UNIVERSITI TEKNOLOGI PETRONAS

**Speed Analysis along Ipoh-Lumut Highway**

by

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Dissertation
submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JULY 2008

Universiti Teknologi PETRONAS
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# CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

(Assoc. Prof. Dr Madzlan Napiah)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2008

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.

LEE KEE FOO

# ABSTRACT

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience and economics. Due to development of Ipoh-Lumut Corridor, the need to address the growing traffic volume and safety on Ipoh-Lumut Highway arises. Speed is also related to Level of Service (LOS) characteristic of a particular highway. This study aims to assess the general roadway speed on Ipoh-Lumut Highway and to propose new set of speed limit. Ipoh-Lumut Highway is being demarcated by normal car odometer during a trial run from Ipoh to Lumut. Spot speed studies will be conducted in stretches demarcated. Based on the similar study conducted in United States of America, speed data collected will be used to set a speed zone along Ipoh-Lumut Highway. Literatures have supported that using $85^{th}$ percentile speed to set an appropriate speed limit will result in a reduction in crashes and an increase in Level of Service.

# ACKNOWLEDGEMENTS

The printed pages in this dissertation reflect the relationships with many generous and inspiring people I have met since the inception of the study.

Many thanks go to my supervisor, Assoc. Prof. Dr Madzlan Napiah. He has been instrumental in allowing this study to be completed. The smooth running of this study is much more a testament to his efforts rather than my own. His great effort in explaining and providing guidance steered me in the correct direction from the beginning until the end of this study. I would have been lost without him.

I would also like to thank Miss Niraku Rosmawati and Mr Kalaikumar for their significant role as Final Year Project Coordinators. I am also indebted to the Civil Engineering Dept laboratory technologists, Zaini and Iskandar for the prompt responses and permission to use the laboratory equipments.

Many thanks also go to Mohamad Nurhafizi and Mohd Raizullan for their supports and assistance. Their ideas and suggestions all along this study proved to be useful and beneficial.

Finally, I would like to express special thanks to Kok Hui Yi. Her positive comments, advices and encouraging nature have been an inspiration throughout.

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# INTRODUCTION

## 1.1 PROJECT BACKGROUND

### 1.1.1 Overview of Perak Road Network

Vast network of major roads and highways in the country made Perak easily accessible from the rest of the country. History of road network in Perak traces back to the North-South trunk road that links it to other major towns in Peninsular Malaysia. With addition of North-South Highway (PLUS) to the network, Perak now is poised to become the economical hub with industries developing nearby Ipoh and Jelapang.

The most recent is the Ipoh-Lumut Highway which cost nearly RM 1.1 billion stretching 65km length from Ipoh towards Sitiawan. The project is crucial for economic growth of Perak and to address the growing traffic volume on the existing trunk road.

As shown in Figure 1, further planned improvement onto Ipoh-Lumut Highway will bring the North-South Expressway within 45 minutes reach of Lumut Port, giving prime access to all major domestic, north, south and central markets.

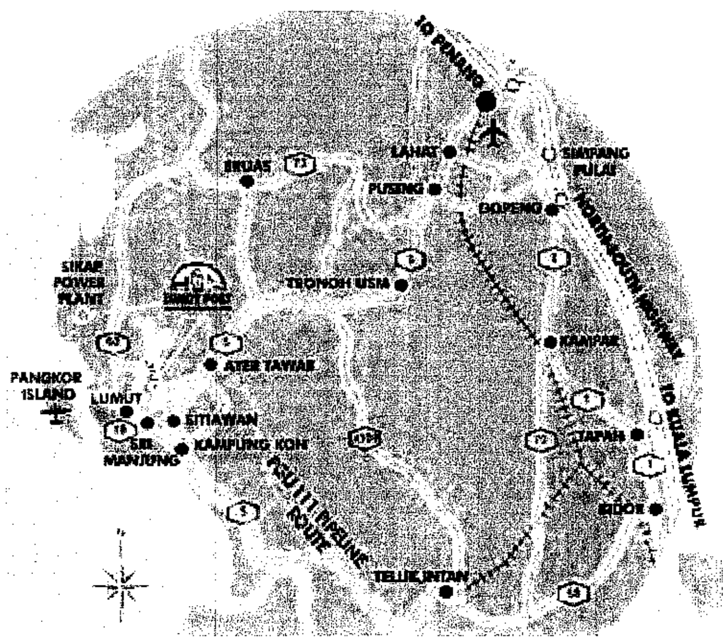



Figure 1: Ipoh-Lumut Highway

Table 1 summarizes the details of Ipoh-Lumut Highway listing all the roads joined together.

Table 1 : Ipoh-Lumut Highway - Federal Route 5

| | |
|---|---|
| **Length** | 65km |
| **Speed Limit** | Up to 90km/hr ( 60km/hr at certain stretch ) |
| **Design Standard** | R5 at 100 km/hr Design Speed |
| **Level of Service** | LOS C (Desirable) |
| **Access Control** | Partial |
| **Direction** | North-South |
| **Start** | Ipoh |
| **Main Destinations** | Menglembu, Bota, Air Tawar, Sitiawan, Lumut, Pangkor Island |
| **End** | Lumut |
| **Construction** | Begins : - Ends : - |
| **Roads Joined** | A1 Jalan Jelapang<br>1 Federal Route 1<br>A8 Batu Gajah Highway<br>73 Federal Route 73<br>109 Federal Route 109<br>72 Federal Route 72<br>71 Federal Route 71<br>18 Federal Route 18<br>100 Lumut Bypass<br>602 Dinding Bypass<br>5 Federal Route 5 |

## 1.2 Background of Study

The functional effectiveness of a highway is measured in terms of its ability to assist and accommodate the flow of vehicles with both safety and efficiency. In order to measure its efficiency, certain parameters associated with the highway must be measured and analyzed. Three primary elements of traffic stream; flow, density and speed will be taken into consideration in this study.

## 1.3 Problem Statement

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience and economics. Speed is also related to Level of Service (LOS) characteristic of a particular highway. Level of Service gauge the level of congestion on a highway in terms of variables such as travel time and traffic speed.

With the development of Ipoh-Lumut Corridor into a socio-economic hub, the need to address the increasing traffic volume and highway safety arises. Speed zoning is hypothesized to increase the Level of Service. Spot speed analysis will be conducted to obtain speed trends of Ipoh-Lumut Highway users.

Furthermore, Ipoh-Lumut Highway is being designed as R5 standard, with design speed of 100km/hr. However, National Maximum Speed Limit imposed on all roads is 90 km/hr. Certain quarters have been calling for an increase in the national speed limit of 90 km/hr to 100 km/hr due to the good standard of highways and roads in Malaysia.

Thus this study will assess whether speed limit increase is feasible along Ipoh-Lumut Highway.

## 1.4 Objectives

The objectives of this study are to:

- Obtain an actual speed profile along Ipoh-Lumut Highway.
- Assess correlation between roadway speed limit violation and Level of Service.
- Speed zoning on stretches of Ipoh-Lumut Highway to increase the Level of Service (LOS) to LOS C or higher & to reduce frequency and severity of road accident.

## 1.5 Scope of Works & Feasibility

Three primary elements of traffic stream; flow, density and speed will be taken into consideration in this study. Given the timeline of 1 year, spot speed data collection along Ipoh-Lumut Highway, highway modeling and design analysis will be conducted.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Speeding

United Kingdom has one of the best road safety track records in Europe. Table 2 summarizes the number of fatalities per 100,000 populations in selected Europe countries.

Table 2: Road Death in Selected Europe countries

| Country | Road Death (Per 100,000 population) |
|---|---|
| United Kingdom | 6 |
| Greece | 19.3* |
| Italy | 11.7 |
| Portugal | 16.1 |
| Spain | 13.2 |
| Germany | 8.3 |
| France | 12.9 |

** Year 2000 data*

*(Source: Speed – Know Your Limit, Department for Transport, London, UK)*

Speed actually contributes to the deaths on the road. Driving at an inappropriate speed is a real problem in rural roads. Despite only 10% of drivers exceeding speed limit on rural roads, over 60% car occupants' death occur on them (Department for Transport, UK 2004). This is because, although the national speed limit applies on the vast majority of rural roads, it is actually difficult to drive at anywhere close to the speed limit, but it is still very possible to drive too fast for the conditions. These include approaching a bend or junction too fast, not negotiating narrow roads properly and overtaking where it is inappropriate to do so.

Inappropriate speed is also a factor where poor weather conditions prevail and when driving at night. It is a commonly held belief that, since roads have far less traffic at night, it is safe to drive at higher speeds. However, it is facts that the average risk of an accident per kilometer traveled between 7.00pm and 7.00am is double that for that between 7.00am and 7.00pm.

In an ideal world all drivers would obey all speed limits at all times. Unfortunately we do not live in an ideal world and for any number of reasons drivers do from time to time fail to stick to the posted limit. Over the years a number of measures have been developed to help drivers stay within the speed limit in force. These measures have the effect of changing the nature or appearance of the road to encourage drivers that a slower speed is appropriate. Local authorities have all the necessary powers to introduce any measure they deem appropriate, but obviously which one would depend on the nature of the problem.

Road humps are the most commonly used and most effective measure, reducing speeds by up to 10mph.They are most effective on urban roads, around schools and in residential areas. They are not usually appropriate for rural areas. Other measures include build outs or chicanes that narrow the road thereby encouraging lower speeds, or road markings that have the visual effect of narrowing the carriageway. Where there is a need to warn drivers to reduce speed when approaching a hazard, vehicle activated signs have proved to be very effective. These designs that remains blank until a vehicle approaching at a certain speed triggers a message to be displayed electronically. These signs can be very effective on rural roads where the national speed limit applies but drivers need to slow down considerably to take account of a crossroad, a sharp bend or other hazard.

## 2.2 Speed Zoning

Speed zoning along Ipoh-Lumut Highway is hypothesized to be able to increase the Level of Service to LOS C or higher. On certain stretch of the highway, the posted speed limit will be increased or decreased. As stated in Uniform Vehicle Code, the purpose of speed zoning is to set a speed limit which "is reasonable and safe for a given section of a roadway". Assuming a direct relationship exist between a change in speed limit and a change in driver behavior, speed zoning results in an increased safety of highways. (ITE Committee 4M-25, 1992)

Generally, traffic law that reflect the behavior of the majority of motorists are found to be successful, while law that arbitrarily restricts the majority of motorists encourage violations, lack public support and usually fail to bring about desirable changes in driving behavior. This is especially true in speed zoning.

Traffic and engineer's investigations should be conducted to obtain an accurate measurement of the speed distribution. Traditional belief is that higher speed limit increases the frequency and severity of crashes. However, based on a 1992 study conducted by US Dept of Transportation, raising speed limits in the region of the 85th percentile speed has an extremely beneficial effect on drivers complying with the posted speed limits. As noted by a number of researchers, the potential for being involved in an accident is highest when traveling at speed much lower or much higher than the majority of motorists, which is variation in the speed within the traffic stream. (FHWA-RD-92-084 US Dept of Transportation, 1992)

As being reported in Speed Zoning for Highways, Roads and Streets, published by Florida Department of Transportation, the speed chosen by a driver is the balance between expedience and safety, and is often subconscious reaction to the environment.

A speed limit for the Ipoh-Lumut Highway is being set during design stage. The posted speed limit on the highway can be lower than the design speed. However, the actual conditions prevailing on Ipoh-Lumut Highway can be worse than the design condition assumed by the traffic engineer. Thus it will be unsafe to use design speed as the speed limit on Ipoh-Lumut Highway.

According to Manual for Uniform Traffic Control Devices (MUTCD), the following factors should be considered prior to setting speed zones:

1. Road surface characteristics, shoulder conditions, grade, alignment and sight distance
2. The 85$^{th}$ percentile speed
3. Roadside development and culture
4. Roadside friction
5. Safe speed for curves and hazardous location within the zone
6. Parking practices and pedestrian activities
7. Reported accident experience for the past 12 months

## 2.3 The 85$^{th}$ Percentile Speed

Speed percentiles are tools used to determine effective and adequate speed limits. The two speed percentiles most important to understand are the 50$^{th}$ and the 85$^{th}$ Percentiles. The 50$^{th}$ percentile is the median speed of the observed data set. This percentile represents the speed at which half of the observed vehicles are below and half of the observed vehicles are above. The 50$^{th}$ percentile of speed represents the average speed of the traffic stream. The 85$^{th}$ percentile is the speed at which 85% of the observed vehicles are traveling at or below. This percentile is used in evaluating/recommending posted speed limits based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe (Johansson-Stenman et al. 2003). In other words, the 85$^{th}$ percentile of speed is normally assumed to be the highest safe speed for a roadway section. Weather conditions may affect speed percentiles. For example, observed speeds may be slower in rainy or snowy conditions.

However there are limitations to the 85$^{th}$ percentile speed method:

1. Great difficulties in measuring condition where drivers freely choose their speed.
2. Often, the 85$^{th}$ percentile speed exceeds the design speed thus raising safety issues

3. Traffic condition such as volume and time of the day can cause great variation to the 85th percentile speed measured in spot speed studies. (Persaud *et al* 1997)
4. It is difficult to collect adequate spot speed sample on roads with very low traffic volume. In this case, trial road runs is used. (ITE Handbook, 1999)
5. The 85th percentile speed method is not suitable for all types of road. Cited example is urban highways where the traffic volume consists of a mix of road users and roadside development. (TRB 1998)

In a survey of speed zoning practices, Parker (1985) found that all states and most local agencies consider the speed of traffic in setting speed limits. In order of importance, several primary factors considered in engineering studies to set speed limits are:

- 85th percentile speed.
- Type and amount of roadside development.
- Accident experience.
- Adjacent Limits.
- 10 mi/h pace (i.e., speed range that contains the largest percentage of vehicles).
- Horizontal and vertical alignment.
- Design speed.
- Average test run speed.
- Pedestrians.

Criteria and procedures for setting appropriate speed limits in Australia (Fildes and Lee, 1993) and Canada (Knowles et al., 1997) are remarkably similar to the methods followed in the United States.

## 2.4 Speed Limit in Malaysia

According to Road Transport Act 1987, the default speed limits in Malaysia are:

- *Expressways*: 110 km/h (70 mph) by default, but may be reduced to 80 km/h or 90 km/h (50-55 mph) at dangerous mountainous stretches, crosswind areas and urban areas with high traffic capacity.
- *Federal roads*: 90 km/h (55 mph) by default (reduced to 80 km/h during festive seasons), 60 km/h (40 mph) in town area.
- *State roads*: 90 km/h (55 mph) by default (reduced to 80 km/h during festive seasons), 60 km/h (40 mph) in town area.

However special speed limits are applicable to heavy vehicles. The speed limits for heavy vehicles are as follows:-

- *Expressways*: 80-90 km/h (50-55 mph)
- *Federal and state roads*: 70-80 km/h (45-50 mph) by default, 60 km/h (40 mph) in urban areas

## 2.5 Level of Service

The efficiency of a completed highway is a measure of the level of service that the road provides, or a measure of the quality of the flow. The 5th Edition Traffic Engineering Handbook published by Institute of Transportation Engineers (ITE) states the individual level of service are characterized in terms of factors such as speed and travel time, freedom to maneuver, traffic interruptions and comfort and convenience. Table 3 shows the measure of effectiveness on various types of roadways.

Six levels of service are defined for each type of facility for which analysis procedures can be done. The levels are given designation from A to F with A being the best operating conditions and F being the worst.

Table 3: Measure of Effectiveness on Various Type of Roadways

| **Type of Facility** | **Measure of Effectiveness** |
|---|---|
| Freeways | |
| • Basic Freeway sections | Density (pc/km/ln) |
| • Weaving areas | Density (pc/km/ln) |
| • Ramp junctions | Flow rates (pc/hr) |
| Multilane Highway | Density (pc/km/ln)<br>Free flow speed (km/hr) |
| Two lane highways | Time delay (%) |
| Signalized Intersection | Average Control Delay (s/veh) |
| Unsignalized Intersection | Average Control Delay (s/veh) |
| Arterials | Average travel speed (km/hr) |

The 1997 Highway Capacity Manual notes that although speed is a major indicator to service quality for drivers, the freedom to maneuver within the traffic stream and proximity to other vehicles are equally important. This is because these other concerns are related to the density of the traffic stream. Further the density increases as the flow increases up to capacity which results in a measure of effectiveness that is sensitive to broad range of flows. Thus density is the primary performance measure to provide an estimate to the level of service. This is shown in Table 4 where the density of vehicle per mile per lane is increasing from Level of Service A to Level of Service F.

Table 4: Level of Service Classification

| **Level of Service** | **Density Range (pc/mi/ln)** |
|---|---|
| A | 0-10.0 |
| B | 10.1-16.0 |
| C | 16.1-24.0 |
| D | 24.1-32.0 |
| E | 32.1-45.0 |
| F | >45.0 |

As noted in Figure 2, speed of vehicle at Level of Service A is at the maximum where the volume is minimal. Further increase in volume will reduce the operating speed, causing the Level of Service dropping to Level of Service B and so on.

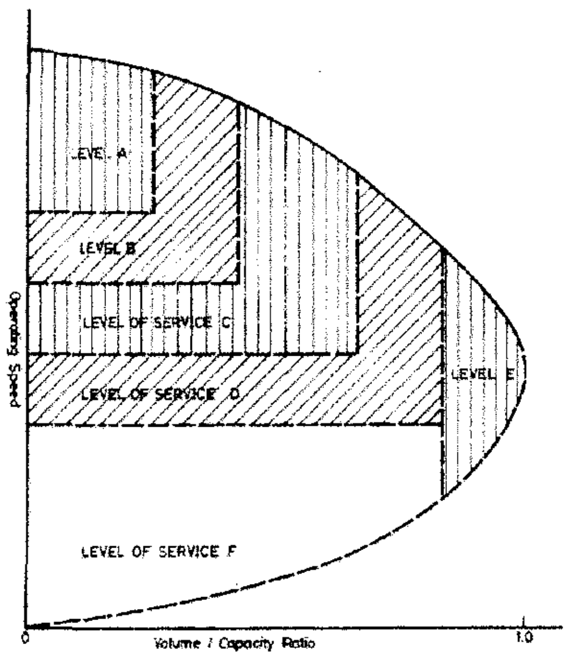



Figure 2: Relationship of Level of Service to Operating Speed and Volume/Capacity Ratio *(Arahan Teknik Jalan 8/86)*

## 2.6 Delay

Amount of travel time actually influence the drivers in choosing their driving speed. The importance and cost of travel time as a function of speed is adequately presented in by the recent experience of the 55-mph (89 km/h) National Maximum Speed Limit (NMSL). According to a review of the NMSL (TRB 1984) estimated that in 1982 motorist were spending about 1 billion extra hours on highways posted at 55 mph because of slower driving speed compared with speeds on these highways in 1973, the year before NMSL were enacted. (TRB 1984) Where most of the additional travel time was expanded by passengers in personal vehicles, it frequently involves small increments in travel time for individual trips.

A limitation to this study conducted by TRB is that the savings from reduced crashes, averted fatalities and serious injuries is not being taken into account in the analysis of time cost of travel. When travel time costs were compared with estimated lives saved and serious injuries averted by the 55-mph (89km/h) travel speed, the time cost worked out to about 40 years of additional driving time per life saved and serious injury avoided.

Travel time costs are not equally distributed either by road type or road user. A 55 mph speed limit results in highest travel time cost for users of Rural Interstate Highways because majority long distance travel, particularly commercial trucks use the Interstate Highways for long cargo haul. However travel time costs on motorists on other road classes were estimated to have much smaller effects, in part a reflection of the role of congestion and roadway geometry in limiting travel speeds on these non limited-access highways.

Travel time costs also tend to be unevenly distributed by road user. The additional travel time attributed to NMSL was borne by motorists engaged in personal travel. Most personal travel (68 percent in 1990) is for shopping, family and other personal business, and social and recreational purposes. Because many of these trips are discretionary and do not have the same economic purpose as work travel, the time value of these trips is lower than for work travel, and by extension, the incremental cost of reduced driving speeds from lower speed limits is also lower. Fortunately, most of these trips are short.

Particular groups of road users—commercial truckers and other business travelers—may be more adversely affected by reduced driving speeds attributable to lower speed limits. These groups drive more miles than the average motorist and often use high-speed roads. The economic cost of increased travel time for these user groups, particularly from lost productivity, can be substantial.

### 2.7 Road Accidents in Malaysia

In the last decade, remarkable growth in economy and industrialization in Malaysia has seen a steady increase in population and motorization. The population increased from 19.5 million to 25.6 million, and in the same period of time, the total length of paved road increased from 60,734 to about 71,814 kilometers while registered vehicles increased from 7,210,089 to 13,878,000 vehicles in 2004. Due to increasing number of vehicles on the road, significant leap in numbers of road accidents has been observed from 1970 to 2004, as being shown in Table 5.

## Table 5: General Road Accident Statistics in Malaysia

| Year | Population | Vehicles registered | Vehicles involved | Road length (km) | No. of accidents | Casualties | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Death | Serious | Slight | Total |
| 1970 | 9,000,399 | 669,294 | 19,433 | 10,715 | 12,704 | 579* | 1,421* | 5,621 | 7,621 |
| 1971 | 9,133,506 | 730,035 | 26,025 | 11,062 | 16,847 | 1,548* | 541* | 6,392 | 8,481 |
| 1972 | 9,873,623 | 802,831 | 34,944 | 11,062 | 22,151 | 1,712* | 631* | 8,373 | 10,716 |
| 1973 | 10,130,672 | 939,951 | 45,916 | 11,062 | 29,286 | 1,922* | 2,504* | 12,176 | 16,602 |
| 1974 | 10,434,592 | 1,090,279 | 39,056 | 11,161 | 24,581 | 2,303* | 744* | 10,285 | 13,332 |
| 1975 | 10,438,137 | 1,267,119 | 75,653 | 12,043 | 48,233 | 2,317 | 2,280 | 14,843 | 19,440 |
| 1976 | 10,472,544 | 1,429,845 | 80,995 | 12,340 | 48,291 | 2,405 | 2,585 | 14,337 | 19,327 |
| 1977 | 10,716,642 | 1,621,271 | 86,688 | 12,637 | 54,222 | 2,512 | 3,033 | 14,760 | 20,305 |
| 1978 | 10,944,500 | 1,829,958 | 91,122 | 13,399 | 56,021 | 2,561 | 3,883 | 15,215 | 21,659 |
| 1979 | 11,188,630 | 1,989,391 | 94,788 | 13,772 | 57,931 | 2,607 | 5,384 | 14,620 | 22,611 |
| 1980 | 11,442,086 | 2,357,386 | 99,485 | 14,446 | 59,084 | 2,568 | 5,097 | 14,739 | 22,404 |
| 1981 | 14,128,354 | 2,901,182 | 107,552 | 31,568 | 63,192 | 2,769 | 4,898 | 14,636 | 22,303 |
| 1982 | 14,506,589 | 3,246,790 | 126,474 | 36,238 | 74,096 | 3,266 | 4,871 | 14,683 | 22,820 |
| 1983 | 14,886,729 | 3,594,943 | 139,006 | 40,664 | 79,150 | 3,550 | 5,656 | 17,351 | 26,557 |
| 1984 | 15,437,683 | 3,941,036 | 140,012 | 42,254 | 80,526 | 3,637 | 5,532 | 16,383 | 25,552 |
| 1985 | 15,866,592 | 4,243,142 | 142,653 | 43,944 | 82,059 | 3,603 | 5,652 | 14,699 | 23,924 |
| 1986 | 16,278,001 | 4,458,735 | 137,175 | 44,100 | 79,804 | 3,525 | 5,442 | 14,290 | 23,257 |
| 1987 | 16,527,973 | 4,595,434 | 131,609 | 44,239 | 76,882 | 3,320 | 5,548 | 12,931 | 21,799 |
| 1988 | 16,921,300 | 4,783,506 | 124,922 | 44,428 | 73,250 | 3,335 | 5,548 | 13,655 | 22,538 |
| 1989 | 17,376,800 | 5,071,786 | 127,279 | 44,592 | 75,626 | 3,773 | 7,249 | 19,015 | 30,037 |
| 1990 | 17,812,000 | 5,462,792 | 146,747 | 50,835 | 87,999 | 4,046 | 8,076 | 17,690 | 29,814 |
| 1991 | 18,178,100 | 5,877,176 | 161,828 | 55,367 | 96,513 | 4,331 | 8,524 | 17,252 | 30,107 |
| 1992 | 18,606,000 | 6,263,383 | 193,421 | 59,796 | 118,554 | 4,557 | 10,634 | 21,071 | 36,262 |
| 1993 | 19,050,000 | 6,712,479 | 220,939 | 59,796** | 135,995 | 4,666 | 11,930 | 25,090 | 41,686 |
| 1994 | 19,494,000 | 7,210,089 | 251,686 | 59,796** | 148,801 | 5,159 | 13,387 | 29,957 | 48,503 |

Source: Royal Malaysia Police 1994

* These figures are regarded as not reliable **Based on 1992 figures

| Year | Population | Vehicles Registered | Road Length (Km) | Number of Accidents | Casualties | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Death | Serious | Slight | Total |
| **1994** | 19,494,000 | 7,210,089 | 60,734 | 148,801 | 5,159 | 13,387 | 29,957 | 48,503 |
| **1995** | 20,096,700 | 6,802,375 | 60,734 | 162,491 | 5,712 | 15,313 | 31,127 | 52,152 |
| **1996** | 21,169,000 | 7,686,684 | 60,734 | 189,109 | 6,304 | 14,218 | 32,953 | 53,475 |
| **1997** | 21,665,600 | 8,550,469 | 63,382 | 215,632 | 6,302 | 14,105 | 36,137 | 56,574 |
| **1998** | 22,679,600 | 9,141,357 | 63,382 | 211,037 | 5,740 | 12,068 | 37,896 | 55,784 |
| **1999** | 22,711,900 | 9,929,951 | 64,981 | 223,166 | 5,794 | 10,366 | 36,777 | 52,937 |
| **2000** | 23,200,000 | 10,589,804 | 64,981 | 250,417 | 6,035 | 9,773 | 34,246 | 50,054 |
| **2001** | 23,263,600 | 11,302,545 | 64,981 | 265,175 | 5,849 | 8,680 | 35,944 | 50,473 |
| **2002** | 23,263,600 | 12,068,144 | 64,981 | 279,237 | 5,887 | 8,424 | 35,171 | 49,482 |
| **2003** | 25,048,300 | 12,868,934 | 71,814 | 298,651 | 6,286 | 9,040 | 37,415 | 52,741 |
| **2004*** | 25,600,000 | 13,878,000 | 71,814 | 326,817 | 6,223 | 9,234 | 38,624 | 54,081 |

* Figures for 2004 have not been finalised

***Source: UPDATES OF ROAD SAFETY STATUS IN MALAYSIA, Road Safety Research Centre, Universiti Putra Malaysia.***

## 2.8 Geometric Design of Road

According to Arahan Teknik Jalan 8/86 published by the Public Works Department Malaysia, Ipoh-Lumut Highway is classified as primary road of being standard R5 with partial access control. It provides high geometrical standard and usually serve long to intermediate distance travel trips with high to medium traveling speed.

Adherence to highway classification standard published in Arahan Teknik Jalan 8/86 enable systematical analysis of speed profile & traffic volume on Ipoh Lumut Highway with respect to the Level of Service.

As shown in Table 6, Ipoh-Lumut Highway is being designed as R5 highway, serving all traffic volume. The access control at the highway is partial access control, which means that preference is given to through traffic by providing access connecting with selected public roads only and by prohibiting crossings at grade or direct private driveway connections.

Table 6: Design Standards

| Area | Road Catagory | Projected ADT | | | | | |
|---|---|---|---|---|---|---|---|
| | | All Traffic Volume | > 100,00 | 10,000 to 3,000 | 3,000 to 1,000 | 1,000 to 150 | < 150 |
| RURAL | Expressway | R6 | - | - | - | - | - |
| | Highway | R5 | - | - | - | - | - |
| | Primary Road | - | R5 | R4 | - | - | - |
| | Secondry Road | - | - | R4 | R3 | - | - |
| | Minor Road | - | - | - | - | R2 | R1 / R1a |
| URBAN | Expressway | U6 | - | - | - | - | - |
| | Arterials | - | U5 | U4 | - | - | - |
| | Collector | - | - | U4 | U3 | - | - |
| | Local Street | - | - | - | U3 | U2 | U1 / U1a |

*Source: Arahan Teknik Jalan 8/86*

Table 7: Access Control (Rural)

| Road Catagory | Design Standard | | | | | |
|---|---|---|---|---|---|---|
| | R6 | R5 | R4 | R3 | R2 | R1 / R1a |
| Expressway | F | - | - | - | - | - |
| Highway | - | P | - | - | - | - |
| Primary Road | - | P | P | - | - | - |
| Secondry Road | - | - | P | P | - | - |
| Minor Road | - | - | - | - | N | N |

NOTE :

F = Full Control of Access
P = Partial Control of Access
N = No Control of Access

*Source: Arahan Teknik Jalan 8/86*

## 2.9 Spot Speed Surveys

### 2.9.1 Spot Speed

The speed of vehicles can be measured instantaneously (spot speed) or averaged over distance or time. The spot speed of a vehicle varies continuously, as the vehicle accelerates or brakes. Spot speed data is used in:

- Determine observance of, and suitability of, existing speed limit
- Establish suitable new speed limits
- Determine a suitable design speed for geometric design of the highway
- Provide information for use in road safety and enforcement programs.
- Assist the location of certain traffic signs.
- Determine speed-flow relationships and traffic densities (May, 1990)

Unlike any other surveys, spot speed surveys are usually concerned with the non-peak periods of flow, when the speeds are higher. For example, where free-flow speeds are needed for setting speed limit, periods of low volume and good weather are specifically chosen.

Definition for target population is particularly important for spot speed surveys, and maybe:

- All vehicles in the traffic stream
- All vehicles with the some choice of speed: for example vehicles at the head of a platoon or single vehicles, on a fairly busy road.
- All vehicles with a free choice of speed: this would be at low flows, when a complete choice is available.

Spot speed data is either collected by a radar gun (which give automated direct measurement) or short-base methods: timing a vehicle over a known short distance, either manually with a stopwatch or automatically using modern loop or twin-tube devices.

### 2.9.2 Speed Radar Gun

The location of the surveys, sampling of vehicles and recording of results are exactly the same as for the manual short base method. The main requirements of the speed radar gun are that the operator is fully trained on the accurate use of the equipment and that the speed radar gun and its operator are concealed from the drivers. Measurement can be made from inside a parked car, but the car should not be parked in any location which affects the speed of the vehicles surveyed.

### 2.9.3 Suitability of Speed Radar Gun Method

Radar speed guns are suited to relatively narrowed roads at low or medium flows, when vehicles travel past the observer individually. They are not suited to heavy traffic volumes, congestion or multilane roads. Furthermore they are complex to use, require significant training of survey staff and are expensive. Methods where vehicles are timed over a short base line are suitable for almost all traffic conditions and types of road. They require only simple and inexpensive equipment, and are less obtrusive; the main problem is overcoming parallax error.

The presence of surveyor, equipment or unusual marking on the road surface can affect driver behavior; the need to make the surveyors inconspicuous can affect choice of survey method and location.

## 2.10 Manual Short Base Method

### 2.10.1 Description

The survey location is usually at the middle of a road link. A specific point is chosen on the link, determined if appropriate by the study objectives. A short base length is created, over which vehicles can be timed. The length will depend on speeds on the road, with longer bases needed for higher speed. Table 8 relates approximate lengths to average speed.

Table 8: Short Base Lengths

| Average Speed of Traffic (km/hr) | Short Base Lengths (m) |
|---|---|
| Below 40 | 25 |
| 40-65 | 50 |
| Above 65 | 75 |

Another approximate guide to length is that no vehicle in the traffic stream should take less than 2 seconds to traverse the short base, in the traffic conditions prevailing during the survey.

### 2.10.2 The Method

The ends of the short base length are marked in the road surface with paint, chalk or tape lines; the lines should be inconspicuous as possible to drivers. Alternatively the downstream line can be defined by the surveyor standing directly opposite to a roadside object on the opposite kerb. The surveyor must always be at downstream end. The short base length must be measured accurately, preferably with metal tape measure rather than a measuring wheel. In addition a, "sampling line" is marked upstream of the start line. The sampling line is needed so that the surveyor can select the sample vehicle before the starts to record its travel time. The surveyor must be able to see the sampling line and both timing lines for all lanes of traffic.

Sample vehicles are selected at the "sampling line". The survey supervisor should define which vehicles are to be surveyed. This might be every $n^{th}$ vehicle or according to some other method to ensure an unbiased sample. For example as the surveyor looks up he notes the first vehicle in any lane to cross the sampling line and selects the next vehicle in any lane to cross the sampling line. This is the "sample vehicle". The surveyor starts the stopwatch as the sample vehicle crosses the upstream start line, and stops it as the same vehicle crosses the downstream line. The time is recorded on the survey form, together with vehicle type and whether or not it was following in a platoon. The procedure is repeated for the next vehicle, and so on through the survey period.

## 2.11 Expected Result of Speed Zoning Based on Literature

### 2.11.1 Safety Point of View

For years, traffic engineering text have supported that motorists tend to ignore unreasonable speed limits. There is very little change in mean or $85^{th}$ percentile speed as result of raising or lowering speed limit. However, accident studies to determine safety effects or altering posted speed limit are seldom conducted. Figure 3 shows the distribution of motorists' speed on highway. Approximately 70% of the drivers are driving within reasonable speed limit according to their own perception of safety.

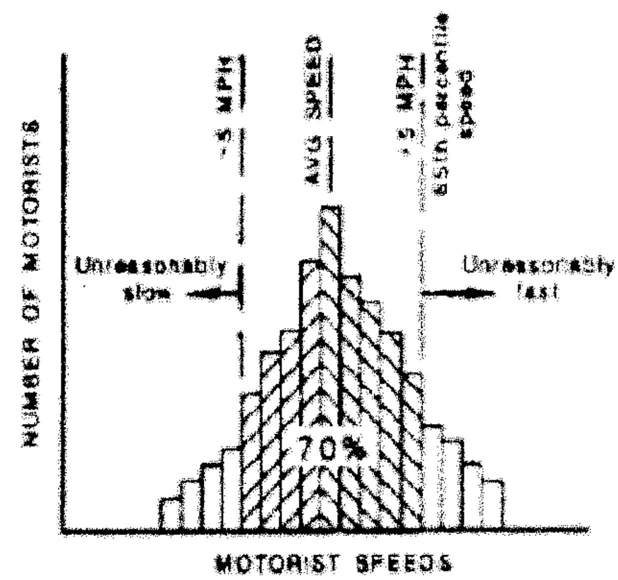



Figure 3: Distribution of motorists speed on highways

According to a study by Turner-Fairbank Highway Research Centre, on the average, the posted speed limit were actually set at 45th percentile speed at the experimental and comparison sites in 22 States in the United States of America. The speed limits were also posted on average between 5 and 16 mi/hr lower than the 85th percentile speed.

In the speed zone established, lowering the speed limits by 5, 10, 15 or 20 mi/hr had a minor effect on vehicle speeds. Similarly by raising speed limits by 5, 10, 15, or 20 mi/hr at the rural and urban sites, an increase in vehicle speeds are not observed. The average change in any of the percentile speed at the experimental sites was less than 1.5 mi/hr regardless whether the speed limit was raised or lowered. Observed in all the sites, there were no changes to the speed for the high-speed drivers.

Accidents at all the 41 experimental sites where the speed limit were raised decreased by 6.7 percent. However, lowering speed limits more than 5 mi/hr below the 85th percentile speed of traffic did not reduce accidents and thus supporting the claim that raising the current speed limit to the region of 85th percentile speed has an extremely beneficial effect on drivers complying with the posted speed limit. Figure 4 shows that the chances of being involved in road accident is lowest at approximately 85th percentile speed.

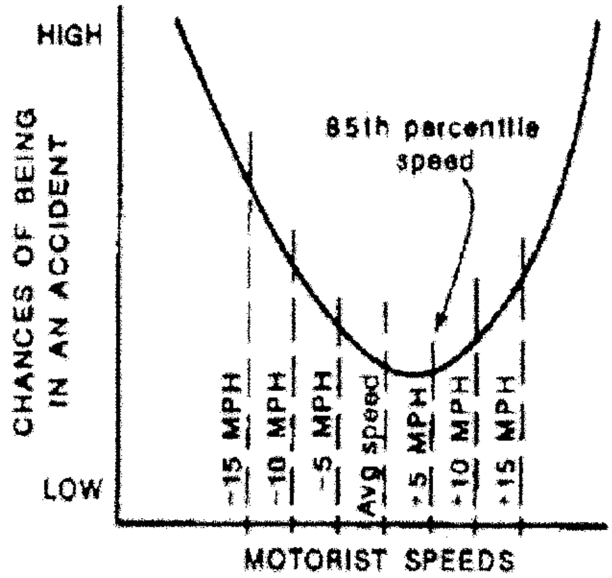



Figure 4 : Chances of being in an accident

Because there were few changes in the speed distribution, the overall effects of speed limit changes on accidents were minor. It is interesting to note that compliance decreased when speed limits were lowered and accidents tended to increase. Conversely, when compliance improved after speed limits are raised, accidents tended to decrease.

According to the study conducted by Turner-Fairbank Highway Research Centre, the data collected during this study indicate that there are no benefits, either from a safety or operational point of view, from establishing speed limits less than the 85th percentile speed. This does not mean that all speed limits should be raised. Traffic and engineer investigations should be conducted to obtain an accurate measure of the speed distribution. Greater emphasis should be placed on using the 85th percentile speed in setting safe and reasonable speed limits. These studies should be repeated as land use and traffic characteristics change.

Lave (1985) concluded that "speed limits designed to reduce the fatality rate should concentrate on reducing variance. This means taking action against slow drivers as well as fast ones." Similarly, Garber and Gadiraju (1988) reported that crash rates increased with increasing variance on all types of roadways and that speeds were higher on roads with higher design speeds, irrespective of the posted speed limits.

According to Lave(1985), “raising the speed limit would result in a fewer crashes in situations where variance was reduced by higher speed limits.”

### 2.11.2 Level of Service Point of View

According to Greenshields model, a linear relationship existed between speed and density. As Level of Service is directly related to density and free-flow speed (Table 4), from LOS point of view, it is expected that speed zoning will increase the quality of service from the baseline condition. The relationship between speed and density id being shown in Figure 5:

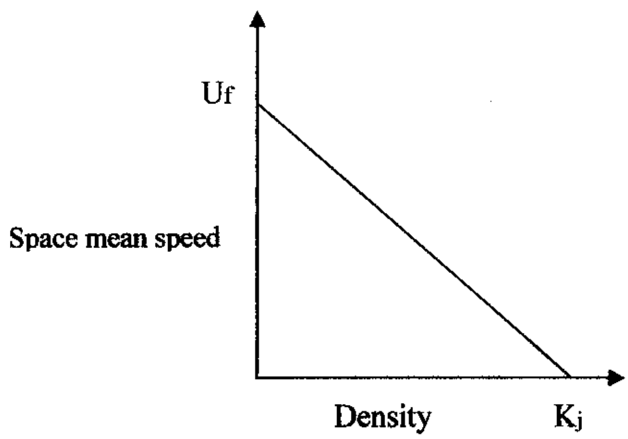



Figure 5: Space mean speed vs density

In 1959, Greenberg observed the traffic flow in the north tube of Lincoln Tunnel. He assumed that high density traffic behaved in a manner similar to continuous fluid. A linear relationship is being reported between speed and density in the form of:

$$\bar{V}_s = \bar{V}_f - \left(\frac{\bar{V}_f}{D_j}\right)D$$

$\bar{V}_s$ = space mean speed

$\bar{V}_f$ = space mean speed for free flow condition

$D_j$ = jam density

From the relationship between speed and density, inter-relationships can be established:

$$Q = \bar{V}_f D - \frac{\bar{V}_f}{D_j} D^2$$

$$Q = D_j \bar{V}_s - \frac{D_j}{\bar{V}_f} \bar{V}_s^2$$

However, earlier study of the traffic flow in the fast lane of the Lincoln Tunnel, New York City by Olcott have been adapted and are used to illustrate the fundamental relationship between density, flow and speed, which is shown in Figure 6.

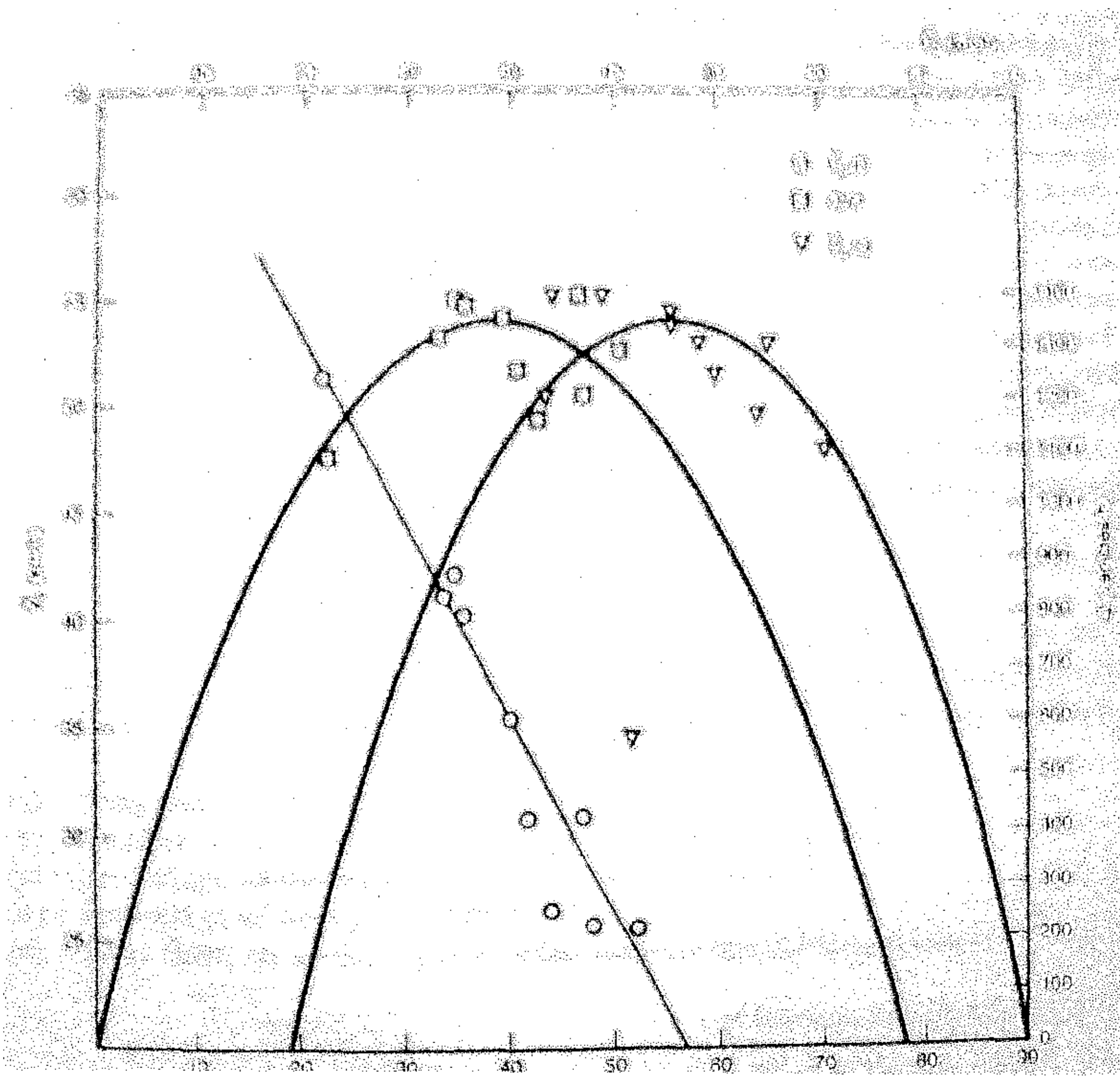



Figure 6: Sample observation by Olcott (1954)

# CHAPTER 3

# METHODOLOGY

## 3.1 Project Works

Because primary concerns of the study are speed, density and flow, considerable amount of resources and time will be spent on collecting speed data. The list of work and work flow are:

1. Demarcation of Ipoh-Lumut Highway with respect to major intersections & traffic lights
2. Measure the distance of each demarcated sections using normal car odometer
3. Conducting spot speed studies on selected stretches of Ipoh Lumut Highway
    - Organize Study Plan
        - Date & time of speed studies : 10AM Monday to Fridays (except public holidays)
        - Number of vehicles : 50 samples for manual method and 50 samples for laser speed gun
        - Relevancy of timing of data collection to objective : To measure or obtain a speed profile that give a better picture on the actual speed profile along Ipoh-Lumut Highway, spot speed studies must be conducted off peak-hours and the traffic is free-flowing.
        - Equipment : Radar Meter or Manual Method
    - Select Appropriate Site and Collect Field Data
        - Site : Demarcated sections of the highway (Refer Table 10 : Demarcation of Ipoh-Lumut Highway)
        - Data Collection : Forms are generated for data collection (Refer Appendix A)
    - Reduce and Analyze Data
        - Data Analysis : Finney's Probit Analysis and Chi-Square Goodness-of-Fit Test (Refer Appendix C & D)

- Data presentation : Frequency Distribution Table (Refer Appendix B)
- Interpret and Report Findings

4. Obtain design standard for Ipoh-Lumut Highway and compare with the prevailing highway now.

## 3.2 Project Planning

Please refer to the Gantt chart attached.

## 3.3 Tools & Equipment

Several equipments are needed in this study.

### 3.3.1 Doppler-Principle Meter: Radar Gun

Doppler meters work on the principle that when a signal is transmitted onto a moving vehicle, the change in frequency between the transmitted signal and the reflected signal is proportional to the speed of moving vehicle. The advantage of this method is that equipment can be located at an area unseen by driver thus significantly reduce the influence on driver behavior.

### 3.3.2 Software

For statistical analysis, standard spreadsheet software such as Microsoft Office Excel 2007 is being used. For the purpose of plotting graph, Graph v3.1 is being used to plot out the normal distribution and cumulative percentage of vehicles.

### 3.3.3 Tools

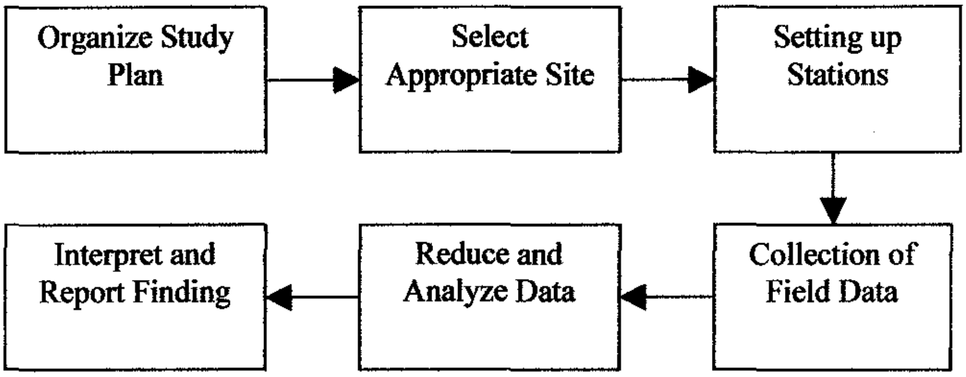
Radar gun will be used to collect the speed data along Ipoh-Lumut Highway.

### 3.4 Health, Safety & Environment

#### 3.4.1 Workplace Hazard Identification

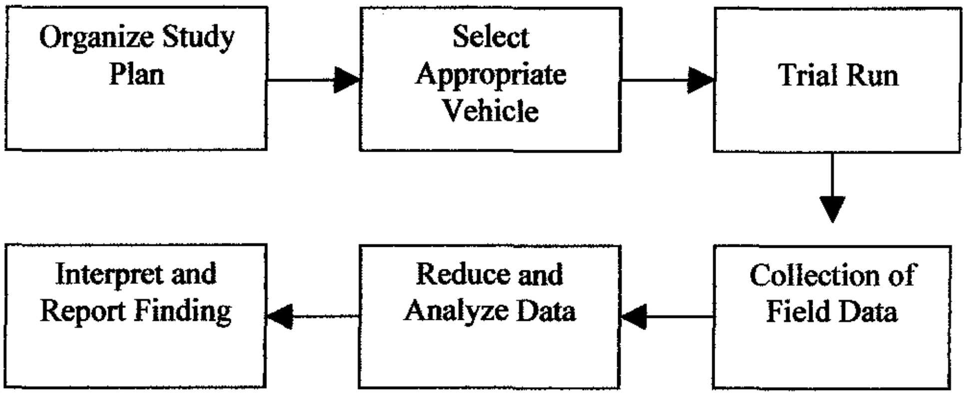
To identify the potential hazard arising from the project works, flow charts of the work processes are developed.

SPOT SPEED STUDIES




Probable hazards occur mostly during the collection of field data where stations needed to be set up out of the road users' sight.

TRAVEL TIME AND DELAY STUDIES




Possible hazards occur mostly during field data collection where drivers' attention should not be distracted from driving in a safe manner.

The possible hazards and safety measures to reduce risks are being summarized in Table 9:

Table 9: Hazard Identification & Safety Measures

| Job | Possible Hazard | Safety Measures |
|---|---|---|
| Spot Speed Studies | • Traffic accident during the data collection<br>• Attack by wild animals at hidden data collection stations (thick bushes) | • Inform the local county police about the field work<br>• Take appropriate measures such as using sulphur to prevent snake attack<br>• Prepare and carry along a list of emergency contact numbers such as local police, fire brigade and hospital |
| Travel Time and Delay Studies | • Traffic accident during the data collection due to distractions | • Inform the local county police about the field work<br>• Soliciting help from colleagues and acquaintances during data collection<br>• Prepare and carry along a list of emergency contact numbers such as local police, fire brigade and hospital |

### 3.4.2 Environment

Environment aspects are the elements of the project activities which can interact with the environment. On the other hand, environment impacts are changes to the environment, adverse or beneficial, wholly or partially resulting from projects' activities.

Analysis of possible environment aspects and impacts are conducted according to the Environmental Management System Guide published by New York State Department of Environment Conservation.

For the time being, no significant environment aspects and impacts are being identified in this project work. However, the identification of environmental aspects and impacts are subjected to periodic review for continual improvement.

# CHAPTER 4

# RESULTS & DISCUSSION

## 4.1 Demarcation of Ipoh-Lumut Highway

By using simple odometer installed in Proton Iswara, the lengths of sections are being measured. The accuracy of the odometer is to the nearest 1000 m length.

Table 10: Demarcation of Ipoh-Lumut Highway

| Section | Distance (km) |
|---|---|
| Jalan Chemur - Jalan Silibin | 5 |
| Jalan Silibin - Ipoh/Lahat | 3 |
| Ipoh/Lahat (I) - Bukit Kledang Indah (I) | 2 |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 4 |
| Pasir Puteh (I) - Pusing/Lahat (I) | 3 |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 4 |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 3 |
| Batu Gajah (F) - Tronoh (II) | 5 |
| Tronoh (II) - Tronoh (I) | 2 |
| Tronoh (I) - Kg Bali (I) | 1 |
| Kg Bali (I) - UTP Gate (I) | 2 |
| UTP Gate (I) - Taman Maju (I) | 2 |
| Taman Maju (I) - UiTM Sri Iskandar (I) | 3 |
| UiTM Sri Iskandar - IKBN (I) | 2 |
| IKBN (I) - Bota (I) | 8 |
| Bota (I) - Titi Gantung | 3 |
| Titi Gantung - Gelung Pepuyu(I) | 3 |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 3 |
| Changkat Chermin - Beruas (I) | 2 |
| Beruas (I) - Pantai Remis (I) | 3 |
| Pantai Remis (I) - Ayer Tawar | 2 |
| Ayer Tawar - Ayer Tawar 2 | 2 |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 1 |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 3 |
| Simpang Lima (I) - Kg Baru (I) | 1 |
| Kg Baru (I) - Traffic Light (SC) | 2 |
| Traffic Light (SC) - Sitiawan (18) | 5 |

| | |
|---|---|
| **Total Distance Measured (km)** | 79 |

*Legend*

*I* : *Intersection*

*F* : *Fly-Over*

*DC* : *Dual Carriageway*

*SC* : *Single Carriageway*

*NOTE: Section is demarcated by referring to road section of Jabatan Kerja Raya Perak Road Map (Published by: Cawangan Jalan, Ibu Pejabat JKR, KL)*

## 4.2 Results & Discussions

Spot speed data collected are being tabulated in frequency distribution table form, as shown in Appendix C.

Chi Square Goodness-of-Fit Test is being used to test whether the speed data collected (observed distribution from field work) conform to normal distribution, as assumed earlier. Calculation of this goodness of fit test is by comparison of observed data with expected data based on the normal distribution. If the discrepancies between observed data and expected data are relatively small, the observed chi-square number will emerge smaller than the critical chi-square number. This in turn means that the data collected from field conform to the normal distribution as assume early, vice versa. Summary of chi-square values calculated are shown in Table 11.

Table 11 : Summary of chi-square values of speed data along Ipoh-Lumut Highway (both directions)

| Road Section | Direction | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ipoh-Lumut | | | | Lumut-Ipoh | | | |
| | Critical Value of $x^2$ Distributions | Degrees of Freedom | $x^2$ of Data | Distribution of Data | Critical Value of $x^2$ Distributions | Degrees of Freedom | $x^2$ of Data | Distribution of Data |
| Jalan Chemur (I) - Jalan Silibin (I) | 23.68 | 14 | 13.26 | Normal | 18.31 | 10 | 7.55 | Normal |
| Jalan Silibin (I) - Ipoh/Falim (I) | 12.59 | 6 | 7.00 | Normal | 22.36 | 13 | 13.61 | Normal |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 21.03 | 12 | 10.57 | Normal | 14.07 | 7 | 8.39 | Normal |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 18.31 | 10 | 5.82 | Normal | 19.68 | 11 | 26.96 | Not Normal |
| Pasir Puteh (I) - Pusing/Lahat (I) | 19.68 | 11 | 22.67 | Not Normal | 19.68 | 11 | 12.30 | Normal |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 15.51 | 8 | 9.04 | Normal | 16.92 | 9 | 9.74 | Normal |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 21.03 | 12 | 26.80 | Not Normal | 22.36 | 13 | 19.44 | Normal |
| Batu Gajah (F) - Tronoh (II) | 23.68 | 14 | 22.59 | Normal | 23.68 | 14 | 15.11 | Normal |
| Tronoh (I) - Tronoh (II) | 21.03 | 12 | 10.10 | Normal | 22.36 | 13 | 16.08 | Normal |
| Tronoh (I) - Kg Bali (I) | 30.14 | 19 | 19.76 | Normal | 23.68 | 14 | 19.87 | Normal |
| Kg Bali (I) - UTP Gate (I) | 21.03 | 12 | 25.06 | Not Normal | 25.00 | 15 | 12.45 | Normal |
| UTP Gate (I) - Taman Maju (I) | 26.30 | 16 | 10.28 | Normal | 23.68 | 14 | 19.84 | Normal |
| Taman Maju (I) - UiTM Sri Iskandar | 19.68 | 11 | 13.34 | Normal | 22.36 | 13 | 8.04 | Normal |
| UiTM Sri Iskandar - IKBN (I) | 26.30 | 16 | 32.05 | Not Normal | 22.36 | 13 | 18.51 | Normal |
| IKBN (I) - Bota Intersection | 23.68 | 14 | 10.83 | Normal | 19.68 | 11 | 20.03 | Not Normal |
| Bota Intersection - Titi Gantung | 23.68 | 14 | 11.43 | Normal | 19.68 | 11 | 9.41 | Normal |
| Titi Gantung - Gelung Pepuyu(I) | 25.00 | 15 | 24.60 | Normal | 19.68 | 11 | 13.93 | Normal |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 22.36 | 13 | 7.18 | Normal | 21.03 | 12 | 7.71 | Normal |
| Changkat Chermin - Beruas (I) | 21.03 | 12 | 9.50 | Normal | 19.68 | 11 | 18.92 | Normal |
| Beruas (I) - Pantai Remis (I) | 19.68 | 11 | 16.37 | Normal | 27.59 | 17 | 28.75 | Not Normal |
| Pantai Remis (I) - Ayer Tawar | 16.92 | 9 | 8.32 | Normal | 21.03 | 12 | 18.45 | Normal |
| Ayer Tawar - Ayer Tawar 2 | 12.59 | 6 | 6.28 | Normal | 15.51 | 8 | 8.04 | Normal |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 16.92 | 9 | 18.29 | Not Normal | 15.51 | 8 | 19.34 | Not Normal |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 18.31 | 10 | 18.88 | Not Normal | 19.68 | 11 | 13.44 | Normal |
| Simpang Lima (I) - Kg Baru (I) | 12.59 | 9 | 5.78 | Normal | 18.31 | 10 | 12.33 | Normal |
| Kg Baru (I) - Traffic Light (SC) | 12.59 | 9 | 2.59 | Normal | 15.51 | 8 | 4.22 | Normal |
| Intersection (SC) - Sitiawan Town (18) | 12.59 | 9 | 12.54 | Normal | 14.07 | 7 | 11.79 | Normal |

As shown in Table 12, for traffic moving from Ipoh towards Lumut direction, 21 out of 27 stretches of demarcation sections conform to normal distribution. The data collected from the remaining 6 sections indicated that speeds at the sections do not conform to normal distribution. For traffic moving from Lumut towards Ipoh direction, 23 out of 27 stretches of demarcated sections conform to normal distribution.

Due to platoon of vehicles and turning traffic into business districts and shops, speed distributions at where sections are crossing into town centres are observed to be not normally distributed. The similar distribution is also observed in areas with heavy roadside development and housing areas. Example of these stretches are Air Tawar – Air Tawar(I) and Taman Maju – UiTM sections.

Table 12: Distribution of traffic speed along Ipoh-Lumut Highway (both direction)

| Road Section | Direction | |
|---|---|---|
| | Ipoh-Lumut | Lumut-Ipoh |
| Jalan Chemur (I) - Jalan Silibin (I) | Normal | Normal |
| Jalan Silibin (I) - Ipoh/Falim (I) | Normal | Normal |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | Normal | Normal |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | Normal | Not Normal |
| Pasir Puteh (I) - Pusing/Lahat (I) | Not Normal | Normal |
| Pusing/Lahat (I) - Batu Gajah/Pusing | Normal | Normal |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | Not Normal | Normal |
| Batu Gajah (F) - Tronoh (II) | Normal | Normal |
| Tronoh (I) - Tronoh (II) | Normal | Normal |
| Tronoh (I) - Kg Bali (I) | Normal | Normal |
| Kg Bali (I) - UTP Gate (I) | Not Normal | Normal |
| UTP Gate (I) - Taman Maju (I) | Normal | Normal |
| Taman Maju (I) - UiTM Sri Iskandar | Normal | Normal |
| UiTM Sri Iskandar - IKBN (I) | Not Normal | Normal |
| IKBN (I) - Bota Intersection | Normal | Not Normal |
| Bota Intersection - Titi Gantung | Normal | Normal |
| Titi Gantung - Gelung Pepuyu(I) | Normal | Normal |
| Gelung Pepuyu (I) - Changkat Chermin (I) | Normal | Normal |
| Changkat Chermin - Beruas (I) | Normal | Normal |
| Beruas (I) - Pantai Remis (I) | Normal | Not Normal |
| Pantai Remis (I) - Ayer Tawar | Normal | Normal |
| Ayer Tawar - Ayer Tawar 2 | Normal | Normal |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | Not Normal | Not Normal |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | Not Normal | Normal |
| Simpang Lima (I) - Kg Baru (I) | Normal | Normal |
| Kg Baru (I) - Traffic Light (SC) | Normal | Normal |
| Intersection (SC) - Sitiawan Town (18) | Normal | Normal |

The 85$^{th}$ percentile speeds for all sections demarcated are being compared against the speed limit, as shown in Table 13.

Table 13: Posted speed limit and 85$^{th}$ percentile speed on Ipoh-Lumut Highway (both directions)

| Road Section | Ipoh-Lumut | | Lumut-Ipoh | |
|---|---|---|---|---|
| | Speed Limit | 85th Percentile Speed | Speed Limit | 85th Percentile Speed |
| Jalan Chemur (I) - Jalan Silibin (I) | 90.0 | 100.0 | 90.0 | 91.0 |
| Jalan Silibin (I) - Ipoh/Falim (I) | 90.0 | 90.0 | 90.0 | 89.0 |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 90.0 | 77.0 | 90.0 | 75.0 |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 90.0 | 80.0 | 90.0 | 80.0 |
| Pasir Puteh (I) - Pusing/Lahat (I) | 90.0 | 85.0 | 90.0 | 85.0 |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 90.0 | 71.0 | 90.0 | 79.0 |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 90.0 | 90.0 | 90.0 | 100.0 |
| Batu Gajah (F) - Tronoh (II) | 90.0 | 95.0 | 90.0 | 94.0 |
| Tronoh (I) - Tronoh (II) | 90.0 | 94.0 | 90.0 | 89.0 |
| Tronoh (I) - Kg Bali (I) | 90.0 | 121.0 | 90.0 | 96.0 |
| Kg Bali (I) - UTP Gate (I) | 90.0 | 97.0 | 90.0 | 110.0 |
| UTP Gate (I) - Taman Maju (I) | 90.0 | 102.0 | 90.0 | 95.0 |
| Taman Maju (I) - UiTM Sri Iskandar | 90.0 | 89.0 | 90.0 | 95.0 |
| UiTM Sri Iskandar - IKBN (I) | 90.0 | 103.0 | 90.0 | 100.0 |
| IKBN (I) - Bota Intersection | 90.0 | 108.0 | 90.0 | 100.0 |
| Bota Intersection - Titi Gantung | 90.0 | 99.0 | 90.0 | 105.0 |
| Titi Gantung - Gelung Pepuyu(I) | 90.0 | 96.0 | 90.0 | 104.5 |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 90.0 | 100.0 | 90.0 | 95.0 |
| Changkat Chermin - Beruas (I) | 90.0 | 102.5 | 90.0 | 95.0 |
| Beruas (I) - Pantai Remis (I) | 90.0 | 100.0 | 90.0 | 102.0 |
| Pantai Remis (I) - Ayer Tawar | 90.0 | 95.0 | 90.0 | 91.5 |
| Ayer Tawar - Ayer Tawar 2 | 60.0 | 71.0 | 60.0 | 75.0 |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 60.0 | 80.0 | 60.0 | 72.5 |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 90.0 | 94.0 | 90.0 | 105.0 |
| Simpang Lima (I) - Kg Baru (I) | 90.0 | 86.0 | 90.0 | 84.5 |
| Kg Baru (I) - Traffic Light (SC) | 90.0 | 89.0 | 90.0 | 92.0 |
| Intersection (SC) - Sitiawan Town (18) | 60.0 | 80.0 | 60.0 | 76.0 |

It is noted that in many sections, 85$^{th}$ percentile speeds are considerably higher than the posted speed limit. The average difference between 85$^{th}$ percentile speed and speed limit on Ipoh-Lumut direction is 5.7 km/hr and 5.0 km/hr. The largest difference observed between 85$^{th}$ percentile speed and posted speed limit is 31 km/hr on Ipoh-Lumut direction while the largest difference observed between 85$^{th}$ percentile speed and posted speed limit is 20 km/hr on Lumut-Ipoh direction. The stretches of concern are Tronoh (I) – Kg Bali (I) and Kg Bali (I) – UTP Gate (I), respectively.

Two way-four lane highway starts from Batu Gajah (F) stretch onwards and terminate at Intersection (SC) which joins Ipoh-Lumut Highway and a particular old Federal Route 5 leading to Sitiawan town. Generally the speeds of vehicles are faster on the two way-four lane sections due to high standard of geometric. Thus, it is physically possible to gain higher speed and influence the "appropriate speed" perceived by the drivers.

Heavy roadside developments have a notably great influence the drivers' speed, regardless of the posted speed limit. This can be observed at Ipoh/Falim (I) – Bukit Kldang Indah (I) section where the 85$^{th}$ percentile speed deduced are 77 km/hr and 75 km/hr even though the posted speed limit is 90 km/hr. However it is of particular interest that 85$^{th}$ percentile speed on Ayer Tawar (I) -Ayer Tawar 2 (I) section is higher than the posted speed limit of 60 km/hr. Because the section is constructed as two way-four lane highway with median and adequate overhead crossings, the driver's perception of "safe speed" is higher than the speed limit.

Generally, speed limit violations on Ipoh-Lumut Highway are high, ranging from 0% to 64%. Table 14 shows the percentage of speed limit violations by drivers.

Table 14: Speed limit violation on Ipoh-Lumut Highway (both directions)

| Road Section | Direction | | | |
|---|---|---|---|---|
| | Ipoh-Lumut | | Lumut-Ipoh | |
| | Speed Limit (km/hr) | Percentage of Speed Limit Violation (%) | Speed Limit (km/hr) | Percentage of Speed Limit Violation (%) |
| Jalan Chemur (I) - Jalan Silibin (I) | 90.0 | 58 | 90.0 | 26 |
| Jalan Silibin (I) - Ipoh/Falim (I) | 90.0 | 14 | 90.0 | 14 |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 90.0 | 2 | 90.0 | 0 |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 90.0 | 6 | 90.0 | 4 |
| Pasir Puteh (I) - Pusing/Lahat (I) | 90.0 | 4 | 90.0 | 8 |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 90.0 | 0 | 90.0 | 0 |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 90.0 | 14 | 90.0 | 30 |
| Batu Gajah (F) - Tronoh (II) | 90.0 | 22 | 90.0 | 22 |
| Tronoh (I) - Tronoh (II) | 90.0 | 22 | 90.0 | 16 |
| Tronoh (I) - Kg Bali (I) | 90.0 | 58 | 90.0 | 26 |
| Kg Bali (I) - UTP Gate (I) | 90.0 | 20 | 90.0 | 38 |
| UTP Gate (I) - Taman Maju (I) | 90.0 | 32 | 90.0 | 22 |
| Taman Maju (I) - UiTM Sri Iskandar | 90.0 | 8 | 90.0 | 20 |
| UiTM Sri Iskandar - IKBN (I) | 90.0 | 34 | 90.0 | 36 |
| IKBN (I) - Bota Intersection | 90.0 | 52 | 90.0 | 34 |
| Bota Intersection - Titi Gantung | 90.0 | 20 | 90.0 | 42 |
| Titi Gantung - Gelung Pepuyu(I) | 90.0 | 20 | 90.0 | 42 |
| Gelung Pepuyu (I)-Changkat Chermin (I) | 90.0 | 28 | 90.0 | 34 |
| Changkat Chermin - Beruas (I) | 90.0 | 36 | 90.0 | 24 |
| Beruas (I) - Pantai Remis (I) | 90.0 | 38 | 90.0 | 28 |
| Pantai Remis (I) - Ayer Tawar | 90.0 | 22 | 90.0 | 16 |
| Ayer Tawar - Ayer Tawar 2 | 60.0 | 50 | 60.0 | 62 |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 60.0 | 64 | 60.0 | 56 |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 90.0 | 40 | 90.0 | 24 |
| Simpang Lima (I) - Kg Baru (I) | 90.0 | 8 | 90.0 | 6 |
| Kg Baru (I) - Traffic Light (SC) | 90.0 | 10 | 90.0 | 22 |
| Traffic Light (SC) - Sitiawan Town (18) | 60.0 | 74 | 60.0 | 84 |

Table 15: Level of Service and Speed Limit Violation

| Road Section | Direction | | | | | |
|---|---|---|---|---|---|---|
| | Ipoh-Lumut | | | Lumut-Ipoh | | |
| | Speed Limit (km/hr) | Percentage of Speed Limit Viola-tion (%) | LOS | Speed Limit (km/hr) | Percentage of Speed Limit Viola-tion (%) | LOS |
| Jalan Chemur (I) - Jalan Silibin (I) | 90.0 | 58 | A | 90.0 | 26 | A |
| Jalan Silibin (I) - Ipoh/Falim (I) | 90.0 | 14 | D | 90.0 | 14 | D |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 90.0 | 2 | D | 90.0 | 0 | D |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 90.0 | 6 | D | 90.0 | 4 | D |
| Pasir Puteh (I) - Pusing/Lahat (I) | 90.0 | 4 | D | 90.0 | 8 | D |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 90.0 | 0 | D | 90.0 | 0 | D |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 90.0 | 14 | D | 90.0 | 30 | C |
| Batu Gajah (F) - Tronoh (II) | 90.0 | 22 | C | 90.0 | 22 | C |
| Tronoh (I) - Tronoh (II) | 90.0 | 22 | C | 90.0 | 16 | C |
| Tronoh (I) - Kg Bali (I) | 90.0 | 58 | A | 90.0 | 26 | C |
| Kg Bali (I) - UTP Gate (I) | 90.0 | 20 | C | 90.0 | 38 | C |
| UTP Gate (I) - Taman Maju (I) | 90.0 | 32 | B | 90.0 | 22 | C |
| Taman Maju (I) - UiTM Sri Iskandar | 90.0 | 8 | D | 90.0 | 20 | C |
| UiTM Sri Iskandar - IKBN (I) | 90.0 | 34 | C | 90.0 | 36 | C |
| IKBN (I) - Bota Intersection | 90.0 | 52 | A | 90.0 | 34 | A |
| Bota Intersection - Titi Gantung | 90.0 | 20 | C | 90.0 | 42 | B |
| Titi Gantung - Gelung Pepuyu(I) | 90.0 | 20 | C | 90.0 | 42 | B |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 90.0 | 28 | C | 90.0 | 34 | B |
| Changkat Chermin - Beruas (I) | 90.0 | 36 | B | 90.0 | 24 | C |
| Beruas (I) - Pantai Remis (I) | 90.0 | 38 | B | 90.0 | 28 | C |
| Pantai Remis (I) - Ayer Tawar | 90.0 | 22 | C | 90.0 | 16 | D |
| Ayer Tawar - Ayer Tawar 2 | 60.0 | 50 | D | 60.0 | 62 | D |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 60.0 | 64 | D | 60.0 | 56 | D |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 90.0 | 40 | B | 90.0 | 24 | B |
| Simpang Lima (I) - Kg Baru (I) | 90.0 | 8 | D | 90.0 | 6 | B |
| Kg Baru (I) - Traffic Light (SC) | 90.0 | 10 | D | 90.0 | 22 | C |
| Traffic Light (SC) - Sitiawan Town (18) | 60.0 | 74 | C | 60.0 | 84 | C |

Table 15 shows the Level of Service of stretches along Ipoh-Lumut Highway and the related speed limit violations. It can be seen that Level of Service is high in stretches where speed limit violation is high, and Level of Service tend to be low. Table 16 summarizes the simple correlation between Level of Service and speed limit violation along Ipoh-Lumut Highway.

Table 16: Co-relation between Level of Service and Speed Limit Violation

| Level of Service | Speed Limit Violation (%) |
|---|---|
| A | <20 |
| B | |
| C | |
| D | >20 |
| E | |
| F | |

# CHAPTER 5

# CONCLUSION & RECOMMENDATION

Principally based on 85$^{th}$ percentile speed, new speed limit is proposed for Ipoh-Lumut Highway, as shown in Table 15 and Table 16.

Table 17: New proposed speed limit on Ipoh-Lumut direction

| Road Section | 85th Percentile Speed (km/hr) | Speed Limit (km/hr) | Recommendation |
|---|---|---|---|
| Jalan Chemur (I) - Jalan Silibin (I) | 100.0 | 90.0 | Maintain at 90km/hr |
| Jalan Silibin (I) - Ipoh/Falim (I) | 90.0 | 90.0 | Maintain at 90km/hr |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 77.0 | 90.0 | Maintain at 90km/hr |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 80.0 | 90.0 | Maintain at 90km/hr |
| Pasir Puteh (I) - Pusing/Lahat (I) | 85.0 | 90.0 | Maintain at 90km/hr |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 71.0 | 90.0 | Maintain at 90km/hr |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 90.0 | 90.0 | Maintain at 90km/hr |
| Batu Gajah (F) - Tronoh (II) | 95.0 | 90.0 | Raise to 100km/hr |
| Tronoh (I) - Tronoh (II) | 94.0 | 90.0 | Raise to 100km/hr |
| Tronoh (I) - Kg Bali (I) | 121.0 | 90.0 | Raise to 100km/hr |
| Kg Bali (I) - UTP Gate (I) | 97.0 | 90.0 | Raise to 100km/hr |
| UTP Gate (I) - Taman Maju (I) | 102.0 | 90.0 | Raise to 100km/hr |
| Taman Maju (I) - UiTM Sri Iskandar | 89.0 | 90.0 | Raise to 100km/hr |
| UiTM Sri Iskandar - IKBN (I) | 103.0 | 90.0 | Raise to 100km/hr |
| IKBN (I) - Bota Intersection | 108.0 | 90.0 | Raise to 100km/hr |
| Bota Intersection - Titi Gantung | 99.0 | 90.0 | Raise to 100km/hr |
| Titi Gantung - Gelung Pepuyu(I) | 96.0 | 90.0 | Raise to 100km/hr |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 100.0 | 90.0 | Raise to 100km/hr |
| Changkat Chermin - Beruas (I) | 102.5 | 90.0 | Raise to 100km/hr |
| Beruas (I) - Pantai Remis (I) | 100.0 | 90.0 | Raise to 100km/hr |
| Pantai Remis (I) - Ayer Tawar | 95.0 | 90.0 | Maintain at 90km/hr |
| Ayer Tawar - Ayer Tawar 2 | 71.0 | 60.0 | Raise to 70km/hr |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 80.0 | 60.0 | Raise to 70km/hr |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 94.0 | 90.0 | Maintain at 90km/hr |
| Simpang Lima (I) - Kg Baru (I) | 86.0 | 90.0 | Maintain at 90km/hr |
| Kg Baru (I) - Traffic Light (SC) | 89.0 | 90.0 | Maintain at 90km/hr |
| Traffic Light (SC) - Sitiawan Town (18) | 80.0 | 60.0 | Maintain at 90km/hr |

Table 18: New proposed speed limit on Lumut-Ipoh direction

| Road Section | 85th Percentile Speed (km/hr) | Speed Limit (km/hr) | Recommendation |
|---|---|---|---|
| Jalan Chemur (I) - Jalan Silibin (I) | 91.0 | 90.0 | Maintain at 90km/hr |
| Jalan Silibin (I) - Ipoh/Falim (I) | 89.0 | 90.0 | Maintain at 90km/hr |
| Ipoh/Falim(I) - Bukit Kledang Indah (I) | 75.0 | 90.0 | Maintain at 90km/hr |
| Bukit Kledang Indah (I) - Pasir Puteh (I) | 80.0 | 90.0 | Maintain at 90km/hr |
| Pasir Puteh (I) - Pusing/Lahat (I) | 85.0 | 90.0 | Maintain at 90km/hr |
| Pusing/Lahat (I) - Batu Gajah/Pusing | 79.0 | 90.0 | Maintain at 90km/hr |
| Batu Gajah/Pusing (I) - Batu Gajah (F) | 100.0 | 90.0 | Maintain at 90km/hr |
| Batu Gajah (F) - Tronoh (II) | 94.0 | 90.0 | Raise to 100km/hr |
| Tronoh (I) - Tronoh (II) | 89.0 | 90.0 | Raise to 100km/hr |
| Tronoh (I) - Kg Bali (I) | 96.0 | 90.0 | Raise to 100km/hr |
| Kg Bali (I) - UTP Gate (I) | 110.0 | 90.0 | Raise to 100km/hr |
| UTP Gate (I) - Taman Maju (I) | 95.0 | 90.0 | Raise to 100km/hr |
| Taman Maju (I) - UiTM Sri Iskandar | 95.0 | 90.0 | Raise to 100km/hr |
| UiTM Sri Iskandar - IKBN (I) | 100.0 | 90.0 | Raise to 100km/hr |
| IKBN (I) - Bota Intersection | 100.0 | 90.0 | Raise to 100km/hr |
| Bota Intersection - Titi Gantung | 105.0 | 90.0 | Raise to 100km/hr |
| Titi Gantung - Gelung Pepuyu(I) | 104.5 | 90.0 | Raise to 100km/hr |
| Gelung Pepuyu (I) - Changkat Chermin (I) | 95.0 | 90.0 | Raise to 100km/hr |
| Changkat Chermin - Beruas (I) | 95.0 | 90.0 | Raise to 100km/hr |
| Beruas (I) - Pantai Remis (I) | 102.0 | 90.0 | Raise to 100km/hr |
| Pantai Remis (I) - Ayer Tawar | 91.5 | 90.0 | Maintain at 90km/hr |
| Ayer Tawar - Ayer Tawar 2 | 75.0 | 60.0 | Raise to 70km/hr |
| Ayer Tawar 2 - Ayer Tawar 3 (DC) | 72.5 | 60.0 | Raise to 70km/hr |
| Ayer Tawar 3 (DC) - Simpang Lima (I) | 105.0 | 90.0 | Maintain at 90km/hr |
| Simpang Lima (I) - Kg Baru (I) | 84.5 | 90.0 | Maintain at 90km/hr |
| Kg Baru (I) - Traffic Light (SC) | 92.0 | 90.0 | Maintain at 90km/hr |
| Traffic Light (SC) - Sitiawan Town (18) | 76.0 | 60.0 | Maintain at 90km/hr |

Speed limit on stretches on Pantai Remis (I) – Ayer Tawar (I) will be maintained at 90 km/hr to avoid sudden change of speed limit from 100 km/hr to 70 km/hr. Gradual reduction in speed limit with adequate warning and sign will help drivers to gradually slow down their vehicles.

Data collection and assessment of general roadway speeds provide invaluable information regarding the particular road of interest. Speed trend deduced from data collected from field can be used to evaluate the current conditions of Ipoh-Lumut Highway and a new set of speed limit will be proposed. A trend is also noted that as roadway geometric improve; drivers tend to go at increasing speed irrespective of the posted speed limit.

Future works arising from this project include developing a relationship model between speed variance and accident rates along Ipoh-Lumut Highway. This requires accident data, which can be obtained from local police stations such as IPD Ipoh and IPD Manjung. The relationship model can be then used to substantiate the claim that crash rates increased with increasing variance on all types of roadways.

There are three principal reasons for regulating drivers' speed choices:

- Externalities, that is, the imposition of risks and uncompensated costs on others because of inappropriate speed choices made by individual drivers;
- Inadequate information that limits a motorist's ability to determine an appropriate driving speed;
- Driver misjudgment of the effects of speed on crash probability and severity.

As conclusion, setting the speed limit to the region of $85^{th}$ percentile speed will have extremely beneficial effect on the compliance of the drivers. In order to reduce speed variance, action should also be taken on slow drivers, as well as fast ones.

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*Appendix A*

FIELD WORK DATA SHEET

Date :
Stretch :
Weather :

Start/End : /
Direction : Ipoh-Lumut / Lumut-Ipoh
Speed Limit :

| Veh No | Speed (km/hr) | Remarks |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |
| 21 | | |
| 22 | | |
| 23 | | |
| 24 | | |
| 25 | | |

*Appendix B*

## Frequency Distribution Table

*Jalan Chemur (I) – Jalan Silibin (I) (Ipoh-Lumut Direction)*

| Class (km/hr) | Class Frequency, f | Percentage Frequency | Cumulative Frequency | Percentage Cumulative Frequency | Deviation | (2) x (6) | (2) X (6)² |
|---|---|---|---|---|---|---|---|
| 55.0 - 59.9 | 1 | 2.0 | 1.0 | 2.0 | -6 | -6 | 36 |
| 60.0 - 64.9 | 3 | 6.0 | 4.0 | 8.0 | -5 | -15 | 75 |
| 65.0 - 69.9 | 1 | 2.0 | 5.0 | 10.0 | -4 | -4 | 16 |
| 70.0 - 74.9 | 7 | 14.0 | 12.0 | 24.0 | -3 | -21 | 63 |
| 75.0 - 79.9 | 9 | 18.0 | 21.0 | 42.0 | -2 | -18 | 36 |
| 80.0 - 84.9 | 2 | 4.0 | 23.0 | 46.0 | -1 | -2 | 2 |
| 85.0 - 89.9 | 11 | 22.0 | 34.0 | 68.0 | 0 | 0 | 0 |
| 90.0 - 94.9 | 5 | 10.0 | 39.0 | 78.0 | 1 | 5 | 5 |
| 95.0 - 99.9 | 4 | 8.0 | 43.0 | 86.0 | 2 | 8 | 16 |
| 100.0 - 104.9 | 3 | 6.0 | 46.0 | 92.0 | 3 | 9 | 27 |
| 105.0 - 109.9 | 1 | 2.0 | 47.0 | 94.0 | 4 | 4 | 16 |
| 110.0 - 114.9 | 2 | 4.0 | 49.0 | 98.0 | 5 | 10 | 50 |
| 115.0 - 119.9 | 0 | 0.0 | 49.0 | 98.0 | 6 | 0 | 0 |
| 120.0 - 124.9 | 0 | 0.0 | 49.0 | 98.0 | 7 | 0 | 0 |
| 125.0 - 129.9 | 0 | 0.0 | 49.0 | 98.0 | 8 | 0 | 0 |
| 130.0 - 134.9 | 1 | 2.0 | 50.0 | 100.0 | 9 | 9 | 81 |
| **Totals** | **50** | | | | | **-21** | **423** |

| | |
|---|---|
| Selected class | 85.0 - 89.9 |
| Mid-class mark | 87.5 |
| Class Interval | 5 |
| Σ col 7 | -21 |
| Σ col 2 | 50 |

Mean Speed 85.4km/hr

| | |
|---|---|
| (2) x (6)² | 423 |
| (2) x (6) | -21 |
| Σ col 2 | 50 |
| Class Interval | 5 |

Standard Deviation 14.39km/hr

*Appendix C*

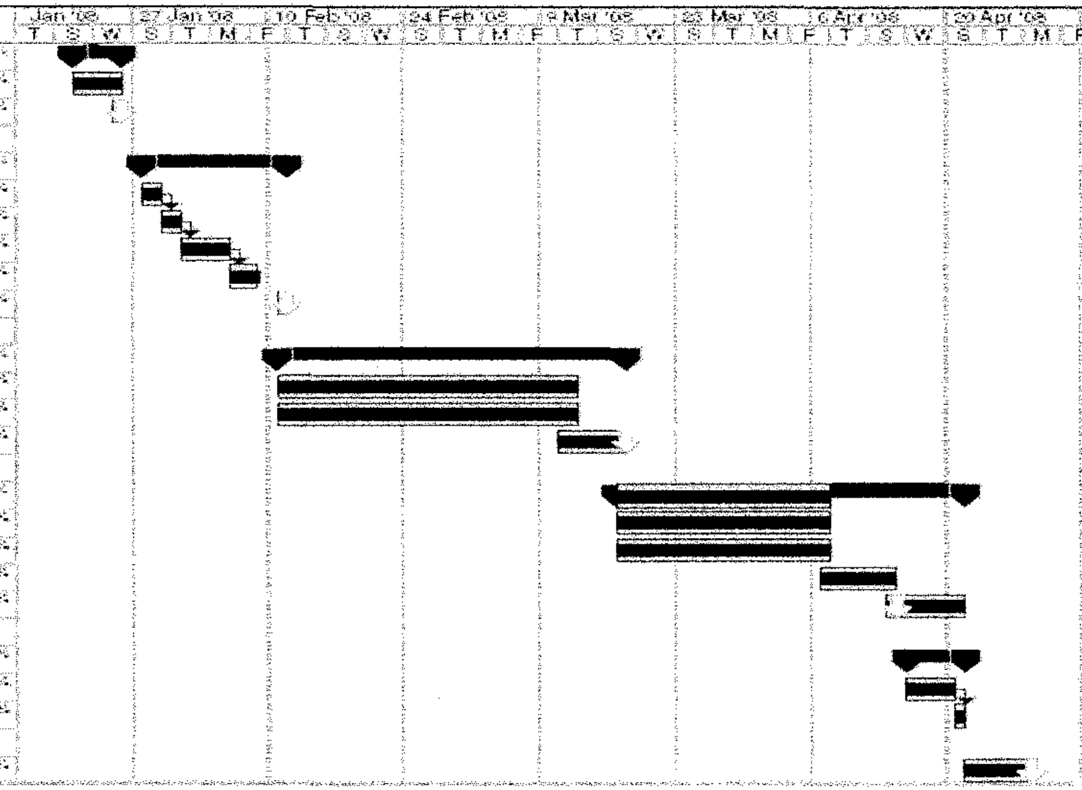
## Chi-Square Goodness-of-Fit Test

*Jalan Chemur (I) – Jalan Silibin (I) (Ipoh-Lumut Direction)*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Upper speed class limit (km/hr) | Col 1 - Mean Speed (km/hr) | Col 2 divided by std deviation | Normal Area | Probability | Theoretical Frequency | Observed Frequency | [ (6)-(7) ] ² / 6 |
| 55 | -30.4 | -2.11258 | -0.48268 | | | | |
| 60 | -25.4 | -1.76511 | -0.46123 | 0.021454 | 1.1 | 1 | 0.004926 |
| 65 | -20.4 | -1.41765 | -0.42185 | 0.039374 | 2.0 | 3 | 0.54024 |
| 70 | -15.4 | -1.07019 | -0.35773 | 0.064121 | 3.2 | 1 | 1.517965 |
| 75 | -10.4 | -0.72272 | -0.26508 | 0.092657 | 4.6 | 7 | 1.209476 |
| 80 | -5.4 | -0.37526 | -0.14627 | 0.118809 | 5.9 | 9 | 1.575804 |
| 85 | -0.4 | -0.0278 | -0.01109 | 0.135179 | 6.8 | 2 | 3.350743 |
| 90 | 4.6 | 0.319666 | 0.125389 | 0.136477 | 6.8 | 11 | 2.555744 |
| 95 | 9.6 | 0.66713 | 0.247655 | 0.122266 | 6.1 | 5 | 0.202745 |
| 100 | 14.6 | 1.014593 | 0.34485 | 0.097195 | 4.9 | 4 | 0.152096 |
| 105 | 19.6 | 1.362057 | 0.41341 | 0.06856 | 3.4 | 3 | 0.053436 |
| 110 | 24.6 | 1.709521 | 0.456323 | 0.042913 | 2.1 | 1 | 0.611696 |
| 115 | 29.6 | 2.056984 | 0.480156 | 0.023833 | 1.2 | 2 | 0.548303 |
| 120 | 34.6 | 2.404448 | 0.491902 | 0.011745 | 0.6 | 0 | 0.587271 |
| 125 | 39.6 | 2.751911 | 0.497038 | 0.005136 | 0.3 | 0 | 0.256802 |
| 130 | 44.6 | 3.099375 | 0.49903 | 0.001993 | 0.1 | 0 | 0.099639 |
| | | | | | | Sum | 13.26689 |

# FYP 1 PLANNER

| ID | Task Name | Start | Finish | % Comp. |
|---|---|---|---|---|
| 1 | Selection of Project Topic | Mon 21/1/08 | Fri 25/1/08 | 100% |
| 2 | Propose Topic | Mon 21/1/08 | Fri 25/1/08 | 100% |
| 3 | Topic Assigned to Students | Fri 25/1/08 | Fri 25/1/08 | 100% |
| 4 | | | | |
| 5 | Preliminary Research Work | Mon 28/1/08 | Mon 11/2/08 | 100% |
| 6 | Introduction | Mon 28/1/08 | Tue 29/1/08 | 100% |
| 7 | Objective | Wed 30/1/08 | Thu 31/1/08 | 100% |
| 8 | List of References/Literature | Fri 1/2/08 | Tue 5/2/08 | 100% |
| 9 | Project Planning | Wed 6/2/08 | Fri 8/2/08 | 100% |
| 10 | Submission of Preliminary Report | Mon 11/2/08 | Mon 11/2/08 | 100% |
| 11 | | | | |
| 12 | Project Work | Mon 11/2/08 | Mon 17/3/08 | 100% |
| 13 | Reference/Literature | Mon 11/2/08 | Wed 12/3/08 | 100% |
| 14 | Practical/Lab Work | Mon 11/2/08 | Wed 12/3/08 | 100% |
| 15 | Prepare Progress Report | Tue 11/3/08 | Mon 17/3/08 | 100% |
| 16 | | | | |
| 17 | Project Work (Continued) | Mon 17/3/08 | Mon 21/4/08 | 100% |
| 18 | Prepare Progress Report | Mon 17/3/08 | Mon 7/4/08 | 100% |
| 19 | Practical/Lab Work | Mon 17/3/08 | Mon 7/4/08 | 100% |
| 20 | Prepare Draft Final Report | Mon 7/4/08 | Mon 14/4/08 | 100% |
| 21 | Submission of Draft Final Report | Mon 14/4/08 | Mon 21/4/08 | 100% |
| 22 | | | | |
| 23 | Oral Presentation (TBA) | Wed 16/4/08 | Mon 21/4/08 | 100% |
| 24 | Preparation Works | Wed 16/4/08 | Sun 20/4/08 | 100% |
| 25 | Presentation Day | Mon 21/4/08 | Mon 21/4/08 | 100% |
| 26 | | | | |
| 27 | Submission of Interim Report | Tue 22/4/08 | Mon 28/4/08 | 100% |




Project: Project1
Date: Thu 27/11/08

# FYP II PLANNER

| | Task Name | Start | Finish | % Comp. |
|---|---|---|---|---|
| 1 | **Project Work** | **Mon 21/7/08** | **Wed 27/8/08** | **100%** |
| 2 | Reference/Literature | Mon 21/7/08 | Mon 28/7/08 | 100% |
| 3 | Practical/Lab Work | Mon 28/7/08 | Fri 22/8/08 | 100% |
| 4 | Prepare Progress Report | Wed 20/8/08 | Fri 22/8/08 | 100% |
| 5 | Submission of Prog Rep 1&2 | Wed 27/8/08 | Wed 27/8/08 | 100% |
| 6 | | | | |
| 7 | **Project Work (Continued)** | **Mon 1/9/08** | **Wed 15/10/08** | **100%** |
| 8 | Practical/Lab Work | Mon 1/9/08 | Tue 7/10/08 | 100% |
| 9 | Prepare Draft Final Report | Wed 8/10/08 | Tue 14/10/08 | 100% |
| 10 | Submission of Draft Final Report | Wed 15/10/08 | Wed 15/10/08 | 100% |
| 11 | | | | |
| 12 | **Oral Presentation (TBA)** | **Mon 20/10/08** | **Wed 29/10/08** | **100%** |
| 13 | Preparation Works | Mon 20/10/08 | Fri 24/10/08 | 100% |
| 14 | Presentation Day | Wed 29/10/08 | Wed 29/10/08 | 100% |
| 15 | | | | |
| 16 | **Submission of Interim Report** | Tue 4/11/08 | Tue 4/11/08 | 100% |