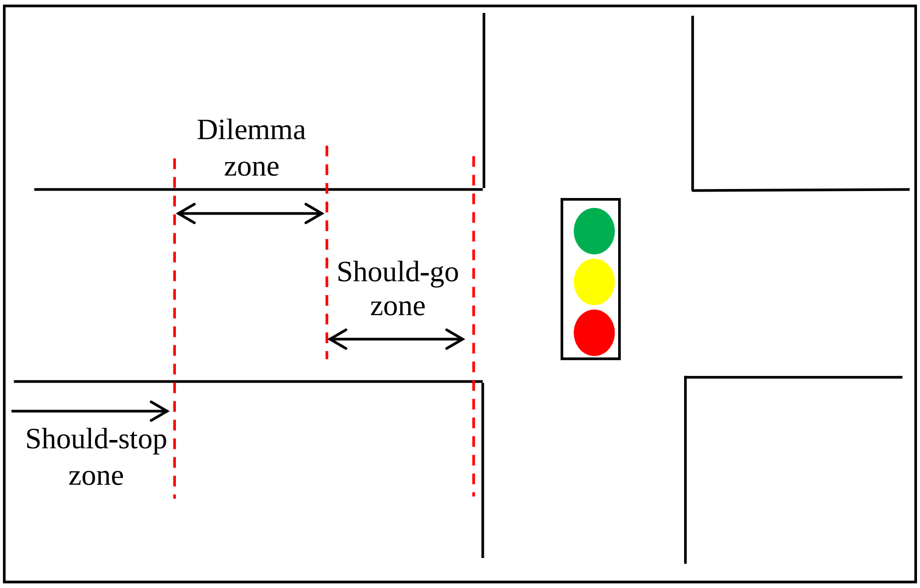


Figure 2-1 (b): Type 2 Dilemma Zone (adopted from Lu et al., 2015)

Compared to Type 1 dilemma zone, Lu et al. (2015) discover that there is optional zone which driver may have trouble to decide when see the yellow light. The driver will encounter this optional zone when the minimum safe stopping distance (X_c) less than the maximum passing distance (X_0).

Many studied have been done regarding the human behaviour and dilemma zone (Hurwitz et al., 2011, Papaioannou, 2007, Lu et al., 2015). According to Hurwitz et al. (2011), Type 2 dilemma zone can cause an accident when the driver makes a sudden deceleration and incorrect estimate of intersection clearance time. These situations will cause rear-end collision, severe right-angle crashed and left-turn head-on collision.

Papaioannou (2007) was conduct study the relationship between driver behaviour, dilemma zone and the safety effects at urban signalized intersection. He stated that dilemma zone usually occurs when the driver approaches the intersection with greater speed. Parallel to research by Zhang et al. (2014), length of dilemma zone will increase when the approaching speed increase.

Sharma, Bullock & Peeta (2011) considered dilemma zone is a zone which have higher risk for collision to occur as the river do not know whether to proceed the intersection or to stop. This phenomena cause of installation green extension at possible high-speed intersection. The objectives of installing this dilemma zone protection are to reduce rear end collision and to reduce the speed when they within the dilemma zone (Sharma et al., 2011).

2.2 Perception Reaction Time (PRT)

Drivers or human behaviour is one of the critical components that affecting the traffic system. Perception reaction time (PRT) is the second critical driver characteristic that need to take a consideration when involving traffic engineering (Roess et al., 2004). Perception reaction time is a time needed for a driver to make an action after they encounter to some events. Roess et al. (2004) stated that the driver need to go through four processes during the perception and reaction time. The processes are detection, identification, decision and response. The same concept also was used by Fu et al. (2016) to explain and defined about PRT which they simplified it into perception, judgement and manipulation.

Like all human characteristic, PRT are varies among drivers because every driver has different time to response and take an action on something. Furthermore, PRT is an important parameter that need to take into consideration to compute stopping sight distance. The current PRT value that recommended by the American Association of State Highway and Transportation (AASHTO) is 2.5s. This value was adopted after all the factor was take into a consideration including driver's age, emotional and physical conditions.

The PRT value that recommended by Institute of Transportation Engineers (ITE) is 1.0s but many studied disagreed and argue that 1.0s for PRT value is not sufficient. Taoka (1989) stated and recommend that PRT value is between 1.5 s-1.8 s since this PRT represented by 75th and 85th percentile of the drivers. Usually the PRT value that obtain from road studies are more shorter compare to the real value (Fu et al., 2016).

A field study that was conducted by Gates et al. (2007) shows that the 15th, 50th and 85th percentile brake reaction time in dilemma zone for first-to-stop vehicles were 0.7 s, 1.0 s and 1.6s. Recent research by Shawarby et al. (2013) that take consideration of rainy weather stated that PRT value increase as time to intersection increase. They also claimed that the PRT value will increase when the vehicles moving towards upgrade section.

Fu et al. (2016) was conducted a study to compare the BPRT value at signalize intersection with and without countdown timer. Their research shows that BPRT without countdown timer was ranged from 0.12 s to 3.8 s while BPRT with countdown timer ranged from 0.04 s to 4.02 s. They also claimed that the value of BPRT was greater than recommended by ITE which 1.0s whether there is presence of countdown timer or not. The study also concluded that BPRT value for 85th percentile with countdown timer (2.52 s) is longer compared to without timer (1.26 s).

Another study that was conducted by Li et al. (2014) shows that BPRT without timer are greater compared to with timer. They claimed that drivers enter the intersection faster when there is presence of countdown timer.

2.3 Braking Distance

Braking distance of a vehicle on a roadway is one of the elements that need to consider when calculating the stopping sight distance. Braking distance can be calculating by using the equation given in the Table 2-2 (a).

Table 2-2 (a): Equation to calculate braking distance (adapted from AASHTO, 2011)

Metric	**US Customary**
$d = 0.039 \frac{V^2}{a}$	$d = 1.075 \frac{V^2}{a}$
where: d = braking diatance, m V = design speed, km/h a = deceleration rate, m/s^2	where: d = braking diatance, ft V = design speed, mph a = deceleration rate, ft/s^2

Design speed is a selected speed used to determine the various geometric design features of the roadway. To determine the design speed, several factors need to be consider such as the topography, operating speed adjacent land use, and functional classification of the highway.

Most of the drivers decelerate their vehicle when faced unexpected situation or object at a rate greater than $4.5m/s^2$ ($14.8ft/s^2$). From the studies, 90^{th} percent of all drivers decelerate their vehicle at a rate greater than $3.4m/s^2$ ($11.2ft/s^2$). Therefore, AASHTO (2011) recommended $3.4m/s^2$ ($11.2ft/s^2$) as the deceleration for determining the stopping sight distance such this deceleration is within the driver's capability to maintain steering control and stay in their lane during the braking process.

2.4 Stopping Sight Distance

Stopping sight distance is a minimum sight distance required for a driver to stop the vehicle after seeing an object during the path without hitting the object. According to AASHTO (2011) sight distance is the length of the roadway ahead that is visible to the driver. This distance should sufficiently enough for a vehicle traveling at or near the design speed to stop before reaching the object.

Stopping sight distance is the summation of distance travelled during driver perception/reaction time and the braking distance (Mannering, Washburn & Kilareski, 2009). This concept also applied by AASHTO (2011) which define stopping sight distance is the sum of the distance traversed during the brake reaction time and the distance to brake the vehicle to a stop. By assuming the worse-case condition (wet pavement conditions) and on level roadways stopping sight distance are expressed as follows,

$$SSD = 0.278Vt + 0.039\frac{V^2}{a}$$

where:

SSD	= Stopping sight distance, m
V	= Design speed, km/h
t	= Brake reaction time, 2.5s
a	= Deceleration rate, 3.4 m/s^2

When the road is on a grade the formula for stopping sight distance will be modified as follows,

$$SSD = \frac{V^2}{254((\frac{a}{9.81}) \pm G)}$$

Where G is the percent of grade divided by 100 and the other parameters are as previously stated.

Reaction time should consider in order to calculate stopping sight distance. Brake reaction time is the interval from the instant that the driver recognizes the existence of an obstacle on the roadway ahead that necessitates braking to the instant that the driver actually applies the brake (AASHTO, 2011). Normally driver who travel with design speed or near the speed will more alert company to driver that travel lesser than the design speed.

Table 2-3 (a) shown the stopping sight distance that was adopted by Malaysia while Table 2-3 (b) shows the minimum stopping distance that was developed by AASHTO (2011) by using the design speed (km/h), 2.5s for break reaction time and 3.4m/s^2 (11.2ft/s^2).

Table 2-3 (a): Minimum Stopping Sight Distance (adopted by Malaysia)

Design Speed (km/h)	Min Stopping Sight Distance (m)
110	250
100	205
90	170
80	140
70	110
60	85
50	65
40	45
30	30

Table 2-3 (b): Stopping Sight Distance on Level Roadways

Metric					U.S. Customary				
Design Speed (km/h)	Brake Reaction Distance (m)	Braking Distance on Level (m)	Stopping Sight Distance		Design Speed (mph)	Brake Reaction Distance (ft)	Braking Distance on Level (ft)	Stopping Sight Distance	
			Cal. (m)	Design (m)				Cal. (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

2.5 Statistical Rationale

2.5.1 The 85th and 15th Percentile Speeds

Statistical technique show that a normal probability distribution will occur when a random sample of traffic is measured. The speed of the vehicles either too fast or too slow can be determine from the frequency distribution curves. This mean that certain percentage of drivers drive too fast for the existing conditions and certain percentage of drivers travel at unreasonably slow speed compared to the trend of traffic can be determine.

Most cumulative speed distribution curves "break" at approximately 15 percent and 85 percent of the total number of observations (Carol, 2015). Figure 2-4 (a) show the example of cumulative speed distribution curve.

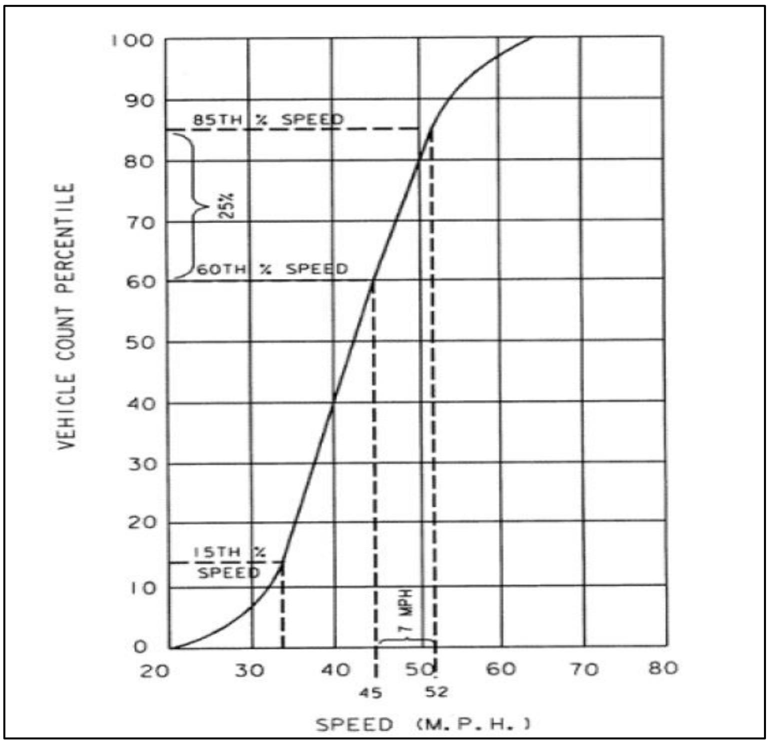


Figure 2-4 (a): Cumulative speed distribution curve (adapted from manual of Procedure for Establishing Speed Zone, 2015)

Vehicles that traveling above the 85th percentile are assuming to be exceeding a safe and reasonable speed while vehicle traveling lower than 15th percentile are considered to be traveling unreasonably slow.

2.4.2 A Measure of Central Tendency

Measure of central tendency is the measurement that specify the approximate centre or middle of the distribution. Usually, central tendency involving of mean speed, the median speed, the modal speed and the pace. Average or mean speed usually is the summation of observed data divided by the number of observation (eq 1).

$$x_{mean} = \frac{\sum n_i S_i}{N}$$

where: n_i = frequency of observation in speed group

S_i = middle speed of speed group

N = total sample size

According to Roess et al. (2004), the median speed can be found from cumulative distribution curve. Median speed always known as 50th percentile speed. From definition, the median speed is equally divided from the distribution. Hence, 50% of the observed data must be less than the 50th percentile speed (Roess, 2004).

The modal speed represented a single value of data which single value of speed for this research. This modal speed usually a value that has a greater frequency within the total of observed data. This type of speed can be found in frequency distribution curve.

2.4.3 A Measure of Dispersion

Measure of dispersion normally describe how wide the data collected spreads from the mean of the distribution. Commonly, the standard deviation and percentile of speed can measure how close the data to the mean value. The standard deviation of collected data can be calculated as shown in equation 2.

$$s = \sqrt{\frac{\sum n_i S_i^2 - N x_{mean}^2}{N-1}}$$

2.4.4 The Standard Normal Distribution

Normal distribution commonly used for statistical distribution which look like a bell-shaped curve as shown in Figure 2-4 (b). The total probability under the curve is 1.00 and as shown in figure below, the curve is equally divided or symmetrically from the mean.

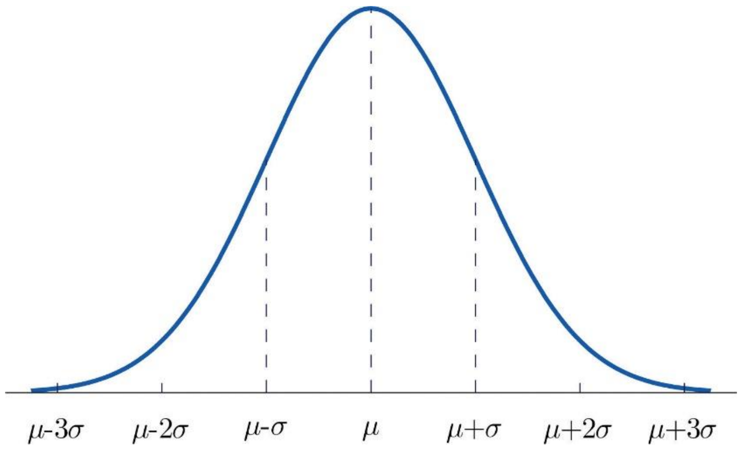


Figure 2-4 (c): Shape of the Normal Distribution Function

Normal distribution usually involving of mean and standard deviation of data set. This can be calculated by computing the value in the formula as shown in equation 3.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-[\frac{(x-u)^2}{2\sigma^2}]}$$

where x = normally distributed statistic

μ = true mean of the distribution

σ = true standard deviation of the distribution

π = 3.14

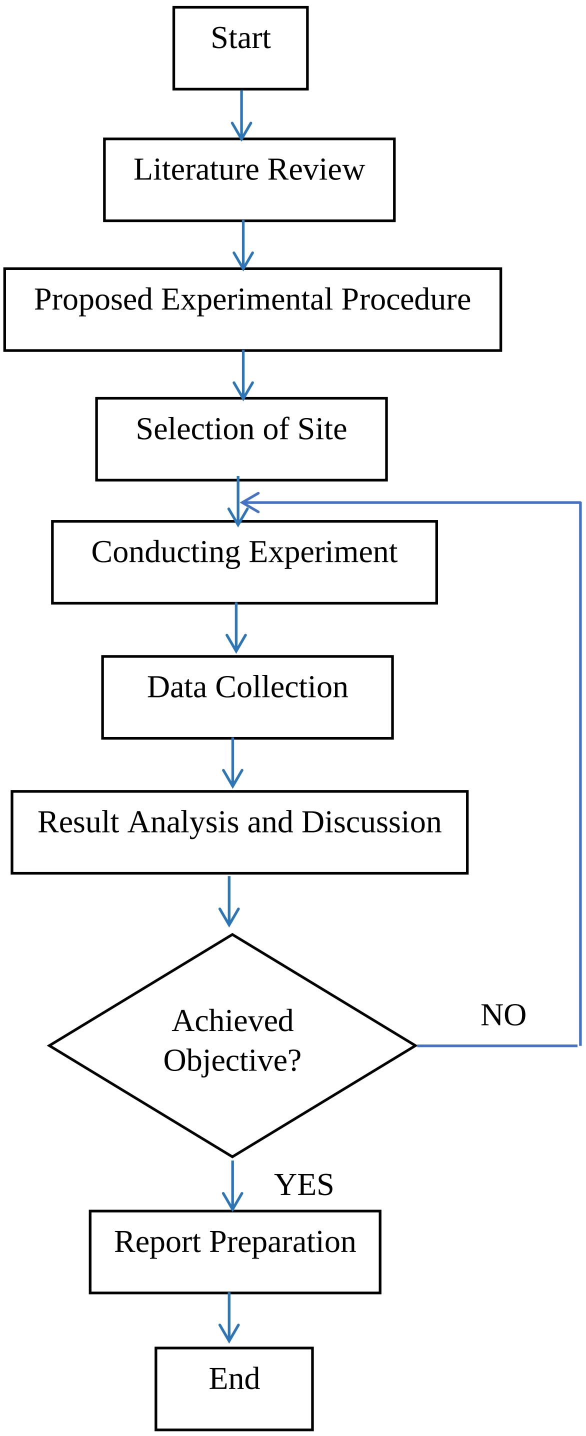
CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describe overall methodology and the project activities in order to conduct the research. These includes the project flowchart, description of project site, data collection and data analysis.

3.2 Flowchart



3.3 Project/Study Sites

One signalized intersection was chosen for field observation in Tronoh, Perak as shown in Figure 3-3 (a). Tronoh is located 28km from Ipoh town. This intersection was in federal road which part of the Ipoh-Lumut Highway. There are several criteria that need to consider for selecting this intersection. The criteria are sufficient sight distance, on the level grades, not influence by countdown timer and on high-speed area.

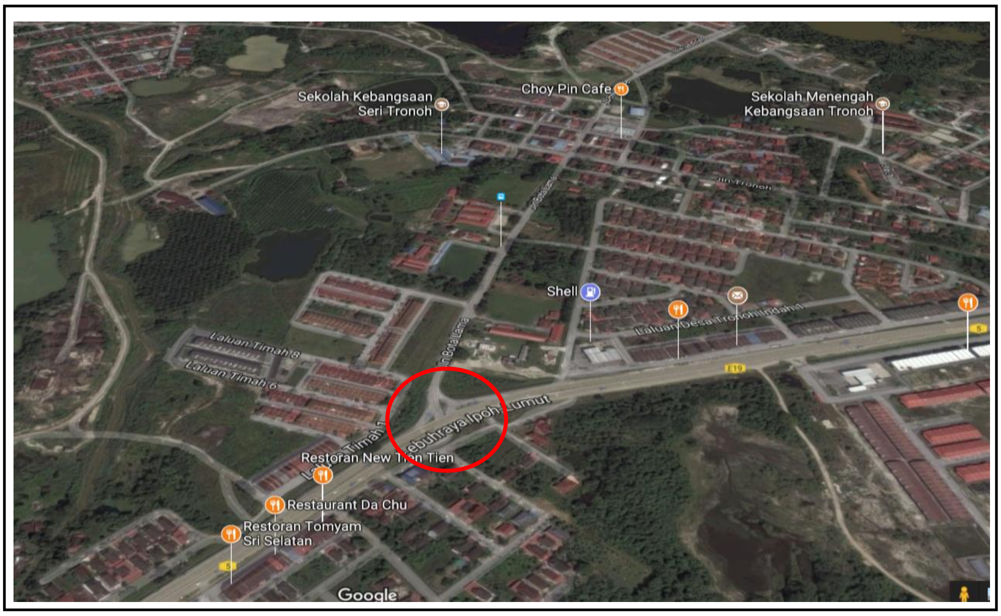


Figure 3-3 (a): Site location (Intersection at Tronoh, Perak)

In this research, the main parameter that was concern is the approaching speed of vehicles. To collect a quality data which is true free flow speeds, the location of speed survey must not influence and give impacts to the behaviour of the drivers (Currin, 2013). This is because usually drivers will slow down their vehicles when they realize the presence of observer and they will think that they are being monitored. This will cause the speed obtained lower than normal speed than it should be.

Furthermore, this intersection known as three-leg or T intersection which is determined by the number of its intersecting legs. According to Road Traffic Volume Malaysia as shown in Appendix 1, road along this intersection is categorize under level of service (LOS) A which defines as free flow traffic and higher speed.

3.4 Data Collection

This section describes on how the field observation, data collection and data analysis are being done throughout this research. In this research, speed measuring device was used for field observation and data collection.

3.4.1 Equipment

In this research, field observation was done to obtain the approaching speed of vehicles before the drivers enter the intersection. ProLaser 4 which is a speed measuring device as shown in Figure 3-4 (a) was used to collect the speed of vehicles throughout the entire survey. The parameter such as speed, distance and time during the observation will be recorded and display on the device’s screen.

Figure 3-4 (a): ProLaser 4 (Adapted from Kustom signals inc, 2014)

The ProLaser 4 has an ability to measure speed from 0km/h up to 320km/h. To ensure this device can perform well during the field observation, range and speed accuracy test were done before the real field observation start. Therefore, the device was point to the stationary objects and make sure the speed reading is 0km/h.

3.4.2 Measuring Vehicle Speeds

In this research, approaching speed of the vehicles was collected under free flow conditions. This is to ensure that the vehicle's speed not influenced by another factor except the road geometry. According to Roess, Prassas and Mcshane (2004), speed studies should not be conducted if the capacity are 750-1000 veh/h/ln. Road traffic volume that conducted by Department of highway planning division shows that the volume of vehicles along the road from Ipoh to Lumut and Lumut to Ipoh does not exceed 750 veh/h/ln.

This survey was done on Monday, Friday and Sunday (weekend) during the AM and PM peak period. Basically, different location has different peak hour which was influence by human activities such as work, school, shopping and many more. According to Falcocchio and Levinson (2015) AM peak hour begins at 6:00 am and ends at 10:00 am while PM peak hour begins at 3:00 pm and ends at 7:00 pm. As shown in Appendix 1, the peak hour for this particular location are 8:00 am to 9:00 am and 5:00 pm to 6:00 pm. Even though this survey was done during peak hours, but it still under free flow conditions which was state by Road Traffic Volume Malaysia that this road under LOS A.

All the measuring approaching speed was recorded in the spot speed studies form as shown in Table 3-4 and Appendix 2. All the data were used for data analysis.

Table 3-4 (a): Table of Speed Zone Survey

Speed, (km)	*Distance, d (m)	Speed, (km)	*Distance, d (m)	Speed, (km)	*Distance, d (m)	Speed, (km)	*Distance, d (m)

3.4.3 Field Observation/Setup

As state before, the field observation or survey was conducted at Tronoh intersection as shown in Figure 3-4 (b). The speed measuring device which is ProLaser 4 was located approximately 350 m from the stop line and aimed at the target (approaching vehicles). The vehicle's speed was measured in both direction which from Ipoh to Lumut (Direction 1) and from Lumut to Ipoh (Direction 2). The layout and 3d perspective of field observation was shown in Figure 3-4 (c) and Figure 3-4 (d). All the parameter that indicate in the illustration are:

v = Approaching speed, km/h

d_1 = Distance between stop line with speed device (350 m)

d^* = Range between speed device with approaching vehicles, m

This field observation or speed survey at Tronoh intersection was conducted from 8:00 am to 9:00 am (morning peak hour) and from 5:00 pm to 6:00 pm (evening peak hour) on sunny days October 06 (Friday), October 08 (Sunday) and October 09 (Monday), 2017. Besides, this study only targeted vehicles that approaching the intersection during the green and yellow phase.

Figure 3-4 (b): Location of field observation

There are several conditions that need to consider during the field observation so that a quality data can be obtained during the survey. The conditions are:

1) Vehicles not influence by slow vehicles such as buses or lorries.
2) Take measurement under clear visibility
3) Not influence by construction or weather
4) Measure only vehicles that have two axles.

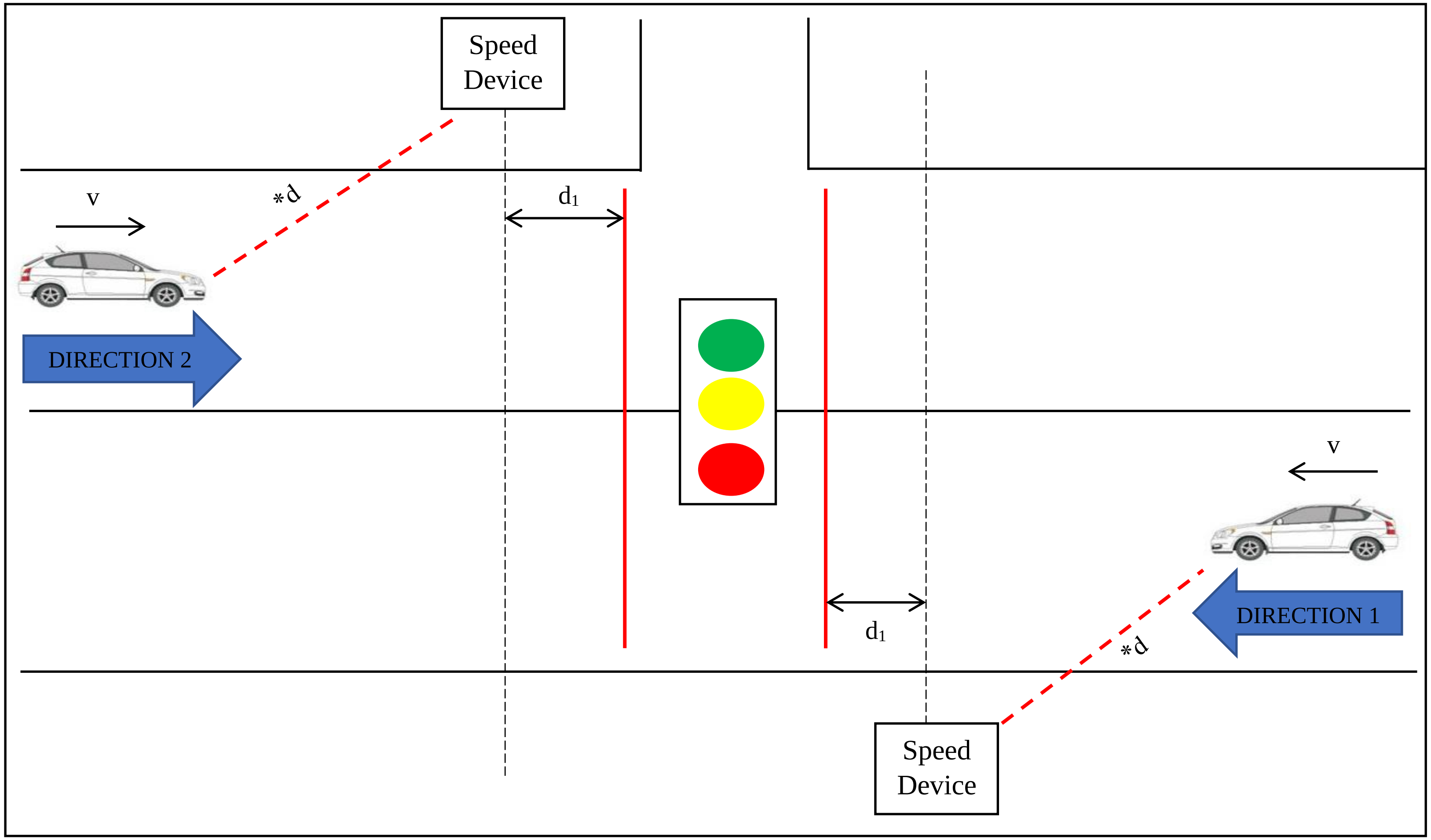


Figure 3-4 (c): Layout of experiment setup

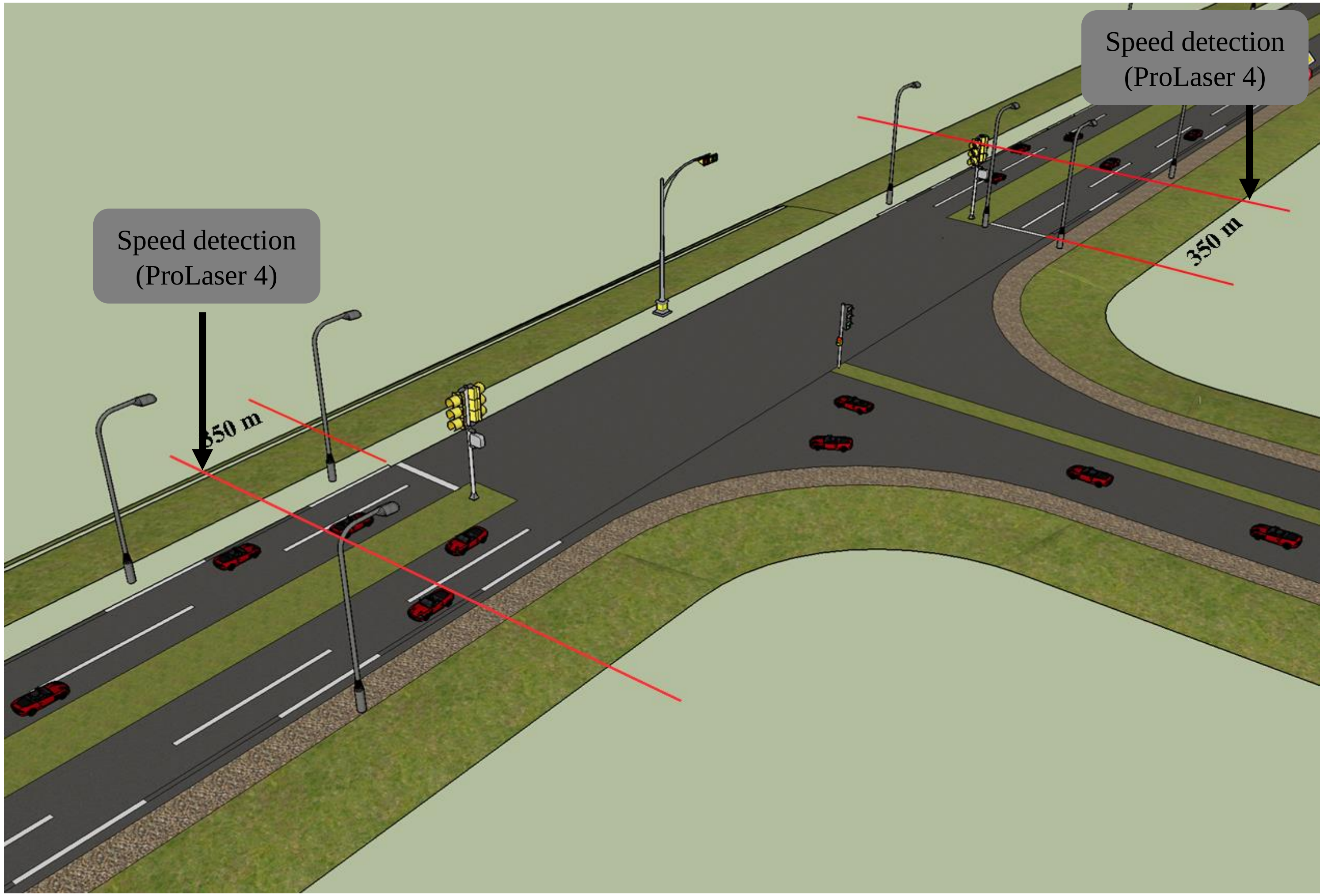


Figure 3-4 (d): 3D perspective of observed signalized intersection

3.5 Data Analysis

All the data that obtain from the field survey need to analyse in a systematic way such as in table, chart and graph format. This is to ensure that the data can be fully understand and describe the results.

3.5.1 Frequency Distribution Table

The raw approaching speed that obtained from the survey will represent in the table form as shown in Table 3-5 (a). This table was known as frequency distribution table. Basically, the speed will be grouped according to their respective speed group. Second column represent the middle speed for each speed group. Middle speed can be calculated from the upper and lower limit of the speed group. The third column of the table shows the number of vehicles at that particular speed group. The frequency of vehicles can be obtained from the recorded data as shown in previous Table 3-4 (a).

The fifth column of the table shows the percentage for each speed group. This percentage can be calculated by using formula,

$$\% = \frac{n_i}{N} \times 100$$

where: n_i = number of frequency

N = total number of samples

The last column of the table shows the cumulative percentage. This can be determined by summation of percentage for each speed group. Formula for this is,

$$cum\% = \left(\frac{\sum n_i}{N}\right) \times 100$$

Table 3-5 (a): Frequency Distribution Table

Approaching Speed (km/h)	Middle Speed (km/h)	Frequency (n_i)	Cumulative Frequency	Percentage (%)	Cumulative Percentage (%)
40-45					
46-50					
51-55					
56-60					

3.5.2 Frequency and Cumulative Distribution Curves

This frequency distribution curve shows the percentage frequency for each of the group speed. This graph can be illustrated by plotted the (%) frequency versus the vehicles speed as shown in Figure 3-5 (a). All the data such as (%) frequency and the speed can be obtained from previous frequency distribution table as shown in Table 3-7 (a).

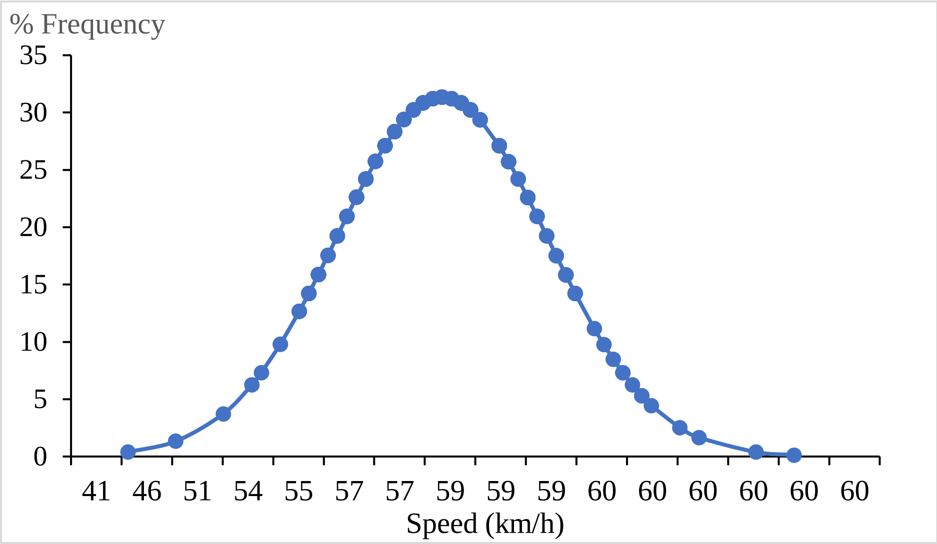


Figure 3-5 (a): Example of Frequency Distribution Curves

For frequency distribution curve, middle speed will be used instead of lower and upper limit speed. For this type of graph, smooth curve line will be used to connect each point (data). Basically, not all the point will be connected but this smooth line will minimize the distance between point and the line. This graph also will show which speed that has higher frequency.

Furthermore, cumulative frequency distribution curves also need to plot as one part of the data analysis. This graph can be obtained by plot cumulative (%) against speed of vehicles as shown in Figure 3-5 (b). Unlike frequency distribution curve, this cumulative frequency distribution curves used upper limit for each speed group as plotting point.

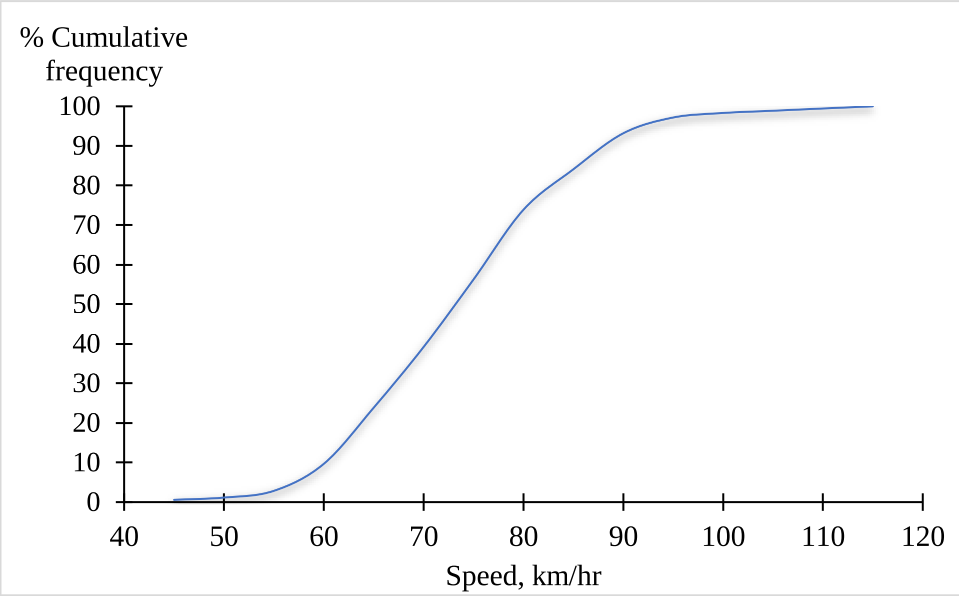


Figure 3-5 (b): Example of Cumulative Frequency Distribution Curves

Basically, both graph can show and illustrate several important parameters that will describe the overall sample distribution. In other words, for this research both graph can help to measure and describe central tendency and data dispersion. For this research, 85^{th} and 15^{th} percentile speeds need to be used to calculate and determine the stopping sight distance. This 85^{th} and 15^{th} percentile speeds can be obtained from cumulative frequency distribution curve.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Field Observation Results

A field observation or survey was conducted at Tronoh intersection as stated in Chapter 3. The purpose of this survey is to collect approaching speed of vehicles and used it to determine the 15th and 85th percentile speed in order to calculate the stopping sight distance.

A sample data of 377 speed of vehicles was collected for three days. As shown in Figure 4-1 (a), most of the drivers drive their car within the ranged of 66 km/hr to 90 km/hr which within the posted speed limit. This figure also shows that speed group between 76km/hr to 80km/hr have a greater number of frequency compared to others.

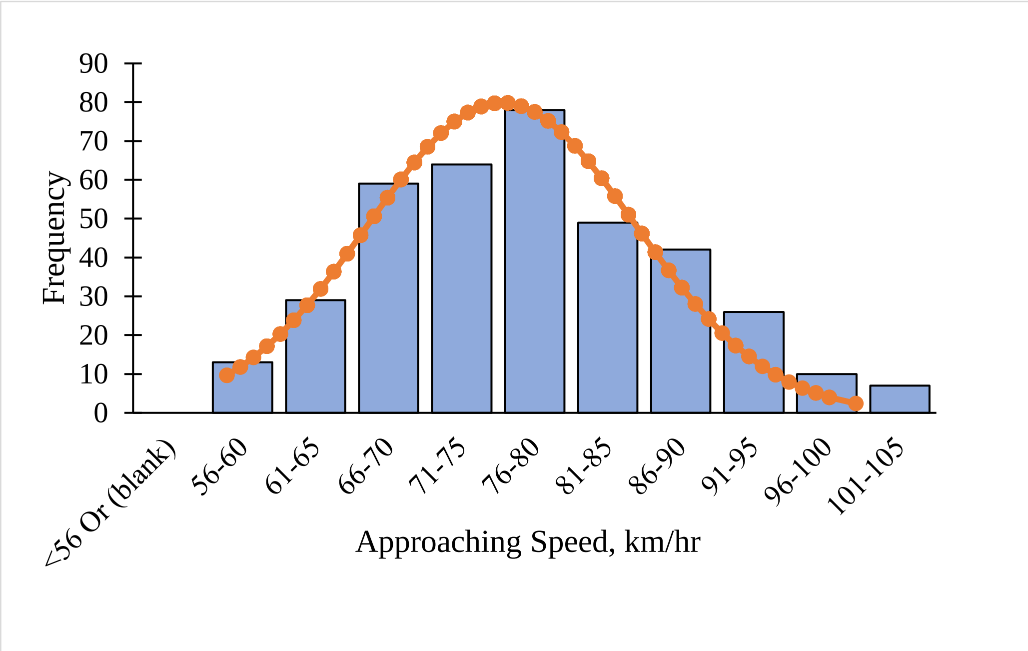


Figure 4-1 (a): Distribution of Approaching Speed at observed signalized intersection

The descriptive statistic of approaching speeds is presented in Table 4-1 (a). At Tronoh intersection, the sample data of approaching speed ranged between 57 km/hr to 104 km/hr with a mean of 77.5 km/hr for individual speed. As shown in Figure 4-1 (a), the data are normally distributed with a standard deviation of 9.994 km/hr.

Table 4-1 (a): Descriptive Statistic of Vehicles Approaching Speed

Statistic	Value
Sample size	377
Minimum	57.0
Maximum	104.0
Mean	77.5
Std. deviation	9.994
Coef. of variation	0.13

The value of standard deviation and coefficient of variation which are 9.994 and 0.13 shows that the data collected are quite widely dispersed around the mean value. The fact that volume of traffic is quite difference during the survey could explain the reason why the data have greater spread from the mean speed.

4.2 Discussion

4.2.1 85th and 15th Percentile of Speed

Frequency and cumulative frequency distribution curves were plotted by using data and information from the frequency distribution table as shown in Table 4-2 (a).

Table 4-2 (a): Frequency Distribution Table for Approaching Speed

Speed Group		Middle Speed (km/h)	Frequency in Group	Frequency in Group (%)	Cumulative Frequency (%)
Lower Limit (km/h)	Upper Limit (km/h)				
51	55	53	0	0	0
56	60	58	13	3.448275862	3.448275862
61	65	63	29	7.692307692	11.14058355
66	70	68	59	15.64986737	26.79045093
71	75	73	64	16.97612732	43.76657825
76	80	78	78	20.68965517	64.45623342
81	85	83	49	12.99734748	77.4535809
86	90	88	42	11.14058355	88.59416446
91	95	93	26	6.896551724	95.49071618
96	100	98	10	2.652519894	98.14323607
101	105	103	7	1.856763926	100
106	110	108	0	0	100

Frequency distribution curve as presented in Figure 4-2 (a) also shows that the value of modal speed is 78.0 km/hr. This modal speed shows most of the drivers are likely to drive at a speed of 78.0 km/hr during the green and yellow phase at the intersection. As shown in Figure 4-2 (b), the value median speed according to group speed is 76.8 km/hr. This value indicates that 50% of the driver drive their vehicles equal or less than 76.8 km/hr.

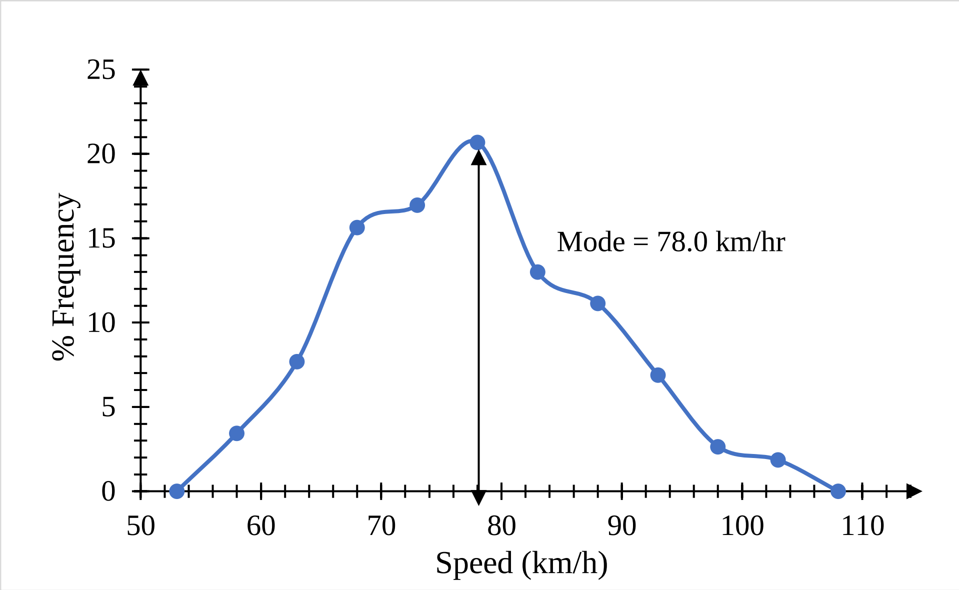


Figure 4-2 (a): Frequency Distribution Curve

Figure 4-2 (b) shows the cumulative speed distribution which have a normal like curve. As shown in the figure, the 85th percentile speed that used to approach the intersection is roughly about 88.2 km/hr. This shows that 85 % of driver drive their vehicles at 88.2 km/hr and below. This indicates that the vehicles move approximately 24.5 m per second during the green and yellow phase. Besides, Figure 4-2 (b) also shows that 15% of driver drive their car at 66.2 km/hr and below during green and yellow phase light.

Using this 85th percentile as reference point, the percentile of vehicles that exceed this speed are not significant. This indicate the percentage of drivers that travel too fast for the existing roadway conditions. Same goes to vehicles that travel below the 15th percentile which represent that the vehicles travel at unreasonably slow speed compared to the trend of traffic along the roadway.

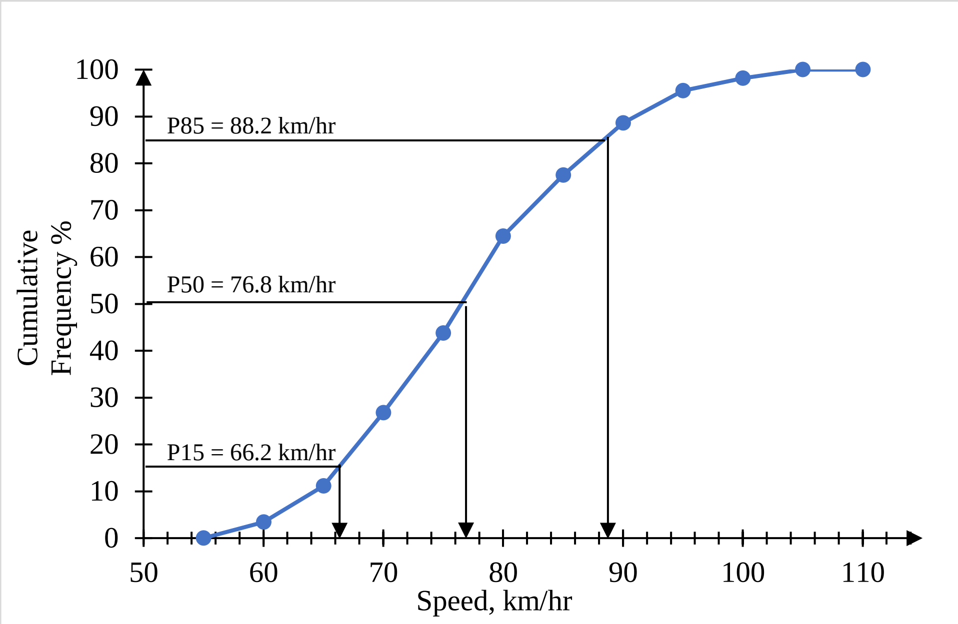


Figure 4-2 (b): Cumulative Frequency Distribution Curves

85th and 15th percentile can be represented as upper and lower limit of the speed. Referred to Figure 4-2 (b), the upper and lower limit speed to approach Tronoh intersection are 88.2 km/hr and 66.2 km/hr.

4.2.2 Testing for Normalcy: The Chi-Square Goodness-of-Fit Test

As displayed in Table 4-2 (b), it is 14.4% possible that a value of 11.137 or greater than that would occur if the distribution were statistically proven as normal distribution. In this research, the probability of 11.137 or higher is 14.4%. This test proved that the observed data (approaching speed) and the assuming mathematical form are not significantly different and shows that the data are normally distributed. This can be explained from Roess et al. (2004) which stated that there is significantly different in data collected when the probability is 5% or less.

Table 4-2 (b): Chi-Square Test for Normalcy on Approaching Speed Data

Average Speed = 77.5 km/hr				Standard Deviation = 9.994 km/hr			Sample Size = 377		
Speed Group		Observed Frequency n	Upper Limit (Std. Normal) zd	Prob. $z \le z_d$	Prob. of occurrence in group	Theoretical Frequency f	Combined Groups n	Combined Groups f	χ^2 Group
Upper Limit (km/h)	Lower Limit (km/h)								
	101	7		1.0000	0.0122	4.5994	7	4.5994	1.2530
100	96	10	2.25135081	0.9878	0.0279	10.5183	10	10.5183	0.0255
95	91	26	1.75105063	0.9599	0.0655	24.6935	26	24.6935	0.0691
90	86	42	1.25075045	0.8944	0.121	45.617	42	45.617	0.2868
85	81	49	0.75045027	0.7734	0.1747	65.8619	49	65.8619	4.3170
80	76	78	0.25015009	0.5987	0.19741	74.42357	78	74.42357	0.1719
75	71	64	-0.25015009	0.40129	0.17466	65.84682	64	65.84682	0.0518
70	66	59	-0.75045027	0.22663	0.12098	45.60946	59	45.60946	3.9313
65	61	29	-1.25075045	0.10565	0.06559	24.72743	29	24.72743	0.7382
60	56	13	-1.75105063	0.04006	0.04006	15.10262	13	15.10262	0.2927
TOTAL		**377**			**1.0000**	**377**	**377**	**377**	**11.137**
p=0.144									

4.2.3 Stopping Sight Distance

As discussed in Chapter 2, concept of stopping sight distance will be used to determine the safe braking line from stopping line at the signalized intersection. In this section, the safe braking line will be determining by using 88.2 km/h and 66.2 km/h as the approaching speed for upper and lower limit, 2.5s as the constant brake perception reaction time and 3.4 m/s^2 as the constant deceleration rate of vehicles.

As shown in Figure 4-2 (c), the theoretical safe braking line for vehicles at the observed intersection is between 97m – 152m from the stopping line. These safe braking line indicate that for vehicles that moving within the 85^{th} percentile speed required at least 152 m from the stopping line to start press their brake in order to stop before traffic light turns to red. This is an area where the vehicles need to start decelerating their car so that they can comfortably stop before the stop line.

Amber light (length of yellow light to red light) at observed signalized intersection is 3 s. Theoretically, with speed of 90 km/hr (design speed), the vehicles moving at 20 m per second and therefore the vehicles need at least 60 m to move within the 3 s of amber light. Based on the results and analysis, the minimum distance from stopping line is 97 m which exceed 60 m so the minimum distance from the calculation can be used. This indicate that the vehicles can pass through the intersection during amber light if they 97 m from the stopping line.

Therefore, for vehicles that moving within the 15^{th} percentile speed need more shorter length to start decelerating their vehicles which is 97m from the stopping line. In this research, 85^{th} percentile speed is more concern compared to 15^{th} percentile speed because usually higher moving speed vehicles have difficulty to decelerate their car during the amber time. This condition usually occurs because of the brake perception reaction time. As mentioned by Zhang et al. (2016), driver's perception reaction time will decrease as approaching speed at yellow onset increased. This claims that vehicles that moving in higher speed have shorter reaction time and tend to proceed their car through the intersection during amber time.

For vehicles that have higher approaching speed, they can use this safe braking line in order to help them to make a decision either to pass through the intersection or start to decelerate their car during the yellow-onset. This is means that the vehicles need to start decelerating their vehicles if during the amber time they still not within the safe braking line because they will not have enough time to clear the intersection even though they increase the acceleration rate. Therefore, the vehicles can successfully clear the intersection during the amber light if they already pass through the safe braking line.

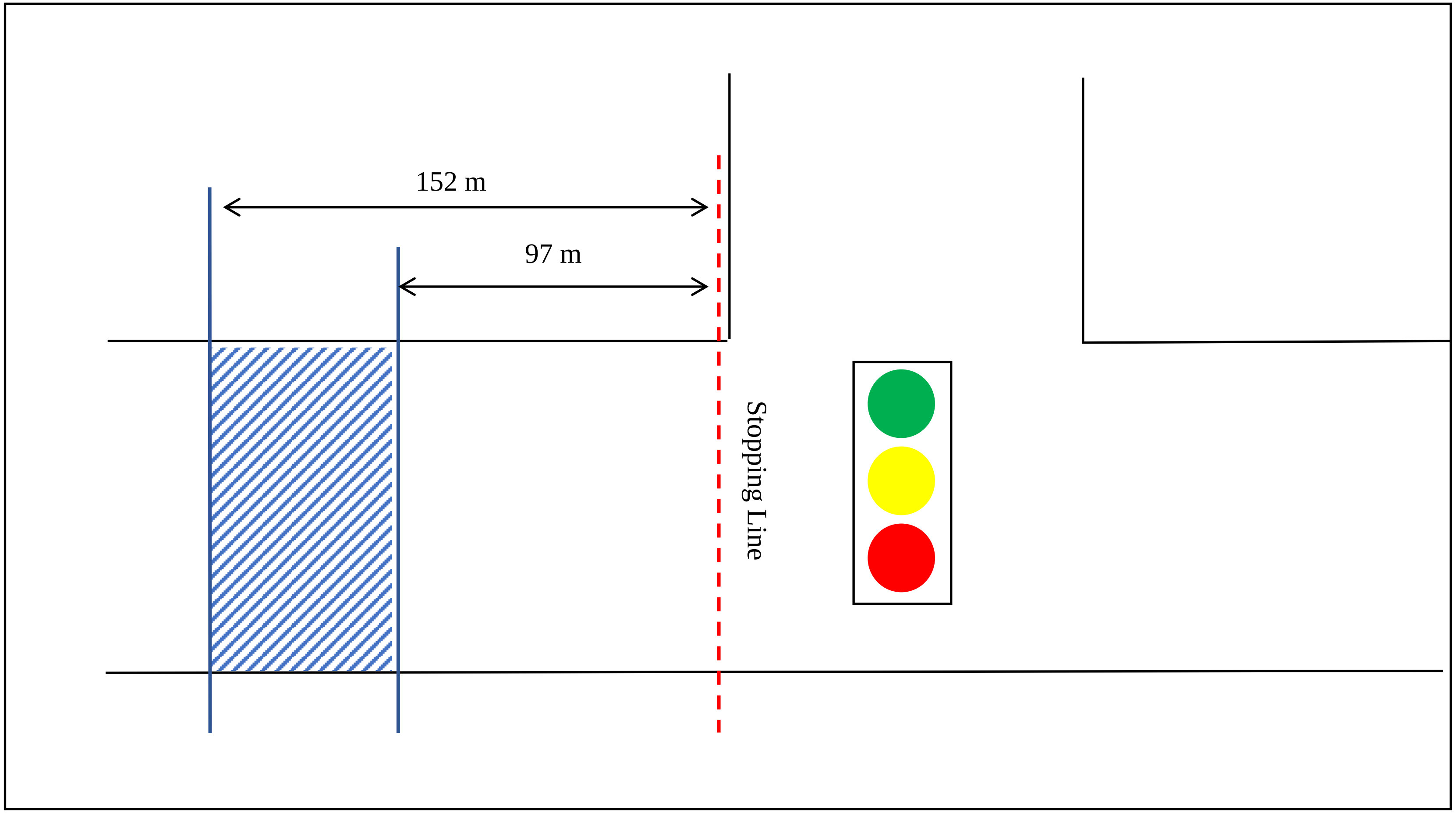


Figure 4-2 (c): Theoretical Safe Breaking Line at Tronoh Intersection

CHAPTER 5

RECOMMENDATION AND CONCLUSION

In this paper, a safe braking line at the signalized intersection was determined by using the concept of stopping sight distance. A total of 377 samples of approaching speed were collected at the intersection in order to get the actual approaching speed and also to the determined the 15th and 85th percentile of speed. From the results of the descriptive statistics, the 15th and 85th percentile of speed is 66.2 km/h and 88.2 km/h. These results show that most of the drivers drive their car within the posted speed limit which is 90km/h. The lower and upper limit of the speed were used in order to determine the distance of safe braking line from the stopping line during yellow-onset time. From the study, it shows that the safe braking line from the stopping line is between 97m to 152m.

The study was conducted in one signalized intersection based on the on-site observation, thus the approaching speed are widely observed. This leads to a greater standard deviation which represent larger spread of the collected data. This current observational study did not uncover the differences in the influences of approaching speed such as weather condition and roadway level condition. Hence, for future study all of this factor need to consider. Besides that, simulation of the traffic also need to be done in order to see the difference impact during at the beginning, middle and three quarters of the yellow light phase. Lastly, approaching speed also need to be investigate in different distance from the stopping in order to see whether the distance of vehicles from the stopping line gives a impact to the approaching speed.

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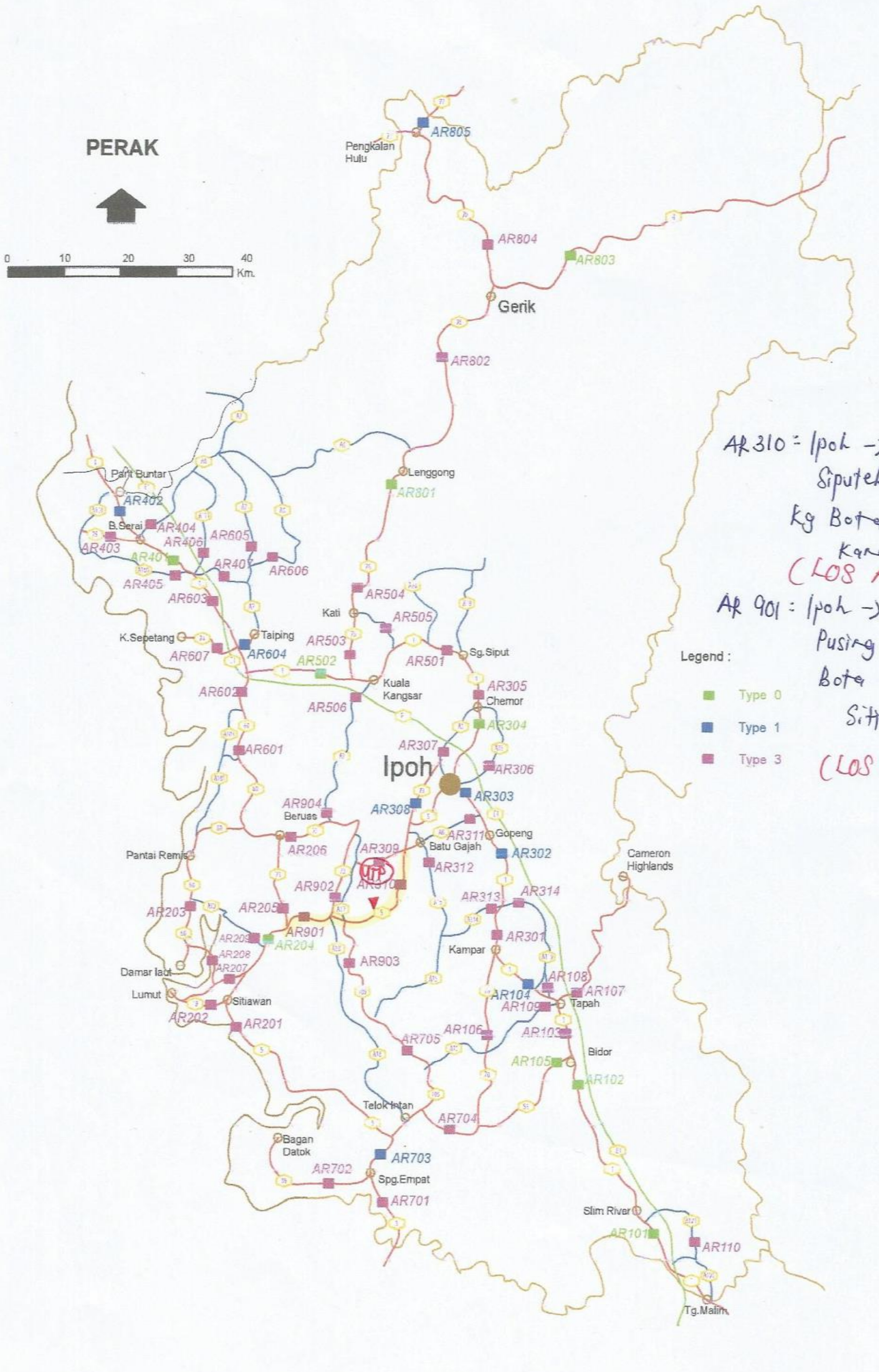
Appendix

1. Road Traffic Volume Malaysia

(14)

1-1 12

Figure A: TRAFFIC CENSUS STATIONS



AR310 = Ipoh -> Siputeh, Kg Bota Kanan.

(LOS A)

AR 901 : Ipoh -> Pusing, Bota Kiri, Sitiawan.

(LOS A)

Station : AR310 (Ipoh-Lumut & Lumut-Ipoh)

NOMBOR STESEN: 04103AR310

AR 310 = Ipoh → Siputeh → Kg Bota Kanan.

HARI PERTAMA

ARAH 1
Hari: RABU
Tarikh: 14/4/2010

Ipoh - lumut

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	105	25	10	15	1	65	221
0700-0800	203	38	31	15	3	118	408
0800-0900	383	36	40	34	5	121	619
0900-1000	319	63	43	60	40	178	703
1000-1100	303	31	61	22	3	63	483
1100-1200	319	58	78	72	5	94	626
1200-1300	335	65	56	31	1	56	544
1300-1400	275	65	48	39	3	47	477
1400-1500	172	12	20	12	22	57	295
1500-1600	142	7	21	30	8	67	275
1600-1700	215	17	21	27	37	91	408
1700-1800	225	90	40	15	15	80	465 ✓
1800-1900	240	85	15	5	5	40	390
1900-2000	170	60	40	20	5	95	390
2000-2100	130	40	10	5	1	80	266
2100-2200	85	30	15	5	1	40	176
Jumlah	3621	722	549	407	155	1292	6746

ARAH 2
Hari: RABU
Tarikh: 14/4/2010

lumut - Ipoh.

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	90	12	17	21	8	64	212
0700-0800	220	40	29	40	13	138	480
0800-0900	350	73	65	42	7	122	659
0900-1000	344	52	104	57	3	101	661
1000-1100	283	51	69	71	2	59	535
1100-1200	329	100	68	50	23	140	710
1200-1300	287	78	49	58	13	94	579
1300-1400	358	45	121	28	7	108	667
1400-1500	190	105	55	85	10	80	525
1500-1600	235	110	65	60	5	65	540
1600-1700	210	125	85	45	5	105	575
1700-1800	240	105	55	30	5	155	590
1800-1900	215	75	35	15	3	115	458
1900-2000	195	25	9	13	8	102	352
2000-2100	140	2	3	7	8	42	202
2100-2200	135	4	2	3	2	37	183
Jumlah	3821	1002	831	625	122	1527	7928

8am - 9am.
5pm - 6pm

KE DUA ARAH : 04103AR310

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	**Jumlah**	
0600-0700	195.0	37.0	27.0	36.0	9.0	129.0	433.0	0600-0700
0700-0800	423.0	78.0	60.0	55.0	16.0	256.0	888.0	0700-0800
0800-0900	733.0	109.0	105.0	76.0	12.0	243.0	1278.0	0800-0900
0900-1000	663.0	115.0	147.0	117.0	43.0	279.0	1364.0	0900-1000
1000-1100	586.0	82.0	130.0	93.0	5.0	122.0	1018.0	1000-1100
1100-1200	648.0	158.0	146.0	122.0	28.0	234.0	1336.0	1100-1200
1200-1300	622.0	143.0	105.0	89.0	14.0	150.0	1123.0	1200-1300
1300-1400	633.0	110.0	169.0	67.0	10.0	155.0	1144.0	1300-1400
1400-1500	362.0	117.0	75.0	97.0	32.0	137.0	820.0	1400-1500
1500-1600	377.0	117.0	86.0	90.0	13.0	132.0	815.0	1500-1600
1600-1700	425.0	142.0	106.0	72.0	42.0	196.0	983.0	1600-1700
1700-1800	465.0	195.0	95.0	45.0	20.0	235.0	1055.0	1700-1800
1800-1900	455.0	160.0	50.0	20.0	8.0	155.0	848.0	1800-1900
1900-2000	365.0	85.0	49.0	33.0	13.0	197.0	742.0	1900-2000
2000-2100	270.0	42.0	13.0	12.0	9.0	122.0	468.0	2000-2100
2100-2200	220.0	34.0	17.0	8.0	3.0	77.0	359.0	2100-2200
Jum -16jam	7442.0	1724.0	1380.0	1032.0	277.0	2619.0	14674.0	

PERATUS HARIAN KLASIFIKASI KENDERAAN

	Motokar Teksi	**Van kecil & Utiliti**	**Lori & Van Besar**	**Lori dengan 3 gandar**	**Bas**	**Motosikal**	**Jumlah**
% - 16 jam	**50.7**	**11.7**	**9.4**	**7.0**	**1.9**	**19.2**	**100.0**

Masa Puncak	**0900-1000**
Jumlah Trafik masa Puncak	**1364**
Jumlah trafik - 16 jam	**14674**

Station : AR901 (Ipoh-Lumut & Lumut-Ipoh)

AR 901 : Ipoh -> pusing -> Bota Kiri, -> Sitiawan.

NOMBOR STESEN: 04103AR901

HARI PERTAMA

ARAH 1
Hari: RABU
Tarikh: 14/4/2010

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	107	13	10	13	4	69	216
0700-0800	365	48	44	24	5	117	603
0800-0900	232	61	35	27	4	72	431
0900-1000	181	43	60	19	6	61	370
1000-1100	267	55	80	37	2	51	492
1100-1200	271	82	93	40	3	48	537
1200-1300	215	58	82	35	2	51	443
1300-1400	281	65	71	40	4	60	521
1400-1500	216	42	59	13	4	52	386
1500-1600	235	47	48	33	9	46	418
1600-1700	276	62	64	22	4	48	476
1700-1800	545	65	75	16	10	100	811
1800-1900	318	62	24	8	5	151	568
1900-2000	168	19	17	22	3	33	262
2000-2100	125	9	12	10	4	24	184
2100-2200	59	5	20	2	1	17	104
Jumlah	3861	736	794	361	70	1000	6822

ARAH 2
Hari: RABU
Tarikh: 14/4/2010

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	180	35	20	20	5	60	320
0700-0800	508	32	29	21	8	144	742
0800-0900	295	33	52	23	5	64	472
0900-1000	224	31	53	27	6	49	390
1000-1100	268	34	51	40	4	71	468
1100-1200	277	36	42	40	1	63	459
1200-1300	285	50	67	50	4	80	536
1300-1400	297	54	60	53	3	60	527
1400-1500	229	47	36	20	2	47	381
1500-1600	272	50	71	27	6	52	478
1600-1700	283	42	53	22	4	63	467
1700-1800	507	36	38	24	5	95	705
1800-1900	353	32	20	21	4	93	523
1900-2000	193	21	11	27	3	44	299
2000-2100	160	10	7	6	5	22	210
2100-2200	102	19	9	5	1	15	151
Jumlah	4433	562	619	426	66	1022	7128

7am - 8am
5pm - 6pm

KE DUA ARAH : 04103AR901

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah	
0600-0700	287.0	48.0	30.0	33.0	9.0	129.0	536.0	0600-0700
0700-0800	873.0	80.0	73.0	45.0	13.0	261.0	1345.0	0700-0800
0800-0900	527.0	94.0	87.0	50.0	9.0	136.0	903.0	0800-0900
0900-1000	405.0	74.0	113.0	46.0	12.0	110.0	760.0	0900-1000
1000-1100	535.0	89.0	131.0	77.0	6.0	122.0	960.0	1000-1100
1100-1200	548.0	118.0	135.0	80.0	4.0	111.0	996.0	1100-1200
1200-1300	500.0	108.0	149.0	85.0	6.0	131.0	979.0	1200-1300
1300-1400	578.0	119.0	131.0	93.0	7.0	120.0	1048.0	1300-1400
1400-1500	445.0	89.0	95.0	33.0	6.0	99.0	767.0	1400-1500
1500-1600	507.0	97.0	119.0	60.0	15.0	98.0	896.0	1500-1600
1600-1700	559.0	104.0	117.0	44.0	8.0	111.0	943.0	1600-1700
1700-1800	1052.0	101.0	113.0	40.0	15.0	195.0	1516.0	1700-1800
1800-1900	671.0	94.0	44.0	29.0	9.0	244.0	1091.0	1800-1900
1900-2000	361.0	40.0	28.0	49.0	6.0	77.0	561.0	1900-2000
2000-2100	285.0	19.0	19.0	16.0	9.0	46.0	394.0	2000-2100
2100-2200	161.0	24.0	29.0	7.0	2.0	32.0	255.0	2100-2200
Jum -16jam	8294.0	1298.0	1413.0	787.0	136.0	2022.0	13950.0	

PERATUS HARIAN KLASIFIKASI KENDERAAN

	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
% - 16 jam	59.5	9.3	10.1	5.6	1.0	14.5	100.0

Masa Puncak	1700-1800
Jumlah Trafik masa Puncak	1516
Jumlah trafik - 16 jam	13950

Station : AR901 (Ipoh-Lumut & Lumut-Ipoh)

AR 910 : Ipoh → pusing → Bota Kiri → Sitiawan.

NOMBOR STESEN: 03143AR901

HARI PERTAMA

ARAH 1 Ipoh ke Sitiwan
Hari: KHAMIS
Tarikh: 13/03/2014

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	376	22	26	14	3	77	518
0700-0800	636	41	51	25	8	198	959
0800-0900	321	76	55	35	6	126	619
0900-1000	372	72	52	49	3	64	612
1000-1100	268	104	93	39	6	69	579
1100-1200	347	80	44	345	4	46	866
1200-1300	468	75	55	50	3	88	739
1300-1400	410	68	83	32	5	78	676
1400-1500	515	51	77	43	5	83	774
1500-1600	447	33	92	39	7	87	705
1600-1700	487	26	91	86	6	91	787
1700-1800	607	35	59	21	6	123	851
1800-1900	589	31	52	20	7	121	820
1900-2000	402	21	37	36	4	71	571
2000-2100	340	12	17	24	2	52	447
2100-2200	250	7	10	12	1	24	304
Jumlah	6835	754	894	870	76	1398	10827

ARAH 2 Sitiwan ke Ipoh
Hari: KHAMIS
Tarikh: 13/03/2014

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	330	40	30	8	2	83	493
0700-0800	667	70	53	13	4	210	1017
0800-0900	333	126	37	10	6	177	689
0900-1000	278	88	96	25	8	68	559
1000-1100	369	80	56	38	1	60	604
1100-1200	240	81	90	35	3	50	499
1200-1300	380	43	49	44	3	74	573
1300-1400	373	165	147	20	6	115	826
1400-1500	438	108	98	47	7	62	780
1500-1600	476	31	104	48	5	72	736
1600-1700	569	40	93	34	7	89	832
1700-1800	619	36	57	28	6	146	892
1800-1900	631	36	48	31	6	98	850
1900-2000	345	15	16	20	5	76	477
2000-2100	290	12	10	14	4	42	372
2100-2200	217	4	6	5	1	17	250
Jumlah	6533	973	990	420	74	1459	10449

KE DUA ARAH : 03143AR901

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah	
0600-0700	706.0	62.0	56.0	22.0	5.0	160.0	1011.0	0600-0700
0700-0800	1303.0	111.0	104.0	38.0	12.0	408.0	1976.0	0700-0800
0800-0900	654.0	202.0	92.0	45.0	12.0	303.0	1308.0	0800-0900
0900-1000	648.0	158.0	148.0	74.0	11.0	132.0	1171.0	0900-1000
1000-1100	637.0	184.0	149.0	77.0	7.0	129.0	1183.0	1000-1100
1100-1200	587.0	161.0	134.0	380.0	7.0	96.0	1365.0	1100-1200
1200-1300	828.0	118.0	104.0	94.0	6.0	162.0	1312.0	1200-1300
1300-1400	783.0	233.0	230.0	52.0	11.0	193.0	1502.0	1300-1400
1400-1500	953.0	159.0	175.0	90.0	12.0	165.0	1554.0	1400-1500
1500-1600	923.0	64.0	196.0	87.0	12.0	159.0	1441.0	1500-1600
1600-1700	1056.0	66.0	184.0	120.0	13.0	180.0	1619.0	1600-1700
1700-1800	1226.0	71.0	116.0	49.0	12.0	269.0	1743.0	1700-1800
1800-1900	1220.0	67.0	100.0	51.0	13.0	219.0	1670.0	1800-1900
1900-2000	747.0	36.0	53.0	56.0	9.0	147.0	1048.0	1900-2000
2000-2100	630.0	24.0	27.0	38.0	6.0	94.0	819.0	2000-2100
2100-2200	467.0	11.0	16.0	17.0	2.0	41.0	554.0	2100-2200
Jum -16jam	13368.0	1727.0	1884.0	1290.0	150.0	2857.0	21276.0	

7am - 8am

5pm - 6pm.

PERATUS HARIAN KLASIFIKASI KENDERAAN

	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
% -16 jam	62.8	8.1	8.9	6.1	0.7	13.4	100.0

Masa Puncak	0700-0800
Jumlah Trafik masa Puncak	1976
Jumlah trafik -16 jam	21276

Station : AR310 (Ipoh-Lumut & Lumut-Ipoh)

AR 310 : Ipoh -> Siputeh -> kg Bota Kanan.

NOMBOR STESEN: 09143AR310

HARI PERTAMA

ARAH 1 Ipoh ke Lumut
Hari: RABU
Tarikh: 24/09/2014

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	188	14	10	27	6	107	352
0700-0800	465	80	58	60	18	250	931
0800-0900	263	26	40	22	6	128	485
0900-1000	430	105	157	102	26	166	986
1000-1100	426	85	188	124	18	140	983
1100-1200	314	105	120	30	6	65	640
1200-1300	382	103	95	58	5	121	764
1300-1400	411	126	95	110	9	102	853
1400-1500	257	42	92	36	7	167	601
1500-1600	506	90	139	28	8	132	903
1600-1700	455	62	40	37	4	69	667
1700-1800	547	81	92	10	7	208	945
1800-1900	547	81	50	11	6	121	816
1900-2000	504	36	17	8	8	123	696
2000-2100	359	32	21	8	3	52	473
2100-2200	116	17	7	1	2	20	163
Jumlah	6172	1085	1221	670	139	1971	11258

ARAH 2 Lumut ke Ipoh
Hari: RABU
Tarikh: 24/09/2014

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
0600-0700	207	12	20	16	4	180	439
0700-0800	325	17	41	52	16	165	616
0800-0900	260	35	70	20	12	130	527
0900-1000	515	125	110	135	51	153	1089
1000-1100	405	151	103	120	26	115	920
1100-1200	430	45	125	155	15	53	823
1200-1300	355	90	65	117	0	85	712
1300-1400	480	30	115	30	4	95	754
1400-1500	323	108	85	39	4	55	614
1500-1600	449	142	66	34	2	59	752
1600-1700	390	56	65	21	3	66	601
1700-1800	495	75	85	6	5	141	807
1800-1900	643	152	65	14	3	108	985
1900-2000	393	41	20	8	7	42	511
2000-2100	300	55	13	7	2	65	442
2100-2200	93	13	0	3	0	12	121
Jumlah	6063	1147	1048	777	154	1524	10713

KE DUA ARAH : 09143AR310

Masa	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah	
0600-0700	395.0	26.0	30.0	43.0	10.0	287.0	791.0	0600-0700
0700-0800	790.0	97.0	99.0	112.0	34.0	415.0	1547.0	0700-0800
0800-0900	523.0	61.0	110.0	42.0	18.0	258.0	1012.0	0800-0900
0900-1000	945.0	230.0	267.0	237.0	77.0	319.0	2075.0	0900-1000
1000-1100	833.0	236.0	291.0	244.0	44.0	255.0	1903.0	1000-1100
1100-1200	744.0	150.0	245.0	185.0	21.0	118.0	1463.0	1100-1200
1200-1300	737.0	193.0	160.0	175.0	5.0	206.0	1476.0	1200-1300
1300-1400	891.0	156.0	210.0	140.0	13.0	197.0	1607.0	1300-1400
1400-1500	580.0	150.0	177.0	75.0	11.0	222.0	1215.0	1400-1500
1500-1600	955.0	232.0	205.0	62.0	10.0	191.0	1655.0	1500-1600
1600-1700	845.0	118.0	105.0	58.0	7.0	135.0	1268.0	1600-1700
1700-1800	1042.0	156.0	177.0	16.0	12.0	349.0	1752.0	1700-1800
1800-1900	1190.0	233.0	115.0	25.0	9.0	229.0	1801.0	1800-1900
1900-2000	897.0	77.0	37.0	16.0	15.0	165.0	1207.0	1900-2000
2000-2100	659.0	87.0	34.0	13.0	5.0	117.0	915.0	2000-2100
2100-2200	209.0	30.0	7.0	4.0	2.0	32.0	284.0	2100-2200
Jum -16jam	12235.0	2232.0	2268.0	1447.0	293.0	3495.0	21971.0	

7am - 8am.
6pm - 7pm.

PERATUS HARIAN KLASIFIKASI KENDERAAN

	Motokar Teksi	Van kecil & Utiliti	Lori & Van Besar	Lori dengan 3 gandar	Bas	Motosikal	Jumlah
% - 16 jam	55.7	10.2	10.3	6.6	1.3	15.9	100.0

Masa Puncak	0900-1000
Jumlah Trafik masa Puncak	2075
Jumlah trafik - 16 jam	21971

Appendix

2. Spot Speed Study (Data Collection Form)

Day 1 (06/10/2017) : Morning Peak Hour

Spot Speed Study

Data Collection Form

Location : Ipoh → Lumut Observer: Aifaa

Date : 6/10/2017 Start Time : 8.07 am End Time : 9.10 am

Weather Condition : Nice Posted Speed :

Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)
78	53.3	62	67.2	63	44.3	71	60.1
61	49.8	63	50.1	77	70.8	91	75.9
69	39.5	58	43.6	73	50.2	91	49.6
65	52.6	87	74.9	57	50.1	69	57.7
60	35.9	85	61.4	91	58.5	71	65.1
68	70.3	78	44.0	72	82.6	77	52.4
68	52.8	77	63.8	66	66.6	82	46.0
82	72.7	59	60.8	68	62.7	74	50.0
66	62.6	54	63.6	86	49.5	~~69~~ 60	61.6
86	48.4	63	57.8	88	75.1	84	58.4
55	64.0	82	79.0	102	60.9	89	81.7
77	65.0	83	69.4	83	62.8	80	62.6
62	56.2	76	44.0	84	39.3	74	42.9
78	63.5	60	58.2	77	68.1	70	43.4
67	44.4	95	64.8	69	55.9	74	54.8
81	69.3	81	55.9	73	55.8	64	60.7
85	54.3	~~78~~ 83	~~63.7~~ 43.5	101	54.5	88	81.0
64	66.6	69	76.0	102	73.0	81	61.4
75	52.9	74	37.5	99	50.0	69	57.0
74	48.5	89	71.3	88	72.3	55	43.3
78	66.0	90	39.1	66	54.3	69	67.2
84	52.3	80	66.0	55	57.3	82	65.5
61	45.3	95	56.3	49	77.7	71	56.1
128	69.8	52	39.4	88	58.2	76	67.1

Day 1 (06/10/20017) : Evening Peak Hour

Spot Speed Study

Data Collection Form

Location : Lumut → Ipoh Observer: Haslina & Diha

Date : 6/10/2017 Start Time : 5.15 pm End Time : 6.00 pm

Weather Condition : After rain Posted Speed : ……………………

Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)
76	74.1	79	52.9	90	36.7	63	27.5
54	40.9	88	49.6	93	33.2	69	37.0
95	60.1	62	43.5	85	33.8	74	37.8
80	53.2	75	51.7	87	41.2	82	45.1
78	57.5	65	33.3	49	19.3	57	22.4
67	34.3	68	33.2	63	41.7	85	40.7
76	46.7	95	38.8	77	35.6	70	58.7
98	72.2	65	25.1	62	25.6	60	46.5
91	79.7	85	30.4	86	55.8	94	51.2
69	56.6	79	55.9	76	44.7	80	48.9
63	45.1	73	33.8	85	28.3	78	34.3
58	42.5	69	28.2	61	30.7	75	29.3
63	55.2	75	35.1	70	31.3	75	42.2
68	70.8	79	50.2	70	47.6	63	24.3
71	37.3	71	32.7	78	39.5	77	51.4
73	59.2	70	37.1	76	37.1	75	41.6
86	76.8	68	40.9	70	23.1	76	35.0
73	58.7	72	35.1	87	48.6	69	39.0
68	62.4	70	33.7	76	28.8	55	42.3
60	34.0	92	41.0	59	42.7	84	27.8

Day 2 (08/10/2017) : Morning Peak Hour

Spot Speed Study

Data Collection Form

Location : Nasi Lemak Jtenah Perak. Observer: Aqyah

Date : 13/10 Start Time : 8.02 am End Time : 9:10 am.

Weather Condition : Good Posted Speed :

Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)
76	40.8	77	46.3	89	48.4	71	41.9
76	46.5	73	53.0	88	41.1	96	47.1
58	36.6	82	58.2	73	43.4	68	51.7
71	41.7	69	43.0	92	56.6	87	62.1
101	43.7	63	42.0	84	54.8	84	58.3
78	39.2	85	48.2	66	47.4	72	45.9
97	47.1	68	43.7	57	47.5	77	45.9
96	52.7	89	46.9	83	44.2	68	38.7
81	36.6	81	41.3	70	50.7	66	40.2
85	49.2	76	45.9	66	38.9	91	47.3
73	59.3	71	37.7	78	44.4	76	54.0
93	69.1	93	40.1	78	74	102	52.4
68	44.7	72	39.3	75	47.5	81	50.3
70	45.6	88	49.5	79	44.3	93	48
74	38.7	68	43.2	80	47.2	76	47.4
88	45.2	75	52.5	86	51.3	67	47.3
89	50.6	69	44.8	85	49.7	84	69.2
75	42.6	69	42.5	78	49.4	83	62.8
78	45.0	61	43.9	69	45.2	90	59.6
78	50.9	75	54.5	92	49.6	84	55.4

Day 2 (08/10/2017) : Evening Peak Hour

Spot Speed Study

Data Collection Form

Location : Ipoh → Lumut Nasi Lemak Perak

Observer: Aifaa Yati

Date : 8/10/2017 Start Time : 5:08 pm End Time : ……………

Weather Condition : Sunny Posted Speed : ………………………

Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)
79	62.1	75	61.1	76	40.0	88.	47.8
83	58.9	93	50.5	78	70.5	71	51.4
75	59.1	70	59.9	76	50.0	71	45.9
67	53.8	69	40.4	77	56.2	83	66.5
93	64.6	81	62.7	72	48.3	84	62.2
85	76.2	77	64.5	80	38.0	78	59.0
74	62.6	73	40.4	80	57.0	78	54.0
86	42.9	64	56.2	75	56.2	79	50.6
101	78.4	78	65.8	70	54.3	74	45.1
80	65.8	69	80.1	84	53.5	92	69.1
78	58.0	64	46.5	78	51.2	88	71.6
77	75.2	84	67.0	80	52.0	89	53.3
76	46.2	88	62.3	83	69.1	104	67.2
110	64.5	74	59.6	75	65.9	87	71.3
98	47.1	66	57.4	85	66.1	75	45.7
87	50.1	73	65.3	87	55.8	100	39.5
67	60.3	74	49.8	78	42.6	77	54.4
76	40.9 ~~60.9~~	78	54.5	77	44.3	91	77.8
72	64.7	76	43.4	79	37.9	89	68.8
72	56.5	70	79.9	85	46.2	67	57.7

Day 3 (09/10/2017) : Evening Peak Hour

Spot Speed Study

Data Collection Form

Location : Lumut → Ipoh Observer: Aifaa Yati

Date : 9/10/2017 Start Time : 5.05 pm End Time :

Weather Condition : Cloudy Posted Speed :

Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)	Speed, (km)	Distance, d (m)
76	32.5	71	71.9	77	72.3		
88	36.1	75	47.5	87	69.4		
65	40.8	90	65.8	72	52.6		
63	29.2	71	88.2	86	45.3		
80	34.6	82	59.0	94	65.0		
65	23.4	86	88.4	74	55.8		
76	37.2	77	86.9	80	95.2		
76	45.6	74	54.3	84	457		
67	31.4	71	63.3	71	55.8		
71	32.7	68	57.5	147	52.6		
95	30.8	57	39.3	85	57.7		
91	53.3	70	52.0	77	71.5		
73	47.6	98	77.7				
74	40.1	70	33.6				
76	36.1	86	43.5				
96	102.2	73	57.4				
78	55.4	64	70.2				
86	58.1	89	65.4				
66	31.1	91	47.6				
65	43.0	91	70.9				