LAPORAN PENYELIDIKAN JANGKA PENDEK USM
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KAJIAN PENILAIAN KEJURUTERAAN LALULINTAS UNTUK SISYEM RANGKAIAN JALAN RAYA DI MALAYSIA

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UNIVERSITI SAINS MALAYSIA
LAPORAN AKHIR PROJEK PENYELIDIKAN JANGKA PENDEK

Penghargaan:

Saya ingin mengucapkan terima kasih yang tertinggi kepada Dekan PPKA PM Dr Sabarudin Mohd, Timbalan Naib Canselor Penyelidikan dan Pembangunan – Profesor Ahyaudin Ali, Universiti Sains Malaysia kerana sudi menganugerahkan geran ini yang telah dimanfaatkan sepenuhnya untuk pembangunan akademik.

1) NAMA PENYELIDIK: P.M. Dr WAN HASHIM WAN IBRAHIM
PENYELIDIK YANG LAIN:

2) PUSAT PENGAJIAN: KEJURUTERAAN AWAM

3) TAJUK PROJEK: KAJIAN PENILAIAN KEJURUTERAAN LALULINTAS UNTUK SISYEM RANGKAIAN JALAN RAYA DI MALAYSIA

4) a) PENEMUAN PROJEK/ABSTRAK (Perlu sediakan 100-200 perkataan dalam bahasa Malaysia dan Inggeris)

Penilaian sistem jaringan jalan raya perlu dibuat menggunakan kaedah penialaian yang betul dan berkesan. Hasil daripada kajian ini telah mengenalpasti kaedah yang paling sesuai untuk mengukur keberkesanan sistem jaringan janal raya di Malaysia. Dua kaedah utama telah dikenalpasti dan dibuat perbandingan dari segi kesesuaiannya untuk keadaan di Malaysia. Dua kaedah tersebut ialah kaedah "moving observer method" dan "kaedah car chasing method". Kedua-dua kaedah telah digunakan untuk mengukur keberkesanan sistem jaringan jalan raya di sekitar Seberang Prai dan juga di Ipoh. Hasil kajian mendapati kaedah "Car Chasing Method" adalah kaedah yang lebih berkesan untuk digunakan dalam penilaian sistem jaraingan jalan raya di Malaysia. Perbandingan kedua-dua kaedah tersebut ditunjukkan dalam Jadual dibawah:

A Comparison between Moving Observer Method and Car Chasing Method

Moving Observer Method	Car Chasing Method
Developed by Wardrop & Charlesworth (1954) by using specified formulas.	Based on Car Following Model (early 1950s by Reuschel, Pipes, Forbes & group of researchers from General Motor).

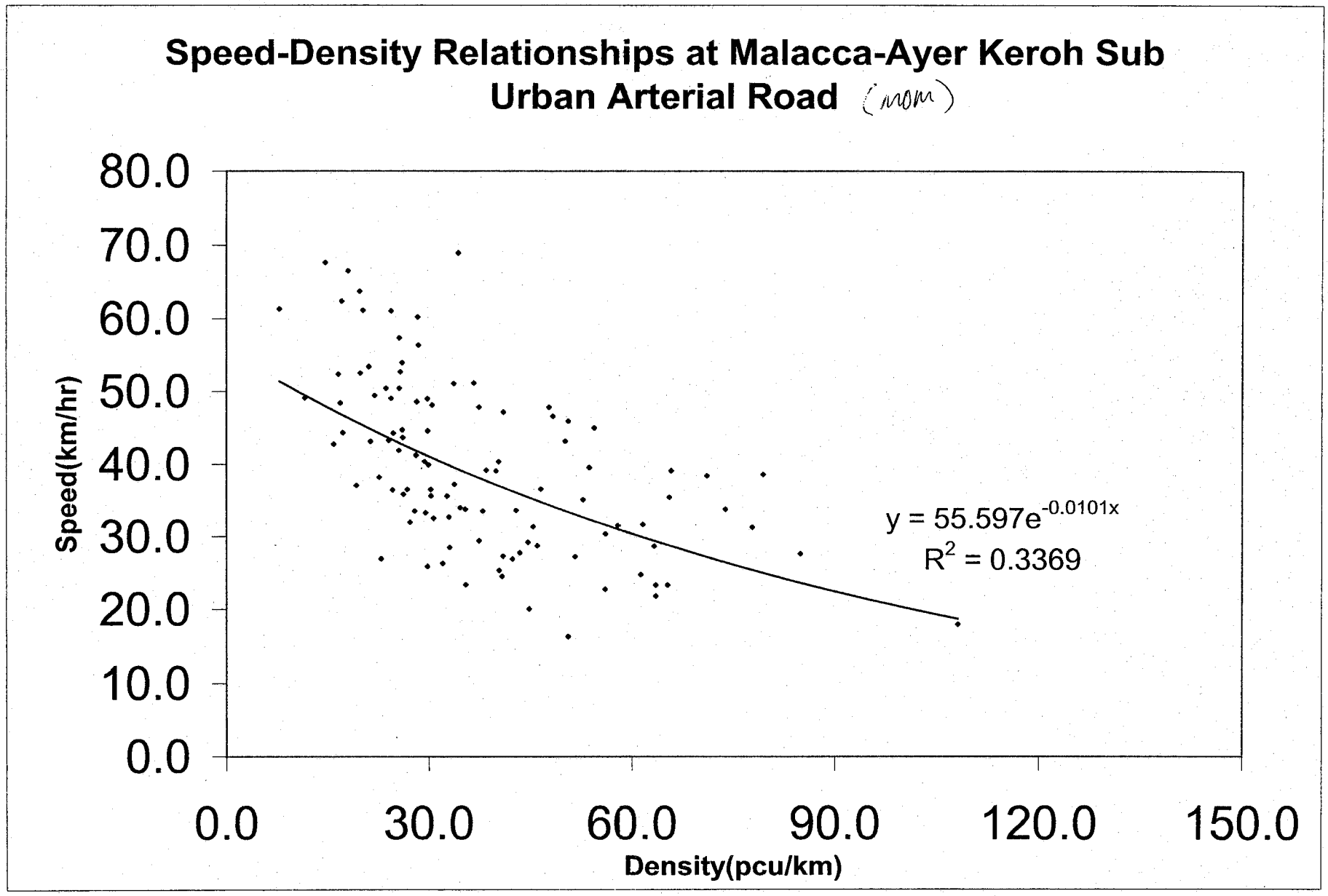
Obtain the travel speed and traffic volume (hourly) data simultaneously.	Only can obtain travel speed data.
Applicable only for 2-way routes where opposing traffic is visible at all times. Must be able to turn around at each end of the test sections.	Applicable for either 1-way or 2-way routes. Not depend to opposing traffic.
At least, 3 persons in the test car (including the driver).	2 persons are enough (including the driver).
The own speed of the test car driver (Obey the speed limit).	The other driver speed (follow the randomly chosen car).
Suitable for light traffic condition/ rural expressway (Hall F.L., 1995).	Suitable for heavy traffic condition (L. C. Edie, 1974).
No major exits or entrances on the study route (Wright, 1973).	Appropriate to conduct the study inside the Central Business District (CBD) (Olszewski *et al.*, 1995).
Both directions (go & back) – 1 set of data.	One direction is enough to get 1 set of data.
Minimum of six test runs in each direction under comparable conditions (Mortimer, 1957).	Minimum of four test runs with confidence level of 95% for traffic operation analysis (Box & Oppenlander, 1976).

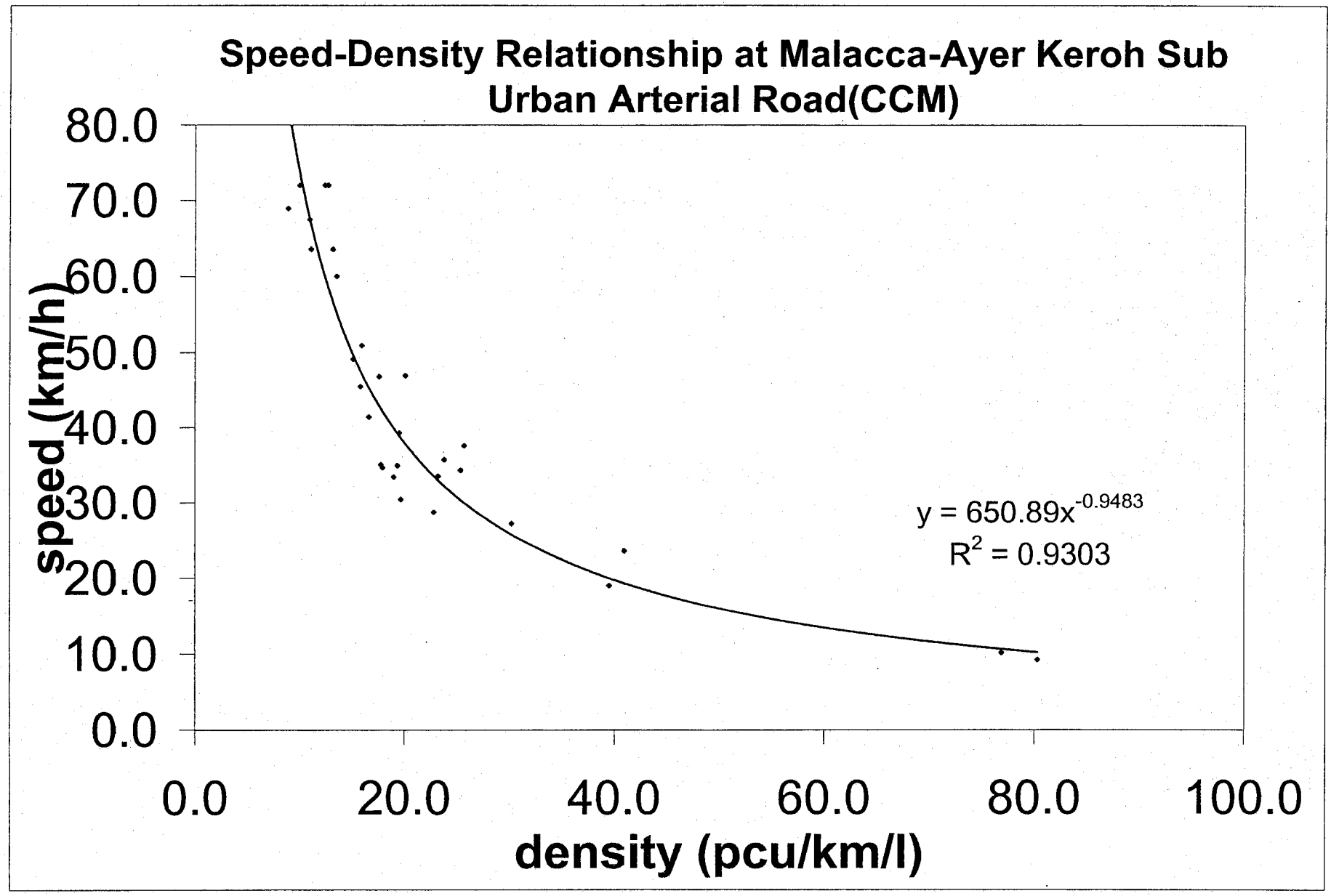
Berdasarkan penemuan tersebut, kaedah "Car Chasing Method" telah digunakan untuk mengenalpasti ciri-ciri kejuruteraan lalu lintas untuk sistem jalan raya di Seberang Prai dan juga di Ipoh. Hasil kajian mendapati, ciri-ciri kejuruteraan lalu lintas untuk sistem jalan raya di kawasan-kawasan tersebut banyak dipengaruhi oleh sistem kawalan lampu isyarat dan juga dipengaruhi oleh jenis-jenis persimpangan yang terdapat di sepanjang jaringan jalan tersebut.

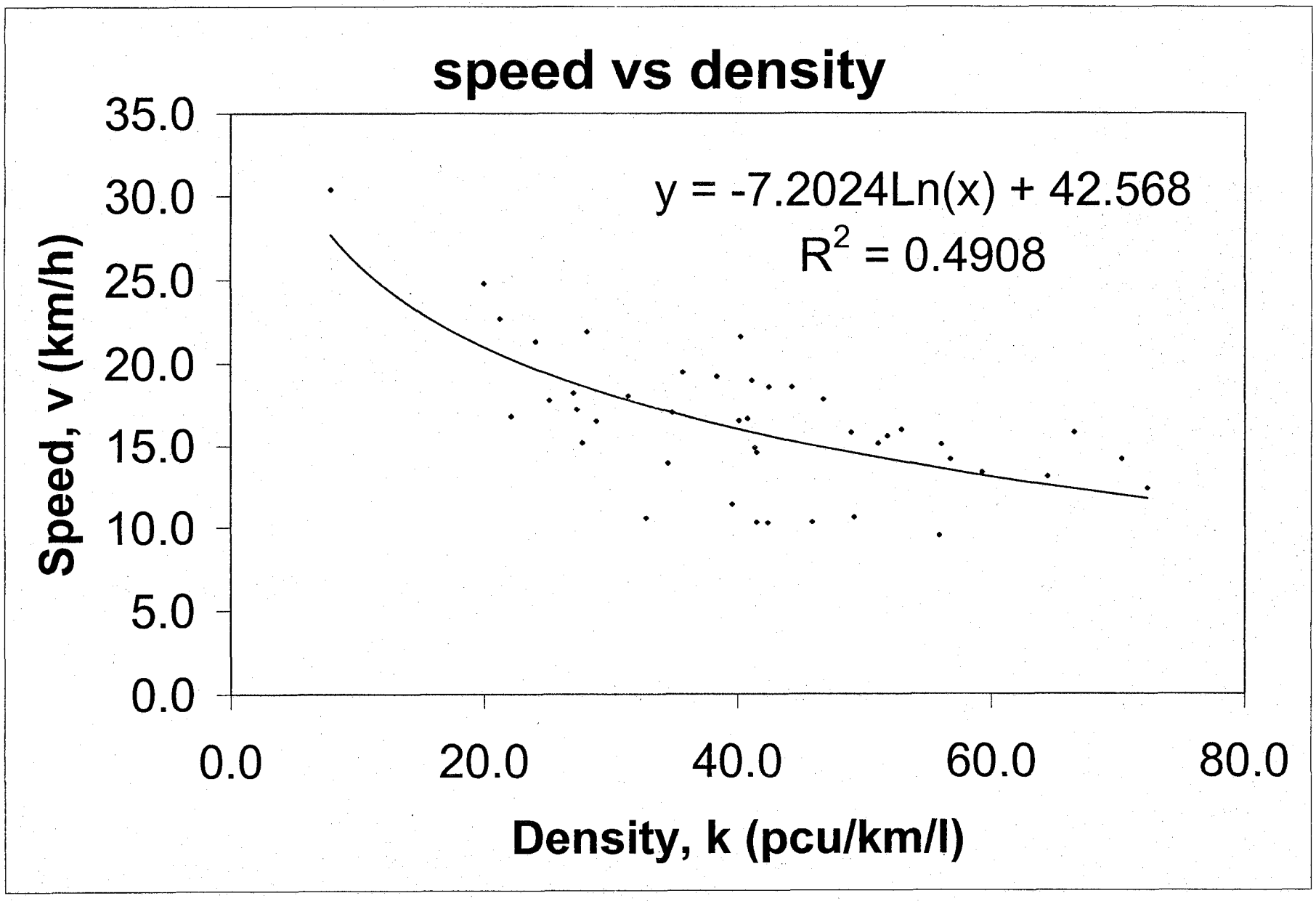
b) Senarai Kata Kunci (dalam BI dan BM) Moving Observer Method, Car Chasing Method

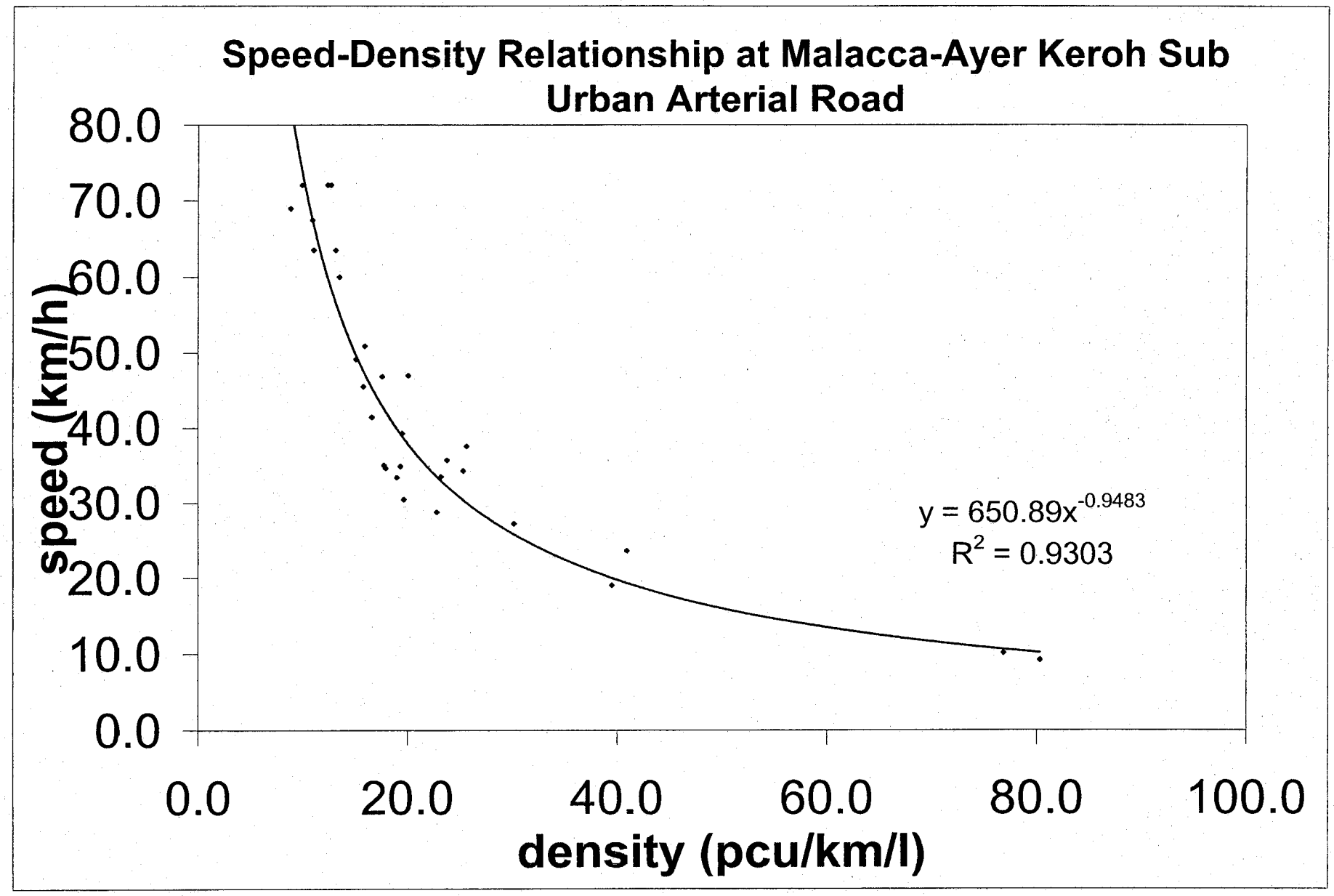
5. Output dan Faedah Projek

(a) Penerbitan (Termasuk laporan/kertas seminar, nyatakan jenis, tajuk, pengarang, tahun terbitan dan dimana diterbitkan/dibentangkan). (Dikepilkan)


Speed-Density Relationships at Malacca-Ayer Keroh Sub Urban Arterial Road (mom)
Speed(km/hr)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
30.0
60.0
90.0
120.0
150.0
Density(pcu/km)
y = 55.597e-0.0101x
R2 = 0.3369


Speed-Density Relationship at Malacca-Ayer Keroh Sub Urban Arterial Road(CCM)
speed (km/h)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
20.0
40.0
60.0
80.0
100.0
density (pcu/km/l)
y = 650.89x^-0.9483
R^2 = 0.9303


speed vs density
y = -7.2024Ln(x) + 42.568
R2 = 0.4908
Speed, v (km/h)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
20.0
40.0
60.0
80.0
Density, k (pcu/km/l)


Speed-Density Relationship at Malacca-Ayer Keroh Sub Urban Arterial Road
speed (km/h)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
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20.0
40.0
60.0
80.0
100.0
density (pcu/km/l)
y = 650.89x^-0.9483
R^2 = 0.9303

Estimating Travel Time of Arterial Road Using Car Chasing Method and Moving Observer Method

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ABSTRACT

An arterial road is a major road usually less than 3km in length connecting important places, which has several signalized intersections located several meters apart and carrying high through traffic volume. There are several basic engineering parameters affecting the performance of arterial roads such as travel time, traffic volume, free-flow speed and stopped delay. Travel time is the time taken by vehicles to traverse a given segment of arterial road. In this paper, estimation of the travel time along several arterial roads using Car Chasing Method and Moving Observer Method is discussed.

Keywords: *Moving Observer, Car Chasing, Arterial Road, Travel Time*

1.0 INTRODUCTION

Traffic flow on arterial roads is influenced by roadside friction, interaction among vehicle and effect of traffic signals. All of these definitely affect the capacity and level of service of the arterial roads. Capacity of the arterial roads is generally considered by the capacity of signalized intersection along those arterial roads. Roadside friction along the arterial roads is characterized by number of access alongside the arterial, land use type, pedestrian activity, parking space and road geometry. For the arterial roads, measure of effectiveness is the average through-vehicle travel speed. Travel speed of arterial roads is determined from the travel time data. According to the US HCM, it is very important to measure and estimate the travel time precisely.

Travel time data can be used to determine the efficiency of a route with respect to its ability to carry traffic volume relative to other routes and to provide the input to capacity analysis of

roadway segments. Travel time is an indication of delay on a broader scale than intersection delay, which only measure the delay on a single intersection on specific approach (Taylor & Abdel-Rahim, 1998). Travel time can be converted to travel speed by dividing the traveled distance with travel time. The travel speed can be used to determine the level of service for arterial roads. Estimation of arterial roads level of service depends on free flow speed and average travel speed as shown in Table 1.

Table 1 : Arterial Road LOS by Class

Arterial Road Class	I	II	III	IV
Range of free flow speed	90 – 70 km/h	70 – 55 km/h	55 – 50 km/h	55 – 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	>41
B	> 56 – 72	> 46 – 59	> 39 – 50	> 32 – 41
C	> 40 – 56	> 33 – 46	> 28 – 39	> 23 – 32
D	> 32 – 40	> 26 – 33	> 22 – 28	> 18 – 23
E	> 26 – 32	> 21 - 26	> 17 - 22	> 14 – 18
F	≤ 26	≤ 21	≤ 17	≤ 14

Source : HCM 2000

The speed flow relationship is another method to estimate the travel time. The travel speed can be estimated based on the observed traffic flow data. Therefore, it is important to estimate a typical speed flow relationship. In this paper, speed flow relationships of several arterial roads are estimated.

2.0 LITERATURE REVIEW

There are several methods being used to estimate travel time. According to Lum, *et al.* (1998), travel times may be observed in two different ways, "stationary observer" method and "moving observer" method. The "stationary observer" method such as license plate matching, computer-based image processing and matching technique does not require test cars (Robertson, 1994). The "moving observer" method such as moving observer method and car chasing method needs a test car for conducting the study. A new methodology for performing travel time studies using global positioning system (GPS) and geographic information system (GIS) technologies also has been done (Quiroga & Bullock, 1998).

3.0 TRAVEL TIME ESTIMATION TECHNIQUES

In this section, two techniques used to estimate travel time is discussed, i.e. Moving Observer Method and Car Chasing Method. Data collection technique for traffic volume is also being discussed.

Moving Observer Method

In this method, all observers will be in a test car during the data collection process. There are a minimum of 3 observers needed to conduct the study. Extra observers are needed especially during peak period. The driver will drive at an average speed and obeyed speed limit of the particular road. The odometer is used to estimate the length of the study zone. The driver will ascertain all the study team regarding the beginning and ending of the study zone. The next observer, records the starting time and ending time for every zone. Along the stretch, the stopping time of test car is recorded. One of the observers will record number of overtaking vehicles and number of vehicles being overtaken by the test car. The last observer records number of vehicles in the opposing direction.

This method is applicable and valid on two-way directions where opposing vehicle is visible at all times. To get the better data and results, the driver must be able to turn around instantaneously at end of the pair run (For run 1 and 2). According to Wright (1973), this method needs to avoid major exits or entrances on the route because the turning traffic can upset the calculations.

The Moving Observer Method was developed by Wardrop and Charlesworth (1954) for urban traffic measurements. Both speed and volume measurements are obtained simultaneously through this method. This method is based on a survey vehicle that travels in both directions on the road. Equations (1), (2) and (3) is used to estimate both speeds and traffic flows for one direction of travel. The terms used in the equations are summarized in Table 2 :

$$q = \frac{x + y}{t_a + t_w} \tag{1}$$

$$\bar{t} = t_w - \frac{y}{q} \tag{2}$$

$$v = \frac{d}{\bar{t}} \tag{3}$$

Table 2 : Terminology for Moving Observer Method

Variables	Descriptions
Q	The estimated flow on the road in the direction of interest.
X	The number of vehicles traveling in the direction of interest, which are met by the survey vehicle while traveling in the opposite direction.
Y	The net number of vehicles that overtake the survey vehicle while traveling in the direction of interest (overtake test car – overtaken by test car)
t_a	The travel time taken for the trip against the stream.
t_w	The travel time for the trip with the stream.
$\bar{t}$	The estimate of mean travel time in the direction of interest.
D	Distance traveled.
V	Average travel speed for each run in the direction of interest.

From the equations, the traffic flow and average travel speed can be obtained simultaneously. It should be note that, the value of average travel speed will be different when the unit of traffic flow is different. The unit of traffic flow used in this study is vehicle/hour or pcu/hour.

The passenger car unit (pcu) used in this study is obtained from Arahan Teknik (Jalan) 8/86, JKR. The respective pcu equivalent values are given as shown in Table 3.

Table 3 : Passenger Car Equivalent Factor

Type of Vehicle	Passenger Car Equivalent Factor
Car and Van	1.00
Medium Lorry	1.75
Heavy Lorry	2.25
Bus	2.25
Motorcycle	0.33

Source : Arahan Teknik (Jalan) 8/86, JKR

Car Chasing Method

In contrast to the Moving Observer Method, Car Chasing Method only requires a test car with a driver and an observer to observe travel time for the study location. For this method, the test car will be driven at another driver-desired speed (Lum, *et al.*, 1998). In order to get representative journey time data, the driver will have to drive at the speed of a randomly chosen car in front. The test car will follow the other car by keeping a safe distance. Based on the Car Following Theory, when a vehicle were separated by a time headway greater than approximately 6 seconds, then the following vehicle was not influenced by the preceding vehicle (Salter, 1989). Therefore, the driver would try to keep the distance with the following car within 6 seconds (time headway) or less. The driver of the test car will follow a randomly chosen car until it leaves the area; parks or the 'chase' requires unsafe and/or illegal maneuvers, in which case the next nearest convenient vehicle is followed. During the transition from one car to another, the test car is driven normally with respect to present traffic condition.

The beginning and ending points on the urban arterial road will be identified and the distance between the two points will be measured. Then the amount of time to travel between the two points and stopping time will be measured. A stop is defined as the absolute cessation of motion of the test vehicle. Several runs back and forth between the two stations will be made. A total number of runs will depend on the length of stretch, traffic volume conditions and the period of study.

Manual traffic counting and video camera were used to obtain the traffic volume data. Classified traffic volumes in both directions, counted in 15-min intervals were recorded at strategic locations, respectively, for the segments of each arterial road surveyed. Vehicles were classified into five categories, i.e. motorcycles, cars, medium lorries, heavy lorries and buses. As of the Moving Observer Method, the passenger car equivalents unit as of Table 3 is used in this study.

Car Chasing Method is applicable and valid on two-way directions or one-way direction. The method is also applicable for heavy traffic volume condition (Edie, 1974).

4.0 DISCUSSIONS

For Moving Observer Method, the study was conducted at 3 different locations, i.e. Taiping, Butterworth and Malacca city. The city of Ipoh, Nibong Tebal and Butterworth were identified as the study locations for the Car Chasing Method. Table 4 and 5 show the detail of study locations. The observations have been done on weekdays and the observation had covered the morning peak hour (0700-0900), afternoon peak hour (1200-1400) and evening peak hour (1600-1800@1700-1900) to get a wider range of traffic volume.

Table 4: Study locations for Moving Observer Method

Site Code	Arterial Name	Arterial Type	Arterial Length	No of Signalized Intersection	Traffic Condition
PRK 001	Jln Taiping–Kamunting	Suburban Arterial	3.9km	4	Medium Stops
PEN 001	Jln Pmtg Pauh-Telaga Air	Suburban Arterial	4.8km	9	High Stops
MLK 001	Jln Ayer Keroh-Melaka	Suburban Arterial	3.8km	6	Low Stops

Table 5: Study locations for Car Chasing Method

Site Code	Arterial Name	Arterial Type	Arterial Length	No of Signalized Intersection	Traffic Condition
PRK 002	Jln Leong Boon Swee (Medan Kidd area)	Urban Arterial	0.6km	2	High Stops
PEN 002	Jln Nibong Tebal-Jawi	Suburban Arterial	4.1km	2	Low Stops
PEN 003	Jln Chain Ferry-New Ferry	Suburban Arterial	5.7km	3	Medium Stops

Figure 1 and 2 show the plots of travel speed and traffic flow data for both methods (combination of all sites). The traffic flow data reach until 3200 pcu/h for Moving Observer Method. The recorded maximum Traffic Flow for Car Chasing Method is about 1600 pcu/h/lane. The plot of speed and traffic flow show that they are scattered and do not following any trend. This is due to the existence of signalized junction along the arterial roads and other side friction factors.

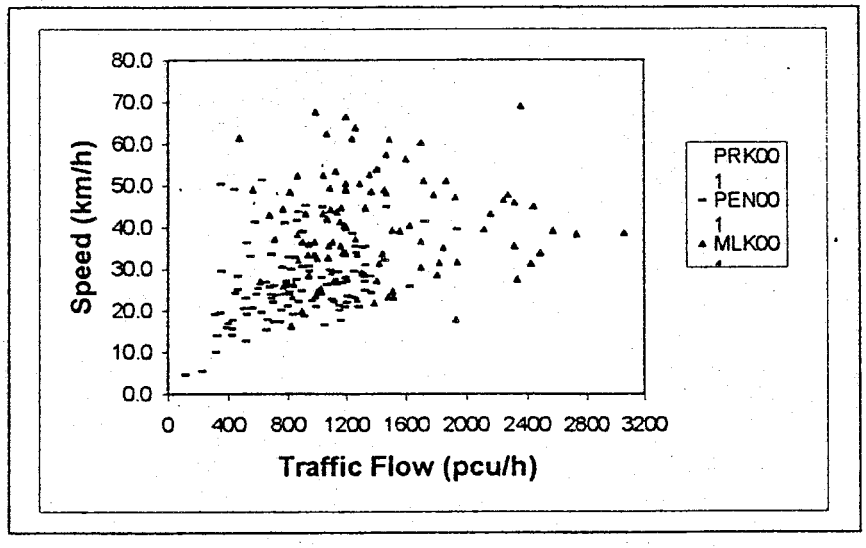

Figure 1: Plots of Speed and Flow for Moving Observer Method

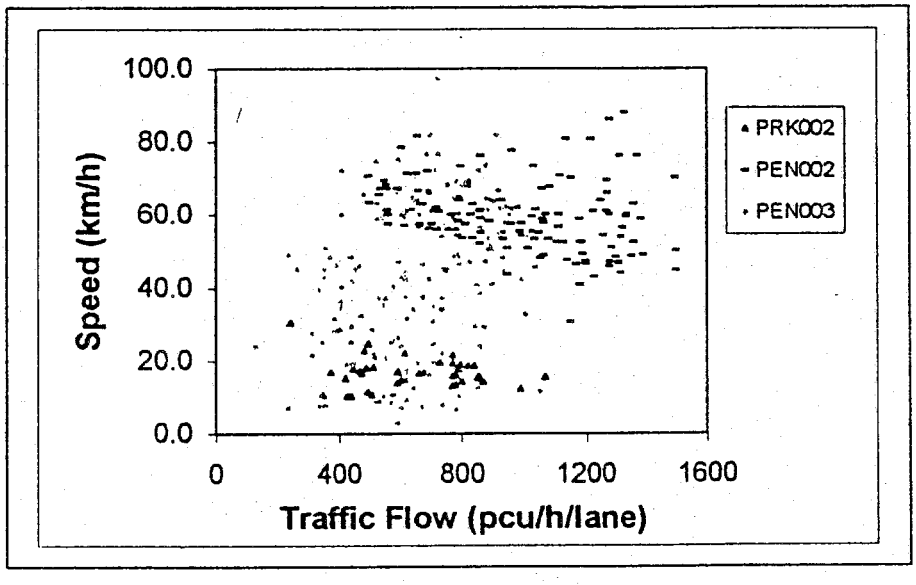

Figure 2: Plots of Speed and Flow for Car Chasing Method

The finding of this study would be expected to contribute to the development of speed and flow relationships based on Malaysian road condition. Figure 3 and 4 show the curve of average travel speed and traffic density. It seems that the goodness of fit (R^2) of the speed-density relationship for Car Chasing Method is higher than the Moving Observer Method as shown in Figure 3 and 4.

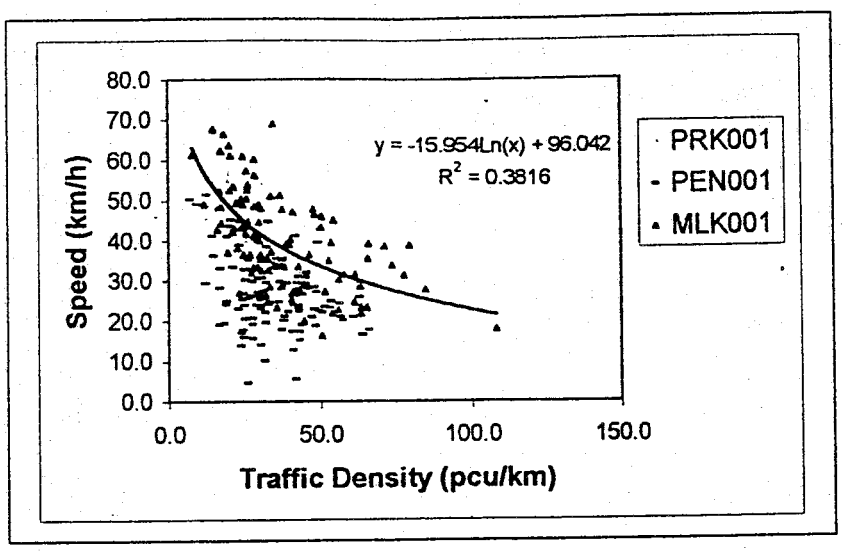

Figure 3: Graph of Speed and Density for Moving Observer Method

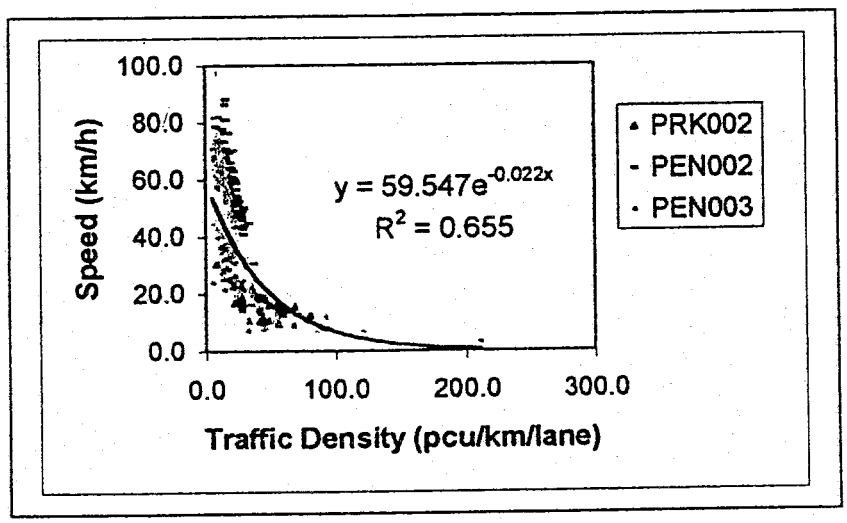

Figure 4: Graph of Speed and Density for Car Chasing Method

Table 6 shows the observed average travel speed during the study periods. The average travel speed range is between 16.3km/h and 59.5km/h for all studied locations. The speed limit for every site range is just between 50km/h and 60km/h.

Arterial roads can be classified based on design category and functional category. Class of arterial roads can be ranged from class I to class IV. Arterial road class depends to the speed limit and side friction such as roadside development, pedestrian activity and access density. For this study, the arterial road class ranges between class II to class IV. The values of average travel speeds can be compared with the level of service (LOS) criteria used in the HCM 2000. It is found that the level of service for site PRK 002 is 'E'. This level shows that such operations are caused by some combination of adverse progression, high signal density, high volumes, extensive delays at critical intersections and inappropriate signal timing. All of these factors are related with the site location, which is close to the Medan Kidd Bus Station

and with inappropriate geometric design. The levels of service for other sites (A, B and C) are acceptable in terms of travel time parameter.

Table 6 : Level of Service for study location

Site Code	Speed Limit (km/h)	Arterial Road Class	Average Travel Speed (km/h)	LOS
PRK 001	60	III	49.6	B
PEN 001	50	IV	26.4	C
MLK 001	60	III	39.7	B
PRK 002	50	IV	16.3	E
PEN 002	60	II	59.5	A
PEN 003	60	III	42.9	B

Table 7 shows the overall comparison of both methods. From the brief information in the table, the responsible agency such as traffic engineer, town planner, and local authorities should be able to choose their own study methodology. The method of conducting the study will be decided by the consultant after checking the site and it will depend on type of arterial, period of study and of course, the cost of study.

Table 7 : Summary of both methodologies

Moving Observer Method	**Car Chasing Method**
Developed by Wardrop & Charlesworth (1954) by using specified equations.	Based on Car Following Model (early 1950s by Reuschel, Pipes, Forbes & group of researchers from General Motor).
Obtain the travel speed and traffic volume (hourly) data simultaneously.	Only can obtain travel speed data.
Applicable only for 2-way routes where opposing traffic is visible at all times. Must be able to turn around at each end of the test sections.	Applicable for either 1-way or 2-way routes.
At least, 3 persons in the test car (including the driver).	2 persons are enough (including the driver).
The test car driver speed (Obey the speed limit).	The other driver speed (follow the randomly chosen car).
Both directions (go & back) – 1 set of data.	One direction is enough to get 1 set of data.
Minimum of six test runs in each direction under comparable conditions (Mortimer, 1957).	Minimum of four test runs with confidence level of 95% for traffic operation analysis (Box & Oppenlander, 1976).

5.0 CONCLUSION

In this paper, average travel speeds are estimated using Moving Observer Method and Car Chasing Method. There are six arterial roads being studied for both methodologies. The speed-density relationships for each study methods are describe in Figure 3 and Figure 4.

ACKNOWLEDGMENTS

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