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UNIVERSITI TEKNOLOGI PETRONAS

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by

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SPEED - DENSITY RELATIONSHIP ON
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A Thesis

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DECLARATION OF THESIS

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hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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I dedicate this work especially to my lovely 'mum',

RASIDAH BINTI SAMSUDIN (born:10.5.1962 – death:27.5.2009)

and my beloved family; Lovely 'dad', my hero brothers and my sweetie sisters,

which has constantly been a part of this success.

Thank you.

PREFACE

Special praises and blessing to Almighty Allah for His guidance, strength and courage from Him for the accomplishment of this thesis. In order to prepare the thesis, many barrier and difficulties I have to be overcome, nevertheless with the co-operation and tolerant from all parties and with His permission, I am successfully to achieve my goal in preparing this thesis.

Through my study at UTP, I have received enormous support from many people. Without their contribution, this thesis would not have been possible.

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ABSTRACT

In Malaysia, motorcycles represented more than half of all registered vehicle population. In addition, motorcyclists contributed almost 70% of all injuries in accidents and almost 60% of the fatal accidents that occurred on Malaysian roads. This alarming figure warrants immediate road safety strategies targeted specifically at motorcyclists. An effective engineering approach to tackle this problem is by segregating these vulnerable road users from other motorized traffic through the provision of an exclusive motorcycle lane. Motorcyclists are compelled by law to use an exclusive motorcycle lane and other vehicles are prohibited by law from using it. Prior to constructing an exclusive motorcycle lane, there is a need to understand the parameters involved in capacity analysis used to assess the supply side, quality of flow and also the design life of this facility. Therefore, this research presents a study to analyse the traffic flow data that collected from the existing motorcycle track of Federal Highway Route 2 by using the mathematical relationships such as Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model. The resulting analysis can be used by engineering practitioners like traffic engineers with a better understanding of motorcyclists' safety needs and incorporate these needs in the upgrading and maintenance of existing roads and the planning, design and construction of new roads. Result indicates that the Drake et al. Model is the most suitable model because of the R-square is 0.7153. It is the highest value of R-square from four other models used in this study.

ABSTRAK

Di Malaysia, motosikal mewakili lebih dari separuh populasi pendaftaran kenderaan. Tambahan pula, penunggang dan pembonceng motosikal menyumbang sebanyak 70% kecederaan akibat kemalangan dan lebih daripada 60% adalah melibatkan kecederaan kritikal serta parah yang melibatkan kemalangan jalanraya di Malaysia. Angka peratusan di atas agak membimbangkan, oleh itu strategi keselamatan jalanraya mestilah di gunakan untuk penungang motosikal. Pendekatan teknik yang berkesan untuk mengatasi masalah ini adalah dengan memisahkan para pengguna motosikal dengan kenderaan bermotor lain melalui penyediaan sebuah lorong khas motosikal. Laluan khas ini hanya untuk motosikal secara eksklusif. Undang - undang penggunaan lorong motosikal mestilah dikuat kuasakan secara keseluruhannya dan kenderaan lain dilarang dari menggunakan lorong ini. Sebelum membina lorong motosikal ini, kita mesti memahami parameter yang terlibat dalam analisis yang digunakan untuk menilai semua kemudahan di kawasan tepi jalan raya, pergerakan kenderaan dan juga kemudahan yang tahan lama. Oleh itu, kajian ini adalah untuk menganalisis pergerakan lalu lintas yang diambil sepanjang lorong motosikal yang ada di Lebuhraya Persekutuan Fasa 2, ia menggunakan hubungan matematik seperti Model Greenshields', Model Greenberg, Model Underwood dan Model Drake et al. Analisis yang digunakan oleh pengamal kejuruteraan seperti para jurutera lalu lintas dengan pemahaman yang lebih baik tentang keperluan keselamatan lorong motorsikal dan memasukkan keperluan ini untuk peningkatan dan penyelenggaraan jalan yang ada serta perancangan, reka bentuk dan pembinaan jalan baru. Keputusan menunjukkan bahawa Model Drake et al. yang paling sesuai kerana R^2 menunjukkan nilai 0.7153. Ini adalah nilai yang tertinggi bagi R^2 daripada empat model lain yang digunakan dalam kajian ini.

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CHAPTER 1

INTRODUCTION

1.1 An Overview

One of the major problems occurring in Malaysia is road accidents, and what makes it worse is that the rates of these accidents are increasing year by year. Road accidents are a critical problem because it involves high costs to the road users. There have been many policies that aim to reduce the number of motorcycle accidents drastically have been implemented because of this, and the situation has improved in the last 6 years. Nowadays, the road accidents are a critical problem because it involved high cost to the road users and the government.

From the Annual Report 2009 by Royal Malaysian Police, it was reported that 397,330 accidents occurred on Malaysian roads, which represented almost 1,089 cases per day. In addition, motorcyclists were contributed 60.3% of fatal accidents that occurred in Malaysia. Figure 1.1 shows the total road accidents (by type) for year 2009.

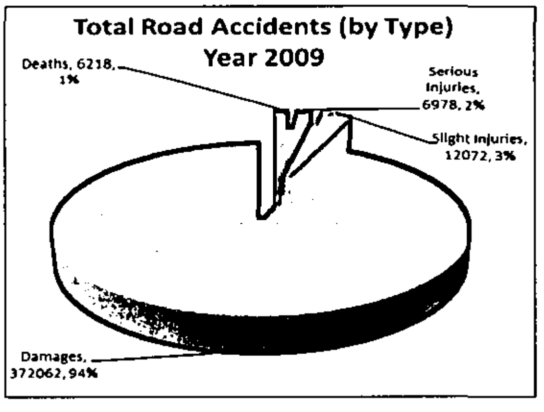


Figure 1.1 : Total Road Accidents in Year 2009
(Source: 2009 Annual Report: Road Accidents Malaysia, Royal Malaysian Police)

On average, 17 cases of fatalities (defined as death within 30 days following an accident) per day with 18.5 people dead, with an average of 24.2 people injured over the same period [1]. There are many factors that contribute to this problem. One of the main factors is the numbers of the vehicles on the road. Besides that, other factors like the attitude of the road users themselves, the mechanical conditions of the vehicles, the conditioning and quality of the roads, and physical and climatic environment.

Table 1.1 : General Road Accident Statistics in Malaysia

Year	Total Accident	Casualties Death	Casualties Serious Injuries	Casualties Slight Injuries	Total Vehicles Involved Accidents	Motorcycles Involved Accidents
2000	250,429	6,035	9,790	34,375	441,386	79,816
2001	265,175	5,854	8,689	35,974	483,351	85,761
2002	279,711	5,891	8,425	35,236	507,846	86,779
2003	298,653	6,286	9,040	37,415	555,634	95,545
2004	326,814	6,228	9,229	38,631	602,153	99,227
2005	328,268	6,188	9,397	31,429	581,136	97,072
2006	341,232	6,287	9,254	19,884	634,182	104,107
2007	363,319	6,282	9,273	18,444	666,027	111,765
2008	373,047	6,527	8,866	16,901	671,078	111,819
2009	397,194	6,745	8,849	31,417	523,310*	85,302*

*The data have been required until third quarter of 2009.

(Source: Department of Statistics, Malaysia)

Table 1.1 shows the general road accident statistics from year 2000 until year 2009. It is clear to see that the increase of total road accidents from 250,429 cases in year 2000 to 397,194 cases in year 2009 is contributed by the increase in the number of motorcycles that involved in road traffic accidents. It was shown that 79,816 motorcycles in year 2000 to 111,819 motorcycles in year 2008 [2].

From the statistic in year 2000 until year 2009, the number of casualties has decreased but the number of fatalities (defined as death within 30 days following an accident) still increasing.

This alarming figure warrants immediate road safety strategies targeted specifically at motorcyclists. An effective engineering approach to tackle this problem is by segregating these vulnerable road users form other motorized traffic through the provision of an exclusive motorcycle lane.

An exclusive motorcycle lane is defined as a roadway meant exclusively for use by motorcycles. Motorcyclists are compelled by law to use it and other vehicles are prohibited by law from using it. Prior to constructing an exclusive motorcycle lane, there is a need to understand the parameters involved in capacity analysis used to assess the supply side, quality of flow and also the design life of this facility.

In order to comprehend the relative significance of these parameters, data were collected at the spots area along the existing motorcycle track of Federal Highway. In previous studies, the flow density relation is used for examining the qualitative signature [3].

The mathematical relationships that describing the traffic flow is used to scrutinize the data collected. There are many mathematical relationships related to the traffic flow and only four types of models used for this study such as Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model.

The analysis resulted with the preliminary models on the relationships between density on direct flow and mean speed on motorcycles lanes. Besides that, simple regression models that relate the optimum speed that can be used in motorcycles lanes were established.

1.2 Problem Statement

In highway and traffic engineering practices, there have been studies on the concept and systematic procedures that need to be taken into consideration before designing the road. The needs of some other "special" road user groups, especially pedestrians, bicyclists, trucks and buses are gradually being acknowledged and their needs reflected in mainstream traffic engineering and management but this has not yet been considered the case for motorcyclists.

Therefore, some study about it should be done as well because it provides engineering practitioners with a better understanding of motorcyclists' safety needs and incorporate these needs in the upgrading and maintenance of existing roads and the planning, design and construction of new roads.

1.3 Objectives of Study

The main objectives that can be highlighted of this study are:

- To develop the traffic flow relationships between speed and density of direct flow on the exclusive motorcycle lane using Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model.
- To compare the traffic flow relationship in each models and then use it as guideline in the future design of exclusive motorcycle lanes.

1.4 Scope of Study

The first step was to determine a suitable location along the Federal Highway Route 2, where the location of the exclusive motorcycle lane as shown in figure 1.2. The final location will be selected based on a comfortable lane width of within 2.0m to 3.7m. The comfortable lane width has been proven by Radin *et al.* [4], which had conducted a study on determination of comfortable safe width in an exclusive motorcycle lane.

Figure 1.2 : The Exclusive Motorcycle Lane along Federal Highway Route 2

Besides that, the roadway conditions will be identified based on the geometrical factors, road furniture and existence of a straight road section of least 100m in length. This is because motorcyclists are able to overtake confidently. At the same time, the sample that will be collected had to be well-distributed to give a true representation of riders. In this study, the number of motorcycles that occupied these selected areas was determined.

The analysis of traffic flow on exclusive motorcycle lanes were done at 3 selected locations along Federal Highway Route 2. For each location, the data were recorded every 2 hours by using video recording technique. The data were measured during peak hours and non-peak hours. The flow rate and mean speed of motorcyclist at five minutes interval was collected continuously for five days. The data will be measured during peak hours and non-peak hours.

The study focused on the issues of the speed data and density of direct flow data that can be creating their linear relationship on exclusive motorcycle lane. This type of lane was based along Federal Highway Route 2. Besides that, the effectiveness of existing model like Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model those are applicable to be adopted in this study.

The final locations are KM15.8 at Batu Tiga from Shah Alam, Selangor to Kuala Lumpur, and KM30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor. The last location was KM31.5 at Batu Tiga from Shah Alam, Selangor to Kuala Lumpur.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The first world motorcycle lane was constructed along the Federal Highway Route 2 in the early seventies, under World Bank Project. In early 1992, an extension of the track was carried out by the Project Lebuhraya Utara Selatan PLUS, under the government's privatization schemes. This extension was part of the improvement programmed to the existing two-lane expressway connecting the Subang International Airport to the town of Shah Alam and Klang.

In November 1993, major sections of the lane were completed ahead of schedule and opened for public use. Nowadays, the exclusive motorcycle lanes can be found in Shah Alam Expressway, Butterworth-Kulim Expressway, Federal Highway, Guthrie Corridor Expressway, Putrajaya-Cyberjaya Expressway, Port of Tanjung Pelepas Highway and all major highways in Putrajaya.

The Federal Highway is well-known as the first expressway in Malaysia to have motorcycle lanes. However, the motorcycle lanes in the Federal Highway are known for its dangers towards motorcyclists, such as it being dark, narrow and poorly-maintained lanes and ramps, dangerous sharp corners, and the nature of the motorcycle lanes themselves to be vulnerable spots for robberies. It is due to the fact that the motorcycle lanes are originally intended for bicycle riders, with the design speed limit as low as 60 km/h.

The Federal Highway Route 2 (FHR2) is a 16-km upgraded expressway connecting Batu Tiga, Shah Alam, Selangor and Sungai Rasau, Klang, Selangor. It consists of 2 toll plazas and is connected to the Federal Highway. The Projek Lebuhraya Utara-Selatan Berhad (PLUS) is a main concession for this road. The official opening date was 11.May.1993 with 6-lane upgraded tolled highway. Figure 2.1 shows the location plan of Federal Highway Route 2 from Subang Airport to 7 Legged Roundabout [5].

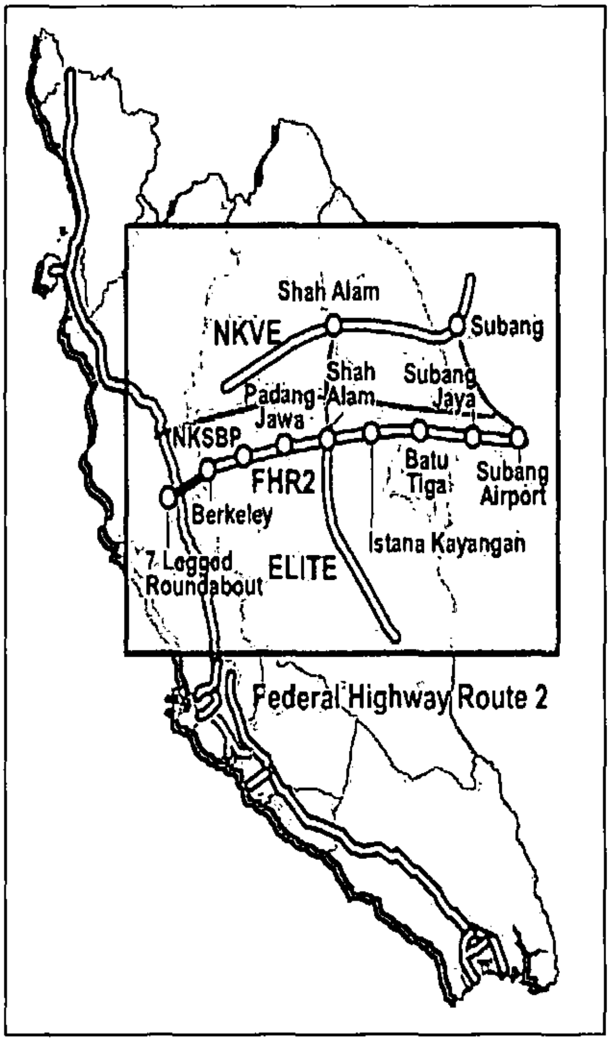


Figure 2.1 : The location plan of Federal Highway Route 2
(Source: PLUS Expressways Bhd., Malaysia)

2.2 Current Scenario

In Malaysia, the total number of registered motorcycle is increasing from year to year. From the statistics of Road Transport Department Malaysia, it was reported that 441,545 motorcycles were registered in Malaysia, which represented 43.4% of total registered vehicles in year 2009 [6]. Table 2.1 shows the list of new registered vehicles in Malaysia (by type and state) for year 2009.

Table 2.1 : New Registered Motor Vehicles By Type And State, in Malaysia, 2009

Year	Motorcycle	Motorcar	Bus	Taxi	Hire & Drive Car	Goods Vehicle	Others	Total
PERLIS	3,329	1,158	10	2	-	31	36	4,566
KEDAH	32,851	13,803	47	38	31	937	504	48,211
PULAU PINANG	41,449	47,307	240	167	50	2,531	576	92,320
PERAK	42,357	32,099	96	11	1	2,324	1,152	78,040
SELANGOR	43,316	33,546	342	1,007	30	5,432	3,792	87,465
W. PERSEKUTUAN	72,646	182,143	649	2,086	1,936	7,784	5,129	272,373
NEGERI SEMBILAN	15,420	14,182	41	96	1	1,037	154	30,931
MELAKA	13,917	16,060	14	42	1	695	190	30,919
JOHOR	60,944	62,703	179	372	1	4,390	1,896	130,485
PAHANG	22,488	17,403	22	44	3	1,209	374	41,543
TERENGGANU	18,062	11,305	21	19	2	543	218	30,170
KELANTAN	23,909	15,575	36	6	1	988	217	40,732
SABAH	20,910	31,394	179	147	52	3,671	2,481	58,834
SARAWAK	29,947	35,276	88	73	26	3,159	2,203	70,772
Total	441,545	513,954	1,964	4,110	2,135	34,731	18,922	1,017,361

(Source: Road Transport Department, Malaysia)

The high percentage of registered motorcycles in Malaysia has shown that motorcycle is the most favourable transportation mode. There are many factors that contribute to this issue. Low cost of ownership and less fuel consumed per kilometre travelled of motorcycle compared to other modes is believed to be main reasons behind it. Besides that, poor quality and inadequate capacity of public transport facilities in Malaysia also contributes to why motorcycle has become the preferred mode choice for road users.

From the table 2.2, the number of nation's population has increases steadily from 23,263,600 populations in 2000 to 27,900,000 population in 2009, a 19.9% increase. As one might expect, the total registered vehicles in Malaysia have also increased from 10,598,804 vehicles to 18,986,404 vehicles over the same period [7].

Table 2.2 : General Road Accident Statistics in Malaysia

Year	Vehicles Registered	Population	Road Length (KM)	Fatality Index Per 10,000 Vehicles	Per 100,000 Population	Per Billion VKT
2000	10,598,804	23,263,600	64,981	5.70	25.90	26.25
2001	11,302,545	23,795,300	64,981	5.17	24.60	23.93
2002	12,018,291	24,425,000	64,981	4.88	24.10	22.71
2003	12,819,248	25,050,000	71,814	4.88	25.10	22.77
2004	13,764,837	25,580,000	71,814	4.51	24.30	21.10
2005	14,816,407	26,130,000	72,400	4.18	23.70	19.58
2006	15,790,732	26,830,000	72,400	3.98	23.60	18.69
2007	16,812,440	27,190,000	74,603	3.73	23.10	17.60
2008	17,969,043	27,540,000	77,225	3.63	23.50	17.65
2009	18,986,404	27,900,000	0*	3.55	23.80	17.28

*The data has not been required.

(Source: Jabatan Keselamatan Jalan Raya, Malaysia)

An increment in overall population does not necessarily mean there will be more increasing for vehicle ownership. However, for Malaysia case, vehicle ownership increased accordingly from 2.19 persons per vehicle in 2000 to 1.47 persons per vehicle in 2009.

On the other hand, the fatality index per 10,000 registered vehicles has dropped from 5.70 in 2000 to 3.55 in 2009. The same downward trend is also seen on road deaths per 100,000 populations. In year 2000, it was recorded that 25.90 road deaths for every 100,000 population and seeing a small decrease to 23.80 road deaths per 100,000 population in year 2009 [8, 9, 10].

From the Malaysian Road Safety Plan 2006-2010, three targets to be achieved by 2010 are two deaths per 10,000 registered vehicles, ten deaths per 100,000 population and ten deaths per 1 billion Vehicle-Kilometer Travelled (VKT) [11]. However, these three targets may not be achieved by 2010 if this trend continues. While the road deaths in Malaysia are decreasing slowly, it is not as good as developed countries.

2.3 Motorcycles are a Part of Traffic

The study related to motorcycle offers a multiplicity of theoretical perspectives in term of identity, class, and gender [12]. In a search for literature that related to the motorcycle facility, the guidelines for geometric design of roads and the guidelines for cycle track that were published by the Public Work Department, Ministry of Works Malaysia seems to be the closest available information [13, 14]. Therefore, motorcycles are an accepted part of traffic and their safety deserves the same attention in the design and management of roads in Malaysia as does that of other road users (Pedestrians, bicyclists, etc). Motorcycles range from low power machines (70cc) to high performance machines (more than 1000cc).

While accepted as part of traffic, motorcycles have particular needs and problems which may not be widely recognized by those responsible for road planning, road design and traffic engineering and management.

While the needs of some other "special" road user groups, especially pedestrians, bicyclists, trucks and buses are gradually being acknowledged and their needs reflected in mainstream traffic engineering and management guidelines has not yet been the case for motorcyclists [15].

Under the Laws of Malaysia, Act 333, Road Transport Act 1987, a motorcycle is defined as motor vehicles with less than four wheels, and the unladed weight of which does not exceed four hundred and fifty kilogram's. Besides that, a motorcyclist is defined as anyone who rides, drags, pushes or propel a two or three-wheeled motor vehicle along a road [16]. Motorcycles are not 'fast bicycles' due to:

a) Motorcycle handling characteristics are different from those of bicycles, especially with regards to speed and positioning of vehicles on traveled way
b) Motorcycles have their own power source, resulting not only in greater speed, but also in greater opportunities to negotiate differing traffic conditions
c) Motorcycle riders are licensed and as such, are allowed on every class of roads (including expressways)
d) Motorcycles are motor vehicles, registered for on-road use.

Besides that, under the Laws of Malaysia, Act 333, Road Transport Act 1987 also, no person under sixteen years of age shall drive a motor vehicle on a road [16]. Riders range from those who are recently licensed to well experienced mature riders (normally riding the bigger capacity motorcycles in the urban areas) and inexperienced mature riders (normally riding smaller capacity motorcycles in the rural areas with little knowledge and or respect of traffic rules and road safety) [17, 18, 19]. Figure 2.2 presents the various type of motorcycle in Malaysia.

Figure 2.2 : Various Type of Motorcycle in Malaysia

2.4 Types of Motorcycle Lane Facilities

In a study related to design of a motorcycle lane [15], it was stated that there are three types of motorcycle lane facilities available in Malaysia such as an exclusive motorcycle lane, an inclusive motorcycle lane and a non-exclusive motorcycle lane.

2.4.1 Exclusive motorcycle lane

This type of motorcycle lane is a complete separate right-of-way established for the sole use of motorcyclists as shown in figure 2.3. This motorcycle lane is defined as a roadway meant exclusively separates motorcyclists from other motorist and normally has a wide right-of-way. It is not developed from an existing carriageway of a wide road. It is noted that all motorcyclists are compelled by law to use it and other vehicles are prohibited by law from use it. Such lane helps in reducing conflicts at crossing an intersection with the provision of underpasses and other related facilities. The width of an exclusive motorcycle lane is normally in the range of 2.0m to 3.5m.

Figure 2.3 : An Exclusive Motorcycle Lane.

2.4.2 Inclusive motorcycle lane

Inclusive motorcycle lane is popular in Malaysia road as shown in figure 2.4. It is developed within the carriageway of an existing road and usually sited on the left hand side of a road where motorcycles are encouraged / required to use while riding along a road. Some form of physical barrier or pavement marking define the corridor that is set aside for motorcyclists and route marking are necessary to define the route and reduce potential conflicts. However, at crossings and intersections, this kind of motorcycle lane ceases as an exclusive lane and conflicts may occur with other modes of transport.

Figure 2.4 : An Inclusive Motorcycle Lane.

2.4.3 Non-exclusive motorcycle lane

Another type of motorcycle lane is non exclusive motorcycle lane as shown in figure 2.5. It is defined as the extra lane or verge or marginal strip on the left hand side of a road where motorcycles are encouraged/required to use while riding along a road. A non exclusive motorcycle lane is a paved shoulder which does not have designated pavement marking and barrier. This lane provides space for motorcyclists but they have to share the space with other motor vehicles.

Figure 2.5 : A Non Exclusive Motorcycle Lane.

2.5 Design of Motorcycle

In a study related to design of motorcycle characteristics [15], it was stated that the design motorcycle – vehicle is represented by the low-to-medium sized motorcycles (less than 250 c.c.) which were found to be the types of motorcycle most commonly used in Malaysia. The side and front view of this design motorcycle vehicle are shown in figure 2.6 and figure 2.7 respectively. The length and width of the motorcycles and the height of the average motorcyclist are major factors that affect the practical capacity when designing facilities for motorcycles [20, 21].

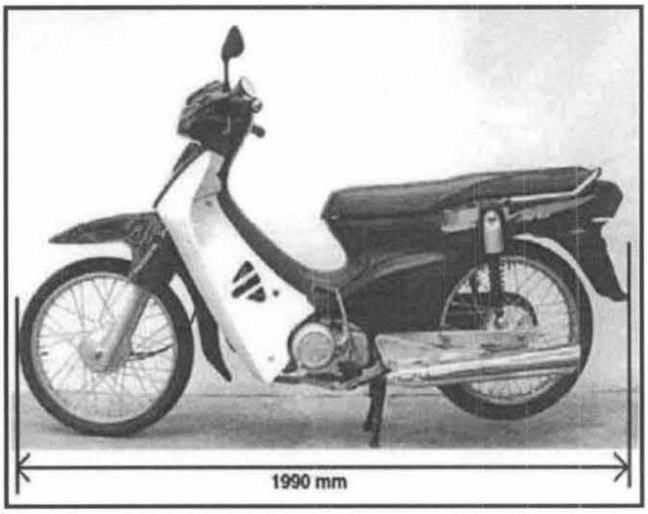


Figure 2.6 : Design of Motorcycle (less than 150c.c.) – Side view

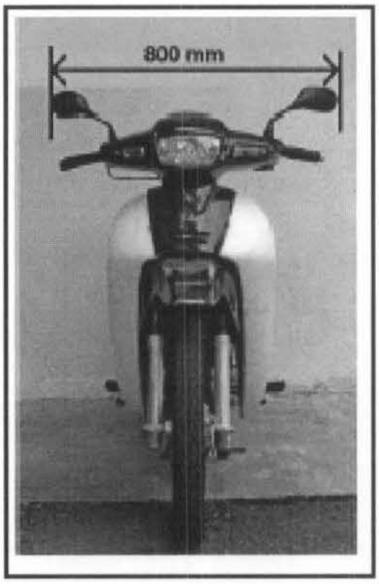


Figure 2.7 : Design of Motorcycle (less than 150 c.c.) – Front view

2.5.1 Static Space of Motorcycle-Rider Unit

Figure 2.8 and figure 2.9 showed the simplified outline and dimensions for a single motorcyclist. The physical breadth is 0.8 m while the length is 2.0 m. The total area of 1.60m^2 (0.8 m x 2.0 m) is the physical space occupied by a static motorcyclist. Note that these figures represented a typical motorcycle with side-mirrors on both sides, and representing a maximum width.

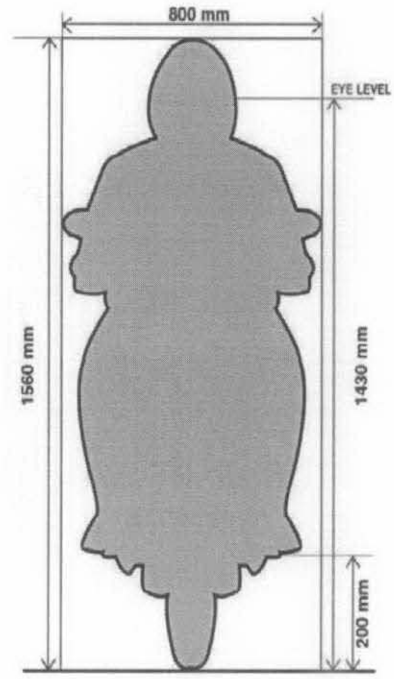


Figure 2.8 : Front Outline of a Static Motorcyclist - Breadth of 0.8 m

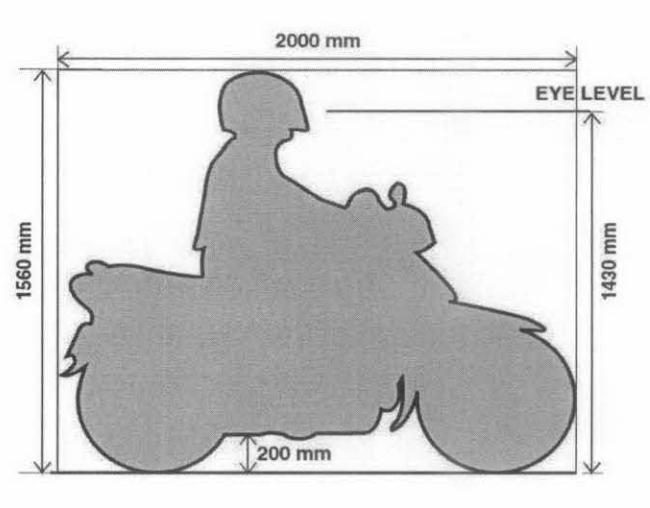


Figure 2.9 : Side Outline of a Static Motorcyclist - Length of 2.0 m

2.5.2 Motorcyclists Side-by-Side Operating Space

The value of the separation distances of side-by-side motorcyclists is 0.50m. Besides that, the speed of motorcycle along the motorcycle lane is 70km/hr and the flow rate along the motorcycle lane is 1200 motorcycles/hr/lane. The side-by –side motorcyclists' separation is illustrated as in figure 2.10.

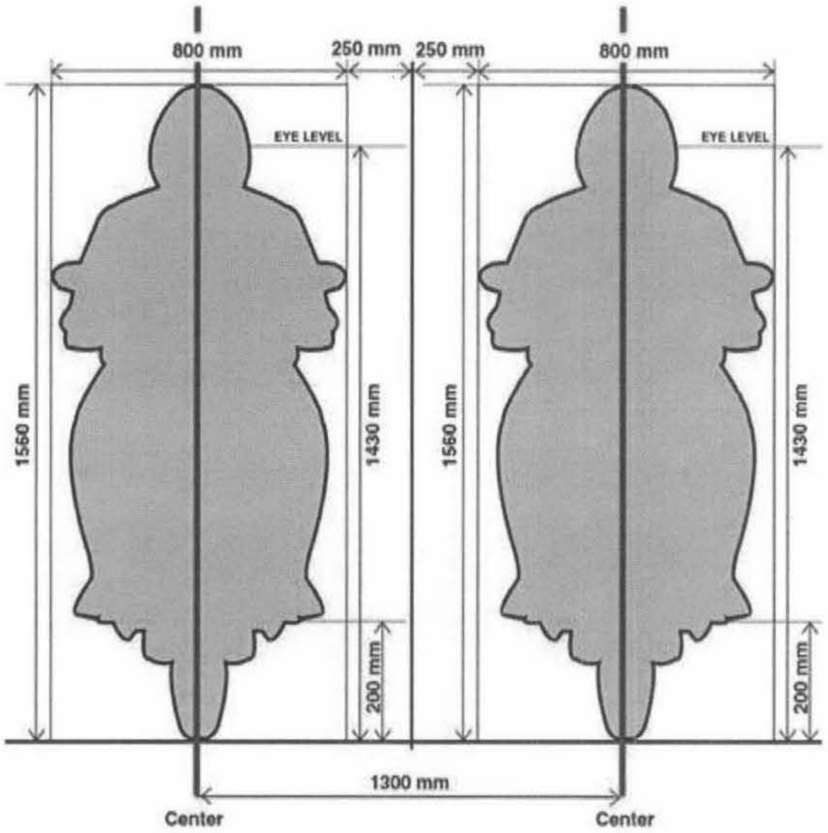


Figure 2.10 : Side-by-Side Motorcyclists Separation Distance of 0.50 m

2.5.3 Operating Space of a Single Motorcyclist

The mean operating width required by a single motorcyclist is 1.3m and as illustrated in figure 2.11. Besides that, the eye level for motorcyclist is 1.43m and the total height of motorcyclist is 1.56m.

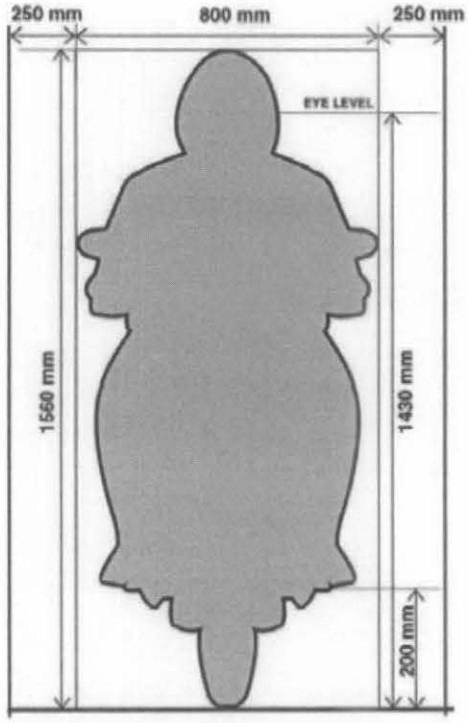


Figure 2.11 : Mean Operating Width of 1.3 m Required by a Motorcyclist

2.6 Macroscopic Models

Macroscopic stream models represent how the behavior of one parameter of traffic flow changes with respect to another. Most important among them is the relation between speed and density. The four commonly used macroscopic models are the Greenshield's Model, Greensberg Model, Underwood Model and Drake et al. Model [22, 23, 24].

A Linear Density relationship is given by :-

$$u = u_f - \frac{u_f}{k_j}\, k \tag{2.1}$$

where :-

u = Speed

u_f = Free flow Speed

k = Density

k_j = Jam Density

From the above relationship, free-flow speed is defined as the theoretical speed of traffic when density is almost to zero. The optimum speed, or so-called critical speed, refers to speed when the maximum flow rate is achieved. The corresponding density at this condition refers to optimum or critical density. The jam density represents the density at which all movements in a traffic stream stop.

Substituting U from the general equation of a traffic stream,

$$\frac{q}{k} = u_f - \frac{u_f}{k_j}\, k \tag{2.2}$$

where :-

$u = \frac{q}{k}$

q = Density value

k = Density at that instant

Interchanging the relationships between the variables velocity, flow and density by successive elimination of one of these variables, we find that as the flow increases, density increases and the speed decreases. At optimum density, flow becomes maximum value. In other words, as the speed increases from zero, flow increases from zero until it becomes q_m (maximum density) at $u = u_f / 2$ and $k = k_j / 2$.

Hence;

$$q_m = \frac{u_f k_j}{4} \quad (2.3)$$

where :-

q_m = Maximum Density

u_f = Freeflow Speed

k_j = Jam Density

Highway capacity manual and all traditional codes use this sets of equations. However practical field data does not follow this relationship accurately. Hence a number of theoretical models have cropped up over the past six decades. Earlier models assumed a single regime that would include a gamut of flow conditions.

2.6.1 Greenshield's Model

Greenshield's Model was able to develop a model of interrupted traffic flow that predicts and explains the trends that are observed in real traffic flows. While this model is not perfect, it is fairly accurate and relatively simple.

Greenshield's made the assumption that, under uninterrupted flow conditions, speed and density are linearly related. In the other term, speed is a linear function of density. Free-flow speed and jam density are required to estimate speed. This relationship is expressed mathematically and graphically below.

$$u = u_f - \frac{u_f}{k_j} k \qquad (2.4)$$

where :-

u = Velocity at any time (kilometres/hour)

u_f = Freeflow Speed (kilometres/hour)

k = Density at that instant (vehicles/kilometre)

k_j = Jam Density (vehicles/kilometre)

This is normally done by collecting velocity and density data in the field, plotting the data and then using linear regression to fit a line through the data points. Greenshield's assumed a linear speed-density relationship as illustrated in figure 2.12 to derive the model. It indicates that when density becomes zero, speed approaches free flow speed.

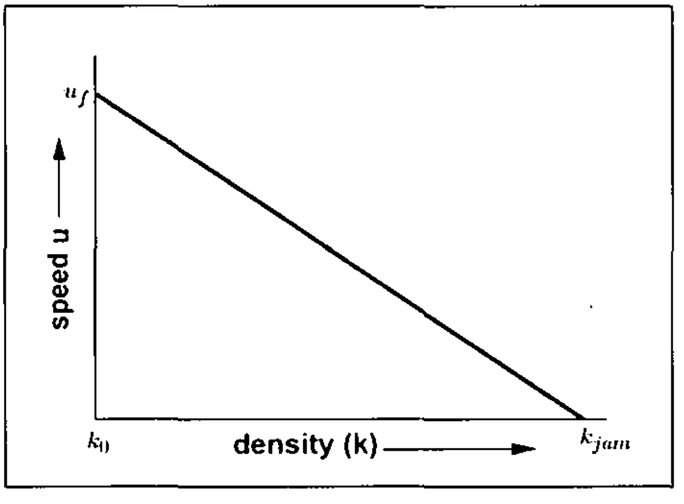


Figure 2.12 : Speed vs. Density by Greenshields Model

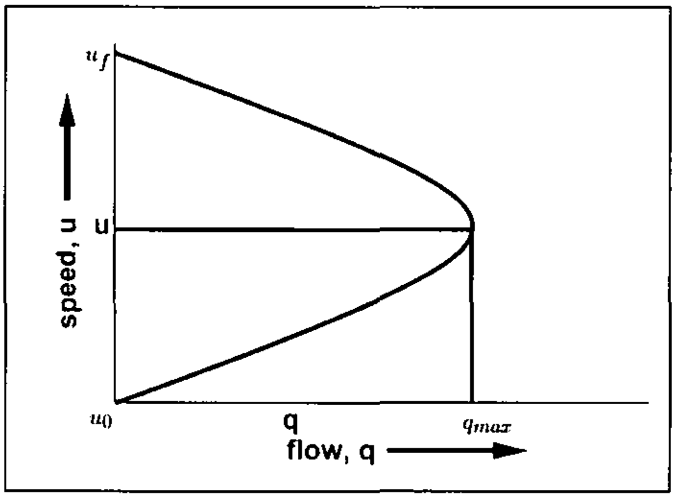


Figure 2.13 : Speed vs. Flow by Greenshields Model

Over the relation between speed and flow established, the relation between flows can be derived. This relation between flow and density is parabolic shape and is shown in figure 2.13. Also, as known that,

$$q = k.v \tag{2.5}$$

Now, substituting equation 2.4 in equation 2.5,

$$q = u_f.k - \frac{u_f}{k_j} k^2 \tag{2.6}$$

Similarly, we can find the relation between speed and flow. For this, put $k = \frac{q}{v}$ in equation 2.4 and solving,

$$q = k_j.v - \frac{k_j}{v_f} v^2 \tag{2.7}$$

This relationship is again parabolic and is shown in figure 2.14. Once the relationship between the fundamental variables of traffic flow is established, the boundary condition can be derived. The boundary conditions that are of interest are jam density, free flow speed and maximum flow.

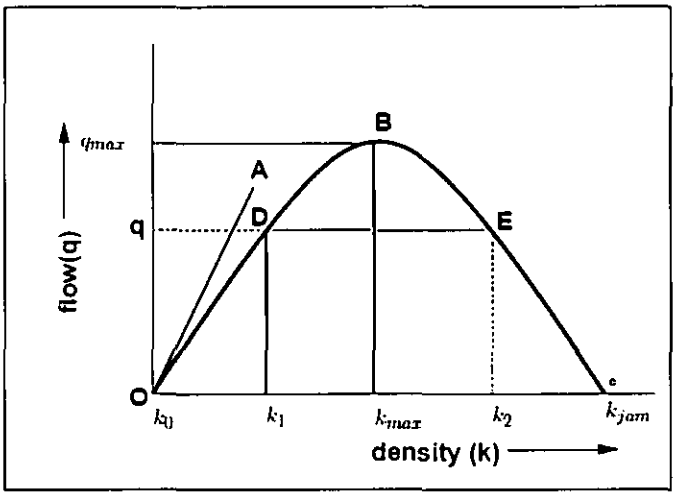


Figure 2.14 : Flow vs. Density by Greenshields Model

To find density at maximum flow, differentiate equation 2.6 with respect to k and equate it to zero, ie.,

$$k = \frac{k_j}{2} \tag{2.8}$$

Denoting the density corresponding to maximum flow as k_0,

$$k_0 = \frac{k_j}{2} \tag{2.9}$$

Therefore, density corresponding to maximum flow is half the jam density. Once get k_0, it can derive for maximum flow, q_{max}. Substituting equation 2.9 in equation 2.6,

$$q_{max} = \frac{v_f . k_j}{4} \tag{2.10}$$

Thus, the maximum flow is one fourth the product of free flow and jam density. Finally, to get the speed at maximum flow, v_0, substitute equation 2.8 in equation 2.4 and get,

$$v_0 = \frac{v_f}{2} \tag{2.11}$$

Therefore, speed at maximum flow is half of the free speed.

2.6.2 Greensberg's Model

Several researchers have used the analogy of fluid flow to develop macroscopic relationships for traffic flow [25, 26, 27]. *Greensberg Model* is a non-linear model where a hydrodynamic analogy is combined with equations of motion in mechanics.

Greenberg assumed a logarithmic relation between speed and density. The main of drawbacks of this model is that as density tends to zero, speed tends to infinity. This shows the inability of the model to predict the speeds at lower density. Figure 2.15 presents average speed versus density.

The velocity is governed by :-

$$u = u_0 \ln \frac{k_j}{k} \tag{2.12}$$

where :-

- u = Speed at any time (kilometer/hour)
- u_o = Optimum speed (kilometer/hour)
- k_j = Jam Density (vehicles/kilometer)
- k = Density at that instant (vehicles/kilometer)

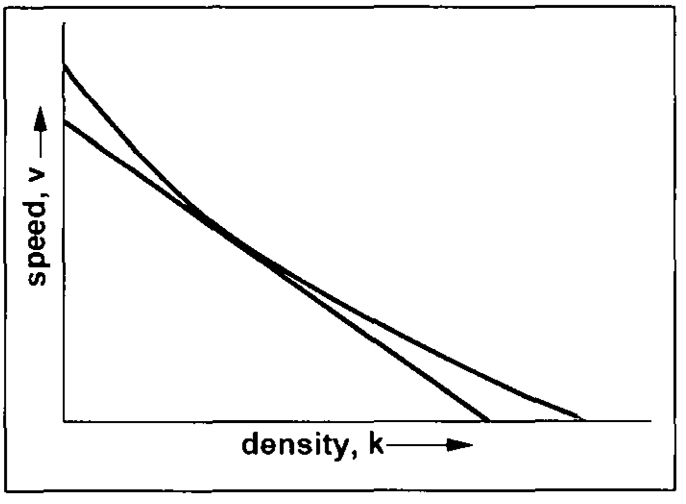


Figure 2.15 : Speed vs. Density by Greenberg Model

2.6.3 Underwood Model

Underwood Model was a new single regime model proposed to account for the problem of free-flow reaching infinity value during free flow condition in the Greensberg Model. The main drawback of this model is that speed becomes zero only when density reaches infinity. Hence, this model cannot be used for predicting speeds at high densities. Figure 2.16 presents average speed versus density for Underwood Model.

According to this theory,

$$u = u_f \, e^{-(k/k_o)} \tag{2.13}$$

where :-

u = Speed at any time (kilometer/hour)

u_f = Free flow speed (kilometer/hour)

k_o = Optimum density (vehicles/kilometer)

k = Density at any time (vehicles/kilometer)

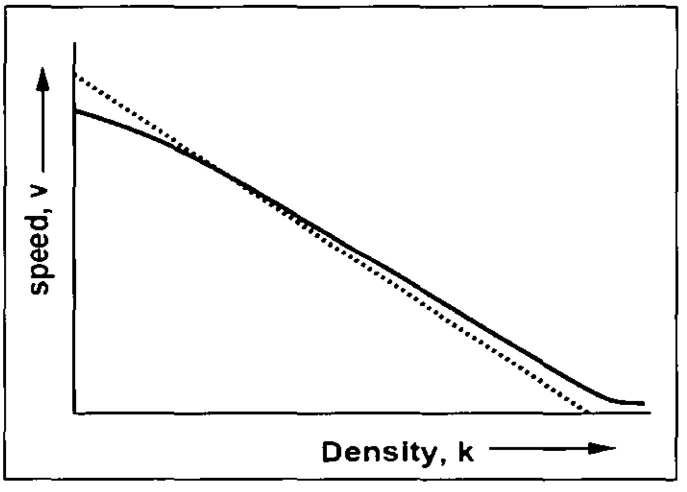


Figure 2.16 : Speed vs. Density by Underwood Model

In the car-following model, by formulating the acceleration of each following vehicle with the leading vehicle, interrelationships between levels of speed–density states are derived. The acceleration of following vehicles is represented by a nonlinear differential equation in which the variables are the speeds of the following vehicles and their headway, as measured by, for example, distances between vehicles.

The model generates the various speed–density functions referred to Underwood Model in the form of the combinations of values taken by the exponents on the variables.

Underwood Model and Drake et al. Model were developed to solve the disadvantage of the Greenberg Model by introducing an exponential speed – density form. The disadvantage of the Greenberg model is that when density approaches zero, free-flow speed increases toward infinity. Both Underwood Model and Drake et al. Model require the knowledge of free-flow speed and optimum density.

Although these models are appropriate for low densities, the disadvantage lies at high densities, where speed asymptotically approaches zero but never actually reaches it. Hence, a maximum flow rate or capacity is needed to be independently assumed or observed.

In term of measurement, jam density is difficult to observe and the estimation of optimum speed is not easy, making the Greenshield's and Greenberg Models unfavorable. The optimum density is also difficult to obtain in the Underwood and Drake et al. Model. However, the free flow speed can be readily measured.

2.6.4 Drake et al. Model

Drake et al. Model proposed a similar model in the form of the half bell-shaped curve model. This model was investigated in an important empirical test then forms a speed-density curve as below. The measure data consists of volume, time mean speed and occupancy. The density was calculated from volume and the time mean speed.

The time mean speed is governed by :-

$$u = u_f \, e^{-0.5(k/k_o)^2} \tag{2.14}$$

where :-

- u = Speed at any time (kilometer/hour)
- u_f = Time mean speed (kilometer/hour)
- k_o = Optimum density (vehicles/kilometer)
- k = Density at that instant (vehicles/kilometer)

2.7 LOS Designation for Motorcycle Lane

Similar to the vehicular traffic streams, the relationship between motorcycle speed and motorcycle density indicated that as motorcycle density increases, motorcycle speed decreases. In a study related to the capacity for uninterrupted motorcycle path, it was found that the motorcycle speed-flow-density relationships for the headway concept and space concept are analogous to vehicular traffic streams [28, 29].

For the headway concept, the motorcycle density is measured in mc/km/lane and table 2.3 and figure 2.17 shows the Level of Service for One-Way Exclusive Motorcycle Lane in Headway Concept.

Table 2.3 : LOS Criteria for One-Way Exclusive Motorcycle Lane (Headway Concept)*

Level of Service	Density (mc/km/ln)	Expected Flows and Speed		
		Average Speed (km/hr)	Flow Rate (mc/hr/ln)	*v/c* Ratio
A	6	53	306	0.10
B	21	45	918	0.30
C	44	35	1530	0.50
D	68	29	1989	0.65
E	235	13	3060	1.00
F	> 235	< 13	Variable	Variable

*Average conditions for 1 minute.

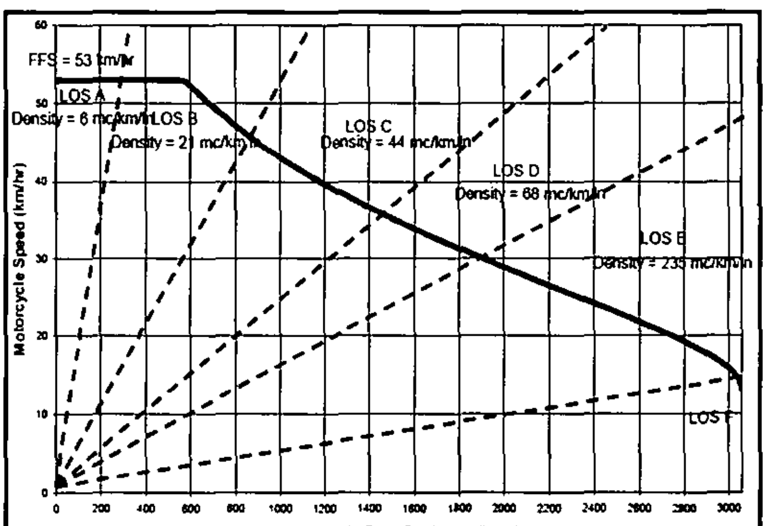


Figure 2.17 : LOS for One-Way Exclusive Motorcycle Lane (Headway Concept)*

*Average conditions for 1 minute.

For the space concept, the motorcycle density is measured in m^2/mc and table 2.4 and figure 2.18 shows the Level of Service for One-Way Exclusive Motorcycle Lane in Space Concept.

Table 2.4 : LOS Criteria for One-Way Exclusive Motorcycle Lane (Space Concept)*

Level of Service	Space (m^2/mc)	Expected Flows and Speed		
		Average Speed (km/hr)	Flow Rate (mc/hr/m)	*v/c* Ratio
A	295	65	221	0.10
B	69	46	662	0.30
C	33	36	1104	0.50
D	21	30	1435	0.65
E	6	13	2207	1.00
F	< 6	< 13	Variable	Variable

*Average conditions for 1 minute.

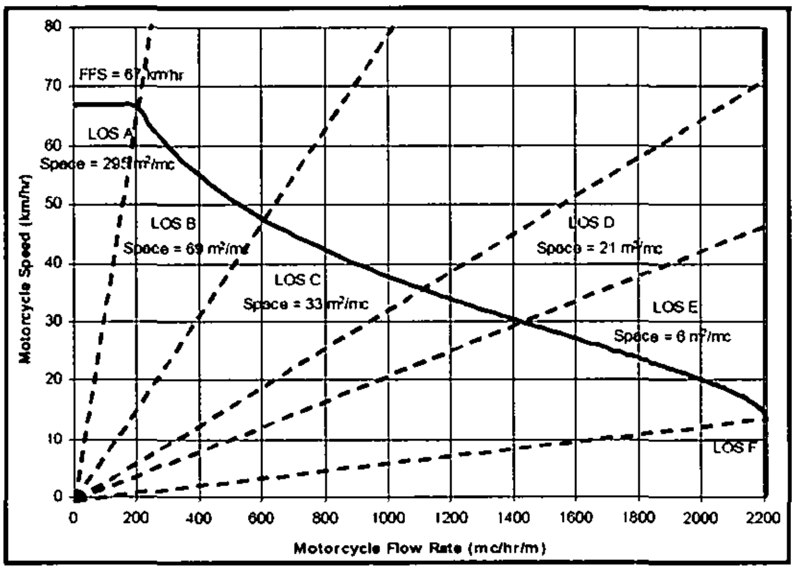


Figure 2.18 : LOS for One-Way Exclusive Motorcycle Lane (Space Concept)*

*Average conditions for 1 minute.

2.8 Level of Service

A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service [22, 23, 24].

Level of service (LOS) is graded on a letter scale from A to F. A being the highest level of service and F being the lowest. At LOS A, traffic flows freely, selecting desired travel speeds with ample passing opportunities. At LOS F, traffic flow is forced, the traffic volume has exceeded the capacity of the roadway to handle it and there are no passing opportunities. LOS D is generally considered to be the lowest tolerable level of service for roadways. Roadway designs attempt to operate at LOS D in only the worst case situations and preferably at higher levels of service.

2.8.1 Level of Service (LOS) A

LOS A is represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The level of comfort and convenience provided to the motorist, passenger or pedestrian is excellent. The driver only needs minimal attention.

2.8.2 Level of Service (LOS) B

LOS B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desire speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from LOS A. The level of comfort and convenience provided is somewhat less than at LOS A, because the presence of others in the traffic stream begins to affect individual behavior. The comfort is excellent, as the driver simply needs to keep an eye on nearby vehicles.

2.8.3 Level of Service (LOS) C

LOS C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level. This is because the driver has a growing impression of being caught between other vehicles.

2.8.4 Level of Service (LOS) D

LOS D represents high-density, but stable flow. The speed and the maneuverability are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Therefore, the road users must constantly avoid collisions with other vehicles. A slight increase of the traffic risks causing some operational problems and saturating the network.

2.7.5 Level of Service (LOS) E

LOS E represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to "give way" to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because even small increases in flow or minor perturbations within the traffic stream will cause breakdowns.

2.8.6 Level of Service (LOS) F

LOS F is used to define forced or breakdown flow in term of unstable speed with the formation of waiting lines at several points. This condition exists wherever the amount of traffic approaching a point exceeds the amount which can traverse it and queues begin to form. Operations within the queue are characterized by stopping and starting. Over and over, vehicles may progress at reasonable speeds for several hundred feet or more, and then be required to stop. It should be noted, however, that in many cases once free of the queue, traffic may resume to normal conditions quite rapidly.

The rate of traffic service is the maximal hourly rate that can cross a point or a road section according to road, traffic and control conditions. Therefore, each road infrastructure has five traffic rates of service (the F level is not used because unstable). Traffic reports also use color codes to illustrate traffic conditions such as green (levels A and B), yellow (levels C and D) and red (levels E and F).

2.9 Semi-Automatic Video Analyser (SAVA) Software

Many researchers in the research works had used video recordings technique of traffic data collection. This technique had made data collection safer and efficient, and the researchers had developed models out from their studies.

Based on Jeffery Archer (2003), the Semi-Automatic Video Analyser (SAVA) program provides a basis for analyzing traffic film data. The program has been designed to interpret the information from digital films recorded in (*.avi) format and (*.mpeg) format. The basic functionality of the program includes being able to step forwards or backwards through the film one frame at a time using the media player controls, arrow keys or the mouse wheel [30].

The program has a timer or clock that keeps track of the relative position of the current frame in the film sequence in terms of time, thus each time the user moves one step forward the clock advances 40 milliseconds. The program also provides the possibility to change the timer in order that it can be synchronized with other sources of logged data. Figure 2.19 shows the illustration of Semi-Automatic Video Analyser (SAVA) Program.

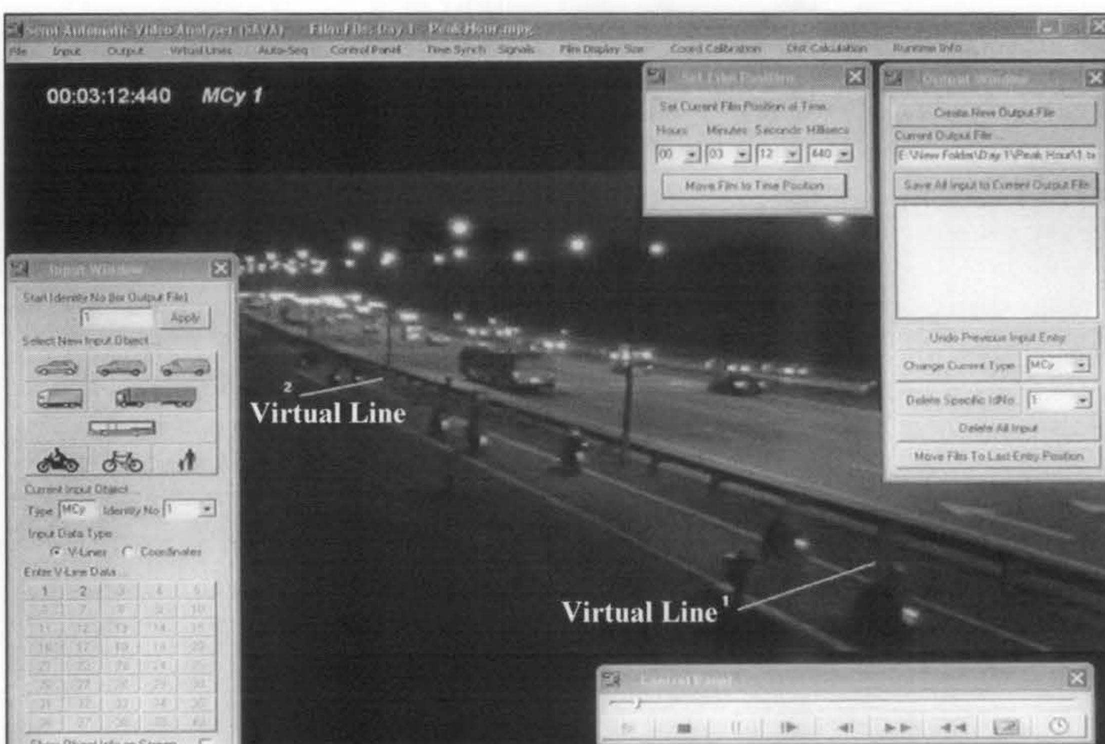


Figure 2.19 : Semi-Automatic Video Analyser (SAVA) Program.

The main function of the program involves the use of virtual lines that can be placed on the screen by the user to log event times for road users. Each time a road user reaches a virtual line, the event can be registered by either clicking on the line representing the virtual line, or clicking on the box in the application. This will result in an event time entry into a log file that consists of the current film time, the virtual line number, the road user type and the road user identification number.

The resulting information from SAVA program analysis can cover 100% of all road users and possible to establish the origin and destinations of all road users. The program generates a text-file (ASCII-file) that includes one row for each event for all vehicles in a chronological order. In order to establish more useful statistical data further processing is required using a statistical package such as Microsoft Office Excel or SPSS.

Basically, figure 2.20 shows the process and sequence of video-captured technique employed in one of the study undertaken related to flow measurement at the Federal Highway, Route 2, where the exclusive motorcycle lane is located. Suitable site was identified that suite the criteria specified in the study was selected. The equipments that were used in the study were video camera with its accessories, computer for data recording and retrieval, and data reduction software.

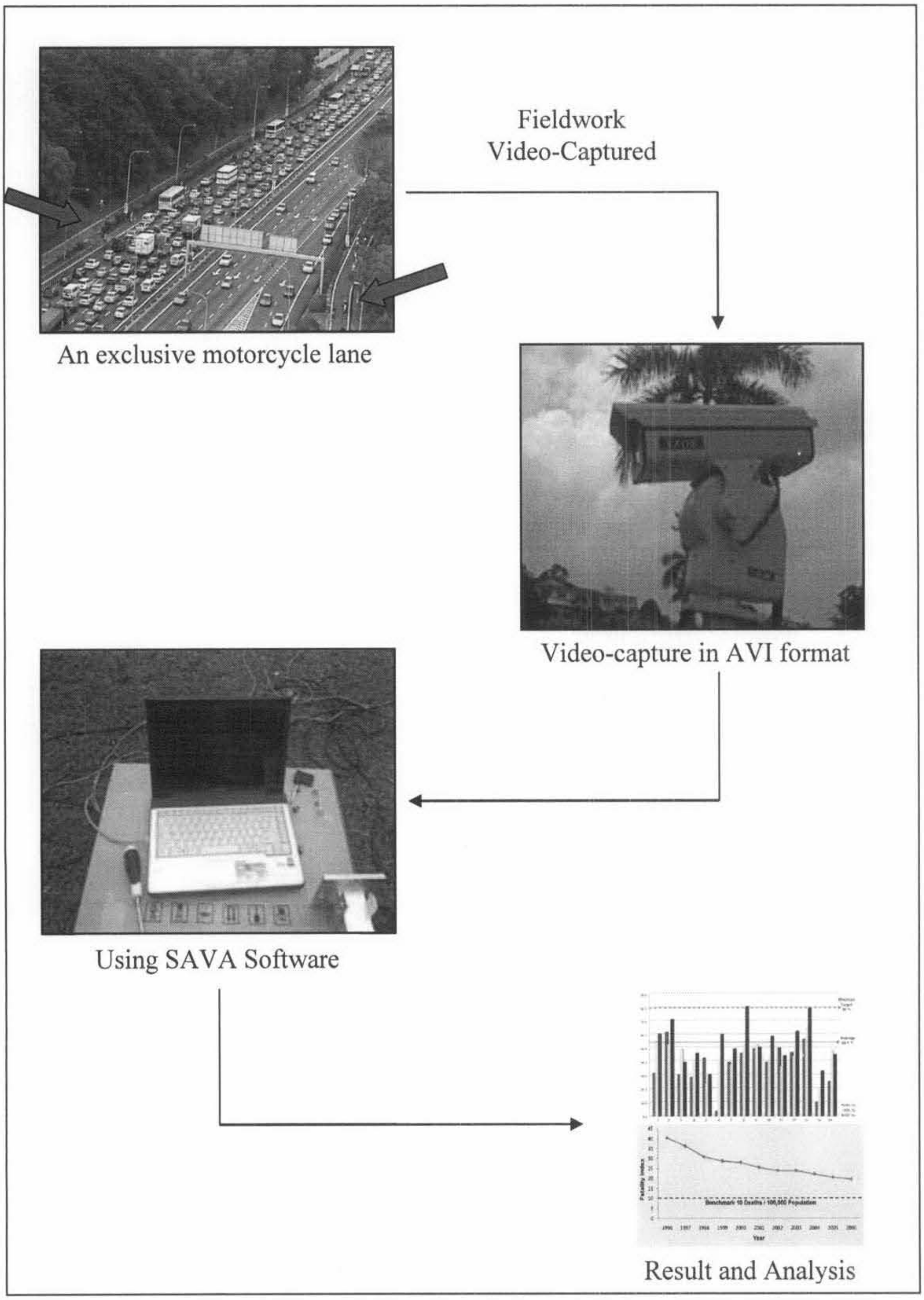


Figure 2.20 : Method of Data Collection using Video-Capture Technique

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In the initial stages of trying to produce this research paper, a few proposals were imposed and discussed. This research does not require any laboratory experiments but focus only on field study. Briefly discussed here are the methods used in preparing this research, which is cross-referenced with journals.

The prime method of the research is where general ideas and the basic conceptions of space rejuvenation will be defined. In terms of data collection, the information that is collected from various articles and journals including the data from the past to present conditions will be stated.

3.2 Selection of Site View

In an attempt to collect data from the stable flow conditions, the study was conducted in a site of the motorcycle path along the Federal Highway, Route 2, in the state of Selangor, Malaysia. There are many locations along the Federal Highway Route 2 that can be considered and taken as a site location. The preferable criteria for a location to be selected must have a good view in the efforts to tabulate data such as speed, flow rate and density.

The final location was selected based on a lane width of within 2.0m to 3.7m, roadway conditions such as geometrical factors, road furniture and existence of a straight road section of least 100m in length to enable riders to overtake confidently in terms of the sample collected had to be well-distributed to give a true representation of riders. Figure 3.1 presents a detail overview of exclusive motorcycle lane along Federal Highway Route 2.

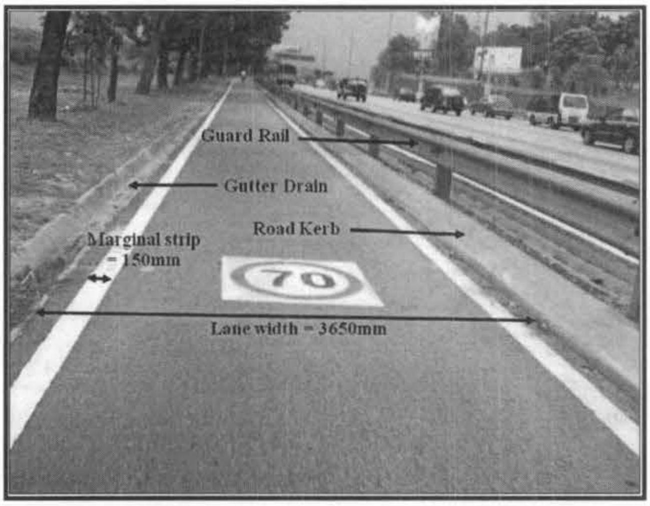


Figure 3.1 : Overview of Exclusive Motorcycle Lane along Federal Highway Route 2

3.3 Selection of Site Location

In this study, three locations are selected as a suitable location of site. The locations selected include KM15.8 at Batu Tiga, KM30.7 at Sungai Way and the KM31.5 at Petaling Jaya, Selangor. Figure 3.2, figure 3.3 and figure 3.4 show the selected site at each location.

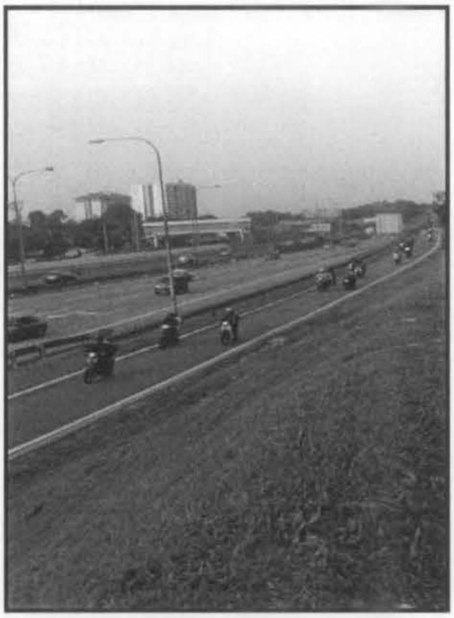


Figure 3.2 : Exclusive Motorcycle Lane at KM15.8 – Batu Tiga from Shah Alam, Selangor to Kuala Lumpur

Figure 3.3 : Exclusive Motorcycle Lane at KM30.7 - Sungai Way from Kuala Lumpur to Shah Alam, Selangor

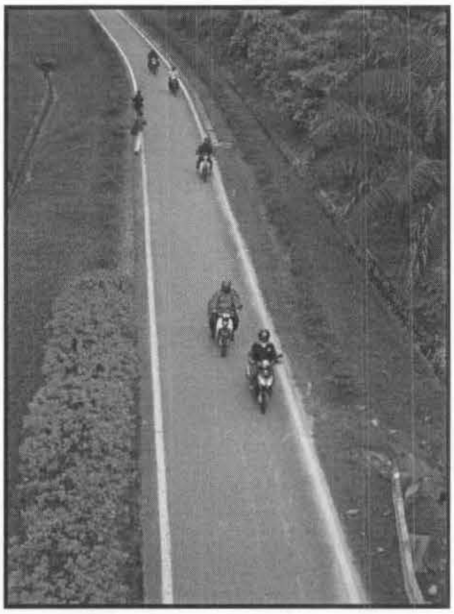


Figure 3.4 : Exclusive Motorcycle Lane at KM31.5 – Petaling Jaya from Shah Alam, Selangor to Kuala Lumpur

3.4 Data Collection Process

After choosing the location, the data were collected using video recording technique. One digital video recorder was set up at a high terrain near the study sites, to capture all traffic movements at specified time periods. This technique required two corresponding persons in the field in order to observe proper positions for video recording and install the video.

After that, the filming traffic operations captured on site were converted into (*.avi) format or (*.mpeg) format files. The video data was recorded for two hours where the first of one hour was during the peak hour and the second hour was during non-peaks. Besides that, the collection of video data was done on working days; Monday to Friday. Table 3.1 presents the detail of video data collection in this study.

Table 3.1 : The Detail of Video Data Collection

Location	Date	Time (Peak Hour)	Time (Non Peak Hour)
KM15.8 – Batu Tiga (Shah Alam, Selangor to Kuala Lumpur)	8.3.2010 to 12.3.2010	7.15 a.m. to 8.15 a.m.	9.45 a.m. to 10.45 a.m.
KM30.7 - Sungai Way (Kuala Lumpur to Shah Alam, Selangor)	15.3.2010 to 19.3.2010	7.15 a.m. to 8.15 a.m.	9.45 a.m. to 10.45 a.m.
KM31.5 – Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)	22.3.2010 to 26.3.2010	7.15 a.m. to 8.15 a.m.	9.45 a.m. to 10.45 a.m.

Besides that, site surveys on the exclusive motorcycle lanes were done as well. The aim is to get an overview of the situation at the site in terms of the facilities that has provided. It should be noted that the data were collected under good weather and dry pavements.

Other instrument used in this stage is the true meter where it is used to measure the length of road in the exclusive motorcycle lane. The data collection from a traffic flow may be presented in a several ways. It depends on the primary use of the data and the type of data reduction that conducted.

3.5 Data Extraction Process

This is the stage where the video recording was transferred to the computer. Computer software was used to extract all the parameters from the video recordings. Key parameters measured at the study were motorcycle volumes and individual motorcycle spot speed. The computer software used to produce all the parameters in this study is the Semi-Automatic Video Analyzer (Sava) Software.

In addition, the number of vehicles were measured and converted to the passenger car unit (PCU) in order to give the effect of an equivalent numbers of passenger cars on the capacity. Appendix A shows two set of data after the data reduction process that applied in this study.

3.6 Data Reduction Process

The *speed* (km/hr) is defined as the rate of movement of the vehicle. This parameter is obtained by measuring the time of vehicles that pass through an interval point on a lane over the selected distance. The sample calculation of measuring the speed is shown below;

Given, Distance = 100m

$= 0.1\text{km}$

Interval time = 4.00s

$$= \frac{3600}{4.00} \text{ hr}$$

$$\text{Therefore, } Speed, v = \frac{(0.1 \times 3600)}{(4.00)}$$

$$= \underline{90.00 \text{ km/hr}}$$

The *average speed* (km/hr) is defined as the arithmetic mean of all observed vehicles speeds. This parameter was obtained by sum of all spot speeds divided by the number of recorded speeds. The sample calculation of measuring the average speed is shown below;

Given, Speed Data

66.45	47.37	56.25
40.91	57.31	67.39

$$\text{Therefore, } Average\ Speed, u = \frac{(66.45+40.91+47.37+57.31+56.25+67.39)}{6}$$

$$= \underline{55.95 \text{ km/hr}}$$

The *density* (veh/km) is defined as the number of vehicles traveling over a unit length of road at an instant in time. This parameter was obtained by sum of all vehicles at the certain time divided by the selected distance. The sample calculation of measuring the density is shown below;

Given, No. of vehicles = 7

Distance = 100m

= 0.1km

Therefore, *Density*, K $= \frac{7}{0.1}$

$= \underline{70 \text{ veh/km}}$

The *density of direct flow* (veh/km) was obtained by sum of density divided by the number of recorded density at an instant in time. The sample calculation of measuring the density of direct flow is shown below;

Given, Density Data

40	30	80
50	70	

Therefore, *Density of direct flow*, K $= \frac{40 + 30 + 80 + 50 + 70}{5}$

$= \underline{54 \text{ veh/km}}$

3.7 Data Analysis Process

Every data that was obtained from the reduction process were transferred and exported to Microsoft Excel Software. This software is used to determine the relationship between average speed and density of direct flow of motorcycle on the exclusive motorcycle lane. A graph of average speed versus density is created to show the relationship of this data.

To illustrate how well field data measurements match with the mathematical models, density and speed values were fitted using least-square regressions, which minimize the difference between the observed data and the relationship calibrated. Table 3.2 presents the four models of Single-Regime Models.

Table 3.2 : The Model of Single-Regime Models

No.	Model	Equations
1.	Greenshields' Model (1934)	$u = u_f - \left(\frac{u_f}{k_j}\right).k$
2.	Greenberg Model (1959)	$u = u_o \ln\left(\frac{k_j}{k}\right)$
3.	Underwood Model (1961)	$u = u_f e^{-(k/k_o)}$
4.	Drake et al. Model (1967)	$u = u_f\ e^{-0.5(k/k_o)^2}$

Initial calibrations were made on speed-density relationships for two reasons. First, the structure of a speed-density curve is monotonically decreasing, and therefore involves simpler mathematical forms than flow-speed or flow-density curves. Secondly, this relationship denotes the most basic interaction of drivers and vehicles on highways [31, 32].

As a result of the linear relationship assumption, the Greenshields' Model can be directly calibrated using least-square regression. However, a transformation process is required in calibrating non-linear relationships in the models proposed by Greenberg Model, Underwood Model and Drake et al Model.

Assuming that, the relationship is in fact in the form y = mx + c, where y represents the dependent variable and x refers to the explanatory variable, the mathematical models can be equivalently expressed in the linear forms as shown in table 3.3.

Table 3.3 : Equivalent Linear Forms of Single-Regime Models

Model	Dependent variable, y	Explanatory variable, x	Intercept, a	Slope, b
Greenshields'	u	k	u_f	$-\frac{u_f}{k_j}$
Greenberg	u	ln(k)	$u_o \ln(k_j)$	$-u_o$
Underwood	ln(u)	k	$\ln(u_f)$	$-\frac{1}{k_o}$
Drake et al.	ln(u)	k^2	$\ln(u_f)$	$-\frac{1}{2k_o^2}$

3.8 Linear Regression Forms

The data analysis of average speed and density of direct flow were computed in comes up with a new macroscopic model. It was based on speed operation for the motorcycle lane. The Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model were selected for the model development.

The selected models help in developing a model of uninterrupted traffic flow. It can be predicted and explained the trends that are observed in real traffic flows. These models also are powerful where it can be derive relationships between average speed and density with linear regression graphically.

For the purpose of conducting this research, the overall framework in terms of the scope of works and this research method is illustrated in figure 3.5. The figure shows the steps and the process on how this research was conducted.

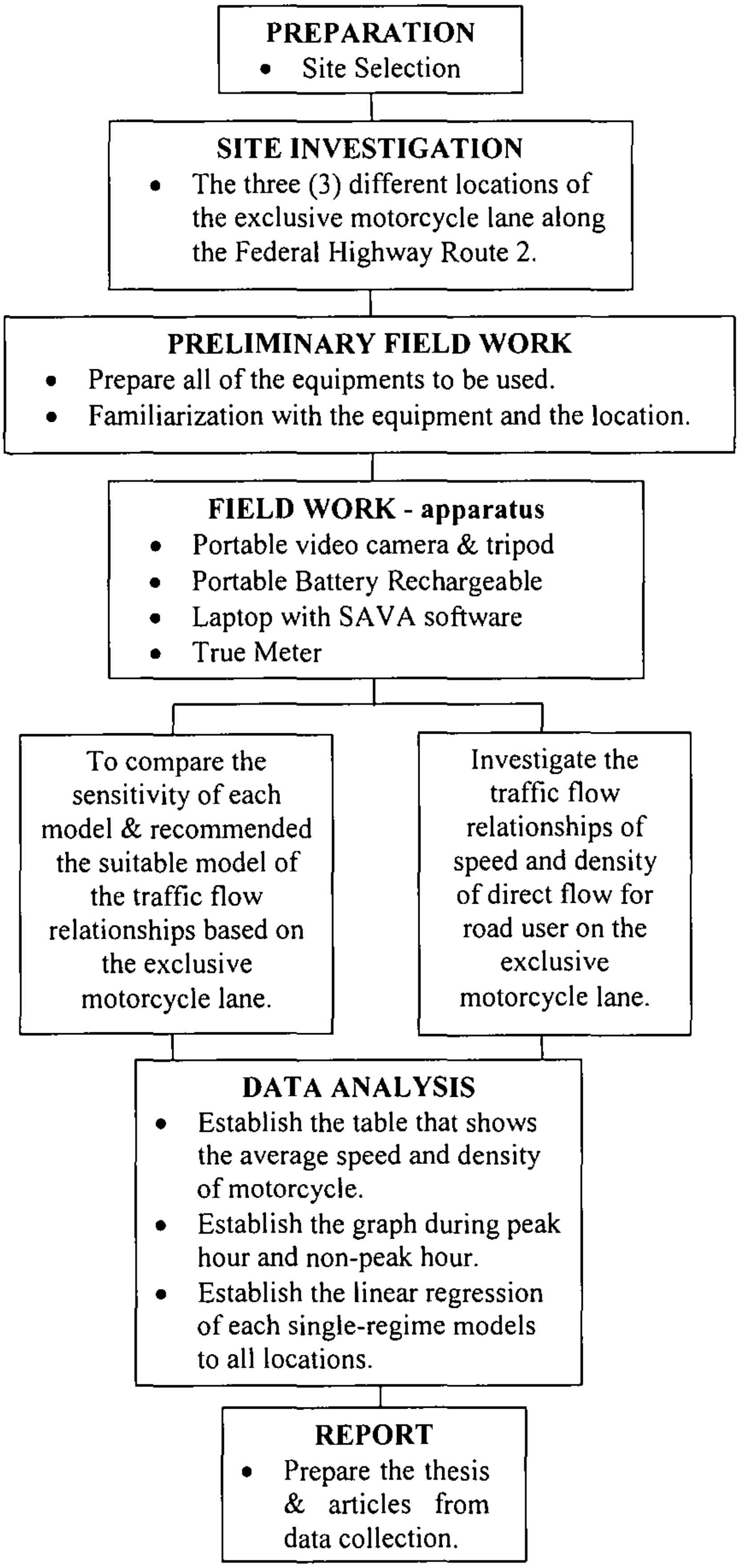


Figure 3.5 : Scope of Work

CHAPTER 4

RESULT, ANALYSIS AND DISCUSSION

4.1 Results

The Semi-Automatic Video Analyzer (SAVA) software was used to extract all the parameters from the video recording that was collected from the site. Table 4.1 shows the data extraction from the SAVA software at KM30.7 - Sungai Way location (Kuala Lumpur to Shah Alam, Selangor).

Table 4.1 : Data Extraction at Sungai Way – Kuala Lumpur to Shah Alam, Selangor

Day	Interval Time (min)	Distance (m)	No. of Mcy	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Density of Direct Flow, k (Mcy/km)
Monday (Non Peak Hour)	0 - 5	100	28	3.04	3.52	3.76	3.60	3.72	16
	5 -10	100	34	3.28	4.04	4.12	3.92	4.92	24
	10 - 15	100	37	3.36	3.56	4.24	4.20	4.52	28
	15 - 20	100	49	3.96	4.08	4.60	3.24	4.40	30
	20 - 25	100	26	3.48	4.12	4.20	4.00	4.16	18
	25 - 30	100	35	4.04	4.04	4.00	5.04	4.92	34
	30 - 35	100	31	4.12	3.84	4.48	4.92	3.92	16
	35 - 40	100	41	3.96	3.92	3.88	4.00	5.12	34
	40 - 45	100	37	4.40	3.56	3.72	4.40	4.92	26
	45 - 50	100	29	3.12	4.32	3.80	4.36	3.80	18
	50 - 55	100	33	3.96	3.76	4.04	4.08	3.96	20
	55 - 60	100	38	3.64	3.24	4.12	3.32	4.60	26
Monday (Peak Hour)	0 - 5	100	87	4.04	4.60	4.48	4.52	5.00	38
	5 -10	100	91	5.20	4.64	4.76	4.80	5.12	42
	10 - 15	100	101	5.08	5.44	4.92	4.48	4.96	40
	15 - 20	100	91	4.92	5.08	4.40	5.20	4.92	44
	20 - 25	100	80	5.80	4.56	4.72	5.00	4.44	36
	25 - 30	100	112	5.88	4.76	4.12	6.04	4.28	48
	30 - 35	100	77	5.32	4.88	4.60	5.12	4.08	34
	35 - 40	100	86	5.52	4.20	5.00	5.40	6.00	44
	40 - 45	100	103	5.04	4.52	5.96	6.16	5.72	52
	45 - 50	100	92	4.88	5.28	4.52	5.84	5.04	44
	50 - 55	100	99	4.96	4.84	5.88	5.04	5.80	46
	55 - 60	100	85	4.68	3.96	4.76	4.88	5.20	30

Tuesday (Non Peak Hour)	0 - 5	100	32	3.88	4.08	4.56	4.56	4.88	26
	5 -10	100	45	4.20	4.00	4.60	4.68	4.04	34
	10 - 15	100	52	3.88	4.24	5.08	3.88	4.68	30
	15 - 20	100	43	3.92	4.16	4.84	3.96	3.16	28
	20 - 25	100	39	4.00	3.56	3.52	4.04	3.32	16
	25 - 30	100	35	3.96	4.40	4.08	3.72	4.28	18
	30 - 35	100	31	3.64	5.28	4.12	5.28	4.72	32
	35 - 40	100	29	3.08	4.76	4.04	4.72	4.20	24
	40 - 45	100	36	3.16	5.04	3.84	4.88	3.52	22
	45 - 50	100	33	4.00	3.76	3.92	5.60	4.04	24
	50 - 55	100	40	3.96	4.96	3.56	5.20	4.20	30
	55 - 60	100	28	4.48	3.60	4.32	3.96	3.68	34
Tuesday (Peak Hour)	0 - 5	100	111	3.96	5.88	3.76	4.40	4.20	38
	5 -10	100	82	5.08	5.28	5.12	5.20	4.12	38
	10 - 15	100	79	5.24	4.72	4.92	5.68	5.36	40
	15 - 20	100	85	5.96	4.88	3.80	4.92	5.44	36
	20 - 25	100	98	6.04	5.60	5.04	4.76	5.92	52
	25 - 30	100	88	5.72	5.20	4.04	4.16	5.08	40
	30 - 35	100	101	4.88	3.96	4.64	5.52	4.88	38
	35 - 40	100	76	4.96	4.40	4.84	5.72	6.04	44
	40 - 45	100	72	4.72	4.28	4.60	5.04	5.16	36
	45 - 50	100	89	5.32	5.32	4.56	5.12	4.48	40
	50 - 55	100	85	5.68	5.72	5.76	4.88	4.60	42
	55 - 60	100	73	5.88	6.12	4.28	4.96	6.16	46
Wednesday (Non Peak Hour)	0 - 5	100	48	3.40	3.24	4.08	3.56	3.68	16
	5 -10	100	39	3.48	3.76	4.20	3.72	3.76	24
	10 - 15	100	43	3.20	4.20	4.52	4.12	4.52	30
	15 - 20	100	34	4.16	3.96	4.28	4.08	4.76	22
	20 - 25	100	30	4.08	4.12	5.04	3.52	4.84	40
	25 - 30	100	38	3.80	3.96	3.84	4.96	4.32	34
	30 - 35	100	44	3.52	4.28	3.28	4.12	4.04	28
	35 - 40	100	51	4.12	4.52	4.60	4.24	4.36	38
	40 - 45	100	47	4.04	3.08	4.32	3.48	5.16	36
	45 - 50	100	36	3.28	3.16	3.96	5.04	4.92	32
	50 - 55	100	47	5.04	4.04	4.52	4.36	5.16	36
	55 - 60	100	43	4.68	5.00	3.60	4.00	4.24	44
Wednesday (Peak Hour)	0 - 5	100	89	5.28	5.12	5.12	5.20	5.16	36
	5 -10	100	78	4.72	5.56	5.24	5.76	5.56	50
	10 - 15	100	103	4.88	5.32	6.12	4.60	5.16	46
	15 - 20	100	97	5.60	4.72	5.72	5.88	6.20	52
	20 - 25	100	69	5.20	5.92	4.88	5.48	5.16	44
	25 - 30	100	72	3.96	5.68	4.96	5.20	5.08	38
	30 - 35	100	85	4.40	5.32	5.84	5.04	4.96	40
	35 - 40	100	74	5.00	5.04	6.16	5.28	4.76	42
	40 - 45	100	83	4.88	4.84	5.96	5.72	5.92	46
	45 - 50	100	80	5.60	4.04	5.76	5.80	5.32	48
	50 - 55	100	74	6.12	4.72	4.52	4.96	5.24	44
	55 - 60	100	68	5.96	4.56	4.60	4.56	5.80	40
Thursday (Non Peak Hour)	0 - 5	100	37	3.32	3.52	3.96	4.36	4.84	18
	5 -10	100	41	3.48	4.96	4.52	4.08	5.12	22
	10 - 15	100	35	3.64	4.12	4.84	4.56	4.20	38
	15 - 20	100	28	4.04	4.24	4.96	3.96	4.12	38
	20 - 25	100	29	3.56	3.48	4.36	4.76	3.92	16
	25 - 30	100	34	3.64	4.08	4.76	4.52	4.04	24
	30 - 35	100	36	4.12	4.12	4.16	4.04	4.68	36
	35 - 40	100	42	4.83	4.04	3.32	4.20	4.12	26
	40 - 45	100	35	4.76	3.84	3.88	4.00	4.32	34
	45 - 50	100	48	3.96	3.92	4.08	3.96	4.72	34
	50 - 55	100	33	3.76	3.56	3.96	3.80	3.52	16
	55 - 60	100	27	4.04	4.32	3.88	3.52	4.08	28

	0 - 5	100	73	4.88	4.76	5.40	4.96	5.84	46
	5 -10	100	94	5.20	5.24	5.20	5.72	6.16	52
	10 - 15	100	95	5.16	5.04	4.76	4.56	5.84	30
	15 - 20	100	85	4.76	4.76	4.60	4.92	5.24	32
	20 - 25	100	101	6.12	4.12	4.16	4.12	5.56	46
Thursday (Peak Hour)	25 - 30	100	79	5.92	4.72	5.72	4.52	4.80	48
	30 - 35	100	84	5.72	4.28	6.16	5.64	5.60	50
	35 - 40	100	89	4.88	5.04	4.32	5.12	4.72	44
	40 - 45	100	84	6.04	5.36	3.88	4.96	4.56	36
	45 - 50	100	75	4.96	4.72	5.56	5.44	4.96	44
	50 - 55	100	94	4.84	6.44	4.80	4.88	5.44	42
	55 - 60	100	69	4.92	4.52	4.16	4.92	6.12	28
	0 - 5	100	32	3.64	3.80	3.76	4.32	4.52	26
	5 -10	100	38	4.28	4.08	4.00	3.44	3.64	24
	10 - 15	100	40	4.12	3.96	4.24	3.88	4.72	34
	15 - 20	100	39	4.20	3.84	5.08	4.72	5.56	36
	20 - 25	100	28	3.48	4.16	5.60	4.68	4.72	18
Friday (Non Peak Hour)	25 - 30	100	35	3.20	3.60	3.64	5.00	4.12	20
	30 - 35	100	27	4.08	4.20	4.08	4.84	3.56	16
	35 - 40	100	38	4.12	3.92	4.60	3.72	5.12	18
	40 - 45	100	31	4.04	4.04	5.12	3.80	4.48	32
	45 - 50	100	38	3.84	4.20	3.84	3.24	3.76	18
	50 - 55	100	32	5.16	3.96	3.92	3.56	3.88	20
	55 - 60	100	25	4.12	3.16	4.24	4.12	3.64	16
	0 - 5	100	79	5.24	5.12	6.32	6.28	5.32	52
	5 -10	100	94	5.72	5.28	6.24	4.96	4.84	42
	10 - 15	100	84	5.04	5.68	6.16	4.88	6.08	50
	15 - 20	100	82	4.84	6.04	5.68	5.72	4.72	36
	20 - 25	100	87	4.40	6.48	4.88	5.80	6.12	44
Friday (Peak Hour)	25 - 30	100	101	5.72	4.96	6.00	4.96	5.60	46
	30 - 35	100	76	4.88	5.32	3.96	5.76	5.36	38
	35 - 40	100	79	4.84	4.88	4.88	5.52	5.88	42
	40 - 45	100	81	6.16	4.76	4.76	4.76	4.84	44
	45 - 50	100	84	5.76	5.84	5.16	4.84	5.36	46
	50 - 55	100	78	4.80	4.92	5.36	5.08	4.76	36
	55 - 60	100	64	5.88	6.00	4.92	5.36	4.96	38

From the table 4.1, it shows the collection of data for five working days for a distance of 100m with a time interval of 5 minutes. The other two sets of data extraction of location KM15.8 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur and KM31.5 Petaling Jaya from Shah Alam, Selangor to Kuala Lumpur can be viewed at Appendix A.

The reduction process of all data extraction should be considered first before getting the parameters used in this study. The data calculation is a obtain data when the reduction process were done as well. Therefore, table 4.2 presents the data calculation for location KM30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor and the other two sets of data calculations can be viewed at Appendix B.

Table 4.2 : Data Calculation at Sungai Way – Kuala Lumpur to Shah Alam, Selangor

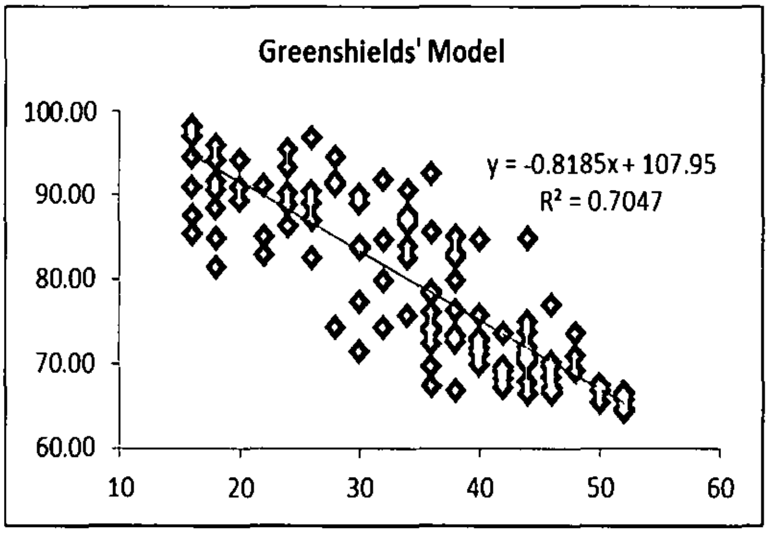
Day	Interval Time (min)	Set 1 Speed (km/hr)	Set 2 Speed (km/hr)	Set 3 Speed (km/hr)	Set 4 Speed (km/hr)	Set 5 Speed (km/hr)	Average Speed, u (km/hr)	ln(u)	Density of Direct Flow, k(Mcy/km)	ln(k)	k^2
Monday (Non Peak Hour)	0-5	118.42	102.27	95.74	100.00	96.77	102.64	4.6313	16	2.7726	256
	5-10	109.76	89.11	87.38	91.84	73.17	90.25	4.5026	24	3.1781	576
	10-15	107.14	101.12	84.91	85.71	79.65	91.71	4.5186	28	3.3322	784
	15-20	90.91	88.24	78.26	111.11	81.82	90.07	4.5006	30	3.4012	900
	20-25	103.45	87.38	85.71	90.00	86.54	90.62	4.5066	18	2.8904	324
	25-30	89.11	89.11	90.00	71.43	73.17	82.56	4.4136	34	3.5264	1156
	30-35	87.38	93.75	80.36	73.17	91.84	85.30	4.4462	16	2.7726	256
	35-40	90.91	91.84	92.78	90.00	70.31	87.17	4.4678	34	3.5264	1156
	40-45	81.82	101.12	96.77	81.82	73.17	86.94	4.4652	26	3.2581	676
	45-50	115.38	83.33	94.74	82.57	94.74	94.15	4.5449	18	2.8904	324
	50-55	90.91	95.74	89.11	88.24	90.91	90.98	4.5107	20	2.9957	400
	55-60	98.90	111.11	87.38	108.43	78.26	96.82	4.5728	26	3.2581	676
Monday (Peak Hour)	0-5	89.11	78.26	80.36	79.65	72.00	79.87	4.3805	38	3.6376	1444
	5-10	69.23	77.59	75.63	75.00	70.31	73.55	4.2980	42	3.7377	1764
	10-15	70.87	66.18	73.17	80.36	72.58	72.63	4.2854	40	3.6889	1600
	15-20	73.17	70.87	81.82	69.23	73.17	73.65	4.2993	44	3.7842	1936
	20-25	62.07	78.95	76.27	72.00	81.08	74.07	4.3051	36	3.5835	1296
	25-30	61.22	75.63	87.38	59.60	84.11	73.59	4.2985	48	3.8712	2304
	30-35	67.67	73.77	78.26	70.31	88.24	75.65	4.3261	34	3.5264	1156
	35-40	65.22	85.71	72.00	66.67	60.00	69.92	4.2473	44	3.7842	1936
	40-45	71.43	79.65	60.40	58.44	62.94	66.57	4.1983	52	3.9512	2704
	45-50	73.77	68.18	79.65	61.64	71.43	70.93	4.2618	44	3.7842	1936
	50-55	72.58	74.38	61.22	71.43	62.07	68.34	4.2244	46	3.8286	2116
	55-60	76.92	90.91	75.63	73.77	69.23	77.29	4.3476	30	3.4012	900
Tuesday (Non Peak Hour)	0-5	92.78	88.24	78.95	78.95	73.77	82.54	4.4132	26	3.2581	676
	5-10	85.71	90.00	78.26	76.92	89.11	84.00	4.4308	34	3.5264	1156
	10-15	92.78	84.91	70.87	92.78	76.92	83.65	4.4267	30	3.4012	900
	15-20	91.84	86.54	74.38	90.91	113.92	91.52	4.5165	28	3.3322	784
	20-25	90.00	101.12	102.27	89.11	108.43	98.19	4.5869	16	2.7726	256
	25-30	90.91	81.82	88.24	96.77	84.11	88.37	4.4815	18	2.8904	324
	30-35	98.90	68.18	87.38	68.18	76.27	79.78	4.3793	32	3.4657	1024
	35-40	116.88	75.63	89.11	76.27	85.71	88.72	4.4855	24	3.1781	576
	40-45	113.92	71.43	93.75	73.77	102.27	91.03	4.5112	22	3.0910	484
	45-50	90.00	95.74	91.84	64.29	89.11	86.20	4.4566	24	3.1781	576
	50-55	90.91	72.58	101.12	69.23	85.71	83.91	4.4298	30	3.4012	900
	55-60	80.36	100.00	83.33	90.91	97.83	90.49	4.5052	34	3.5264	1156

	0-5	90.91	61.22	95.74	81.82	85.71	83.08	4.4198	38	3.6376	1444
	5-10	70.87	68.18	70.31	69.23	87.38	73.19	4.2931	38	3.6376	1444
	10-15	68.70	76.27	73.17	63.38	67.16	69.74	4.2447	40	3.6889	1600
	15-20	60.40	73.77	94.74	73.17	66.18	73.65	4.2993	36	3.5835	1296
	20-25	59.60	64.29	71.43	75.63	60.81	66.35	4.1950	52	3.9512	2704
Tuesday	25-30	62.94	69.23	89.11	86.54	70.87	75.74	4.3273	40	3.6889	1600
(Peak Hour)	30-35	73.77	90.91	77.59	65.22	73.77	76.25	4.3340	38	3.6376	1444
	35-40	72.58	81.82	74.38	62.94	59.60	70.26	4.2523	44	3.7842	1936
	40-45	76.27	84.11	78.26	71.43	69.77	75.97	4.3303	36	3.5835	1296
	45-50	67.67	67.67	78.95	70.31	80.36	72.99	4.2903	40	3.6889	1600
	50-55	63.38	62.94	62.50	73.77	78.26	68.17	4.2220	42	3.7377	1764
	55-60	61.22	58.82	84.11	72.58	58.44	67.04	4.2052	46	3.8286	2116
	0-5	105.88	111.11	88.24	101.12	97.83	100.84	4.6135	16	2.7726	256
	5-10	103.45	95.74	85.71	96.77	95.74	95.49	4.5590	24	3.1781	576
	10-15	112.50	85.71	79.65	87.38	79.65	88.98	4.4884	30	3.4012	900
	15-20	86.54	90.91	84.11	88.24	75.63	85.09	4.4437	22	3.0910	484
	20-25	88.24	87.38	71.43	102.27	74.38	84.74	4.4396	40	3.6889	1600
Wednesday	25-30	94.74	90.91	93.75	72.58	83.33	87.06	4.4666	34	3.5264	1156
(Non Peak	30-35	102.27	84.11	109.76	87.38	89.11	94.53	4.5489	28	3.3322	784
Hour)	35-40	87.38	79.65	78.26	84.91	82.57	82.55	4.4134	38	3.6376	1444
	40-45	89.11	116.88	83.33	103.45	69.77	92.51	4.5273	36	3.5835	1296
	45-50	109.76	113.92	90.91	71.43	73.17	91.84	4.5200	32	3.4657	1024
	50-55	71.43	89.11	79.65	82.57	69.77	78.50	4.3631	36	3.5835	1296
	55-60	76.92	72.00	100.00	90.00	84.91	84.77	4.4399	44	3.7842	1936
	0-5	68.18	70.31	70.31	69.23	69.77	69.56	4.2422	36	3.5835	1296
	5-10	76.27	64.75	68.70	62.50	64.75	67.39	4.2106	50	3.9120	2500
	10-15	73.77	67.67	58.82	78.26	69.77	69.66	4.2436	46	3.8286	2116
	15-20	64.29	76.27	62.94	61.22	58.06	64.56	4.1675	52	3.9512	2704
	20-25	69.23	60.81	73.77	65.69	69.77	67.85	4.2174	44	3.7842	1936
Wednesday	25-30	90.91	63.38	72.58	69.23	70.87	73.39	4.2958	38	3.6376	1444
(Peak Hour)	30-35	81.82	67.67	61.64	71.43	72.58	71.03	4.2631	40	3.6889	1600
	35-40	72.00	71.43	58.44	68.18	75.63	69.14	4.2361	42	3.7377	1764
	40-45	73.77	74.38	60.40	62.94	60.81	66.46	4.1966	46	3.8286	2116
	45-50	64.29	89.11	62.50	62.07	67.67	69.13	4.2359	48	3.8712	2304
	50-55	58.82	76.27	79.65	72.58	68.70	71.20	4.2656	44	3.7842	1936
	55-60	60.40	78.95	78.26	78.95	62.07	71.73	4.2728	40	3.6889	1600
	0-5	108.43	102.27	90.91	82.57	74.38	91.71	4.5187	18	2.8904	324
	5-10	103.45	72.58	79.65	88.24	70.31	82.84	4.4170	22	3.0910	484
	10-15	98.90	87.38	74.38	78.95	85.71	85.06	4.4434	38	3.6376	1444
	15-20	89.11	84.91	72.58	90.91	87.38	84.98	4.4424	38	3.6376	1444
	20-25	101.12	103.45	82.57	75.63	91.84	90.92	4.5100	16	2.7726	256
Thursday	25-30	98.90	88.24	75.63	79.65	89.11	86.30	4.4579	24	3.1781	576
(Non Peak	30-35	87.38	87.38	86.54	89.11	76.92	85.47	4.4481	36	3.5835	1296
Hour)	35-40	74.53	89.11	108.43	85.71	87.38	89.03	4.4890	26	3.2581	676
	40-45	75.63	93.75	92.78	90.00	83.33	87.10	4.4671	34	3.5264	1156
	45-50	90.91	91.84	88.24	90.91	76.27	87.63	4.4731	34	3.5264	1156
	50-55	95.74	101.12	90.91	94.74	102.27	96.96	4.5743	16	2.7726	256
	55-60	89.11	83.33	92.78	102.27	88.24	91.15	4.5125	28	3.3322	784
	0-5	73.77	75.63	66.67	72.58	61.64	70.06	4.2493	46	3.8286	2116
	5-10	69.23	68.70	69.23	62.94	58.44	65.71	4.1852	52	3.9512	2704
	10-15	69.77	71.43	75.63	78.95	61.64	71.48	4.2695	30	3.4012	900
	15-20	75.63	75.63	78.26	73.17	68.70	74.28	4.3078	32	3.4657	1024
	20-25	58.82	87.38	86.54	87.38	64.75	76.97	4.3435	46	3.8286	2116
Thursday	25-30	60.81	76.27	62.94	79.65	75.00	70.93	4.2617	48	3.8712	2304
(Peak Hour)	30-35	62.94	84.11	58.44	63.83	64.29	66.72	4.2005	50	3.9120	2500
	35-40	73.77	71.43	83.33	70.31	76.27	75.02	4.3178	44	3.7842	1936

	40-45	59.60	67.16	92.78	72.58	78.95	74.22	4.3070	36	3.5835	1296
	45-50	72.58	76.27	64.75	66.18	72.58	70.47	4.2552	44	3.7842	1936
	50-55	74.38	55.90	75.00	73.77	66.18	69.05	4.2348	42	3.7377	1764
	55-60	73.17	79.65	86.54	73.17	58.82	74.27	4.3077	28	3.3322	784
Friday (Non Peak Hour)	0-5	98.90	94.74	95.74	83.33	79.65	90.47	4.5050	26	3.2581	676
	5-10	84.11	88.24	90.00	104.65	98.90	93.18	4.5345	24	3.1781	576
	10-15	87.38	90.91	84.91	92.78	76.27	86.45	4.4596	34	3.5264	1156
	15-20	85.71	93.75	70.87	76.27	64.75	78.27	4.3602	36	3.5835	1296
	20-25	103.45	86.54	64.29	76.92	76.27	81.49	4.4005	18	2.8904	324
	25-30	112.50	100.00	98.90	72.00	87.38	94.16	4.5450	20	2.9957	400
	30-35	88.24	85.71	88.24	74.38	101.12	87.54	4.4721	16	2.7726	256
	35-40	87.38	91.84	78.26	96.77	70.31	84.91	4.4416	18	2.8904	324
	40-45	89.11	89.11	70.31	94.74	80.36	84.72	4.4394	32	3.4657	1024
	45-50	93.75	85.71	93.75	111.11	95.74	96.01	4.5645	18	2.8904	324
	50-55	69.77	90.91	91.84	101.12	92.78	89.28	4.4918	20	2.9957	400
	55-60	87.38	113.92	84.91	87.38	98.90	94.50	4.5486	16	2.7726	256
Friday (Peak Hour)	0-5	68.70	70.31	56.96	57.32	67.67	64.19	4.1619	52	3.9512	2704
	5-10	62.94	68.18	57.69	72.58	74.38	67.15	4.2070	42	3.7377	1764
	10-15	71.43	63.38	58.44	73.77	59.21	65.25	4.1782	50	3.9120	2500
	15-20	74.38	59.60	63.38	62.94	76.27	67.31	4.2094	36	3.5835	1296
	20-25	81.82	55.56	73.77	62.07	58.82	66.41	4.1958	44	3.7842	1936
	25-30	62.94	72.58	60.00	72.58	64.29	66.48	4.1969	46	3.8286	2116
	30-35	73.77	67.67	90.91	62.50	67.16	72.40	4.2822	38	3.6376	1444
	35-40	74.38	73.77	73.77	65.22	61.22	69.67	4.2438	42	3.7377	1764
	40-45	58.44	75.63	75.63	75.63	74.38	71.94	4.2759	44	3.7842	1936
	45-50	62.50	61.64	69.77	74.38	67.16	67.09	4.2061	46	3.8286	2116
	50-55	75.00	73.17	67.16	70.87	75.63	72.37	4.2817	36	3.5835	1296
	55-60	61.22	60.00	73.17	67.16	72.58	66.83	4.2021	38	3.6376	1444

From the data calculation, all the data that obtained were transferred and imported to Microsoft Excel Software. A graph of average speed versus density of direct flow is created to show the relationship of this data. Besides that, the linear graphs of Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model are created to show the best fit of all data collection.

Figure 4.1(a) and figure 4.1(b) presents the graph of each model that is applied in this study for location KM30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor. The other two set graph of each model that applied in this study can be viewed at Appendix C.



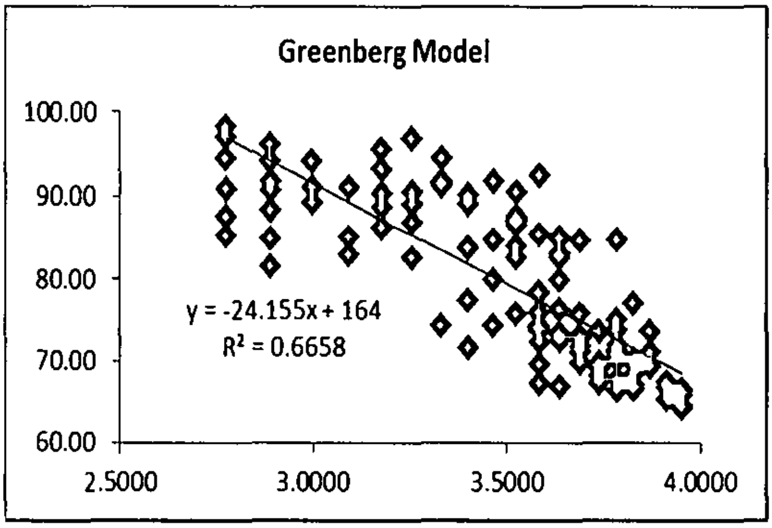
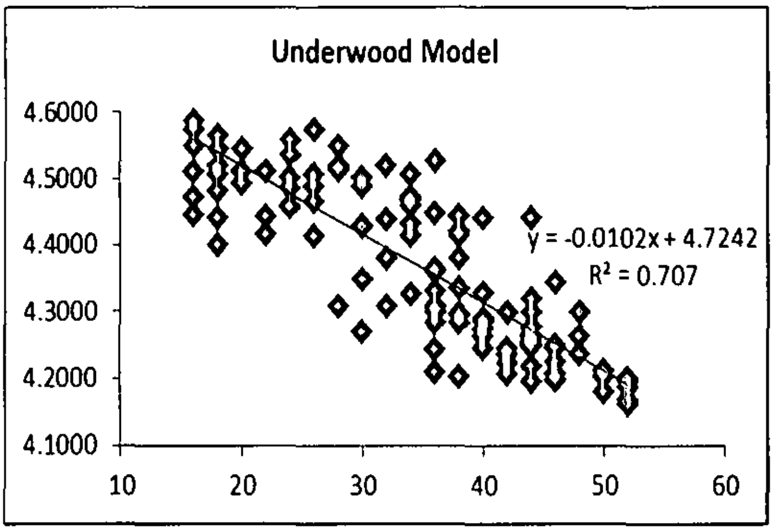


Figure 4.1(a) : A Graph of Greenshields' Model and Greenberg Model for location at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)



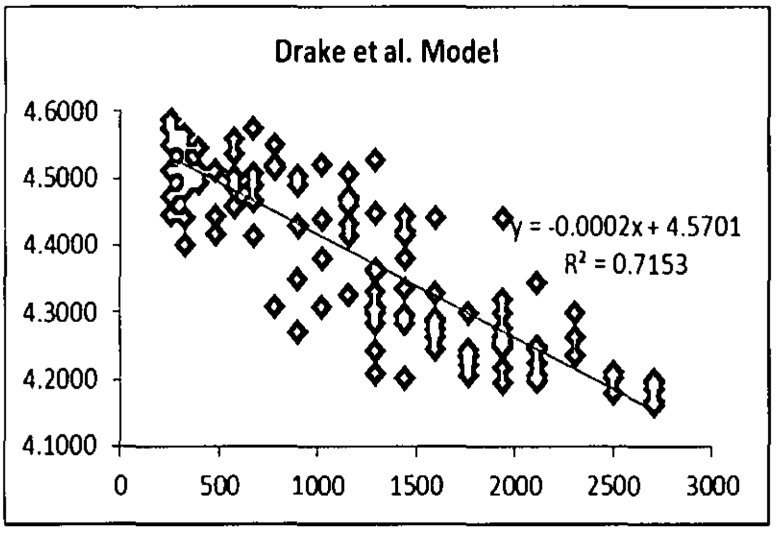


Figure 4.1(b) : A Graph of Underwood Model and Drake et al. Model for location at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

Figure 4.2 shows the histogram of average speed for location KM 30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor and the other two histogram data collections of average speed can be viewed at Appendix D.

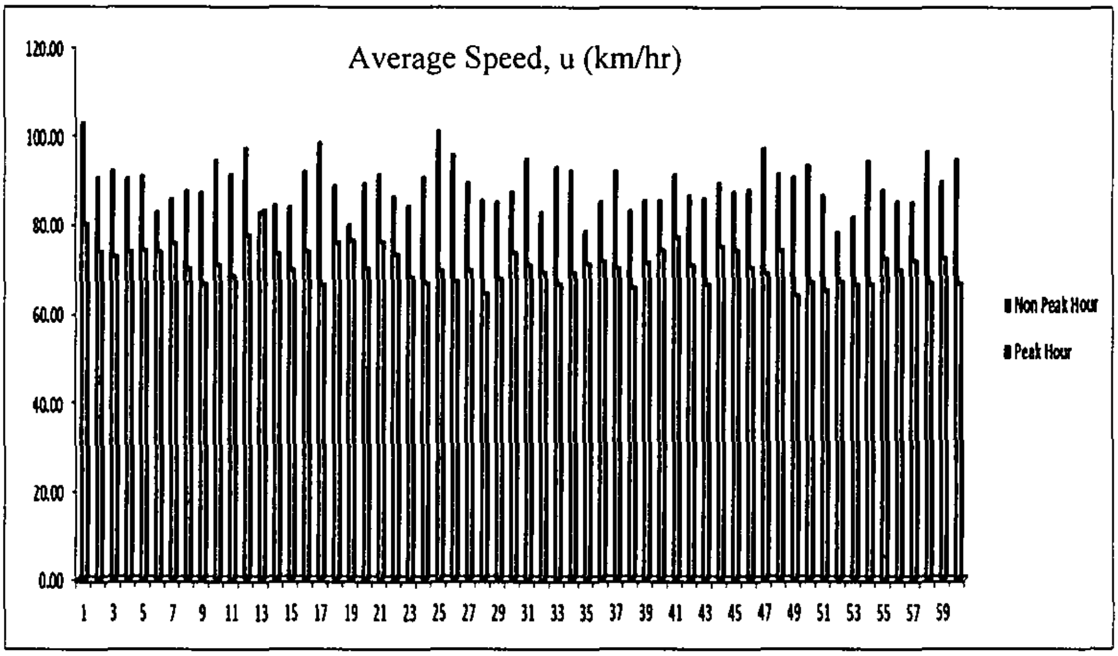


Figure 4.2 : Histogram of Average Speed at KM30.7- Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the figure 4.2, it presents that the average speed for non-peak hour condition is higher than peak hour condition. The average speed refers to the sum of spot speed of five selected motorcyclists divided by five numbers of recorded speeds. The number of motorcycle in peak hour is higher than the number of motorcycle in non-peak hour. Under non-peak hour conditions, motorcyclists move at speeds that are controlled by the motorcycles and the roadway conditions.

Figure 4.3 shows the histogram of density of direct flow for location KM 15.8 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur and the other two histogram data collections of density of direct flow can be viewed at Appendix E.

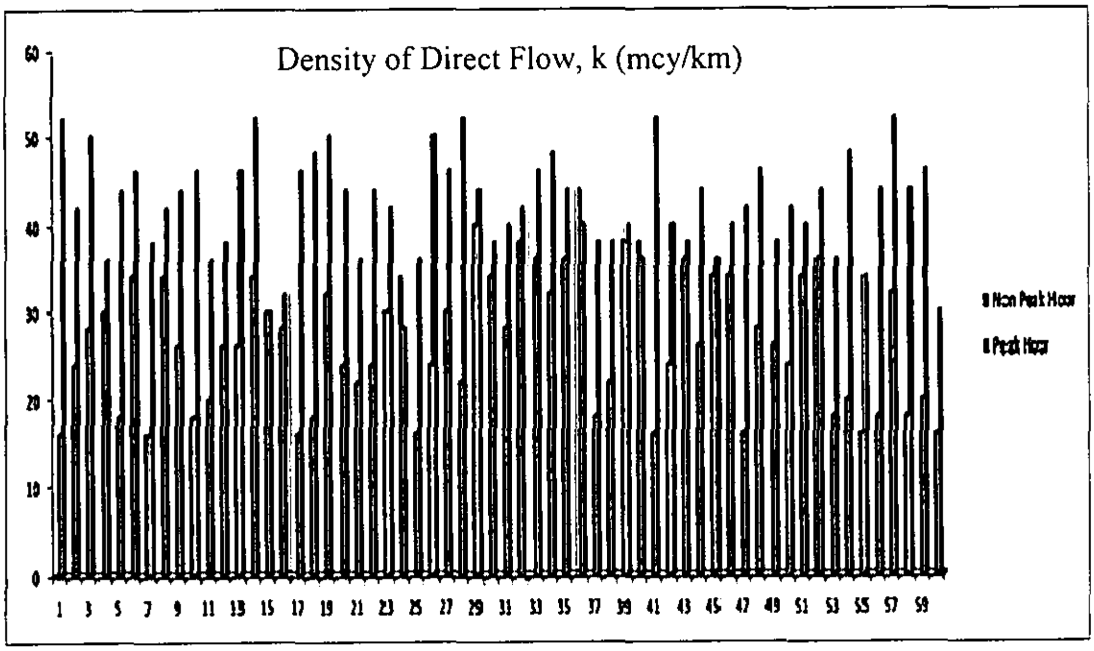


Figure 4.3 : Histogram of Density of Direct Flow at KM30.7- Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the figure 4.3, it shows that the density of direct flow for peak hour condition is higher than non-peak hour condition. It is because the value of density of direct flow is based on the number of motorcycle that passed through the study location. Under low-density conditions, motorcyclists no longer worry about other motorcycles. They move at speeds that are controlled by the performance of their motorcycles and the conditions of the roadway. This phenomenon can cause traffic accidents that can lead to injuries and/or death.

4.3 Analysis

From the data calculation, four set of graphs that show the speed-density relationship can be determined. The each graph was using Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model.

Figure 4.4, Figure 4.5, figure 4.6 and figure 4.7 present the graph of speed-density relationship using four models that applied in this study. The figure shows the graph of density versus speed for location KM30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor.

On the other hand, the two sets of graphs for location KM15.8 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur and KM31.5 Petaling Jaya from Shah Alam, Selangor to Kuala Lumpur can be viewed at Appendix F.

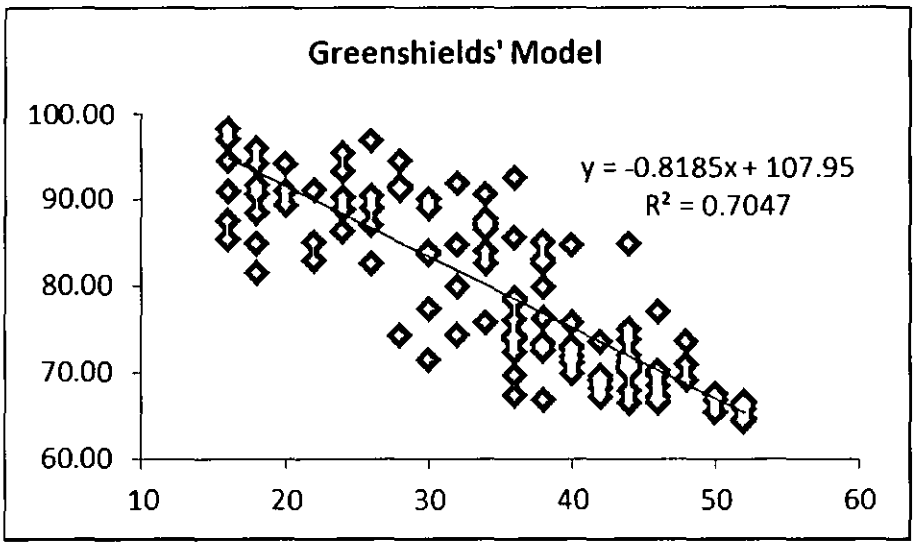


Figure 4.4 : A Graph of Density vs Speed of Greenshields' Model at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the graph above,

y = -0.8185x + 107.95

Intercept, a = u_f

$= \underline{107.95 \text{ km/hr}}$

Slope, b = $-\dfrac{u_f}{k_j}$

Therefore, $-\dfrac{u_f}{k_j} = -0.8185$

$-\dfrac{107.95}{k_j} = -0.8185$

$k_j = \dfrac{-107.95}{-0.8185}$

$= \underline{132 \text{ mc/km}}$

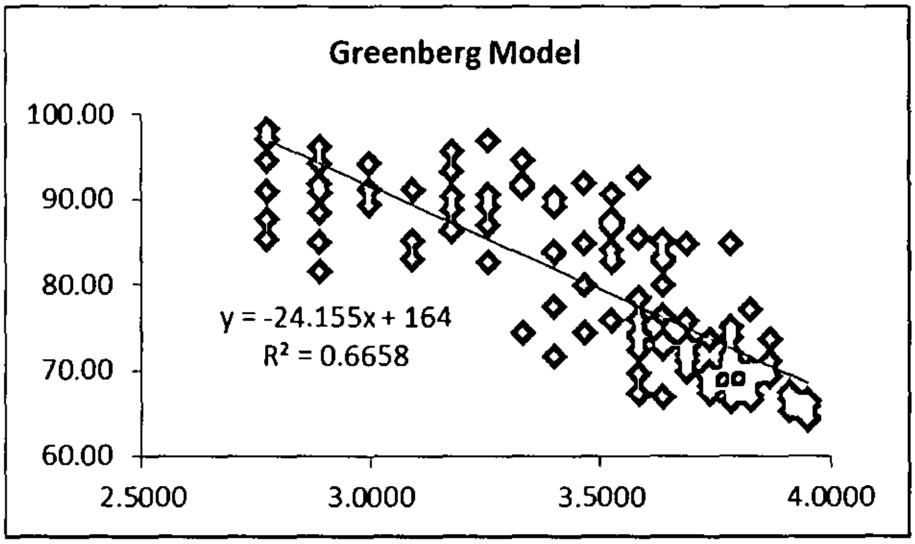


Figure 4.5 : A Graph of Density vs Speed of Greenberg Model at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the graph above,

$y = -24.155x + 164$

Slope, $b = -u_o$

$-u_o = -24.155$

$\underline{= 24.16 \text{ km/hr}}$

Intercept, $a = u_o \ln(k_j)$

$\underline{= 164}$

Therefore, $u_o \ln(k_j) = 164$

$24.155 \ln(k_j) = 164$

$\ln(k_j) = \dfrac{164.00}{24.155}$

$\ln(k_j) = 6.789$

$k_j = e^{7.552}$

$\underline{= 889 \text{ mc/km}}$

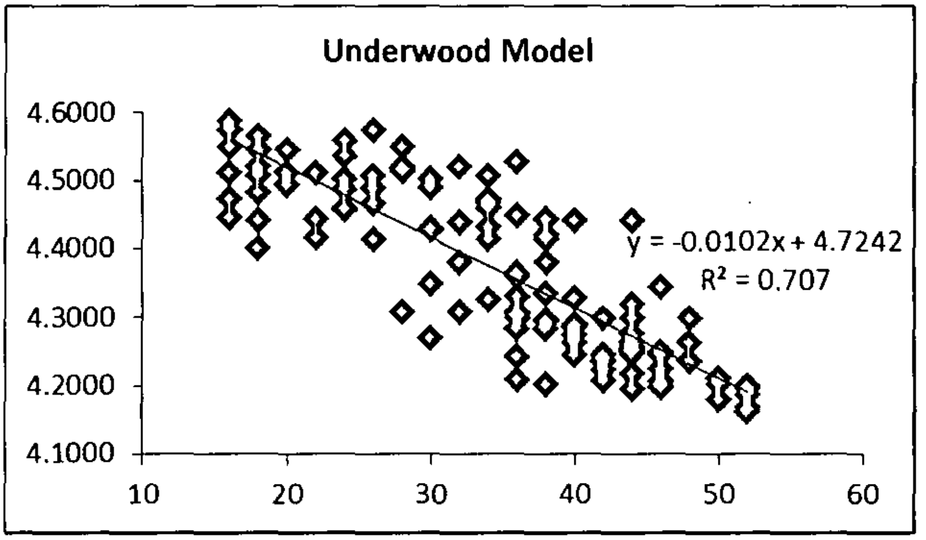


Figure 4.6 : A Graph of Density vs Speed of Underwood Model at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the graph above,

$y = -0.0102x + 4.7242$

Intercept, $a = \ln(u_f)$

$\ln(u_f) = 4.7242$

$= \underline{112.64 \text{ km/hr}}$

Slope, $b = -\dfrac{1}{k_o}$

$= \underline{-0.0102}$

Therefore, $-\dfrac{1}{k_o} = -0.0102$

$-\dfrac{1}{k_o} = -0.0102$

$k_o = \dfrac{-1}{-0.0102}$

$= \underline{99 \text{ mc/km}}$

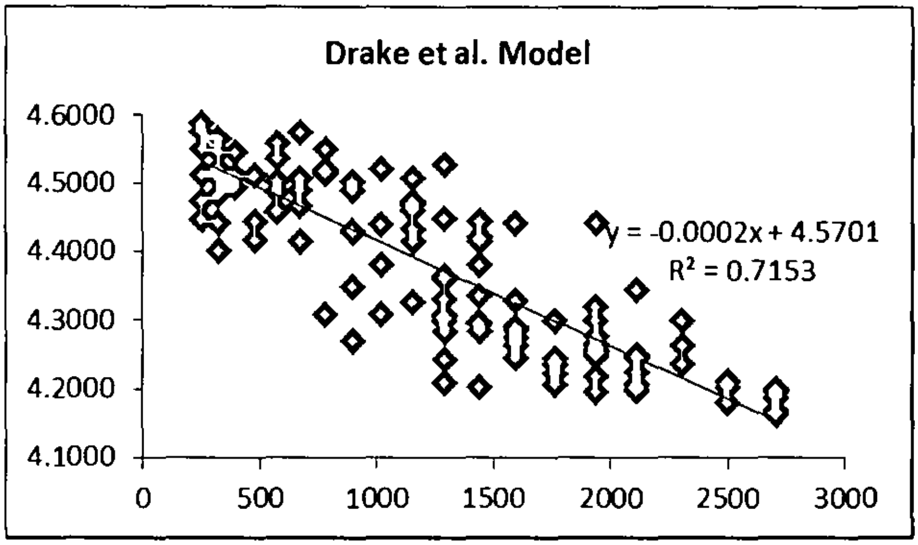


Figure 4.7 : A Graph of Density vs Speed of Drake et al. Model at KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)

From the graph above,

$y = -0.0002x + 4.5701$

Intercept, $a = \ln(u_f)$

$\ln(u_f) = 4.5701$

$= \underline{96.55 \text{ km/hr}}$

Slope, $b = -\dfrac{1}{2k_o^2}$

$= \underline{-0.0002}$

Therefore, $-\dfrac{1}{2k_o^2} = -0.0002$

$-\dfrac{1}{2k_o^2} = -0.0002$

$2k_o^2 = \dfrac{-1}{-0.0002}$

$= \underline{50 \text{ mc/km}}$

From the figure 4.4, figure 4.5, figure 4.6 and figure 4.7, four sets of model estimation results were developed, based on the datasets. Table 4.3 presents the estimation results in form of linear regression for the four single-regime models that have been used in this study.

Table 4.3 : Linear Regression Forms of Single-Regime Models at Three Locations

Location / Model	Batu 3 – Shah Alam, Selangor to Kuala Lumpur	Sungai Way – Kuala Lumpur to Shah Alam, Selangor	Petaling Jaya – Shah Alam, Selangor to Kuala Lumpur
Greenshields' Model	y = -0.6639x + 103.25 (R^2 = 0.6458)	y = -0.8185x + 107.95 (R^2 = 0.7047)	y = -0.5474x + 100.47 (R^2 = 0.6045)
Greenberg Model	y = -19.829x + 149.75 (R^2 = 0.6057)	y = -24.155x + 164 (R^2 = 0.6658)	y = -16.427x + 138.76 (R^2 = 0.5650)
Underwood Model	y = -0.0083x + 4.667 (R^2 = 0.6573)	y = -0.0102x + 4.7242 (R^2 = 0.7070)	y = -0.0068x + 4.630 (R^2 = 0.6118)
Drake et al. Model	y = -0.0001x + 4.5383 (R^2 = 0.6657)	y = -0.0002x + 4.5701 (R^2 = 0.7153)	y = -0.0001x + 4.5283 (R^2 = 0.6271)

From table 4.3 indicates that the Drake et al. Model is the best model to be applied in this study. This is because the highest value of R-square for the four types of single-regime model used in this study.

4.4 Verification Analysis

Based on the results from table 4.3, the verification analysis should be done also to confirm the best model set is compatible or not with the other location studies. Therefore, a set of data was taken from KM18.3 at Batu 3 location from Shah Alam, Selangor to Kuala Lumpur. Table 4.4 presents all the data calculation for that location after the data reduction process done as well using SAVA Software.

Table 4.4 : Data Calculation at KM18.3 - Batu 3 (Shah Alam, Selangor to Kuala Lumpur)

Interval Time (min)	Distance (m)	No. of Mcy	Set 1	Set 2	Set 3	Set 4	Set 5	Average Speed, u (km/hr)	ln(u)	Density of Direct Flow, k (Mcy/km)	k^2
			Speed (km/hr)	Speed (km/hr)	Speed (km/hr)	Speed (km/hr)	Speed (km/hr)				
0 - 5	100	28	118.42	102.27	95.74	100.00	96.77	102.64	4.6313	16	256
5 -10	100	34	109.76	89.11	87.38	91.84	73.17	90.25	4.5026	24	576
10 - 15	100	37	107.14	101.12	84.91	85.71	79.65	91.71	4.5186	28	784
15 - 20	100	49	90.91	88.24	78.26	111.11	81.82	90.07	4.5006	30	900
20 - 25	100	26	103.45	87.38	85.71	90.00	86.54	90.62	4.5066	18	324
25 - 30	100	35	89.11	89.11	90.00	71.43	73.17	82.56	4.4136	34	1156
30 - 35	100	31	87.38	93.75	80.36	73.17	91.84	85.30	4.4462	16	256
35 - 40	100	41	90.91	91.84	92.78	90.00	70.31	87.17	4.4678	34	1156
40 - 45	100	37	81.82	101.12	96.77	81.82	73.17	86.94	4.4652	26	676
45 - 50	100	29	115.38	83.33	94.74	82.57	94.74	94.15	4.5449	18	324
50 - 55	100	33	90.91	95.74	89.11	88.24	90.91	90.98	4.5107	20	400
55 - 60	100	38	98.90	111.11	87.38	108.43	78.26	96.82	4.5728	26	676
0 - 5	100	87	89.11	78.26	80.36	79.65	72.00	79.87	4.3805	38	1444
5 -10	100	91	69.23	77.59	75.63	75.00	70.31	73.55	4.2980	42	1764
10 - 15	100	101	70.87	66.18	73.17	80.36	72.58	72.63	4.2854	40	1600
15 - 20	100	91	73.17	70.87	81.82	69.23	73.17	73.65	4.2993	44	1936
20 - 25	100	80	62.07	78.95	76.27	72.00	81.08	74.07	4.3051	36	1296
25 - 30	100	112	61.22	75.63	87.38	59.60	84.11	73.59	4.2985	48	2304
30 - 35	100	77	67.67	73.77	78.26	70.31	88.24	75.65	4.3261	34	1156
35 - 40	100	86	65.22	85.71	72.00	66.67	60.00	69.92	4.2473	44	1936
40 - 45	100	103	71.43	79.65	60.40	58.44	62.94	66.57	4.1983	52	2704
45 - 50	100	92	73.77	68.18	79.65	61.64	71.43	70.93	4.2618	44	1936
50 - 55	100	99	72.58	74.38	61.22	71.43	62.07	68.34	4.2244	46	2116
55 - 60	100	85	76.92	90.91	75.63	73.77	69.23	77.29	4.3476	30	900

From the data calculation, the obtained data were transferred and imported into a graph of linear equation, $y = -0.0002x + 4.5701$.Therefore, a linear graph with a 5% error bars have been made to show all data collection.

The recommended number of test runs to obtained overall speed, travel time or traffic volume within certain limits of error and with 90% confidence level are given by previous researcher, L.J. Pignataro [33].

Figure 4.8 presents the graph of verification process for location KM18.3 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur.

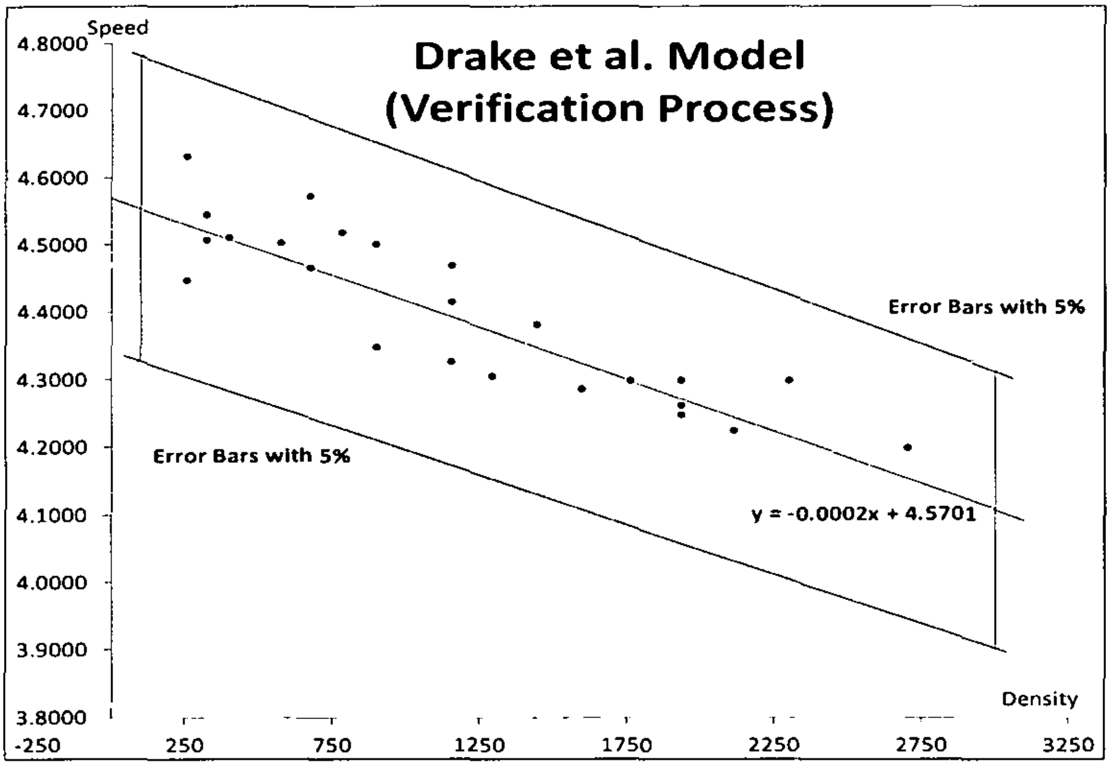


Figure 4.8: A Graph of Verification Process for location KM18.3 - Batu Tiga (Shah Alam, Selangor to Kuala Lumpur)

Data mentioned in figure 4.8 shows the Drake et al. Model is the best model to be applied in this study. This is because the data from table 4.6 are plotted on a graph of linear equation, y = -0.0002x + 4.5701 produce less than 5% of error bars.

4.5 Discussion

In this section, the traffic flow parameters for each model that applied in this study were identified. Table 4.5 is showing the traffic flow parameters for Single-Regime Models in KM30.7 Sungai Way location of Kuala Lumpur to Shah Alam, Selangor.

Table 4.5 : Traffic Flow Parameters for Sungai Way – Kuala Lumpur to Shah Alam, Selangor

Parameters	Models			
	Greenshields'	Greenberg	Underwood	Drake et al.
Optimum speed, u_o (km/hr)	-	24.16	-	-
Free-flow speed, u_f (km/hr)	107.95	∞	112.64	96.55
Optimum density, k_o (veh/km)	-	-	99	50
Jam density, k_j (veh/km)	132	889	∞	∞

The other two sets of graphs for location KM15.8 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur and KM31.5 at Petaling Jaya from Shah Alam, Selangor to Kuala Lumpur can be viewed at Appendix G.

Conclusively, table 4.5 shows the values of free-flow speed and the optimum speed for this study were 96.55km/hr and 50veh/km respectively. In addition, it can produce a new macroscopic model based on the speed-density operation for the exclusive motorcycle lane.

Table 4.6 shows a new macroscopic of single-regime model for location KM30.7 at Sungai Way from Kuala Lumpur to Shah Alam, Selangor.

Table 4.6 : New Macroscopic of Single-Regime Models

Model \ Location	Sungai Way – Kuala Lumpur to Shah Alam, Selangor
Greenshields' Model	$u = 107.95 - 0.8185k$
Greenberg Model	$u = 24.16 \ln (889/k)$
Underwood Model	$u = 112.64\, e^{-(k/99)}$
Drake et al. Model	$u = 96.55\, e^{-0.5(k/50)^2}$

On the other hand, the two sets of graphs for location KM15.8 at Batu 3 from Shah Alam, Selangor to Kuala Lumpur and KM31.5 at Petaling Jaya from Shah Alam, Selangor to Kuala Lumpur can be viewed at Appendix G.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In Malaysia, motorcycles are often the most affordable means of transport due to the proliferation of small and inexpensive; therefore, they form a large proportion of road traffic collisions users. However, motorcyclists are also one of the most vulnerable road users.

This paper studied the speed – density relationship of motorcycle only using an exclusive motorcycle lane in Federal Highway Route 2. From the study that have been carried out and completed, the data analysis has shown:

- Greenshield's Model, $u = 107.95 - 0.8185k$
- Greenberg Model, $u = 24.16 \ln (889/k)$
- Underwood Model, $u = 112.64\ e^{-(k/99)}$
- Drake et al., $u = 96.55\ e^{-0.5(k/50)^2}$

The conclusion from the data show that a Drake et al. Model is a most suitable model that can be applied to the traffic flow relationship based on exclusive motorcycle lane. It is because Drake et al. give the best fit with an $R^2 = 0.7153$ in this study. Based on these results, the Drake at al. Model is adopted for estimating the optimum density and the free-flow speed in this study.

The optimum density is corresponding to the optimum speed of motorcycle and the maximum flow rate. On the other hand, the free-flow speed is the mean speed that motorcyclist will travel on a roadway when the density of motorcycle is low. Therefore, the optimum density and the free-flow speed for this study are 50veh/km and 96.55 km/hr respectively.

From the free-flow speed result, it can be concluded that although the speed limit of motorcycle travelling in motorcycle lane on Federal Highway area is 70km/hr, sometimes motorcyclist ignores it. Under low-density conditions, motorcyclists no longer worry about other motorcycles. They subsequently proceed at speeds that are controlled by the performance of their motorcycles and the conditions of the roadway. This phenomenon can cause traffic accidents that can lead to injuries and/or death.

The average speed for non-peak hour condition is higher than peak hour condition. It is because the number of motorcycle in peak hour is higher than the number of motorcycle in non-peak hour. Therefore, the density of direct flow for peak hour condition is higher than non-peak hour condition. It means that the value of density of direct flow is based on the number of motorcycle that passed through the study location.

This study may give many benefits and increasing the quality of work among a traffic engineers. It is also important to increase the level of work productivity in term of design on exclusive motorcycle lane. On the other hand, the quality of exclusive lane can be improved in order to enhance the safety of the motorcyclist especially and for the other road users.

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Appendix A

Table of Data Extraction at KM15.8 – Batu 3 (Shah Alam, Selangor to Kuala Lumpur)

Day	Interval Time (min)	Distance (m)	No. of Mcy	Set 1 Time (s)	Set 2 Time (s)	Set 3 Time (s)	Set 4 Time (s)	Set 5 Time (s)	Density of Direct Flow, k
Monday (Non Peak Hour)	0-5	100	39	4.08	3.44	3.56	4.04	3.76	26
	5-10	100	28	3.08	4.12	4.60	3.84	5.08	30
	10-15	100	41	3.32	3.64	4.52	4.16	5.20	16
	15-20	100	53	4.08	4.56	4.80	3.36	5.16	22
	20-25	100	27	3.52	4.36	4.24	4.08	3.84	28
	25-30	100	33	4.76	4.08	4.04	5.76	5.08	34
	30-35	100	39	3.28	3.84	4.56	5.08	3.84	24
	35-40	100	28	4.48	3.88	3.96	4.28	5.72	30
	40-45	100	40	4.32	3.68	3.80	4.16	5.04	20
	45-50	100	36	3.64	4.68	3.92	4.80	3.72	32
	50-55	100	28	4.08	3.80	4.28	4.60	3.92	22
	55-60	100	40	3.76	3.32	4.36	3.16	4.16	16
Monday (Peak Hour)	0-5	100	98	4.00	4.32	4.52	4.64	5.28	40
	5-10	100	86	5.00	4.40	4.60	4.64	5.44	42
	10-15	100	104	4.96	5.32	4.52	4.16	5.12	40
	15-20	100	89	4.20	4.52	4.60	5.32	5.04	28
	20-25	100	92	5.92	4.48	4.24	4.96	3.96	42
	25-30	100	121	5.76	4.16	4.04	6.28	5.04	44
	30-35	100	81	5.24	4.32	4.56	5.44	3.92	32
	35-40	100	67	5.44	4.00	5.20	5.36	6.64	48
	40-45	100	112	4.92	4.16	6.04	6.12	5.56	46
	45-50	100	94	4.68	5.04	4.44	5.68	4.12	32
	50-55	100	101	4.80	4.52	6.00	4.64	5.72	44
	55-60	100	82	4.56	3.96	4.68	4.08	4.24	30
Tuesday (Non Peak Hour)	0-5	100	26	3.24	3.96	4.48	4.76	4.12	16
	5-10	100	54	4.16	4.12	3.56	4.68	4.24	18
	10-15	100	60	3.64	4.32	3.96	5.32	5.04	24
	15-20	100	30	4.12	4.28	3.36	4.28	3.52	28
	20-25	100	45	4.16	3.92	5.04	4.20	4.92	36
	25-30	100	40	3.52	3.76	4.08	3.96	4.28	28
	30-35	100	35	3.04	5.08	4.40	3.92	4.68	34
	35-40	100	41	3.76	4.04	4.60	4.16	5.16	26
	40-45	100	28	3.24	4.00	4.52	4.12	3.56	22
	45-50	100	37	4.12	4.68	3.44	4.76	3.84	26
	50-55	100	32	4.36	4.60	4.12	4.88	4.64	30
	55-60	100	39	4.20	3.84	4.16	4.92	3.76	38
Tuesday (Peak Hour)	0-5	100	103	4.20	5.72	4.48	4.60	4.64	34
	5-10	100	74	5.32	5.04	5.28	4.16	4.00	36
	10-15	100	96	5.04	4.44	4.72	5.80	5.28	46
	15-20	100	87	6.08	5.08	5.68	4.80	4.32	52
	20-25	100	131	6.16	5.80	4.72	3.92	5.88	50
	25-30	100	95	4.76	4.92	4.08	4.04	5.04	34
	30-35	100	102	5.68	4.32	6.08	5.52	4.32	48
	35-40	100	80	4.04	4.12	3.88	4.72	6.08	32
	40-45	100	78	4.52	4.08	4.56	4.76	4.72	38
	45-50	100	99	4.04	4.88	5.04	5.40	3.96	34
	50-55	100	84	5.40	5.60	5.44	4.88	4.52	52
	55-60	100	87	5.76	5.72	4.16	4.56	6.12	40
Wednesday (Non Peak Hour)	0-5	100	51	3.32	3.40	3.76	3.72	5.12	16
	5-10	100	42	3.28	3.76	4.12	3.80	5.04	16
	10-15	100	53	3.12	4.20	4.36	4.48	4.36	34
	15-20	100	29	4.20	3.96	4.60	4.32	6.04	36
	20-25	100	36	3.92	4.12	3.56	3.68	5.16	22
	25-30	100	34	3.60	3.96	4.88	5.12	5.44	24
	30-35	100	41	3.48	4.28	5.04	4.92	4.40	34
	35-40	100	38	3.36	4.52	3.72	4.68	4.80	28
	40-45	100	39	3.28	3.08	4.32	3.64	5.84	32
	45-50	100	57	4.16	3.16	4.60	6.08	4.64	36
	50-55	100	40	4.20	3.84	4.52	4.56	5.52	38
	55-60	100	44	4.08	4.52	3.76	4.12	4.32	18

	0-5	100	91	6.08	4.16	5.32	5.60	5.04	44
	5-10	100	87	4.48	6.12	5.68	5.92	5.44	52
	10-15	100	116	5.56	5.12	6.24	4.96	4.36	50
	15-20	100	104	4.72	3.96	4.60	5.76	6.32	48
	20-25	100	75	4.08	6.04	4.16	5.20	5.16	28
Wednesday (Peak Hour)	25-30	100	93	4.88	5.84	4.88	4.60	5.44	46
	30-35	100	82	4.76	5.64	5.68	4.80	4.40	30
	35-40	100	68	5.12	4.56	6.48	4.16	4.80	38
	40-45	100	89	5.00	5.28	4.52	4.08	6.04	32
	45-50	100	78	5.80	4.56	4.56	6.08	4.64	36
	50-55	100	94	5.04	4.84	4.72	4.56	5.52	48
	55-60	100	92	4.08	4.92	3.84	4.12	5.32	32
	0-5	100	48	3.52	4.48	3.96	4.60	5.20	26
	5-10	100	43	3.96	3.68	4.52	5.08	6.08	34
	10-15	100	27	3.04	4.16	4.84	4.84	4.08	32
	15-20	100	36	3.40	3.84	4.96	3.84	4.48	24
	20-25	100	31	3.60	4.04	4.36	4.52	4.24	18
Thursday (Non Peak Hour)	25-30	100	40	3.72	4.28	4.76	4.48	4.00	28
	30-35	100	28	4.04	3.40	4.16	3.68	5.12	30
	35-40	100	25	4.28	4.80	3.32	4.16	4.04	20
	40-45	100	32	4.52	3.28	3.88	3.84	4.84	32
	45-50	100	29	4.44	4.56	4.08	4.04	4.60	38
	50-55	100	31	4.08	3.46	3.96	4.28	4.12	34
	55-60	100	40	3.40	4.04	3.88	3.40	4.36	28
	0-5	100	67	4.40	4.40	5.40	4.60	5.20	30
	5-10	100	114	4.72	5.68	5.20	5.52	6.08	50
	10-15	100	92	4.16	5.04	4.76	4.84	4.08	36
	15-20	100	107	5.12	4.68	4.60	5.04	4.48	38
	20-25	100	85	6.04	4.00	4.16	4.04	4.24	28
Thursday (Peak Hour)	25-30	100	82	6.20	4.84	5.72	4.64	4.00	48
	30-35	100	79	5.40	4.12	6.16	4.84	5.12	40
	35-40	100	93	4.56	5.00	4.32	4.60	4.04	32
	40-45	100	78	6.00	5.04	3.88	4.56	4.84	34
	45-50	100	128	5.92	4.56	5.56	5.76	4.60	50
	50-55	100	92	4.08	6.56	4.80	4.28	5.32	34
	55-60	100	80	4.40	4.04	4.16	4.72	3.96	38
	0-5	100	48	3.56	4.64	4.48	4.80	4.60	22
	5-10	100	45	3.16	4.32	4.12	3.28	3.56	18
	10-15	100	39	4.48	4.52	4.80	4.56	4.88	36
	15-20	100	41	4.32	3.36	3.84	3.46	5.00	28
	20-25	100	37	4.24	3.32	4.40	4.04	4.92	30
Friday (Non Peak Hour)	25-30	100	33	3.56	3.52	4.64	4.64	4.68	20
	30-35	100	39	3.76	4.56	4.04	4.32	3.64	16
	35-40	100	27	3.84	3.88	4.80	4.60	6.08	36
	40-45	100	41	3.68	4.00	4.36	3.84	4.56	36
	45-50	100	25	3.20	4.16	4.56	3.40	3.92	20
	50-55	100	36	4.20	4.28	3.60	3.76	4.16	16
	55-60	100	40	4.24	3.20	4.12	5.12	4.24	24
	0-5	100	81	5.40	4.92	4.76	6.04	5.88	50
	5-10	100	105	5.56	4.32	6.08	4.72	4.16	44
	10-15	100	74	4.80	5.72	4.80	4.44	5.68	48
	15-20	100	89	5.24	5.12	3.88	4.16	4.88	38
	20-25	100	132	5.60	4.24	4.76	5.04	4.60	36
Friday (Peak Hour)	25-30	100	95	4.60	4.92	4.52	3.80	5.56	44
	30-35	100	69	4.16	6.60	4.04	5.20	4.12	34
	35-40	100	86	4.48	5.32	4.80	5.08	6.12	48
	40-45	100	80	5.32	4.00	4.04	4.60	4.36	30
	45-50	100	75	5.12	5.64	4.24	4.16	5.08	44
	50-55	100	79	4.56	4.60	5.20	4.04	4.16	34
	55-60	100	67	4.08	6.12	3.96	5.28	4.16	36

Table of Data Extraction at KM31.5 - Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)

Day	Interval Time (min)	Distance (m)	No. of Mcy	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Set 1 Time (s)	Density of Direct Flow, k
Monday (Non Peak Hour)	0 - 5	100	32	3.40	4.64	4.76	5.12	4.04	24
	5 -10	100	29	3.76	4.32	4.68	5.04	3.84	26
	10 - 15	100	35	4.20	4.52	5.32	4.36	4.16	22
	15 - 20	100	41	3.96	3.36	4.28	6.04	3.36	30
	20 - 25	100	33	4.12	3.32	4.20	5.16	4.08	20
	25 - 30	100	30	3.96	3.52	3.96	5.44	5.76	36
	30 - 35	100	27	4.28	4.56	3.92	4.40	5.08	18
	35 - 40	100	39	4.52	3.88	4.16	4.80	4.28	34
	40 - 45	100	42	3.08	4.00	4.12	5.84	4.16	24
	45 - 50	100	44	3.16	4.16	4.76	4.64	4.80	20
	50 - 55	100	51	3.84	4.28	4.88	5.52	4.60	22
	55 - 60	100	24	4.52	3.20	4.92	4.32	3.16	16
Monday (Peak Hour)	0 - 5	100	69	5.04	5.28	6.04	4.20	6.08	40
	5 -10	100	72	5.44	5.44	4.72	5.32	4.48	44
	10 - 15	100	67	4.36	5.12	4.44	3.96	5.56	42
	15 - 20	100	74	6.32	5.04	4.16	4.40	4.72	46
	20 - 25	100	86	5.16	3.96	5.04	5.00	4.08	34
	25 - 30	100	96	5.44	5.04	3.80	4.88	4.88	50
	30 - 35	100	102	4.40	3.92	5.20	5.60	4.76	36
	35 - 40	100	78	4.80	6.64	5.08	6.12	5.12	52
	40 - 45	100	85	6.04	5.56	4.60	4.52	5.00	48
	45 - 50	100	72	4.64	4.12	4.16	4.04	5.80	40
	50 - 55	100	64	5.52	5.72	4.04	5.40	5.04	48
	55 - 60	100	78	5.32	4.24	5.28	5.76	4.08	36
Tuesday (Non Peak Hour)	0 - 5	100	23	3.32	4.48	4.12	4.80	3.76	26
	5 -10	100	31	3.28	3.68	4.24	3.28	5.08	16
	10 - 15	100	29	3.12	4.16	5.04	4.56	5.20	30
	15 - 20	100	40	4.20	3.84	3.52	4.60	5.16	28
	20 - 25	100	34	3.92	4.04	4.92	4.32	3.84	16
	25 - 30	100	31	3.60	4.28	4.28	3.96	5.08	18
	30 - 35	100	30	3.48	3.40	4.68	4.52	3.84	18
	35 - 40	100	27	3.36	4.80	4.04	3.60	5.72	24
	40 - 45	100	47	3.28	3.28	4.36	5.12	5.04	22
	45 - 50	100	42	4.16	4.56	5.16	5.24	3.72	24
	50 - 55	100	37	4.20	3.46	4.92	3.76	3.92	30
	55 - 60	100	24	4.08	4.04	5.16	5.12	4.16	34
Tuesday (Peak Hour)	0 - 5	100	71	4.32	4.60	4.24	4.16	5.60	38
	5 -10	100	86	4.40	5.52	5.16	6.12	5.92	52
	10 - 15	100	105	5.32	4.84	4.80	5.12	4.96	40
	15 - 20	100	96	4.52	5.04	5.24	3.96	5.76	36
	20 - 25	100	91	4.48	4.04	5.60	6.04	5.20	52
	25 - 30	100	87	4.16	4.64	4.60	5.84	4.60	40
	30 - 35	100	92	4.32	4.84	4.16	5.64	4.80	38
	35 - 40	100	74	4.00	4.60	4.48	4.56	4.16	44
	40 - 45	100	81	4.16	4.56	5.32	5.28	4.08	36
	45 - 50	100	79	5.04	5.76	5.12	4.56	6.08	50
	50 - 55	100	81	4.52	4.28	4.56	4.84	4.56	42
	55 - 60	100	72	3.96	4.72	4.08	4.92	4.12	36
Wednesday (Non Peak Hour)	0 - 5	100	26	3.96	4.48	3.24	4.60	3.56	28
	5 -10	100	31	4.52	4.12	4.16	3.56	4.60	24
	10 - 15	100	40	4.84	4.80	3.64	4.88	4.52	30
	15 - 20	100	36	3.16	3.84	4.12	5.00	4.80	22
	20 - 25	100	35	3.32	4.00	4.16	4.92	4.24	18
	25 - 30	100	50	4.28	4.40	3.52	4.68	4.04	34
	30 - 35	100	31	4.72	4.36	3.04	3.64	4.56	18
	35 - 40	100	44	4.20	4.08	3.76	6.08	3.96	38
	40 - 45	100	27	3.52	3.32	3.24	4.56	3.80	16
	45 - 50	100	21	4.08	4.56	4.12	3.92	3.92	32
	50 - 55	100	32	3.96	3.60	4.36	4.16	4.28	36
	55 - 60	100	19	3.88	4.12	4.20	4.24	4.36	44

Wednesday (Peak Hour)	0 - 5	100	81	4.60	4.76	5.20	4.40	4.52	38
	5 -10	100	73	4.16	6.08	6.08	4.72	4.60	50
	10 - 15	100	92	5.80	4.80	4.08	4.16	4.52	46
	15 - 20	100	87	4.80	3.88	4.48	5.12	4.60	48
	20 - 25	100	98	3.92	4.76	4.24	6.04	4.24	44
	25 - 30	100	76	4.04	4.52	4.00	6.20	4.04	38
	30 - 35	100	88	5.52	4.04	5.12	5.40	4.56	40
	35 - 40	100	95	4.72	4.80	4.04	4.56	5.20	42
	40 - 45	100	78	4.76	4.04	4.84	6.00	6.04	52
	45 - 50	100	81	5.40	4.24	4.60	5.92	4.44	44
	50 - 55	100	73	4.88	5.20	5.32	4.08	6.00	48
	55 - 60	100	59	4.56	3.96	3.96	4.40	4.68	40
Thursday (Non Peak Hour)	0 - 5	100	24	5.20	3.56	3.96	3.76	4.12	16
	5 -10	100	36	6.08	3.16	3.88	4.12	3.96	20
	10 - 15	100	38	4.08	4.48	4.20	4.36	4.28	38
	15 - 20	100	41	4.48	4.32	3.88	4.60	4.52	36
	20 - 25	100	44	3.72	4.24	4.00	3.56	3.08	16
	25 - 30	100	28	3.80	3.56	4.40	4.88	3.16	24
	30 - 35	100	27	4.04	3.76	4.36	3.52	3.96	36
	35 - 40	100	21	4.12	3.84	4.08	4.08	4.04	26
	40 - 45	100	34	4.48	3.68	3.32	4.12	3.72	24
	45 - 50	100	40	4.60	3.20	4.68	4.04	5.28	34
	50 - 55	100	36	4.12	4.20	4.60	3.84	4.72	16
	55 - 60	100	28	4.36	4.24	3.84	3.92	4.88	28
Thursday (Peak Hour)	0 - 5	100	67	5.40	5.88	4.64	4.92	4.64	48
	5 -10	100	81	5.20	4.16	4.64	4.32	4.00	52
	10 - 15	100	75	4.76	5.68	4.16	5.72	5.28	50
	15 - 20	100	79	4.60	4.88	5.32	5.12	4.32	32
	20 - 25	100	86	4.16	4.60	4.76	4.24	5.88	46
	25 - 30	100	98	5.72	5.56	4.12	4.92	5.04	48
	30 - 35	100	87	6.16	4.12	4.72	6.60	4.32	50
	35 - 40	100	93	4.32	6.12	4.28	5.32	6.08	52
	40 - 45	100	67	3.88	4.36	5.04	4.00	4.72	28
	45 - 50	100	82	5.56	5.08	5.36	5.64	3.96	44
	50 - 55	100	81	4.80	4.16	4.72	4.60	4.52	42
	55 - 60	100	65	4.16	4.16	4.08	6.12	6.12	36
Friday (Non Peak Hour)	0 - 5	100	22	3.72	3.52	4.48	4.60	4.08	30
	5 -10	100	29	3.80	3.96	3.56	5.08	3.80	28
	10 - 15	100	27	4.48	3.04	3.96	4.84	3.96	32
	15 - 20	100	31	4.32	3.40	3.36	3.40	4.60	34
	20 - 25	100	40	3.72	4.20	5.04	3.48	5.00	18
	25 - 30	100	38	3.80	3.24	4.08	3.20	3.36	22
	30 - 35	100	26	4.04	4.00	4.92	4.16	3.96	20
	35 - 40	100	17	4.12	5.04	3.92	4.08	4.48	20
	40 - 45	100	48	3.64	4.52	3.12	4.04	4.32	30
	45 - 50	100	29	6.08	4.44	3.96	3.84	3.64	18
	50 - 55	100	32	4.56	4.08	3.64	3.92	4.08	22
	55 - 60	100	25	4.12	3.40	4.04	3.40	3.76	16
Friday (Peak Hour)	0 - 5	100	89	5.32	5.72	4.40	4.00	4.48	52
	5 -10	100	69	5.68	5.04	5.68	5.00	5.28	52
	10 - 15	100	74	6.24	4.44	5.04	4.96	4.72	50
	15 - 20	100	87	4.60	5.08	4.68	4.20	5.68	36
	20 - 25	100	73	4.16	5.80	4.00	3.96	4.72	42
	25 - 30	100	85	4.88	4.92	4.84	4.40	4.08	46
	30 - 35	100	96	5.68	4.32	4.12	5.00	6.08	36
	35 - 40	100	.115	6.48	4.12	5.00	4.88	3.88	40
	40 - 45	100	91	4.52	4.08	5.04	5.60	4.56	42
	45 - 50	100	87	4.56	4.88	4.56	6.12	5.04	46
	50 - 55	100	73	4.72	5.60	6.56	4.80	5.44	50
	55 - 60	100	61	3.84	5.72	4.04	4.56	4.16	38

Appendix B

Data Calculation at KM15.8 – Batu 3 (Shah Alam, Selangor to Kuala Lumpur)

Day	Interval Time (min)	Distance (m)	No. of Mcy	Set 1		Set 2		Set 3		Set 4		Set 5		Average Speed, u (km/hr)	ln(u)	Density of Direct Flow, k (Mcy/km)	ln(k)	k^2
				Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)					
	0-5	100	39	4.08	88.24	3.44	104.65	3.56	101.12	4.04	89.11	3.76	95.74	95.77	4.5620	26	3.2581	676
	5-10	100	28	3.08	116.88	4.12	87.38	4.60	78.26	3.84	93.75	5.08	70.87	89.43	4.4934	30	3.4012	900
	10-15	100	41	3.32	108.43	3.64	98.90	4.52	79.65	4.16	86.54	5.20	69.23	88.55	4.4836	16	2.7726	256
	15-20	100	53	4.08	88.24	4.56	78.95	4.80	75.00	3.36	107.14	5.16	69.77	83.82	4.4287	22	3.0910	484
	20-25	100	27	3.52	102.27	4.36	82.57	4.24	84.91	4.08	88.24	3.84	93.75	90.35	4.5037	28	3.3322	784
Monday (Non Peak Hour)	25-30	100	33	4.76	75.63	4.08	88.24	4.04	89.11	5.76	62.50	5.08	70.87	77.27	4.3473	34	3.5264	1156
	30-35	100	39	3.28	109.76	3.84	93.75	4.56	78.95	5.08	70.87	3.84	93.75	89.41	4.4933	24	3.1781	576
	35-40	100	28	4.48	80.36	3.88	92.78	3.96	90.91	4.28	84.11	5.72	62.94	82.22	4.4094	30	3.4012	900
	40-45	100	40	4.32	83.33	3.68	97.83	3.80	94.74	4.16	86.54	5.04	71.43	86.77	4.4633	20	2.9957	400
	45-50	100	36	3.64	98.90	4.68	76.92	3.92	91.84	4.80	75.00	3.72	96.77	87.89	4.4761	32	3.4657	1024
	50-55	100	28	4.08	88.24	3.80	94.74	4.28	84.11	4.60	78.26	3.92	91.84	87.44	4.4709	22	3.0910	484
	55-60	100	40	3.76	95.74	3.32	108.43	4.36	82.57	3.16	113.92	4.16	86.54	97.44	4.5793	16	2.7726	256
	0-5	100	98	4.00	90.00	4.32	83.33	4.52	79.65	4.64	77.59	5.28	68.18	79.75	4.3789	40	3.6889	1600
	5-10	100	86	5.00	72.00	4.40	81.82	4.60	78.26	4.64	77.59	5.44	66.18	75.17	4.3197	42	3.7377	1764
	10-15	100	104	4.96	72.58	5.32	67.67	4.52	79.65	4.16	86.54	5.12	70.31	75.35	4.3221	40	3.6889	1600
	15-20	100	89	4.20	85.71	4.52	79.65	4.60	78.26	5.32	67.67	5.04	71.43	76.54	4.3379	28	3.3322	784
	20-25	100	92	5.92	60.81	4.48	80.36	4.24	84.91	4.96	72.58	3.96	90.91	77.91	4.3556	42	3.7377	1764
Monday (Peak Hour)	25-30	100	121	5.76	62.50	4.16	86.54	4.04	89.11	6.28	57.32	5.04	71.43	73.38	4.2957	44	3.7842	1936
	30-35	100	81	5.24	68.70	4.32	83.33	4.56	78.95	5.44	66.18	3.92	91.84	77.80	4.3541	32	3.4657	1024
	35-40	100	67	5.44	66.18	4.00	90.00	5.20	69.23	5.36	67.16	6.64	54.22	69.36	4.2393	48	3.8712	2304
	40-45	100	112	4.92	73.17	4.16	86.54	6.04	59.60	6.12	58.82	5.56	64.75	68.58	4.2280	46	3.8286	2116
	45-50	100	94	4.68	76.92	5.04	71.43	4.44	81.08	5.68	63.38	4.12	87.38	76.04	4.3312	32	3.4657	1024
	50-55	100	101	4.80	75.00	4.52	79.65	6.00	60.00	4.64	77.59	5.72	62.94	71.03	4.2632	44	3.7842	1936
	55-60	100	82	4.56	78.95	3.96	90.91	4.68	76.92	4.08	88.24	4.24	84.91	83.98	4.4306	30	3.4012	900
	0-5	100	26	3.24	111.11	3.96	90.91	4.48	80.36	4.76	75.63	4.12	87.38	89.08	4.4895	16	2.7726	256
	5-10	100	54	4.16	86.54	4.12	87.38	3.56	101.12	4.68	76.92	4.24	84.91	87.37	4.4702	18	2.8904	324
	10-15	100	60	3.64	98.90	4.32	83.33	3.96	90.91	5.32	67.67	5.04	71.43	82.45	4.4122	24	3.1781	576
	15-20	100	30	4.12	87.38	4.28	84.11	3.36	107.14	4.28	84.11	3.52	102.27	93.00	4.5326	28	3.3322	784
	20-25	100	45	4.16	86.54	3.92	91.84	5.04	71.43	4.20	85.71	4.92	73.17	81.74	4.4035	36	3.5835	1296
Tuesday (Non Peak Hour)	25-30	100	40	3.52	102.27	3.76	95.74	4.08	88.24	3.96	90.91	4.28	84.11	92.25	4.5246	28	3.3322	784
	30-35	100	35	3.04	118.42	5.08	70.87	4.40	81.82	3.92	91.84	4.68	76.92	87.97	4.4770	34	3.5264	1156
	35-40	100	41	3.76	95.74	4.04	89.11	4.60	78.26	4.16	86.54	5.16	69.77	83.88	4.4294	26	3.2581	676
	40-45	100	28	3.24	111.11	4.00	90.00	4.52	79.65	4.12	87.38	3.56	101.12	93.85	4.5417	22	3.0910	484
	45-50	100	37	4.12	87.38	4.68	76.92	3.44	104.65	4.76	75.63	3.84	93.75	87.67	4.4735	26	3.2581	676

	50-55	100	32	4.36	82.57	4.60	78.26	4.12	87.38	4.88	73.77	4.64	77.59	79.91	4.3809	30	3.4012	900
	55-60	100	39	4.20	85.71	3.84	93.75	4.16	86.54	4.92	73.17	3.76	95.74	86.98	4.4657	38	3.6376	1444
Tuesday (Peak Hour)	0-5	100	103	4.20	85.71	5.72	62.94	4.48	80.36	4.60	78.26	4.64	77.59	76.97	4.3434	34	3.5264	1156
	5-10	100	74	5.32	67.67	5.04	71.43	5.28	68.18	4.16	86.54	4.00	90.00	76.76	4.3407	36	3.5835	1296
	10-15	100	96	5.04	71.43	4.44	81.08	4.72	76.27	5.80	62.07	5.28	68.18	71.81	4.2740	46	3.8286	2116
	15-20	100	87	6.08	59.21	5.08	70.87	5.68	63.38	4.80	75.00	4.32	83.33	70.36	4.2536	52	3.9512	2704
	20-25	100	131	6.16	58.44	5.80	62.07	4.72	76.27	3.92	91.84	5.88	61.22	69.97	4.2480	50	3.9120	2500
	25-30	100	95	4.76	75.63	4.92	73.17	4.08	88.24	4.04	89.11	5.04	71.43	79.51	4.3759	34	3.5264	1156
	30-35	100	102	5.68	63.38	4.32	83.33	6.08	59.21	5.52	65.22	4.32	83.33	70.89	4.2612	48	3.8712	2304
	35-40	100	80	4.04	89.11	4.12	87.38	3.88	92.78	4.72	76.27	6.08	59.21	80.95	4.3938	32	3.4657	1024
	40-45	100	78	4.52	79.65	4.08	88.24	4.56	78.95	4.76	75.63	4.72	76.27	79.75	4.3788	38	3.6376	1444
	45-50	100	99	4.04	89.11	4.88	73.77	5.04	71.43	5.40	66.67	3.96	90.91	78.38	4.3615	34	3.5264	1156
	50-55	100	84	5.40	66.67	5.60	64.29	5.44	66.18	4.88	73.77	4.52	79.65	70.11	4.2501	52	3.9512	2704
	55-60	100	87	5.76	62.50	5.72	62.94	4.16	86.54	4.56	78.95	6.12	58.82	69.95	4.2478	40	3.6889	1600
Wednesday (Non Peak Hour)	0-5	100	51	3.32	108.43	3.40	105.88	3.76	95.74	3.72	96.77	5.12	70.31	95.43	4.5584	16	2.7726	256
	5-10	100	42	3.28	109.76	3.76	95.74	4.12	87.38	3.80	94.74	5.04	71.43	91.81	4.5197	16	2.7726	256
	10-15	100	53	3.12	115.38	4.20	85.71	4.36	82.57	4.48	80.36	4.36	82.57	89.32	4.4922	34	3.5264	1156
	15-20	100	29	4.20	85.71	3.96	90.91	4.60	78.26	4.32	83.33	6.04	59.60	79.56	4.3766	36	3.5835	1296
	20-25	100	36	3.92	91.84	4.12	87.38	3.56	101.12	3.68	97.83	5.16	69.77	89.59	4.4952	22	3.0910	484
	25-30	100	34	3.60	100.00	3.96	90.91	4.88	73.77	5.12	70.31	5.44	66.18	80.23	4.3849	24	3.1781	576
	30-35	100	41	3.48	103.45	4.28	84.11	5.04	71.43	4.92	73.17	4.40	81.82	82.80	4.4164	34	3.5264	1156
	35-40	100	38	3.36	107.14	4.52	79.65	3.72	96.77	4.68	76.92	4.80	75.00	87.10	4.4670	28	3.3322	784
	40-45	100	39	3.28	109.76	3.08	116.88	4.32	83.33	3.64	98.90	5.84	61.64	94.10	4.5444	32	3.4657	1024
	45-50	100	57	4.16	86.54	3.16	113.92	4.60	78.26	6.08	59.21	4.64	77.59	83.10	4.4201	36	3.5835	1296
	50-55	100	40	4.20	85.71	3.84	93.75	4.52	79.65	4.56	78.95	5.52	65.22	80.66	4.3902	38	3.6376	1444
	55-60	100	44	4.08	88.24	4.52	79.65	3.76	95.74	4.12	87.38	4.32	83.33	86.87	4.4644	18	2.8904	324
Wednesday (Peak Hour)	0-5	100	91	6.08	59.21	4.16	86.54	5.32	67.67	5.60	64.29	5.04	71.43	69.83	4.2460	44	3.7842	1936
	5-10	100	87	4.48	80.36	6.12	58.82	5.68	63.38	5.92	60.81	5.44	66.18	65.91	4.1883	52	3.9512	2704
	10-15	100	116	5.56	64.75	5.12	70.31	6.24	57.69	4.96	72.58	4.36	82.57	69.58	4.2425	50	3.9120	2500
	15-20	100	104	4.72	76.27	3.96	90.91	4.60	78.26	5.76	62.50	6.32	56.96	72.98	4.2902	48	3.8712	2304
	20-25	100	75	4.08	88.24	6.04	59.60	4.16	86.54	5.20	69.23	5.16	69.77	74.67	4.3131	28	3.3322	784
	25-30	100	93	4.88	73.77	5.84	61.64	4.88	73.77	4.60	78.26	5.44	66.18	70.72	4.2588	46	3.8286	2116
	30-35	100	82	4.76	75.63	5.64	63.83	5.68	63.38	4.80	75.00	4.40	81.82	71.93	4.2757	30	3.4012	900
	35-40	100	68	5.12	70.31	4.56	78.95	6.48	55.56	4.16	86.54	4.80	75.00	73.27	4.2942	38	3.6376	1444
	40-45	100	89	5.00	72.00	5.28	68.18	4.52	79.65	4.08	88.24	6.04	59.60	73.53	4.2977	32	3.4657	1024
	45-50	100	78	5.80	62.07	4.56	78.95	4.56	78.95	6.08	59.21	4.64	77.59	71.35	4.2676	36	3.5835	1296
	50-55	100	94	5.04	71.43	4.84	74.38	4.72	76.27	4.56	78.95	5.52	65.22	73.25	4.2939	48	3.8712	2304
	55-60	100	92	4.08	88.24	4.92	73.17	3.84	93.75	4.12	87.38	5.32	67.67	82.04	4.4072	32	3.4657	1024
	0-5	100	48	3.52	102.27	4.48	80.36	3.96	90.91	4.60	78.26	5.20	69.23	84.21	4.4333	26	3.2581	676
	5-10	100	43	3.96	90.91	3.68	97.83	4.52	79.65	5.08	70.87	6.08	59.21	79.69	4.3782	34	3.5264	1156
	10-15	100	27	3.04	118.42	4.16	86.54	4.84	74.38	4.84	74.38	4.08	88.24	88.39	4.4818	32	3.4657	1024
	15-20	100	36	3.40	105.88	3.84	93.75	4.96	72.58	3.84	93.75	4.48	80.36	89.26	4.4916	24	3.1781	576

Thursday (Non Peak Hour)	20-25	100	31	3.60	100.00	4.04	89.11	4.36	82.57	4.52	79.65	4.24	84.91	87.25	4.4687	18	2.8904	324
	25-30	100	40	3.72	96.77	4.28	84.11	4.76	75.63	4.48	80.36	4.00	90.00	85.37	4.4471	28	3.3322	784
	30-35	100	28	4.04	89.11	3.40	105.88	4.16	86.54	3.68	97.83	5.12	70.31	89.93	4.4991	30	3.4012	900
	35-40	100	25	4.28	84.11	4.80	75.00	3.32	108.43	4.16	86.54	4.04	89.11	88.64	4.4846	20	2.9957	400
	40-45	100	32	4.52	79.65	3.28	109.76	3.88	92.78	3.84	93.75	4.84	74.38	90.06	4.5005	32	3.4657	1024
	45-50	100	29	4.44	81.08	4.56	78.95	4.08	88.24	4.04	89.11	4.60	78.26	83.13	4.4204	38	3.6376	1444
	50-55	100	31	4.08	88.24	3.46	104.05	3.96	90.91	4.28	84.11	4.12	87.38	90.94	4.5102	34	3.5264	1156
	55-60	100	40	3.40	105.88	4.04	89.11	3.88	92.78	3.40	105.88	4.36	82.57	95.25	4.5565	28	3.3322	784
Thursday (Peak Hour)	0-5	100	67	4.40	81.82	4.40	81.82	5.40	66.67	4.60	78.26	5.20	69.23	75.56	4.3249	30	3.4012	900
	5-10	100	114	4.72	76.27	5.68	63.38	5.20	69.23	5.52	65.22	6.08	59.21	66.66	4.1996	50	3.9120	2500
	10-15	100	92	4.16	86.54	5.04	71.43	4.76	75.63	4.84	74.38	4.08	88.24	79.24	4.3725	36	3.5835	1296
	15-20	100	107	5.12	70.31	4.68	76.92	4.60	78.26	5.04	71.43	4.48	80.36	75.46	4.3236	38	3.6376	1444
	20-25	100	85	6.04	59.60	4.00	90.00	4.16	86.54	4.04	89.11	4.24	84.91	82.03	4.4071	28	3.3322	784
	25-30	100	82	6.20	58.06	4.84	74.38	5.72	62.94	4.64	77.59	4.00	90.00	72.59	4.2849	48	3.8712	2304
	30-35	100	79	5.40	66.67	4.12	87.38	6.16	58.44	4.84	74.38	5.12	70.31	71.44	4.2688	40	3.6889	1600
	35-40	100	93	4.56	78.95	5.00	72.00	4.32	83.33	4.60	78.26	4.04	89.11	80.33	4.3861	32	3.4657	1024
	40-45	100	78	6.00	60.00	5.04	71.43	3.88	92.78	4.56	78.95	4.84	74.38	75.51	4.3242	34	3.5264	1156
	45-50	100	128	5.92	60.81	4.56	78.95	5.56	64.75	5.76	62.50	4.60	78.26	69.05	4.2349	50	3.9120	2500
	50-55	100	92	4.08	88.24	6.56	54.88	4.80	75.00	4.28	84.11	5.32	67.67	73.98	4.3038	34	3.5264	1156
	55-60	100	80	4.40	81.82	4.04	89.11	4.16	86.54	4.72	76.27	3.96	90.91	84.93	4.4418	38	3.6376	1444
Friday (Non Peak Hour)	0-5	100	48	3.56	101.12	4.64	77.59	4.48	80.36	4.80	75.00	4.60	78.26	82.47	4.4124	22	3.0910	484
	5-10	100	45	3.16	113.92	4.32	83.33	4.12	87.38	3.28	109.76	3.56	101.12	99.10	4.5962	18	2.8904	324
	10-15	100	39	4.48	80.36	4.52	79.65	4.80	75.00	4.56	78.95	4.88	73.77	77.54	4.3508	36	3.5835	1296
	15-20	100	41	4.32	83.33	3.36	107.14	3.84	93.75	3.46	104.05	5.00	72.00	92.05	4.5224	28	3.3322	784
	20-25	100	37	4.24	84.91	3.32	108.43	4.40	81.82	4.04	89.11	4.92	73.17	87.49	4.4715	30	3.4012	900
	25-30	100	33	3.56	101.12	3.52	102.27	4.64	77.59	4.64	77.59	4.68	76.92	87.10	4.4670	20	2.9957	400
	30-35	100	39	3.76	95.74	4.56	78.95	4.04	89.11	4.32	83.33	3.64	98.90	89.21	4.4910	16	2.7726	256
	35-40	100	27	3.84	93.75	3.88	92.78	4.80	75.00	4.60	78.26	6.08	59.21	79.80	4.3795	36	3.5835	1296
	40-45	100	41	3.68	97.83	4.00	90.00	4.36	82.57	3.84	93.75	4.56	78.95	88.62	4.4843	36	3.5835	1296
	45-50	100	25	3.20	112.50	4.16	86.54	4.56	78.95	3.40	105.88	3.92	91.84	95.14	4.5554	20	2.9957	400
	50-55	100	36	4.20	85.71	4.28	84.11	3.60	100.00	3.76	95.74	4.16	86.54	90.42	4.5045	16	2.7726	256
	55-60	100	40	4.24	84.91	3.20	112.50	4.12	87.38	5.12	70.31	4.24	84.91	88.00	4.4773	24	3.1781	576
Friday (Peak Hour)	0-5	100	81	5.40	66.67	4.92	73.17	4.76	75.63	6.04	59.60	5.88	61.22	67.26	4.2086	50	3.9120	2500
	5-10	100	105	5.56	64.75	4.32	83.33	6.08	59.21	4.72	76.27	4.16	86.54	74.02	4.3043	44	3.7842	1936
	10-15	100	74	4.80	75.00	5.72	62.94	4.80	75.00	4.44	81.08	5.68	63.38	71.48	4.2694	48	3.8712	2304
	15-20	100	89	5.24	68.70	5.12	70.31	3.88	92.78	4.16	86.54	4.88	73.77	78.42	4.3621	38	3.6376	1444
	20-25	100	132	5.60	64.29	4.24	84.91	4.76	75.63	5.04	71.43	4.60	78.26	74.90	4.3162	36	3.5835	1296
	25-30	100	95	4.60	78.26	4.92	73.17	4.52	79.65	3.80	94.74	5.56	64.75	78.11	4.3582	44	3.7842	1936
	30-35	100	69	4.16	86.54	6.60	54.55	4.04	89.11	5.20	69.23	4.12	87.38	77.36	4.3485	34	3.5264	1156
	35-40	100	86	4.48	80.36	5.32	67.67	4.80	75.00	5.08	70.87	6.12	58.82	70.54	4.2562	48	3.8712	2304
	40-45	100	80	5.32	67.67	4.00	90.00	4.04	89.11	4.60	78.26	4.36	82.57	81.52	4.4009	30	3.4012	900
	45-50	100	75	5.12	70.31	5.64	63.83	4.24	84.91	4.16	86.54	5.08	70.87	75.29	4.3214	44	3.7842	1936
	50-55	100	79	4.56	78.95	4.60	78.26	5.20	69.23	4.04	89.11	4.16	86.54	80.42	4.3872	34	3.5264	1156
	55-60	100	67	4.08	88.24	6.12	58.82	3.96	90.91	5.28	68.18	4.16	86.54	78.54	4.3636	36	3.5835	1296

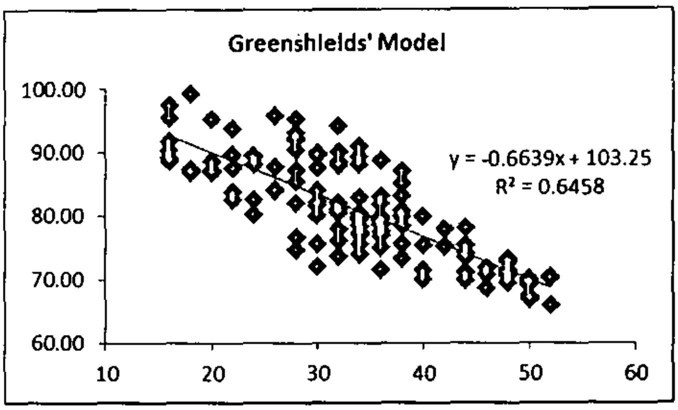
Data Calculation at KM31.5 - Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)

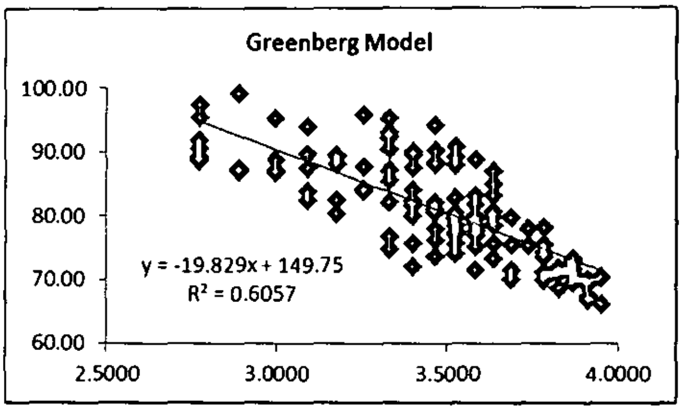
Day	Interval Time (min)	Distance (m)	No. of Mcy	Set 1		Set 2		Set 3		Set 4		Set 5		Average Speed, u (km/hr)	ln(u)	Density of Direct Flow, k (Mcy/km)	ln(k)	k^2
				Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)					
Monday (Non Peak Hour)	0-5	100	32	3.40	105.88	4.64	77.59	4.76	75.63	5.12	70.31	4.04	89.11	83.70	4.4273	24	3.1781	576
	5-10	100	29	3.76	95.74	4.32	83.33	4.68	76.92	5.04	71.43	3.84	93.75	84.24	4.4336	26	3.2581	676
	10-15	100	35	4.20	85.71	4.52	79.65	5.32	67.67	4.36	82.57	4.16	86.54	80.43	4.3874	22	3.0910	484
	15-20	100	41	3.96	90.91	3.36	107.14	4.28	84.11	6.04	59.60	3.36	107.14	89.78	4.4974	30	3.4012	900
	20-25	100	33	4.12	87.38	3.32	108.43	4.20	85.71	5.16	69.77	4.08	88.24	87.91	4.4763	20	2.9957	400
	25-30	100	30	3.96	90.91	3.52	102.27	3.96	90.91	5.44	66.18	5.76	62.50	82.55	4.4134	36	3.5835	1296
	30-35	100	27	4.28	84.11	4.56	78.95	3.92	91.84	4.40	81.82	5.08	70.87	81.52	4.4008	18	2.8904	324
	35-40	100	39	4.52	79.65	3.88	92.78	4.16	86.54	4.80	75.00	4.28	84.11	83.62	4.4262	34	3.5264	1156
	40-45	100	42	3.08	116.88	4.00	90.00	4.12	87.38	5.84	61.64	4.16	86.54	88.49	4.4829	24	3.1781	576
	45-50	100	44	3.16	113.92	4.16	86.54	4.76	75.63	4.64	77.59	4.80	75.00	85.74	4.4513	20	2.9957	400
	50-55	100	51	3.84	93.75	4.28	84.11	4.88	73.77	5.52	65.22	4.60	78.26	79.02	4.3697	22	3.0910	484
	55-60	100	24	4.52	79.65	3.20	112.50	4.92	73.17	4.32	83.33	3.16	113.92	92.51	4.5274	16	2.7726	256
Monday (Peak Hour)	0-5	100	69	5.04	71.43	5.28	68.18	6.04	59.60	4.20	85.71	6.08	59.21	68.83	4.2316	40	3.6889	1600
	5-10	100	72	5.44	66.18	5.44	66.18	4.72	76.27	5.32	67.67	4.48	80.36	71.33	4.2673	44	3.7842	1936
	10-15	100	67	4.36	82.57	5.12	70.31	4.44	81.08	3.96	90.91	5.56	64.75	77.92	4.3557	42	3.7377	1764
	15-20	100	74	6.32	56.96	5.04	71.43	4.16	86.54	4.40	81.82	4.72	76.27	74.60	4.3122	46	3.8286	2116
	20-25	100	86	5.16	69.77	3.96	90.91	5.04	71.43	5.00	72.00	4.08	88.24	78.47	4.3627	34	3.5264	1156
	25-30	100	96	5.44	66.18	5.04	71.43	3.80	94.74	4.88	73.77	4.88	73.77	75.98	4.3304	50	3.9120	2500
	30-35	100	102	4.40	81.82	3.92	91.84	5.20	69.23	5.60	64.29	4.76	75.63	76.56	4.3381	36	3.5835	1296
	35-40	100	78	4.80	75.00	6.64	54.22	5.08	70.87	6.12	58.82	5.12	70.31	65.84	4.1873	52	3.9512	2704
	40-45	100	85	6.04	59.60	5.56	64.75	4.60	78.26	4.52	79.65	5.00	72.00	70.85	4.2606	48	3.8712	2304
	45-50	100	72	4.64	77.59	4.12	87.38	4.16	86.54	4.04	89.11	5.80	62.07	80.54	4.3887	40	3.6889	1600
	50-55	100	64	5.52	65.22	5.72	62.94	4.04	89.11	5.40	66.67	5.04	71.43	71.07	4.2637	48	3.8712	2304
	55-60	100	78	5.32	67.67	4.24	84.91	5.28	68.18	5.76	62.50	4.08	88.24	74.30	4.3081	36	3.5835	1296
Tuesday (Non Peak Hour)	0-5	100	23	3.32	108.43	4.48	80.36	4.12	87.38	4.80	75.00	3.76	95.74	89.38	4.4929	26	3.2581	676
	5-10	100	31	3.28	109.76	3.68	97.83	4.24	84.91	3.28	109.76	5.08	70.87	94.62	4.5499	16	2.7726	256
	10-15	100	29	3.12	115.38	4.16	86.54	5.04	71.43	4.56	78.95	5.20	69.23	84.31	4.4345	30	3.4012	900
	15-20	100	40	4.20	85.71	3.84	93.75	3.52	102.27	4.60	78.26	5.16	69.77	85.95	4.4538	28	3.3322	784
	20-25	100	34	3.92	91.84	4.04	89.11	4.92	73.17	4.32	83.33	3.84	93.75	86.24	4.4571	16	2.7726	256
	25-30	100	31	3.60	100.00	4.28	84.11	4.28	84.11	3.96	90.91	5.08	70.87	86.00	4.4543	18	2.8904	324
	30-35	100	30	3.48	103.45	3.40	105.88	4.68	76.92	4.52	79.65	3.84	93.75	91.93	4.5210	18	2.8904	324
	35-40	100	27	3.36	107.14	4.80	75.00	4.04	89.11	3.60	100.00	5.72	62.94	86.84	4.4640	24	3.1781	576
	40-45	100	47	3.28	109.76	3.28	109.76	4.36	82.57	5.12	70.31	5.04	71.43	88.76	4.4860	22	3.0910	484
	45-50	100	42	4.16	86.54	4.56	78.95	5.16	69.77	5.24	68.70	3.72	96.77	80.15	4.3838	24	3.1781	576
	50-55	100	37	4.20	85.71	3.46	104.05	4.92	73.17	3.76	95.74	3.92	91.84	90.10	4.5009	30	3.4012	900
	55-60	100	24	4.08	88.24	4.04	89.11	5.16	69.77	5.12	70.31	4.16	86.54	80.79	4.3919	34	3.5264	1156
	0-5	100	71	4.32	83.33	4.60	78.26	4.24	84.91	4.16	86.54	5.60	64.29	79.46	4.3753	38	3.6376	1444

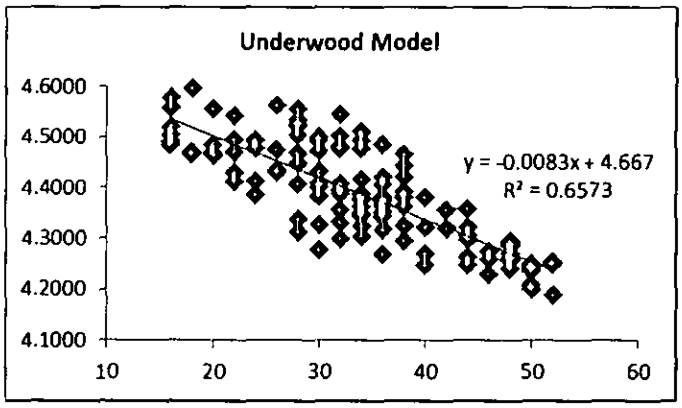
	5-10	100	86	4.40	81.82	5.52	65.22	5.16	69.77	6.12	58.82	5.92	60.81	67.29	4.2090	52	3.9512	2704
	10-15	100	105	5.32	67.67	4.84	74.38	4.80	75.00	5.12	70.31	4.96	72.58	71.99	4.2765	40	3.6889	1600
	15-20	100	96	4.52	79.65	5.04	71.43	5.24	68.70	3.96	90.91	5.76	62.50	74.64	4.3126	36	3.5835	1296
	20-25	100	91	4.48	80.36	4.04	89.11	5.60	64.29	6.04	59.60	5.20	69.23	72.52	4.2838	52	3.9512	2704
Tuesday	25-30	100	87	4.16	86.54	4.64	77.59	4.60	78.26	5.84	61.64	4.60	78.26	76.46	4.3367	40	3.6889	1600
(Peak Hour)	30-35	100	92	4.32	83.33	4.84	74.38	4.16	86.54	5.64	63.83	4.80	75.00	76.62	4.3388	38	3.6376	1444
	35-40	100	74	4.00	90.00	4.60	78.26	4.48	80.36	4.56	78.95	4.16	86.54	82.82	4.4167	44	3.7842	1936
	40-45	100	81	4.16	86.54	4.56	78.95	5.32	67.67	5.28	68.18	4.08	88.24	77.91	4.3556	36	3.5835	1296
	45-50	100	79	5.04	71.43	5.76	62.50	5.12	70.31	4.56	78.95	6.08	59.21	68.48	4.2265	50	3.9120	2500
	50-55	100	81	4.52	79.65	4.28	84.11	4.56	78.95	4.84	74.38	4.56	78.95	79.21	4.3721	42	3.7377	1764
	55-60	100	72	3.96	90.91	4.72	76.27	4.08	88.24	4.92	73.17	4.12	87.38	83.19	4.4212	36	3.5835	1296
	0-5	100	26	3.96	90.91	4.48	80.36	3.24	111.11	4.60	78.26	3.56	101.12	92.35	4.5256	28	3.3322	784
	5-10	100	31	4.52	79.65	4.12	87.38	4.16	86.54	3.56	101.12	4.60	78.26	86.59	4.4612	24	3.1781	576
	10-15	100	40	4.84	74.38	4.80	75.00	3.64	98.90	4.88	73.77	4.52	79.65	80.34	4.3863	30	3.4012	900
	15-20	100	36	3.16	113.92	3.84	93.75	4.12	87.38	5.00	72.00	4.80	75.00	88.41	4.4820	22	3.0910	484
	20-25	100	35	3.32	108.43	4.00	90.00	4.16	86.54	4.92	73.17	4.24	84.91	88.61	4.4842	18	2.8904	324
Wednesday	25-30	100	50	4.28	84.11	4.40	81.82	3.52	102.27	4.68	76.92	4.04	89.11	86.85	4.4641	34	3.5264	1156
(Non Peak	30-35	100	31	4.72	76.27	4.36	82.57	3.04	118.42	3.64	98.90	4.56	78.95	91.02	4.5111	18	2.8904	324
Hour)	35-40	100	44	4.20	85.71	4.08	88.24	3.76	95.74	6.08	59.21	3.96	90.91	83.96	4.4304	38	3.6376	1444
	40-45	100	27	3.52	102.27	3.32	108.43	3.24	111.11	4.56	78.95	3.80	94.74	99.10	4.5961	16	2.7726	256
	45-50	100	21	4.08	88.24	4.56	78.95	4.12	87.38	3.92	91.84	3.92	91.84	87.65	4.4733	32	3.4657	1024
	50-55	100	32	3.96	90.91	3.60	100.00	4.36	82.57	4.16	86.54	4.28	84.11	88.83	4.4867	36	3.5835	1296
	55-60	100	19	3.88	92.78	4.12	87.38	4.20	85.71	4.24	84.91	4.36	82.57	86.67	4.4621	44	3.7842	1936
	0-5	100	81	4.60	78.26	4.76	75.63	5.20	69.23	4.40	81.82	4.52	79.65	76.92	4.3427	38	3.6376	1444
	5-10	100	73	4.16	86.54	6.08	59.21	6.08	59.21	4.72	76.27	4.60	78.26	71.90	4.2753	50	3.9120	2500
	10-15	100	92	5.80	62.07	4.80	75.00	4.08	88.24	4.16	86.54	4.52	79.65	78.30	4.3605	46	3.8286	2116
	15-20	100	87	4.80	75.00	3.88	92.78	4.48	80.36	5.12	70.31	4.60	78.26	79.34	4.3738	48	3.8712	2304
	20-25	100	98	3.92	91.84	4.76	75.63	4.24	84.91	6.04	59.60	4.24	84.91	79.38	4.3742	44	3.7842	1936
Wednesday	25-30	100	76	4.04	89.11	4.52	79.65	4.00	90.00	6.20	58.06	4.04	89.11	81.19	4.3967	38	3.6376	1444
(Peak Hour)	30-35	100	88	5.52	65.22	4.04	89.11	5.12	70.31	5.40	66.67	4.56	78.95	74.05	4.3047	40	3.6889	1600
	35-40	100	95	4.72	76.27	4.80	75.00	4.04	89.11	4.56	78.95	5.20	69.23	77.71	4.3530	42	3.7377	1764
	40-45	100	78	4.76	75.63	4.04	89.11	4.84	74.38	6.00	60.00	6.04	59.60	71.74	4.2731	52	3.9512	2704
	45-50	100	81	5.40	66.67	4.24	84.91	4.60	78.26	5.92	60.81	4.44	81.08	74.35	4.3087	44	3.7842	1936
	50-55	100	73	4.88	73.77	5.20	69.23	5.32	67.67	4.08	88.24	6.00	60.00	71.78	4.2736	48	3.8712	2304
	55-60	100	59	4.56	78.95	3.96	90.91	3.96	90.91	4.40	81.82	4.68	76.92	83.90	4.4296	40	3.6889	1600
	0-5	100	24	5.20	69.23	3.56	101.12	3.96	90.91	3.76	95.74	4.12	87.38	88.88	4.4873	16	2.7726	256
	5-10	100	36	6.08	59.21	3.16	113.92	3.88	92.78	4.12	87.38	3.96	90.91	88.84	4.4869	20	2.9957	400
	10-15	100	38	4.08	88.24	4.48	80.36	4.20	85.71	4.36	82.57	4.28	84.11	84.20	4.4332	38	3.6376	1444
	15-20	100	41	4.48	80.36	4.32	83.33	3.88	92.78	4.60	78.26	4.52	79.65	82.88	4.4173	36	3.5835	1296
	20-25	100	44	3.72	96.77	4.24	84.91	4.00	90.00	3.56	101.12	3.08	116.88	97.94	4.5843	16	2.7726	256
Thursday	25-30	100	28	3.80	94.74	3.56	101.12	4.40	81.82	4.88	73.77	3.16	113.92	93.07	4.5334	24	3.1781	576
(Non Peak	30-35	100	27	4.04	89.11	3.76	95.74	4.36	82.57	3.52	102.27	3.96	90.91	92.12	4.5231	36	3.5835	1296

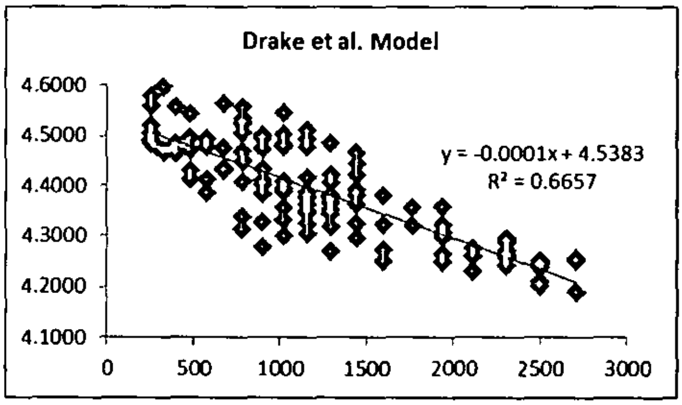
Hour)	35-40	100	21	4.12	87.38	3.84	93.75	4.08	88.24	4.08	88.24	4.04	89.11	89.34	4.4925	26	3.2581	676
	40-45	100	34	4.48	80.36	3.68	97.83	3.32	108.43	4.12	87.38	3.72	96.77	94.15	4.5449	24	3.1781	576
	45-50	100	40	4.60	78.26	3.20	112.50	4.68	76.92	4.04	89.11	5.28	68.18	84.99	4.4426	34	3.5264	1156
	50-55	100	36	4.12	87.38	4.20	85.71	4.60	78.26	3.84	93.75	4.72	76.27	84.27	4.4341	16	2.7726	256
	55-60	100	28	4.36	82.57	4.24	84.91	3.84	93.75	3.92	91.84	4.88	73.77	85.37	4.4470	28	3.3322	784
Thursday (Peak Hour)	0-5	100	67	5.40	66.67	5.88	61.22	4.64	77.59	4.92	73.17	4.64	77.59	71.25	4.2662	48	3.8712	2304
	5-10	100	81	5.20	69.23	4.16	86.54	4.64	77.59	4.32	83.33	4.00	90.00	81.34	4.3986	52	3.9512	2704
	10-15	100	75	4.76	75.63	5.68	63.38	4.16	86.54	5.72	62.94	5.28	68.18	71.33	4.2674	50	3.9120	2500
	15-20	100	79	4.60	78.26	4.88	73.77	5.32	67.67	5.12	70.31	4.32	83.33	74.67	4.3131	32	3.4657	1024
	20-25	100	86	4.16	86.54	4.60	78.26	4.76	75.63	4.24	84.91	5.88	61.22	77.31	4.3478	46	3.8286	2116
	25-30	100	98	5.72	62.94	5.56	64.75	4.12	87.38	4.92	73.17	5.04	71.43	71.93	4.2757	48	3.8712	2304
	30-35	100	87	6.16	58.44	4.12	87.38	4.72	76.27	6.60	54.55	4.32	83.33	71.99	4.2766	50	3.9120	2500
	35-40	100	93	4.32	83.33	6.12	58.82	4.28	84.11	5.32	67.67	6.08	59.21	70.63	4.2575	52	3.9512	2704
	40-45	100	67	3.88	92.78	4.36	82.57	5.04	71.43	4.00	90.00	4.72	76.27	82.61	4.4141	28	3.3322	784
	45-50	100	82	5.56	64.75	5.08	70.87	5.36	67.16	5.64	63.83	3.96	90.91	71.50	4.2697	44	3.7842	1936
	50-55	100	81	4.80	75.00	4.16	86.54	4.72	76.27	4.60	78.26	4.52	79.65	79.14	4.3713	42	3.7377	1764
	55-60	100	65	4.16	86.54	4.16	86.54	4.08	88.24	6.12	58.82	6.12	58.82	75.79	4.3280	36	3.5835	1296
Friday (Non Peak Hour)	0-5	100	22	3.72	96.77	3.52	102.27	4.48	80.36	4.60	78.26	4.08	88.24	89.18	4.4907	30	3.4012	900
	5-10	100	29	3.80	94.74	3.96	90.91	3.56	101.12	5.08	70.87	3.80	94.74	90.47	4.5051	28	3.3322	784
	10-15	100	27	4.48	80.36	3.04	118.42	3.96	90.91	4.84	74.38	3.96	90.91	91.00	4.5108	32	3.4657	1024
	15-20	100	31	4.32	83.33	3.40	105.88	3.36	107.14	3.40	105.88	4.60	78.26	96.10	4.5654	34	3.5264	1156
	20-25	100	40	3.72	96.77	4.20	85.71	5.04	71.43	3.48	103.45	5.00	72.00	85.87	4.4529	18	2.8904	324
	25-30	100	38	3.80	94.74	3.24	111.11	4.08	88.24	3.20	112.50	3.36	107.14	102.75	4.6323	22	3.0910	484
	30-35	100	26	4.04	89.11	4.00	90.00	4.92	73.17	4.16	86.54	3.96	90.91	85.95	4.4537	20	2.9957	400
	35-40	100	17	4.12	87.38	5.04	71.43	3.92	91.84	4.08	88.24	4.48	80.36	83.85	4.4290	20	2.9957	400
	40-45	100	48	3.64	98.90	4.52	79.65	3.12	115.38	4.04	89.11	4.32	83.33	93.27	4.5355	30	3.4012	900
	45-50	100	29	6.08	59.21	4.44	81.08	3.96	90.91	3.84	93.75	3.64	98.90	84.77	4.4399	18	2.8904	324
	50-55	100	32	4.56	78.95	4.08	88.24	3.64	98.90	3.92	91.84	4.08	88.24	89.23	4.4912	22	3.0910	484
	55-60	100	25	4.12	87.38	3.40	105.88	4.04	89.11	3.40	105.88	3.76	95.74	96.80	4.5726	16	2.7726	256
Friday (Peak Hour)	0-5	100	89	5.32	67.67	5.72	62.94	4.40	81.82	4.00	90.00	4.48	80.36	76.56	4.3380	52	3.9512	2704
	5-10	100	69	5.68	63.38	5.04	71.43	5.68	63.38	5.00	72.00	5.28	68.18	67.67	4.2147	52	3.9512	2704
	10-15	100	74	6.24	57.69	4.44	81.08	5.04	71.43	4.96	72.58	4.72	76.27	71.81	4.2740	50	3.9120	2500
	15-20	100	87	4.60	78.26	5.08	70.87	4.68	76.92	4.20	85.71	5.68	63.38	75.03	4.3179	36	3.5835	1296
	20-25	100	73	4.16	86.54	5.80	62.07	4.00	90.00	3.96	90.91	4.72	76.27	81.16	4.3964	42	3.7377	1764
	25-30	100	85	4.88	73.77	4.92	73.17	4.84	74.38	4.40	81.82	4.08	88.24	78.27	4.3602	46	3.8286	2116
	30-35	100	96	5.68	63.38	4.32	83.33	4.12	87.38	5.00	72.00	6.08	59.21	73.06	4.2913	36	3.5835	1296
	35-40	100	115	6.48	55.56	4.12	87.38	5.00	72.00	4.88	73.77	3.88	92.78	76.30	4.3346	40	3.6889	1600
	40-45	100	91	4.52	79.65	4.08	88.24	5.04	71.43	5.60	64.29	4.56	78.95	76.51	4.3374	42	3.7377	1764
	45-50	100	87	4.56	78.95	4.88	73.77	4.56	78.95	6.12	58.82	5.04	71.43	72.38	4.2820	46	3.8286	2116
	50-55	100	73	4.72	76.27	5.60	64.29	6.56	54.88	4.80	75.00	5.44	66.18	67.32	4.2095	50	3.9120	2500
	55-60	100	61	3.84	93.75	5.72	62.94	4.04	89.11	4.56	78.95	4.16	86.54	82.26	4.4098	38	3.6376	1444

Appendix C

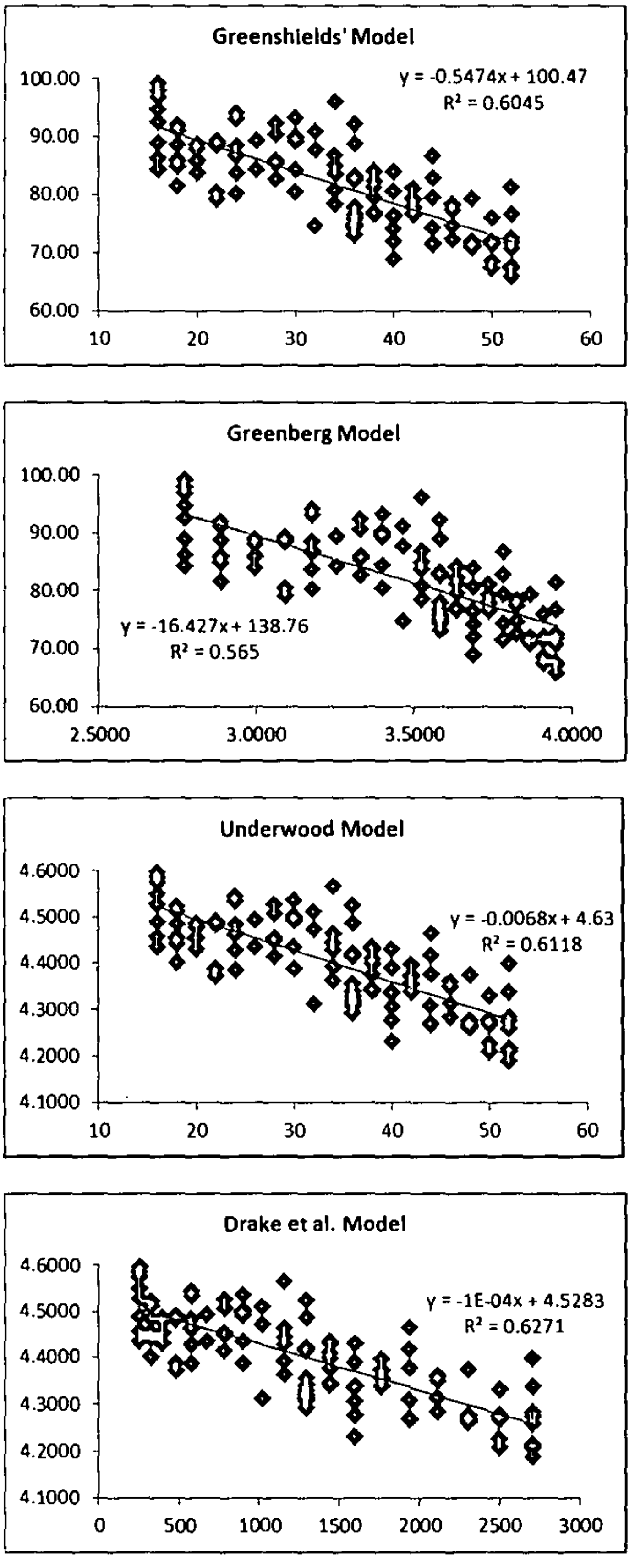








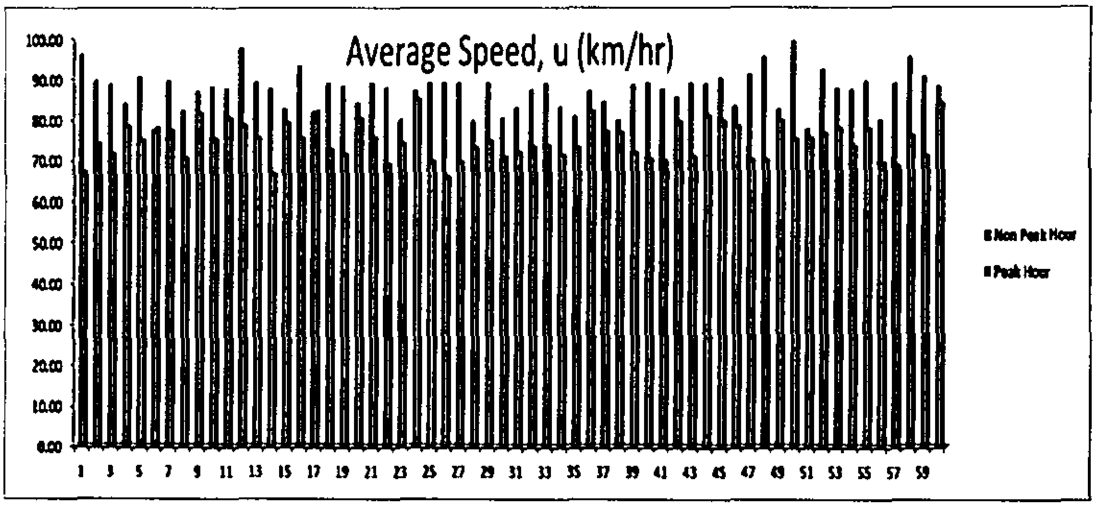
A Graph of Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model for location at KM15.8 – Batu 3 (Shah Alam, Selangor to Kuala Lumpur)



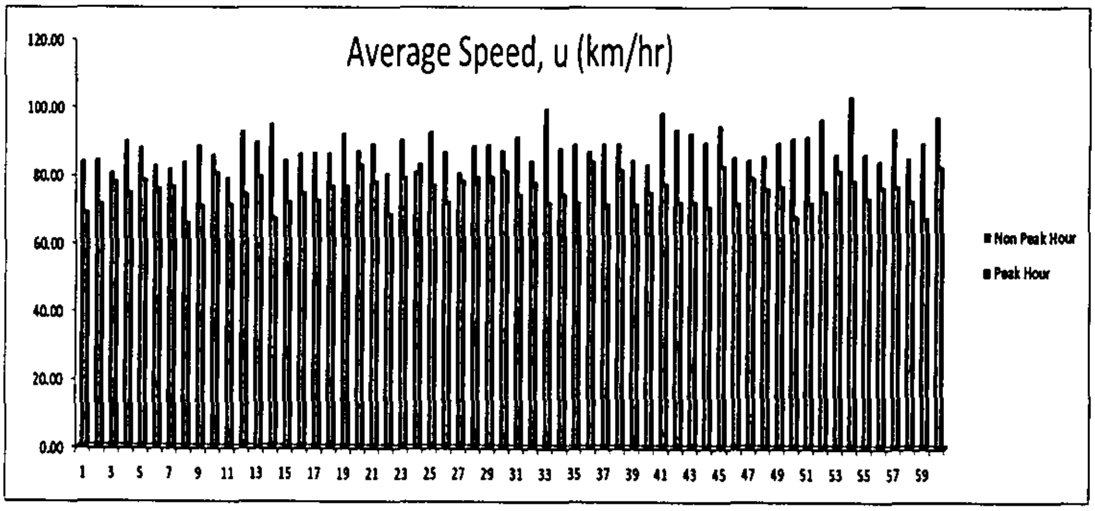
A Graph of Greenshields' Model, Greenberg Model, Underwood Model and Drake et al. Model for location at KM31.5 – Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)

Appendix D

Histogram of Average Speed at KM15.8 – Batu 3 (Shah Alam, Selangor to Kuala Lumpur)

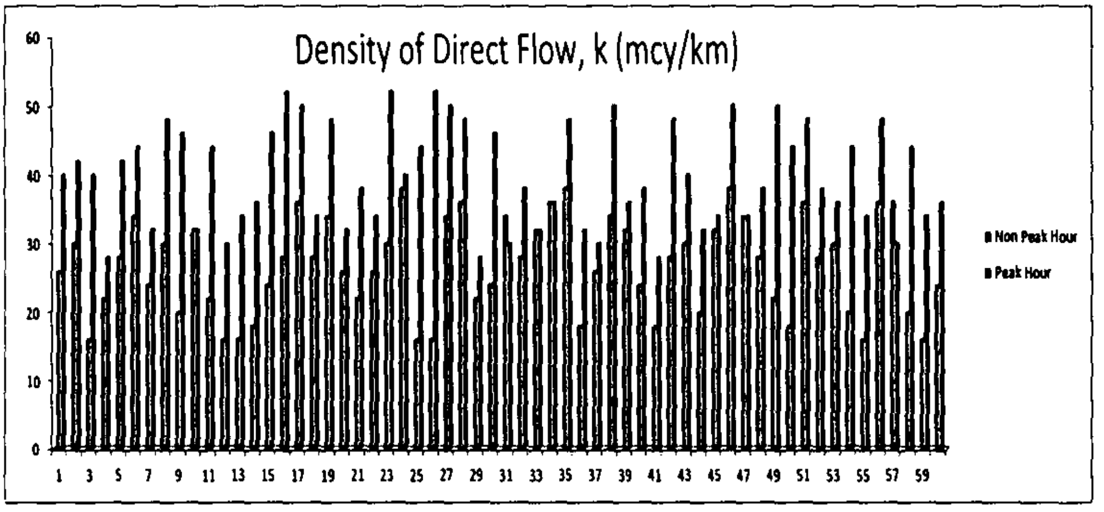


Histogram of Average Speed at KM31.5 - Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)

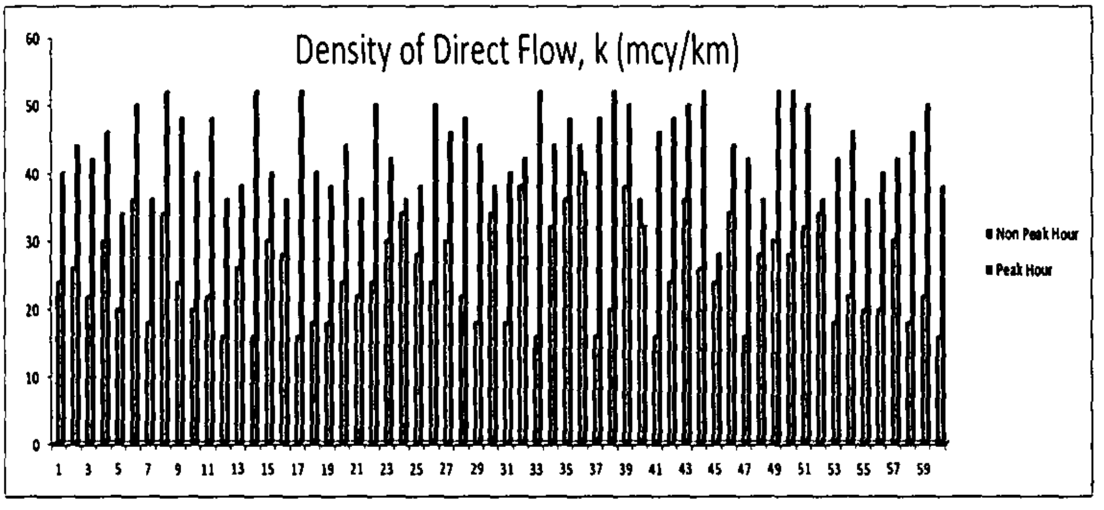


Appendix E

Histogram of Density of Direct Flow at KM15.8 – Batu 3 (Shah Alam, Selangor to Kuala Lumpur)

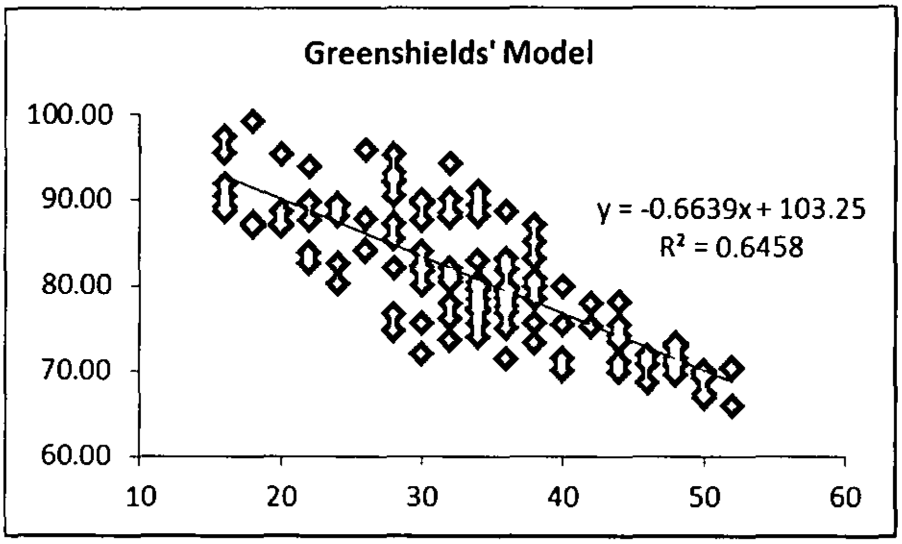


Histogram of Density of Direct Flow at KM31.5 - Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)



Appendix F

Graph KM30.7 – Sungai Way (Kuala Lumpur to Shah Alam, Selangor)



From the Figure 4.4,

$y = -0.6639x + 103.25$

Intercept, $a = u_f$

$a = \underline{103.25 \text{ km/hr}}$

Slope, $b = -\frac{u_f}{k_j}$

Therefore, $-\frac{u_f}{k_j} = -0.6639$

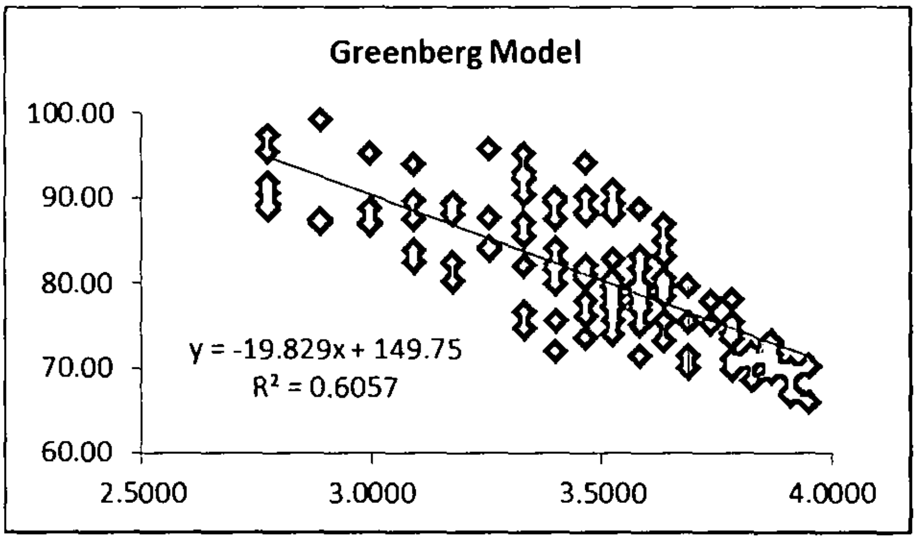
$-\frac{103.25}{k_j} = -0.6639$

$k_j = \frac{-103.25}{-0.6639}$

$k_j = \underline{156 \text{ mc/km}}$

⟹ **u = 103.25 – 0.6639k**

$$u = u_f - \left(\frac{u_f}{k_j}\right).k$$



From the Figure 4.5,

y = -19.829x + 149.75

Slope, b = $- u_o$

$- u_o$ = - 19.829

u_o = 19.83 km/hr

Intercept, a = $u_o \ln (k_j)$

a = 149.75

Therefore, $u_o \ln (k_j) = 149.75$

$19.829 \ln (k_j) = 149.75$

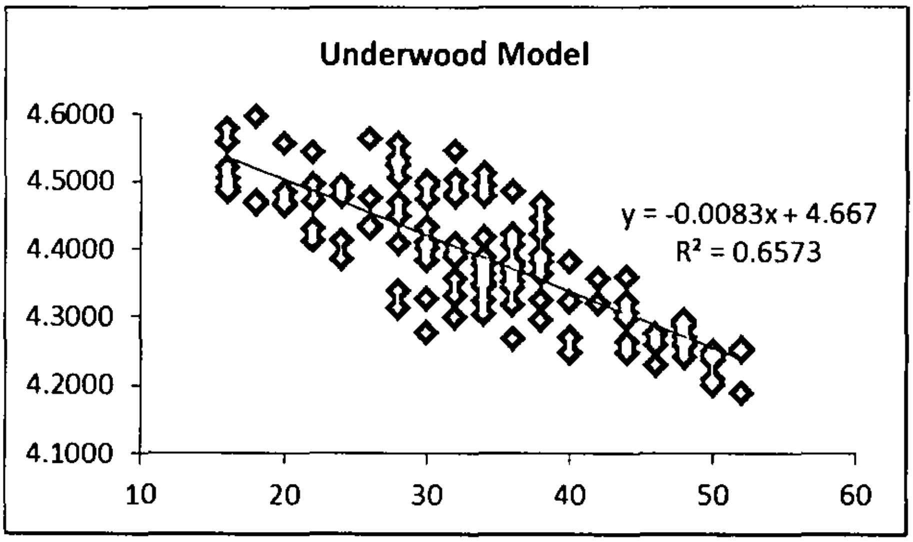
$\ln (k_j) = \frac{149.75}{19.829}$

$\ln (k_j) = 7.552$

k_j = 1905 mc/km

⟹ u = 19.83 ln (1905/k)

$$u = u_o \ln\left(\frac{k_j}{k}\right)$$



From the Figure 4.6,

y = -0.0083x + 4.667

Intercept, a = $\ln(u_f)$

$\ln(u_f) = 4.667$

u_f = 106.38 km/hr

Slope, b = $-\dfrac{1}{k_o}$

b = - 0.0083

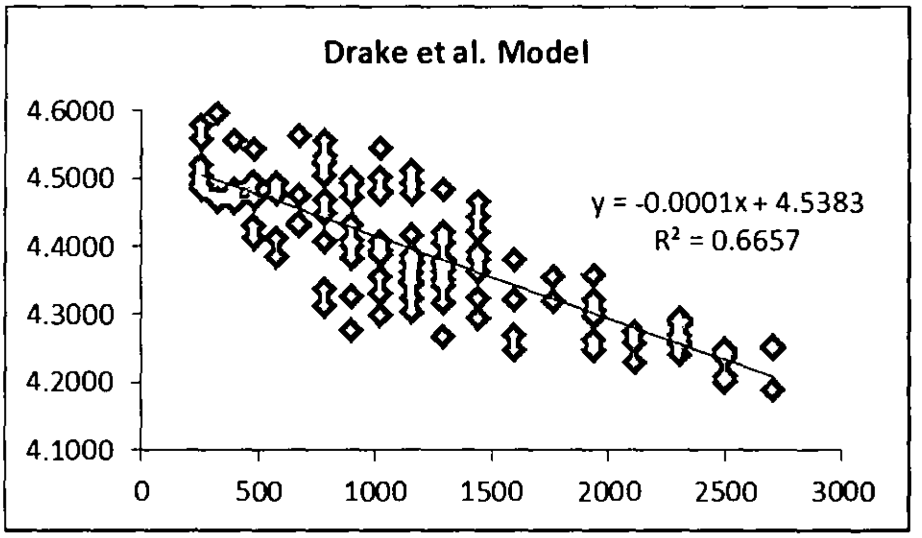
Therefore, $-\dfrac{1}{k_o} = -0.0083$

$-\dfrac{1}{k_o} = -0.0083$

k_o = 121 mc/km

⟹ **$u = 106.38\, e^{-(k/121)}$**

$$u = u_f e^{-(k/k_o)}$$



From the Figure 4.7,

$y = -0.0001x + 4.5383$

Intercept, $a = \ln(u_f)$

$\ln(u_f) = 4.5383$

u_f = 93.53km/hr

Slope, $b = -\dfrac{1}{2k_o^2}$

$b = -0.0001$

Therefore, $-\dfrac{1}{2k_o^2} = -0.0001$

$-\dfrac{1}{2k_o^2} = -0.0001$

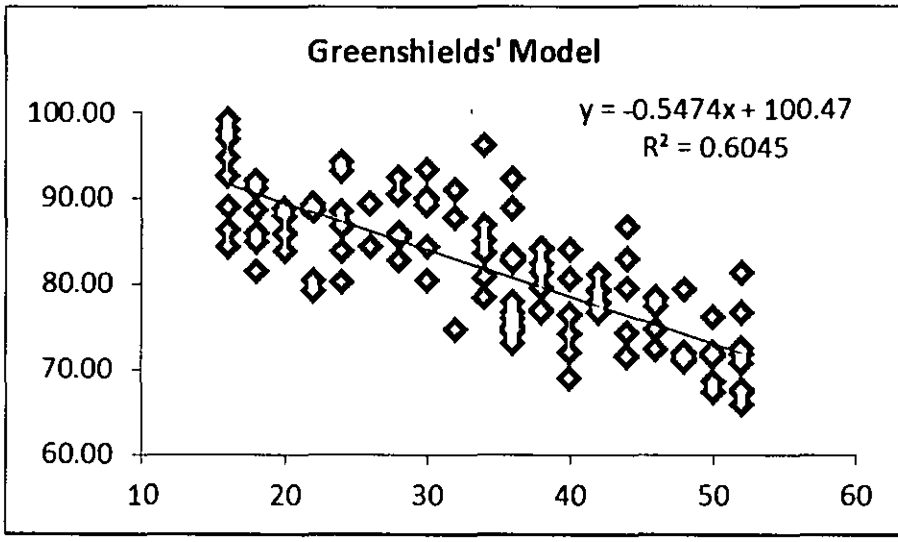
$2k_o^2 = \dfrac{-1}{-0.0001}$

k_o = 71 mc/km

$\Longrightarrow$ $u = 93.53\ e^{-0.5(k/71)^2}$

$u = u_f\ e^{-0.5(k/k_o)^2}$

Graph KM31.5 – Petaling Jaya (Shah Alam, Selangor to Kuala Lumpur)



From the graph above,

y = -0.5474x + 100.47

Intercept, a = u_f

= 100.47 km/hr

Slope, b = $- \frac{u_f}{k_j}$

Therefore, $- \frac{u_f}{k_j} = - 0.5474$

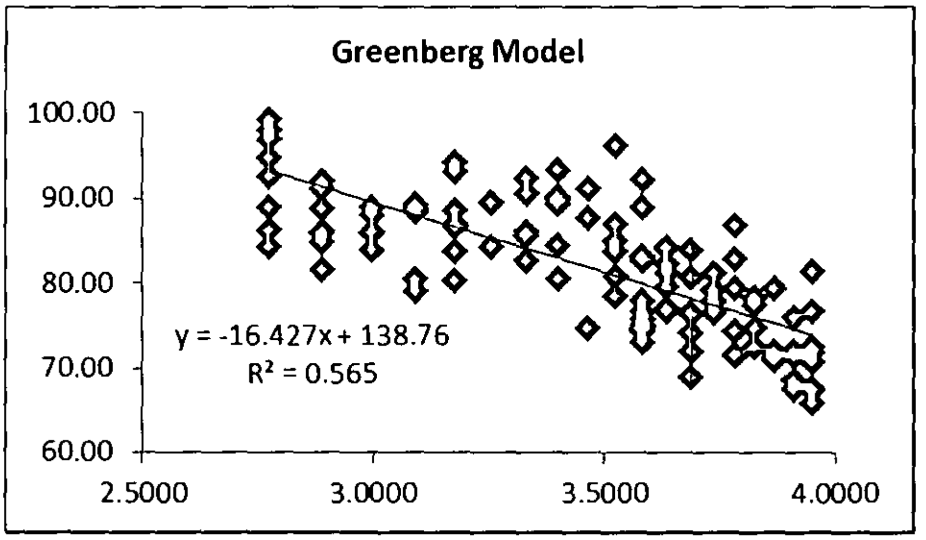
$- \frac{100.47}{k_j} = - 0.5474$

$k_j = \frac{- 100.47}{- 0.5474}$

= 184 mc/km

⟹ **u = 100.47 – 0.5474k**

$$u = u_f - \left(\frac{u_f}{k_j}\right).k$$



From the graph above,

$y = -16.427x + 138.76$

Slope, $b = -u_o$

$-u_o = -16.427$

$= \underline{16.43 \text{ km/hr}}$

Intercept, $a = u_o \ln(k_j)$

$= \underline{138.76}$

Therefore, $u_o \ln(k_j) = 138.76$

$16.427 \ln(k_j) = 138.76$

$\ln(k_j) = \dfrac{138.76}{16.427}$

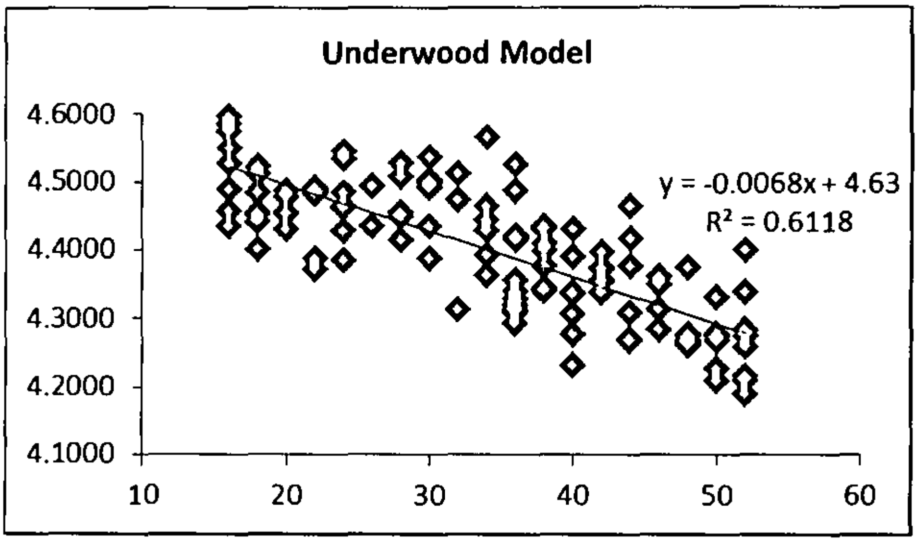
$\ln(k_j) = 8.447$

$k_j = e^{8.447}$

$= \underline{4662 \text{ mc/km}}$

⟹ **u = 16.43 ln (4662/k)**

$$u = u_o \ln\left(\frac{k_j}{k}\right)$$



From the graph above,

y = -0.0068x + 4.630

Intercept, a = $\ln(u_f)$

$\ln(u_f)$ = 4.630

= 102.51 km/hr

Slope, b = $-\frac{1}{k_o}$

= - 0.0068

Therefore, $-\frac{1}{k_o} = -0.0068$

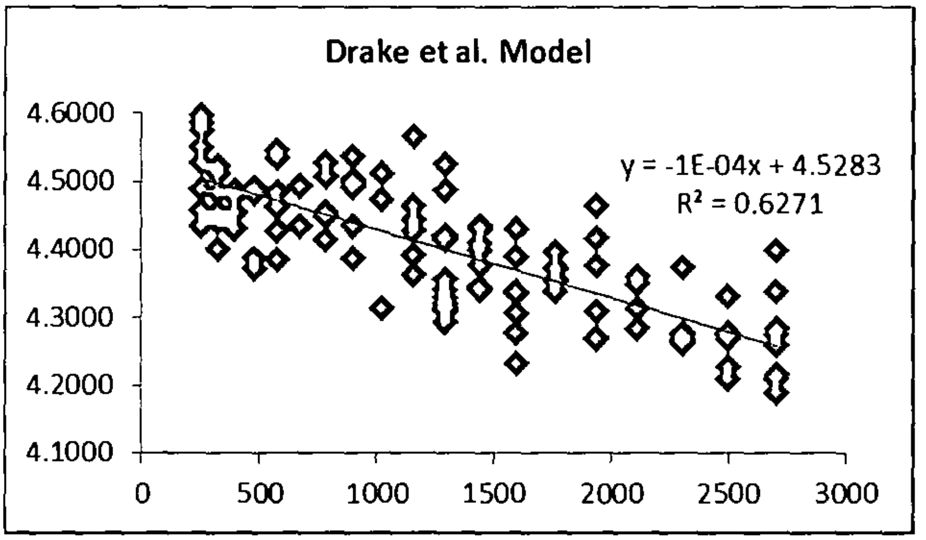
$-\frac{1}{k_o} = -0.0068$

$k_o = \frac{-1}{-0.0068}$

= 147 mc/km

⟹ **u = 102.51 $e^{-(k/147)}$**

$u = u_f e^{-(k/k_o)}$



From the graph above,

y = -0.0001x + 4.5283

Intercept, a = $\ln(u_f)$

$\ln(u_f)$ = 4. 5283

= 92.60 km/hr

Slope, b = $-\frac{1}{2k_o^2}$

= - 0.0001

Therefore, $-\frac{1}{2k_o^2} = -0.0001$

$-\frac{1}{2k_o^2} = -0.0001$

$2k_o^2 = \frac{-1}{-0.0001}$

= 71 mc/km

$\Longrightarrow$ $u = 92.60\ e^{-0.5(k/71)^2}$

$u = u_f\ e^{-0.5(k/k_o)^2}$

Appendix G

Traffic Flow Parameters for Batu 3 – Kuala Lumpur to Shah Alam, Selangor

Parameters	Models			
	Greenshields'	Greenberg	Underwood	Drake et al.
Optimum speed, u_o (km/hr)	-	19.83	-	-
Free-flow speed, u_f (km/hr)	103.25	∞	106.38	93.53
Optimum density, k_o (veh/km)	-	-	121	71
Jam density, k_j (veh/km)	156	1905	∞	∞

Traffic Flow Parameters for Petaling Jaya – Kuala Lumpur to Shah Alam, Selangor

Parameters	Models			
	Greenshields'	Greenberg	Underwood	Drake et al.
Optimum speed, u_o (km/hr)	-	16.43	-	-
Free-flow speed, u_f (km/hr)	100.47	∞	102.51	92.60
Optimum density, k_o (veh/km)	-	-	147	71
Jam density, k_j (veh/km)	184	1662	∞	∞

Appendix H

New Macroscopic of Single-Regime Models

Location / Model	Batu 3 – Shah Alam, Selangor to Kuala Lumpur	Sungai Way – Kuala Lumpur to Shah Alam, Selangor	Petaling Jaya – Shah Alam, Selangor to Kuala Lumpur
Greenshields' Model	$u = 103.25 - 0.6639k$	$u = 107.95 - 0.8185k$	$u = 100.47 - 0.5474k$
Greenberg Model	$u = 19.83 \ln(1905/k)$	$u = 24.16 \ln(889/k)$	$u = 16.43 \ln(4662/k)$
Underwood Model	$u = 106.38\ e^{-(k/121)}$	$u = 112.64\ e^{-(k/99)}$	$u = 102.51\ e^{-(k/147)}$
Drake et al. Model	$u = 93.53\ e^{-0.5(k/71)^2}$	$u = 96.55\ e^{-0.5(k/50)^2}$	$u = 92.60\ e^{-0.5(k/71)^2}$