Traffic Characteristics Along Ipoh-Lumut Highway And Their Effects to the Level of Service Along the Corridor

by

Ahmad Syahid bin Ahmad Sulong (3337)

DESSERTATION REPORT

Submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment for the requirement of the
BACHELOR OF CIVIL ENGINEERING (Hons)
(CIVIL ENGINEERING)

June 2007

University Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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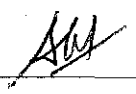
Approved by,

(Assoc. Prof. Dr. Mazlan Napiah)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2007

CERTIFICATION OF ORIGINALITY

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



AHMAD SYAHID BIN AHMAD SULONG

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ABSTRACT

The Ipoh-Lumut Highway route has become one of the busiest road networks in state of Perak as a lot of vehicles travelling along the new development region that spans along this arterial route. Therefore, there is no question that number of vehicles is increasing everyday.

With respect to that situation, the level of service of the existing road facilities will drop after years and this may results on delay of the developments around the vicinity. Then, there is a justification of upgrading the current road networks to become more capable on handling the escalating number of vehicle entering the networks in the forthcoming years.

Due to that, this report will detail the traffic characteristics from Jelapang toll exit to Falim. Particularly, the studies done are divided into three main analysis, namely volume counts and vehicle classification, spot speed studies, and travel time and delay studies. All of those data will be used to evaluate the existing level of service of the facilities. In addition, this data also will be used to assist the planning for the upgrading scheme.

Consequently, better level of service can be attain thus will boost the development of the area and promote high economic advancement in the future.

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CHAPTER 1 : INTRODUCTION

1.1 Background of Study

Ipoh-lumut highway is one the busiest road networks in state of Perak. The highway starts from Jelapang and ends at the shores of Lumut which is about 70km apart. This highway connects to vital places such as Ipoh, Batu Gajah, Tronoh, Bandar Seri Iskandar, Bota, Parit and port of Lumut. This project study will start from Jelapang signalized intersection as the 1st focal point to Falim signalized intersection as the last focal point.

1.2 Problem Statement

Increase in traffic flow due to, partial to limited access control and limited lanes affected the level of service. High proportion of double line or no passing zone at almost of the road delayed the travel time of vehicle. Lack of lighting facilities limited the sight distance when traveling at night.

1.3 Objective and Scope of Study

Determine the characteristic of traffic along Ipoh-Lumut highway and analyse the affect of the traffic behaviour to the Level of Service. Upgrading the road will help to the continuous development of the area. This study will be focusing on:

- Study the volume of the traffic
- Spot speed study

All of these studies will be done by doing site surveying and data analysis.

CHAPTER 2 : LITERATURE REVIEW

Traffic capacity, queue discharge rates and vehicle speeds at work zones were equally essential in assessment of work zone performance and traffic operation.[1] Developed and developing countries throughout the world have accumulated a diverse base of experience with respect to the institutional, regulatory, and financial aspects of building and operating better road systems.[2] Traffic control basically addresses the issue of controlling current traffic demands. Many cities in the US have used this strategy as a tool to control traffic within cities as well as between cities. However, traffic control alone cannot control traffic properly and thereby solve the issue of congestion.[3] The congestion has resulted from unprecedented growth in traffic on rural segments of Iowa interstates. Traffic volumes have reached levels that are unlike those experienced in the past. The congestion on rural interstates is particularly problematic because in rural areas there are few, if any, parallel diversion routes and through traffic traveling long distances, may be relatively unfamiliar with local conditions and alternative routes.[4] In order to analyze traffic characteristics at highway work zones; traffic flow has been measured through various types of traffic measuring devices. Using these traffic counters, vehicle speed and volume can be recorded at select spots along roadways.[5] There are a lot of accidents occur along this Ipoh-Lumut highway. Improving night-time visibility can be a major factor in reducing accidents; moreover, improving visibility for drivers on wet nights has long been identified as requiring more attention.[6]

2.1 Level of Service and Its Classification

Level of service is a measure by which transportation planners reckon the quality of service on transportation devices, or transportation infrastructure, generally linked to transportation time (the shorter, the better) and thus to speed.

The system works using the letters A through F, with A being the best and F being the worst. **LOS A** is the best, described as conditions where traffic flows at or above the posted speed limit and all motorists have complete mobility between lanes. LOS A occurs late at night in urban areas, frequently in rural areas.

LOS B is slightly more congested, with some impingement of maneuverability; two motorists might be forced to drive side by side, limiting lane changes. LOS B does not reduce speed from LOS A.

LOS C has more congestion than B, where ability to pass or change lanes is not always assured. LOS C is the target for urban highways in many places. At LOS C most experienced drivers are comfortable, roads remain safely below but efficiently close to capacity, and posted speed is maintained.

LOS D is perhaps the level of service of a busy shopping corridor in the middle of a weekday, or a functional urban highway during commuting hours: speeds are somewhat reduced, motorists are hemmed in by other cars and trucks. In busier urban areas this level of service is sometimes the goal for peak hours, as attaining LOS C would require a prohibitive cost in bypass roads and lane additions.

LOS E is a marginal service state. Flow becomes irregular and speed varies rapidly, but rarely reaches the posted limit. On highways this is consistent with a road over its designed capacity.

LOS F is the lowest measurement of efficiency for a road's performance. Flow is forced; every vehicle moves in lockstep with the vehicle in front of it, with frequent drops in speed to nearly zero mph. Technically, a road in a constant traffic jam would be below LOS F. This is because LOS does not describe an instant state, but rather an average or typical service. For example, a highway might operate at LOS D for the AM peak hour, but have traffic consistent with LOS C some days, LOS E or F others, and come to a dead halt once every few weeks. Since no highway comes to a traffic jam every day, LOS F is an adequate description for a road that you cannot trust to get you where you want to go safely and reliably.

The Highway Capcity Manual and AASHTO-Geometric Design of Highways and Streets ("Green Book") list the following levels of service: "A= Free flow B=Reasonably free flow C=Stable flow D=Approaching unstable flow E=Unstable flow F=Forced or breakdown flow

The level of service characerizes the operating conditions on the facility in terms of traffic performance measures related to speed and travel time, freedom to manuever, traffic interruptions, and comfort and convenience."[7]

2.2 Type of highway

A two-lane highway is defined as a two-lane roadway with one lane for use by traffic in each direction. Passing other vehicles requires use of the opposing lane. With volumes and geometric constraints increases, the ability to pass decreases and platoon of vehicles are formed. This results in delaying the travel time. The LOS for two-lane highways is based on mobility.

2.3 Traffic Light Intersection

Intersection counts are used for timing traffic signals, designing channelization, planning turn prohibitions, computing capacity, analyzing high crash intersection, and evaluating congestion.

2.4 Spot Speed Studies

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics. Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. The data gathered in spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. This study is primarily used to determine the distribution of traffic speeds at specific location. This study may use any of these three methods[8]:

- Stopwatch - The stopwatch method can be used to successfully complete a spot speed study using a small sample size taken over a relatively short period of time. The stopwatch method is a quick and inexpensive method for collecting speed data.
- Radar meter - A radar meter is a commonly used device for directly measuring speeds in spot speed studies. This device may be hand-held, mounted in a vehicle, or mounted on a tripod. The effective measuring distance for radar meters ranges from 200 feet up to 2 miles. A radar meter requires line-of-sight to accurately measure speed and is easily operated by one person. If traffic is heavy or the sampling strategy is complex, two radar units may be needed. Different sized vehicles and the detection of the observation vehicle may affect radar readings. Large vehicles such as trucks

and buses send the strongest return signal to the radar meters and as a result smaller vehicles may not be detected. If there is a presence of large vehicles, the observer may need to record the speeds of vehicles that are alone. Also, some vehicles are equipped with radar detectors to warn them that a radar unit is operating in their vicinity. Drivers will slow down when warned by a detector. It is not unusual for other drivers to slow down also. This slowing will affect the study results. The radar unit may be turned off while not in use so radar detectors cannot detect it.

- Pneumatic road tubes - The pneumatic road tube method is normally used for longer data collection time periods than those of either the stopwatch or radar meter method. Using this method, pneumatic tubes are placed in the travel lanes and are connected to recorders located at the side of the road. The automatic recorders are capable of storing large amounts of individual vehicle data or even larger amounts of vehicle classification data. The collected data are downloaded from the recorder to a laptop computer or portable floppy disk drive in the field, or via telephone modem to a centrally located computer.

2.4.1 Traffic speed percentiles

Two important vehicle speed percentiles calculated from spot speed study data sets are the 50th and the 85th percentiles. The 50th percentile is the median speed of vehicles at the study location (the observed data set). This data means that half of the observed vehicles are going faster than the 50th percentile speed and the other half are slower. The 85th percentile represents the speed at or below which 85 percent of the observed motorists are traveling. The 85th percentile is normally used by the traffic engineer to set the speed limit as it is considered as the highest safe speed for a roadway section.

2.5 Volumes Studies

This study is conducted to determine number, movements, and classifications of roadway vehicles at a given location. These data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or document traffic volume trends. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. For example, an intersection count may be conducted during the peak flow period. If so, manual count with 15-minute intervals could be used to obtain the traffic volume data.

Two methods are available for conducting traffic volume counts: (1) manual and (2) automatic. Manual counts are typically used to gather data for determination of vehicle classification, turning movements, direction of travel, pedestrian movements, or vehicle occupancy. Automatic counts are typically used to gather data for determination of vehicle hourly patterns, daily or seasonal variations and growth trends, or annual traffic estimates. The selection of study method should be determined using the count period. The count period should be representative of the time of day, day of month, and month of year for the study area. For example, counts at a summer resort would not be taken in January. The count period should avoid special event or compromising weather conditions. Count periods may range from 5 minutes to 1 year. Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods. For example, if you were conducting a 2-hour peak period count, eight 15-minute counts would be required.[9]

2.6 LOS Analysis

In analyzing Level of Service, there are some equations and tables that need to be use in order to obtain Level of Service of any particular road.

To obtain a LOS value, a Percent Time Spent Following must be calculated first.

$$PTSF = BPTSF + f_{d/np} \qquad (2.6.1)$$

BPTSF, the Base Percent Time Spent Following for both directions can be computed using equation 3.4.2:

$$BPTSF = 100(1 - e^{-0.000879vp}) \qquad (2.6.2)$$

Where;

PTSF = percent time spent following in the direction analyzed.

BPTSF = base percent time spent following in the direction analyzed.

F_{np} = adjustment in PTSF to account for the combined effect of (1) percent of directional distribution of traffic and (2) percent of passing zones. Values for varioustwo-way flow rates can be obtain in table 9.3(Garber/Hoel)

V_p = passenger-car equivalent flow rate for peak 15 minutes in the analysis direction pc/h

The next step is to calculate the v_p:

$$V_p = V / (PHF)(f_G)(f_{HV}) \qquad (2.6.3)$$

V = demand volume for the entire peak hour, veh/h

PHF = Peak Hour Factor, V/(4) (peak 15-min volume)

f_G = grade adjustment factor for level or rolling terrain (table 9.4 – Garber/Hoel)

f_{HV} = adjustment factor to account for heavy vehicles in the traffic stream and is computed using equation 3.4.4

$f_{HV} = 1 / (1 + P_T(E_T - 1) + P_R(E_R - 1))$ (2.6.4)

P_T and P_R = the decimal portion of trucks (and buses) and RVs in the traffic stream. For example if there are 22 percent trucks in the traffic stream, then = 0.22

E_T and E_R = the passenger car equivalent for trucks and RVs respectively. (Table 9.3 – Garber/Hoel)

Since the values of the E_T and E_R are a function of two-way flow rates in pc/h, an iterative process is required in which a trial value of V_p is computed using appropriate values of E_T and E_R. If the second value of V_p is within the range used to determine truck and RV equivalents, the computed value is correct. If not, a second iteration is required using the next higher range of flow rate.

To obtain a LOS value, another indicator may be use, using the average travel speed (ATS) for a two-way segment.

Average Travel Speed, ATS = FFS - 0.0076Vp – f_{np} (2.6.5)

Where;

FFS = free flow speed, the mean speed at low flow when volumes are, 200 pc/h
fnp = adjustment for percentage of no-passsing zones. (table 9.6 Garber and Hoel)
Vp = passenger-car equivalent flow rate for the peak 15-min period.

To find FFS with the following conditions:

1) Field measurement at volumes > 200veh/h
2) Field data are available

Free Flow Speed, FFS = $S_{FM} + 0.00776(V_f/f_{HV})$ (2.6.6)

Where;

S_{FM} = mean speed of traffic measured in the field.

V_f = observed flow rate.

f_{HV} = adjustment factor for heavy vehicle.

Values from ATS and PTSF will be use to determine the LOS and if the of PTSF and ATS do not correspond to the same LOS, the lower value is used. Table 1 and Table 2 are reprinted from Highway Capacity Manual, HCM 2000.

LOS	Percent Time Spent Following (PTSF)	Average Travel Speed (ATS) (mi/h) or (km/h)
A	≤ 35	> 55 or > 90
B	>35-50	>50-55 or >80-90
C	>50-65	>45-50 or >70-80
D	>65-80	>40-45 or > 60-70
E	>80	≤ 40 or ≤ 60

Table 1 : Level Of Service criteria of two-Lane Highway in Class 1

LOS	Percent Time Spent Following
A	≤ 40
B	> 40-55
C	> 55-70
D	> 70-85
E	> 85

Table 2 : Level of Service for two-lane highways

2.6 aaSIDRA Software

SIDRA (Signalised & unsignalised Intersection Design and Research Aid) is an international software package (also known as SIDRA). It is a time-proven advanced analytical tool for evaluation of alternative intersection designs in terms of capacity, level of service, a wide range of performance measures including delay, queue length, stops, fuel consumption, pollutant emissions and operating cost.

SIDRA can be used to evaluate roundabouts (both single lane and multi lane), signalised at-grade intersections, single-point urban interchanges, signalised pedestrian crossings, two-way stop and give-way sign-control and all-way stop sign control (US practice), all in one package.

In the USA, SIDRA is recognised by the US Highway Capacity Manual, FHWA Roundabout Guide and various local roundabout guides. In Australia, SIDRA is endorsed by Parts 2, 5, 6 and 7 of the Guide to Traffic Engineering Practice, a major publication of AUSTROADS (the Association of Australian State, Territory and Federal Road and Transport Authorities).[11]

CHAPTER 3 : METHODOLOGY

3.1 Procedure Identification

The methodology and procedure that was used in the researched of finding the performance of the highway is divided into four parts:

3.1.1 Literature Review and Information Gathering

Before starting this project all necessary data and information from various books, journals, internets and thesis is collected and studied to have a clear picture of this project.

3.1.2 Site Survey

There are 7 identified spot that need to be surveyed. The survey was divided into two part; reconnaissance survey and traffic survey. Reconnaissance survey is basically to identify the appropriate and potential road for this study. This survey also to determine some data that might be useful for traffic analysis such as:

1. location of the road
2. road hierarchy (function)
3. road characteristics (length, width, design speed, posted speed)

3.1.3 Data Analysis

The data obtain will be calculated to gain the final LOS of the studied segment. To gain the LOS, other calculations for the survey such as volume in the east/west bound direction, average travel time, mean speed, modal speed, median speed, 85^{th} percentile and standard deviation.

3.1.4 Report Writing

The final phase of this research is report writing where all the findings and results of this project are collected, compiled and analysed as a part of the course requirements.

3.2 Equipments

Equipments are needed during the phase of site survey to obtain data for analysis. Video recording camera, radar meter (laser gun), computer with aaSIDRA software and data sheet are needed.

3.3 Engineering Traffic Survey

Basically there are 2 types of study that will be conducted at each of the highway segment. This is stated below:

1. spot speed studies
2. volume studies

For the spot speed studies, manual method using the laser gun will be used. 100 speed readings were collected for each spot speed study. The data obtain will be use to produce to form a set of speed data for analysis and then reverted into graphs and tables.

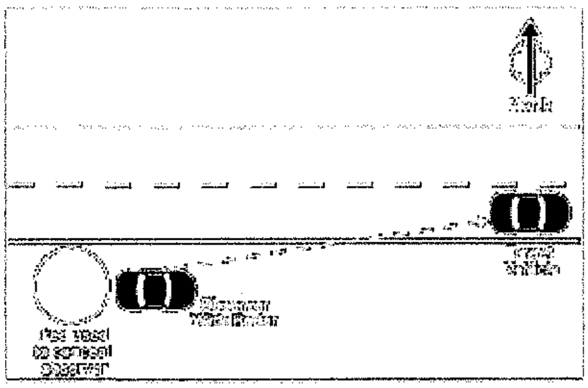

Figure 1 : Spot Speed Study

Next is volume studies. To collect the volume of vehicles at each segment, video camera will be use to record the vehicles and will be calculated manually afterwards. The count will starts from 8.30 pm to 10.30 pm and divided on 15 minutes basis. The vehicles are divided into 3 classes; class 1, class 2 and class 3.

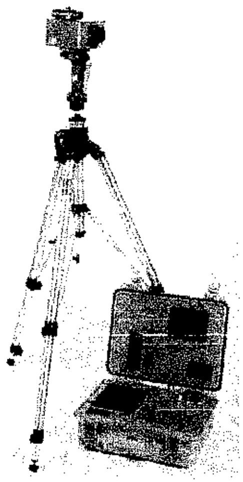

Figure 2 : Laser Speed Gun

3.4 Analysis of Traffic using aaSIDRA

Traffic Analysis will be done using aaSIDRA software to determine Level of Service (LOS) for both current and forecasted traffic volumes. By using aaSIDRA most of the variables value will be set into default value except for the number of Lanes, parking conditions (yes/no), demand volume by movement (veh/h), peak hour factor, percent heavy vehicles(%) and approach speed(km/h).

3.4.1 Traffic Light intersection forecasting.

Traffic forecasting is done to forecast volume of the specific junction by using average annual growth the volume in 10 years was forecasted. For traffic forecasting of year 2017, using the average annual growth of urban area in Malaysia; a value of 5% was used.

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Volume Study result:

The surveying will be done at 7 different places along the highway. The survey is done from 8.30 pm to 10.30 pm. However, the data obtain from survey is somehow different from the data collected from JKR. This is maybe because some of the surveying is done during school holidays.

Survey 1

Date : 27.11.2006 (Monday)
Direction : Jelapang to Falim (point 1)
Time : 8.45 pm to 10.15 pm
Wheater : Fine

Table 3a : Data from volume study at segment 1

Time (p.m)	Class 1	Class 2	Class 3	Total
8.45	70	4	13	87
9.00	65	8	12	85
9.15	77	6	6	89
9.30	53	6	15	74
9.45	75	6	12	93
10.00	53	3	9	65
Total	393	33	67	493

Date : 27.11.2006 (Monday)

Direction : Falim to Jelapang (point 1)

Time : 8.45 pm to 10.15 pm

Wheater : Fine

Table 3b : Data from volume study at segment 1

Time (p.m)	Class 1	Class 2	Class 3	Total
8.45	51	5	7	63
9.00	59	9	7	75
9.15	55	6	3	64
9.30	60	5	25	70
9.45	41	11	11	63
10.00	48	6	4	58
Total	314	36	57	407

Survey 2

Date : 30.11.2006 (Thursday)

Direction : Jelapang to Falim (point 2)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 4a : Data from volume study at segment 2

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	56	6	16	78
8.45	58	4	10	72
9.00	50	8	8	66
9.15	61	3	11	75
9.30	59	4	9	72
9.45	49	3	11	63
10.00	43	7	8	58
10.15	46	4	12	62
Total	422	39	85	546

Date : 30.11.2006 (Thursday)

Direction : Falim to Jelapang (point 2)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 4b : Data from volume study at segment 2

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	56	5	16	77
8.45	51	3	20	74
9.00	50	11	12	73
9.15	49	7	15	71
9.30	60	5	11	76
9.45	53	10	9	72
10.00	56	7	16	79
10.15	45	9	13	67
Total	420	57	112	589

Survey 3

Date : 28.1.2007 (Sunday)

Direction : Jelapang to Falim (point 3)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 5a : Data from volume study at segment 3

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	49	5	20	74
8.45	60	3	11	74
9.00	53	10	12	75
9.15	45	5	7	57
9.30	53	7	5	65
9.45	53	4	15	72
10.00	40	6	3	49
10.15	43	4	10	57
Total	396	44	83	523

Date : 28.1.2006 (Sunday)

Direction : Falim to Jelapang (point 3)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 5b : Data from volume study at segment 3

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	50	3	20	73
8.45	53	5	13	71
9.00	60	10	15	85
9.15	43	13	17	73
9.30	53	4	11	68
9.45	54	9	10	73
10.00	56	10	16	82
10.15	43	7	15	65
Total	412	61	119	590

Survey 4

Date : 29.1.2007 (Monday)

Direction : Jelapang to Falim (point 4)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 6a : Data from volume study at segment 4

Time (p.m)	**Class 1**	**Class 2**	**Class 3**	**Total**
8.30	250	10	95	355
8.45	189	11	101	301
9.00	227	16	91	334
9.15	300	9	80	389
9.30	295	13	115	423
9.45	223	9	93	325
10.00	195	12	89	296
10.15	231	10	94	335
Total	1910	90	758	2758

Date : 29.1.2007 (Monday)

Direction : Falim to Jelapang (point 4)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 6b : Data from volume study at segment 4

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	180	11	81	272
8.45	193	9	95	297
9.00	198	14	85	297
9.15	230	13	102	345
9.30	221	10	113	344
9.45	243	9	86	338
10.00	201	10	79	290
10.15	212	13	83	308
Total	1678	89	724	2491

Survey 5

Date : 9.2.2007 (Friday)

Direction : Jelapang to Falim (point 5)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 7a : Data from volume study at segment 5

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	225	9	81	315
8.45	295	13	101	409
9.00	255	14	96	365
9.15	201	10	115	326
9.30	199	12	109	320
9.45	212	9	94	315
10.00	235	11	83	329
10.15	225	7	94	326
Total	1847	85	773	2705

Date : 9.2.2007 (Friday)

Direction : Falim to Jelapang (point 5)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 7b : Data from volume study at segment 5

Time (p.m)	**Class 1**	**Class 2**	**Class 3**	**Total**
8.30	193	11	91	295
8.45	201	12	98	311
9.00	211	17	87	315
9.15	230	12	138	380
9.30	253	7	120	380
9.45	189	13	75	277
10.00	218	11	96	325
10.15	224	14	75	313
Total	1719	97	780	2596

ìurvey 6

)ate : 17.3.2007 (Saturday)

)irection : Jelapang to Falim (point 5)

ſime : 8.30 pm to 1030 pm

Vhether : Fine

Table 8a : Data from volume study at segment 6

ſime (p.m)	Class 1	Class 2	Class 3	Total
ꜫ.30	250	9	90	349
ꜫ.45	302	11	120	432
).00	255	15	90	360
).15	220	6	130	356
).30	180	7	121	308
).45	210	11	86	307
10.00	240	13	99	352
10.15	260	7	115	382
Total	1917	79	851	2846

)ate : 17.3.2007 (Saturday)

)irection : Falim to Jelapang (point 5)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 8b : Data from volume study at segment 6

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	200	10	123	333
8.45	215	9	115	339
9.00	225	15	101	341
9.15	225	7	145	377
9.30	260	19	117	396
9.45	190	13	80	283
10.00	220	10	81	311
10.15	235	9	90	334
Total	1770	92	852	2714

Survey 7

Date : 1.4.2007 (Sunday)

Direction : Jelapang to Falim (point 7)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 9a : Data from volume study at segment 7

Time (p.m)	Class 1	Class 2	Class 3	Total
8.30	253	9	99	361
8.45	312	10	115	437
9.00	243	18	87	348
9.15	215	5	125	345
9.30	192	8	129	329
9.45	201	13	95	309
10.00	239	12	90	341
10.15	245	8	105	358
Total	1900	83	845	2828

Date : 1.4.2007 (Saturday)

Direction : Falim to Jelapang (point 7)

Time : 8.30 pm to 1030 pm

Whether : Fine

Table 9b : Data from volume study at segment 7

Time (p.m)	**Class 1**	**Class 2**	**Class 3**	**Total**
8.30	212	12	117	341
8.45	210	11	119	338
9.00	232	9	99	340
9.15	207	11	135	353
9.30	189	15	160	364
9.45	199	10	95	304
10.00	236	9	102	347
10.15	235	15	116	366
Total	1520	92	943	2555

4.2 Spot Speed Study result:

The data collected determine the speed characteristic of the whole population of vehicles raveling on the study site. Statistical methods are used to analyzed this data. The data are converted into a frequency distribution table (table 10 and table 11) and the arithmetic nean speed derived.

Table 10 : Frequency distribution table for segment 1

	Class Midvalue	Class Frequency	Fiui	% of observation In class	Cumulative % of Observations	F(ui-U)2
9	40	1	40	1	1	948.64
9	42	2	84	2	3	348.48
9	44	0	0	0	3	0
9	46	1	46	1	4	615.04
9	48	2	96	2	6	1270.08
9	50	1	50	1	7	432.64
9	52	3	156	3	10	21777.12
9	54	0	0	0	10	0
9	56	3	168	3	13	28343.52
9	58	5	290	5	18	240243.2
9	60	3	180	3	21	35773.92
9	62	5	310	5	26	286083.2
9	64	0	0	0	26	0
.9	66	8	528	8	34	1672255
.9	68	5	340	5	39	362343.2
.9	70	5	350	5	44	389763.2
.9	72	7	504	7	51	1313636
.9	74	9	666	9	60	3188367
.9	76	11	836	11	71	6440841

9	78	6	468	6	77	946607
9	80	5	400	5	82	541863.2
9	82	3	246	3	85	92085.12
9	84	4	336	4	89	281324.2
9	86	3	258	3	92	105131.5
9	88	2	176	2	94	22134.08
9	90	3	270	3	97	119041.9
9	92	1	92	1	98	449.44
9	94	1	94	1	99	538.24
9	96	1	96	1	100	635.04
		100	7080			

From table 10, the Arithmetic mean speed, $\bar{U} = \sum f_i u_i / \sum f_i = 70.8$ km/h is obtained for segment 1.

Table 11 : Frequency distribution table for segment 2

Class Midvalue	Class Frequency	Fiui	% of observation In class	Cumulative % of Observations	F(ui-U)2
22	1	22	1	1	2162.25
24	0	0	0	1	0
26	0	0	0	1	0
28	1	28	1	2	1640.25
30	0	0	0	2	0
32	1	32	1	3	1332.25
34	1	34	1	4	1190.25
36	0	0	0	4	0
38	0	0	0	4	0
40	0	0	0	4	0
42	0	0	0	4	0
44	4	176	4	8	46225
46	2	92	2	10	1104.5
48	2	96	2	12	1512.5
50	1	50	1	13	342.25
52	4	208	4	17	77841
54	3	162	3	20	26226.75
56	3	168	3	23	29700.75
58	3	174	3	26	33390.75
60	7	420	7	33	864865.75
62	3	186	3	36	41418.75
64	4	256	4	40	140625
66	7	462	7	47	1083895.75
68	3	204	3	50	55080.75
70	7	490	7	57	1243635.75

	72	8	576	8	65	2060450
	74	3	222	3	68	70686.75
	76	2	152	2	70	13944.5
	78	7	546	7	77	1596043.75
	80	2	160	2	79	16744.5
	82	3	246	3	82	94518.75
	84	3	252	3	85	101016.75
	86	2	172	2	87	21424.5
	88	1	88	1	88	380.25
	90	2	180	2	90	24864.5
	92	0	0	0	90	0
	94	4	376	4	94	378225
	96	1	96	1	95	756.25
	98	1	98	1	96	870.25
)	100	1	100	1	97	992.25
.9	102	1	102	1	98	1122.25
.9	104	0	0	0	98	0
.9	106	1	106	1	99	1406.25
.9	108	0	0	0	99	0
.9	110	0	0	0	99	0
.9	112	0	0	0	99	0
.9	114	1	114	1	100	2070.25
			6846			

From table 11, the Arithmetic mean speed, $\bar{U} = \sum f_i u_i / \sum f_i = 68.5$ km/h is obtained for segment 2.

From figure 3 & 4, the histogram of observed vehicles' speeds, frequency distribution shows the speed corresponding to the highest point, Modal Speed = 76 km/h (segment 1) and 72 km/h (segment 2)

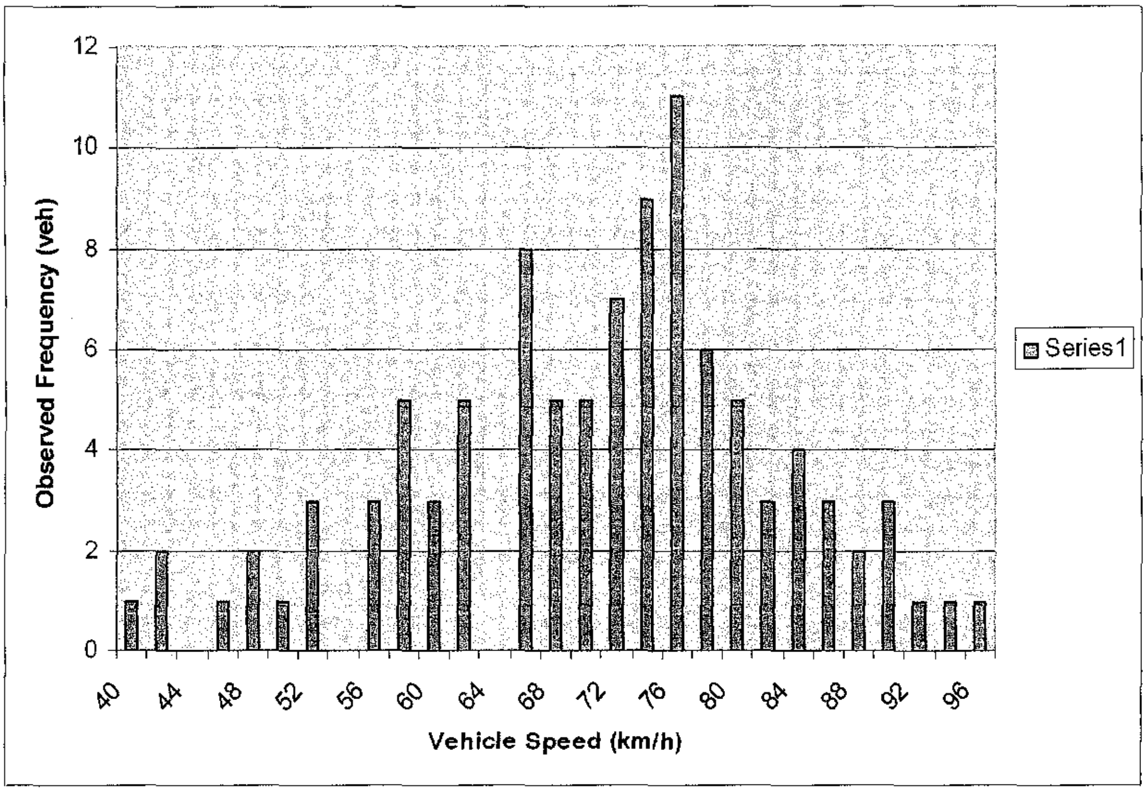

Figure 3: Histogram of observed vehicles' speed for segment 1

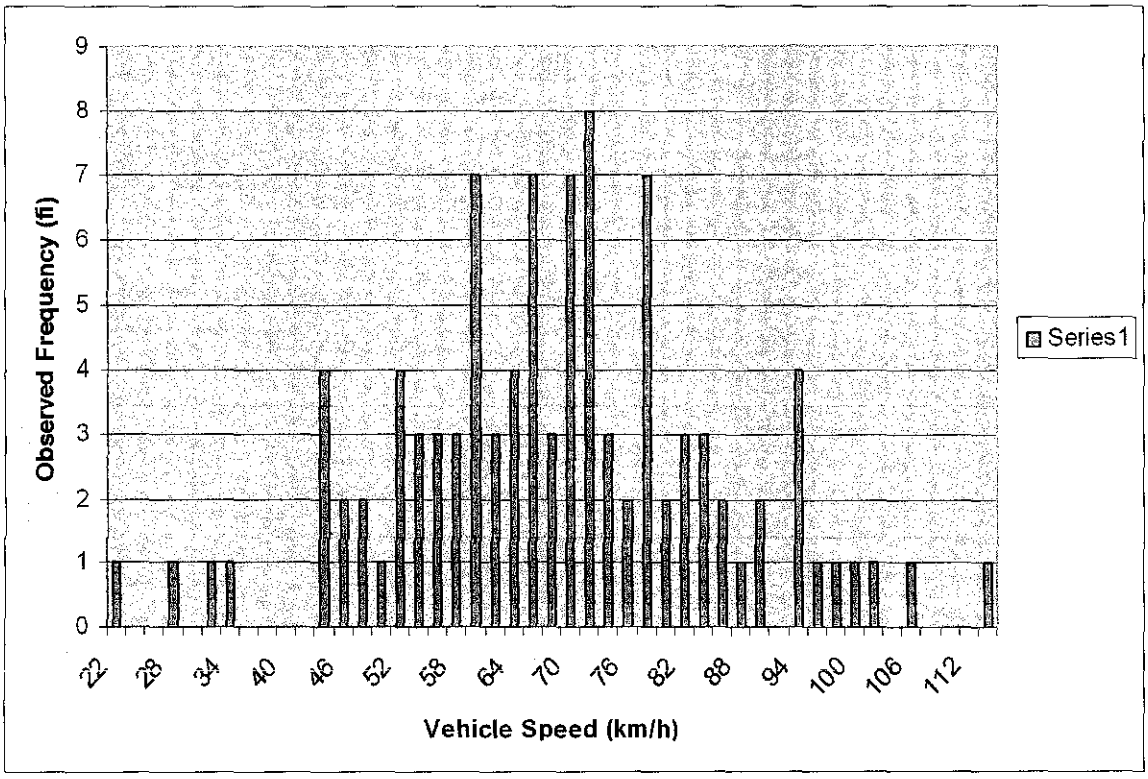

Figure 4: Histogram of observed vehicles' speed for segment 2

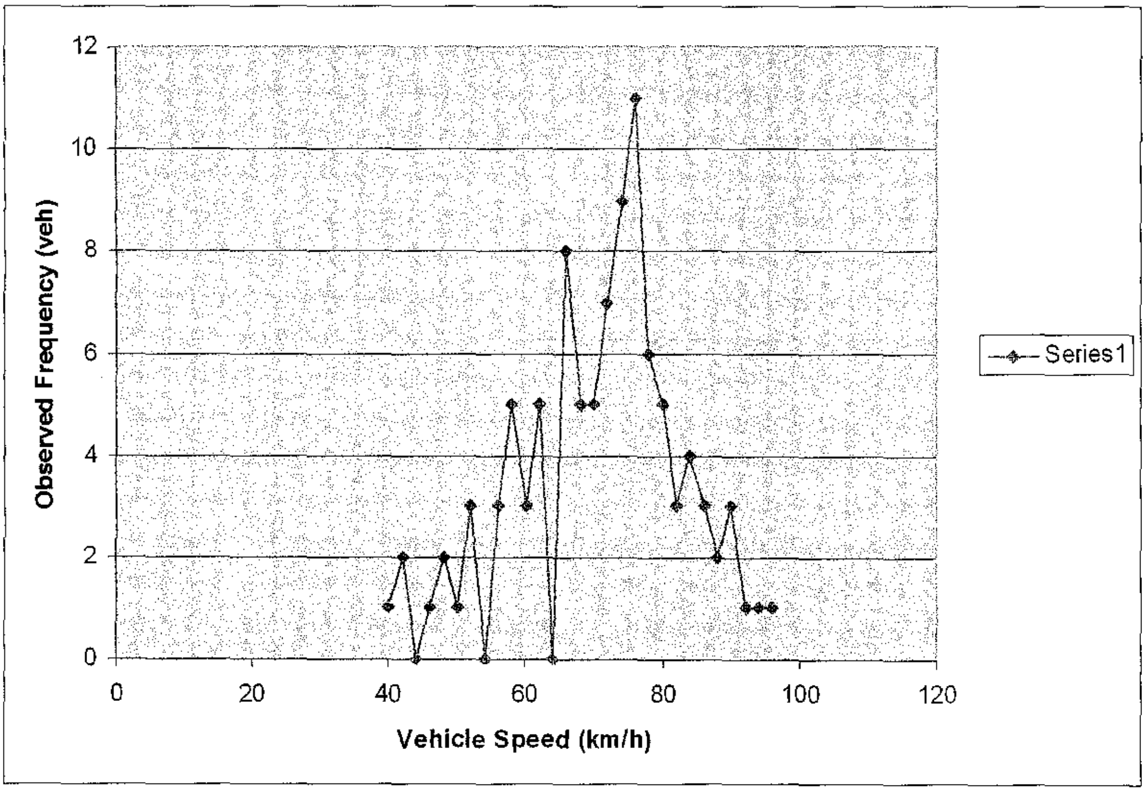

Figure 5: Frequency distribution graph for segment 1

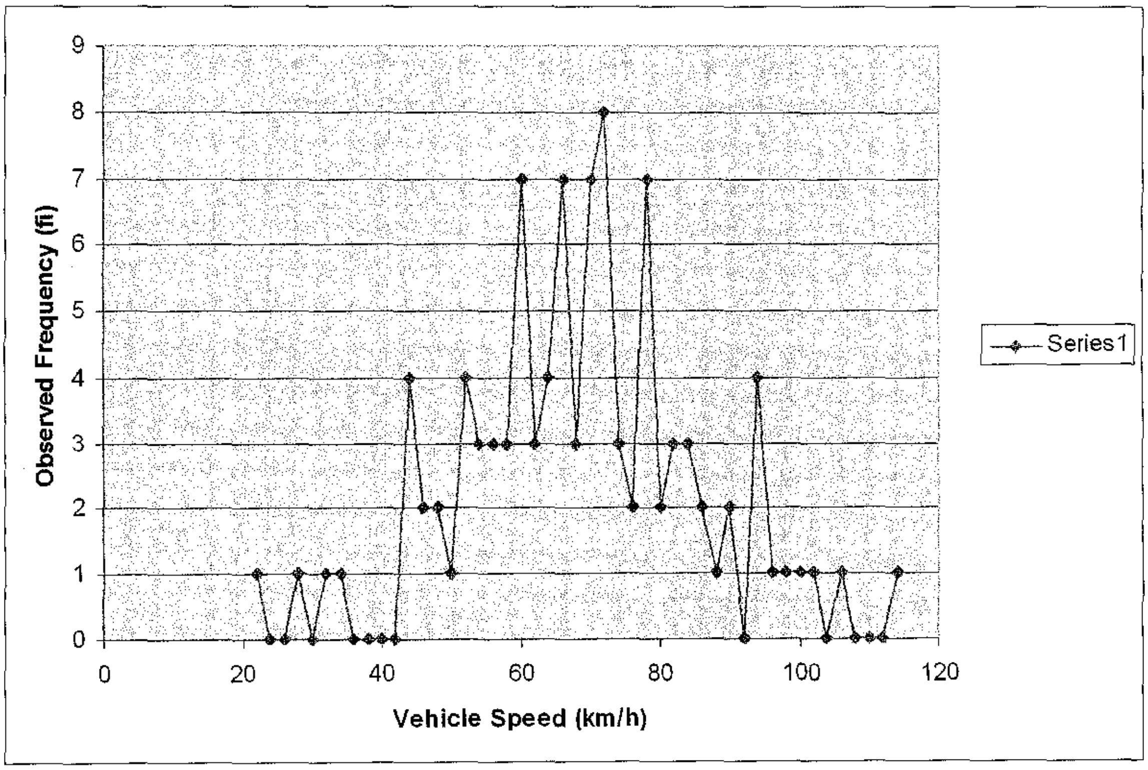

Figure 6: Frequency distribution graph for segment 2

For segment 1, the median speed is 72 km/h, the 85th percentile is 81 km/h.

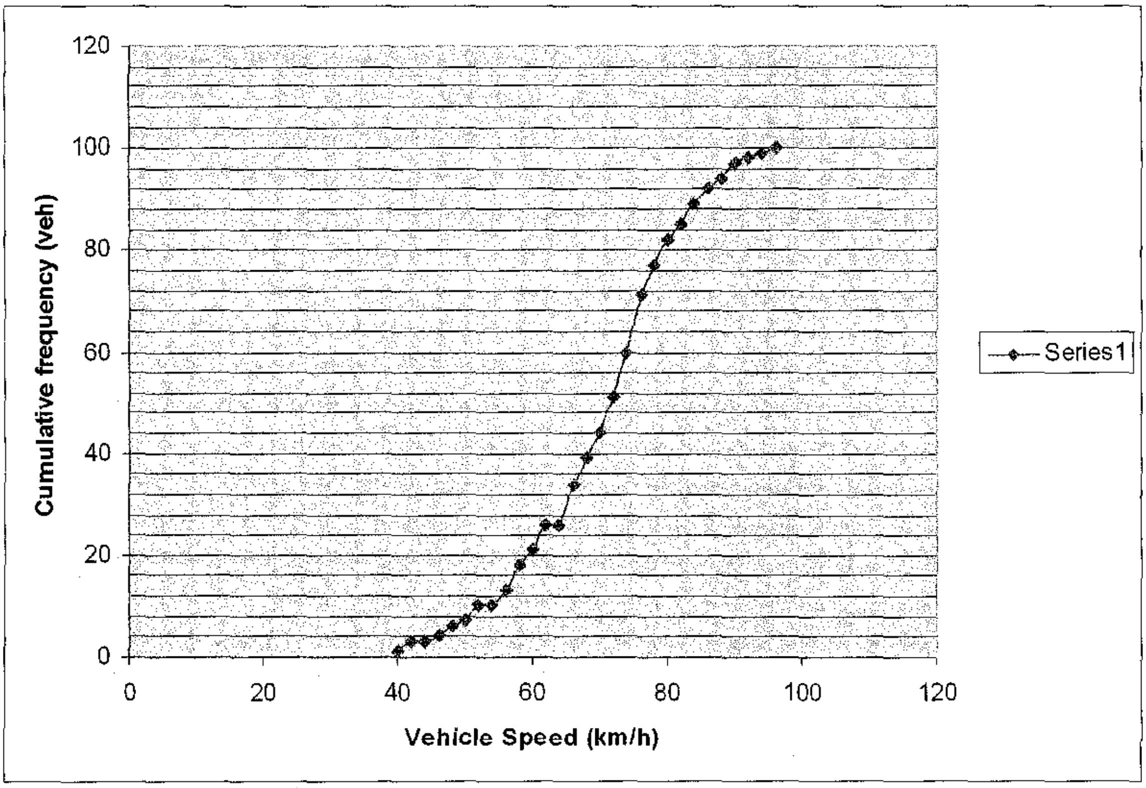

Figure 7: Cumulative distribution graph for segment 1

For segment 2, the median speed is 69 km/h, the 85th percentile is 83 km/h

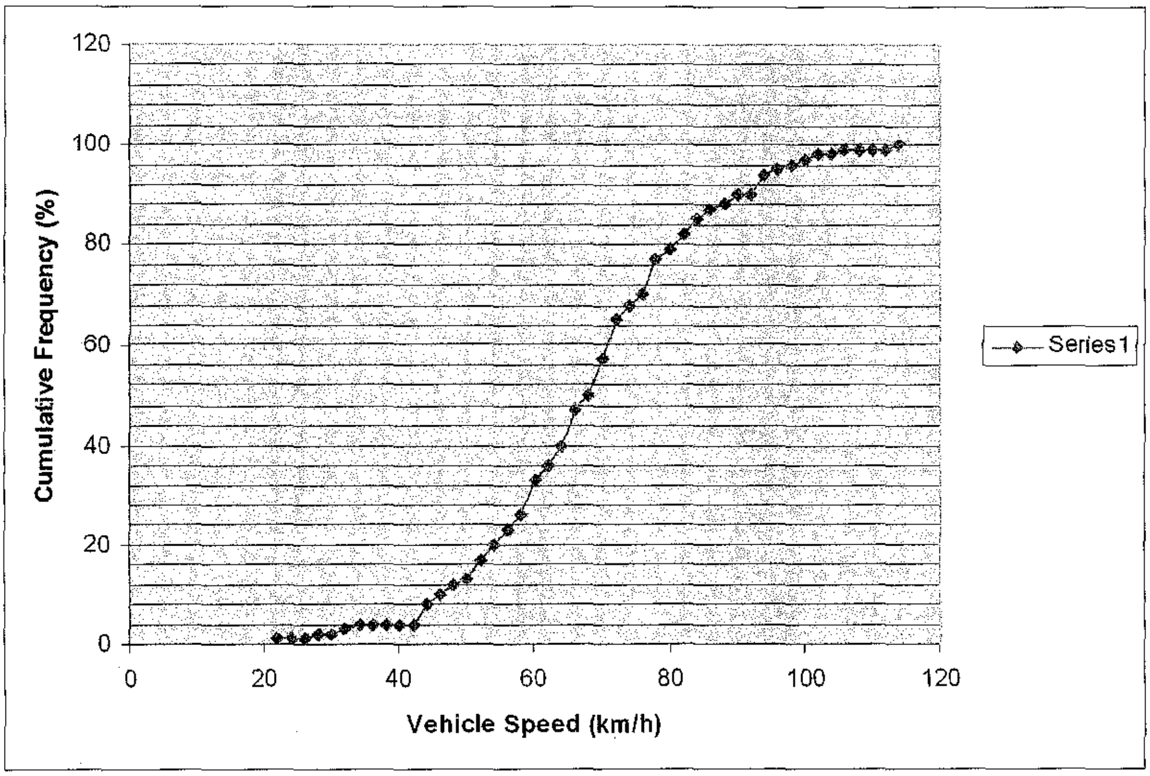

Figure 8: Cumulative distribution graph for segment 2

4.3 Junction Movement Result

Figure 9, 10, 11, 12, and 13 shows the traffic volumes at traffic light intersection L1, L2, L3, L4 and L5 respectively.

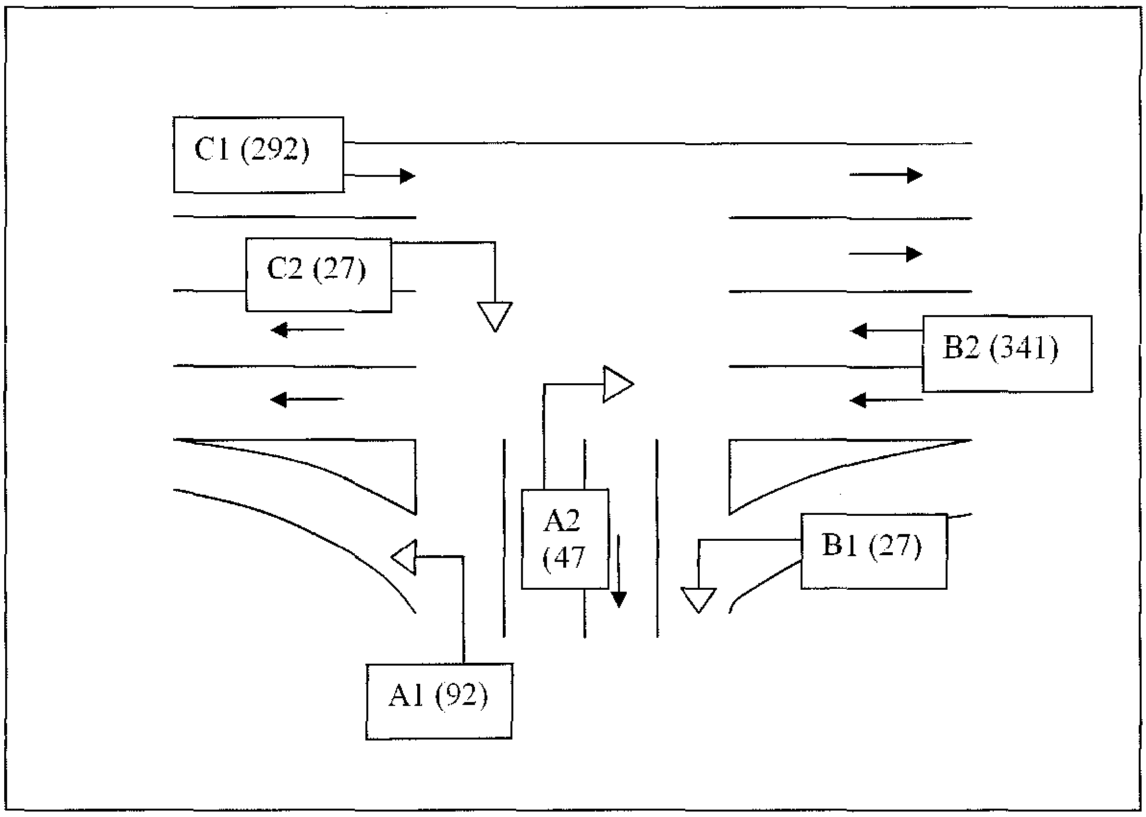

Figure 9: Intersection volume at traffic Light at L1

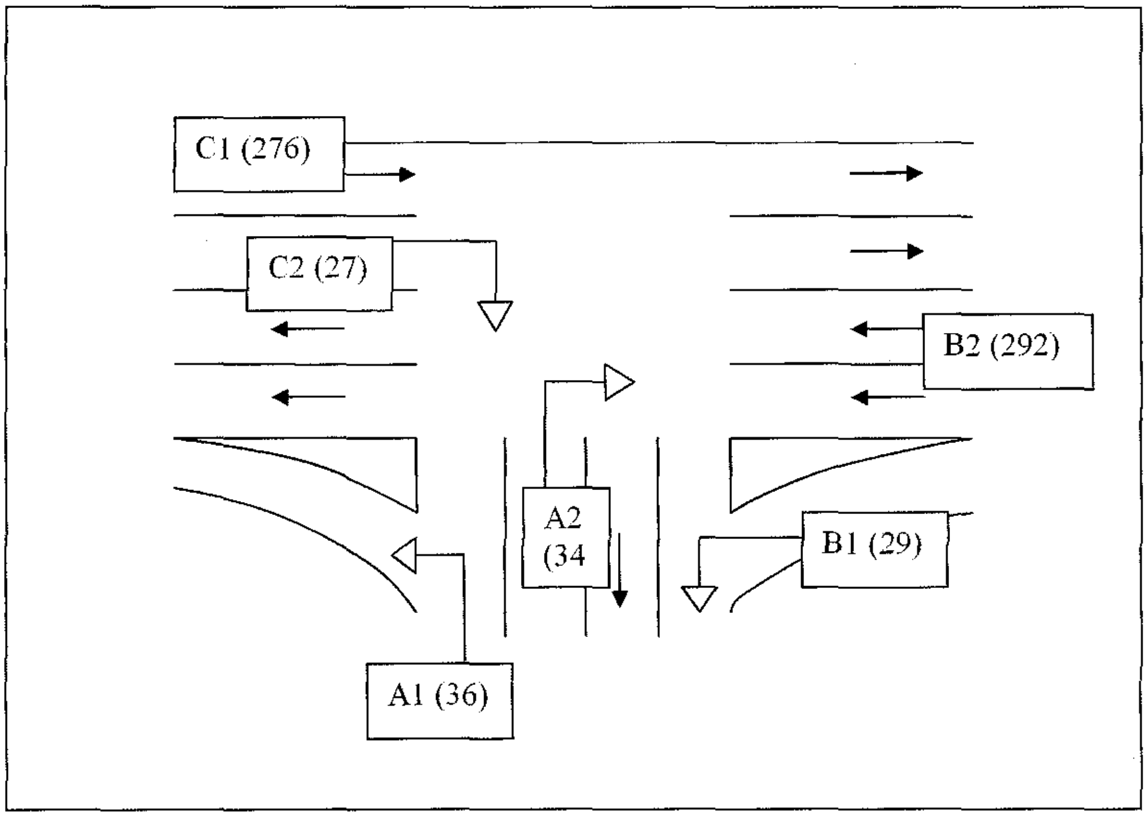

Figure 10: Intersection volume at traffic Light at L2

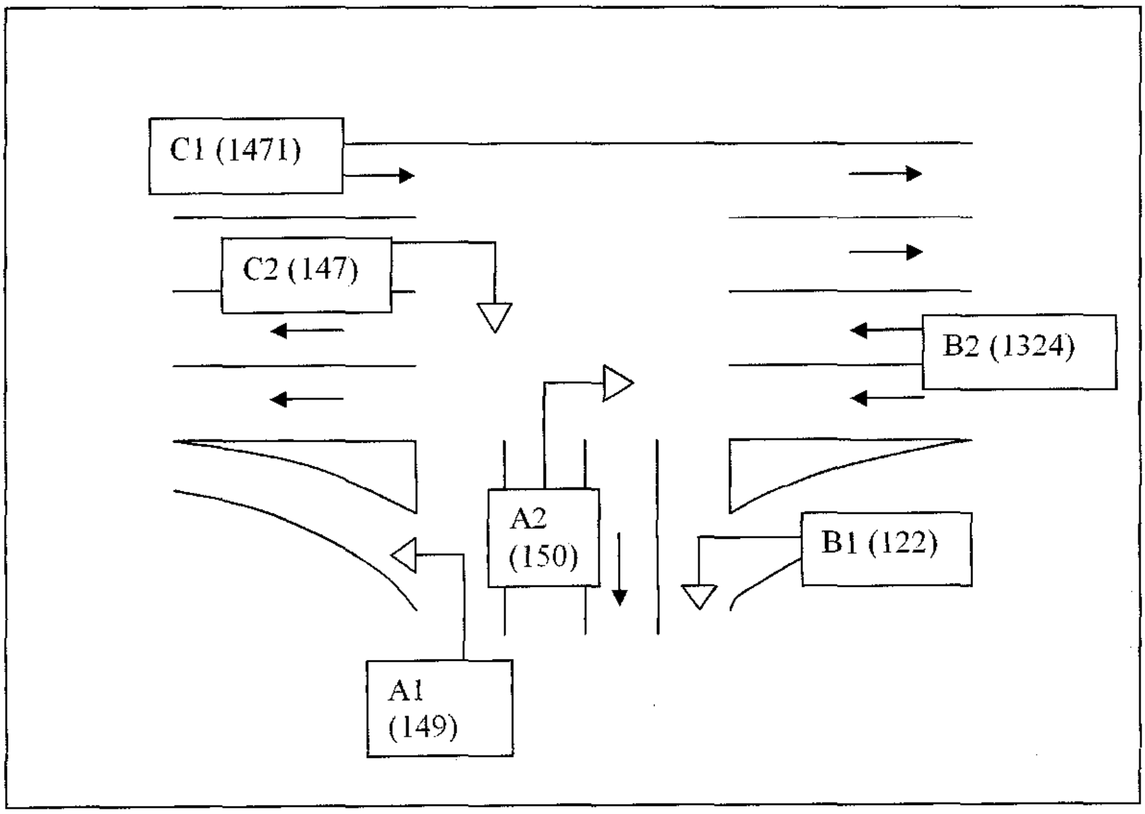

Figure 11: Intersection volume at traffic Light at L3

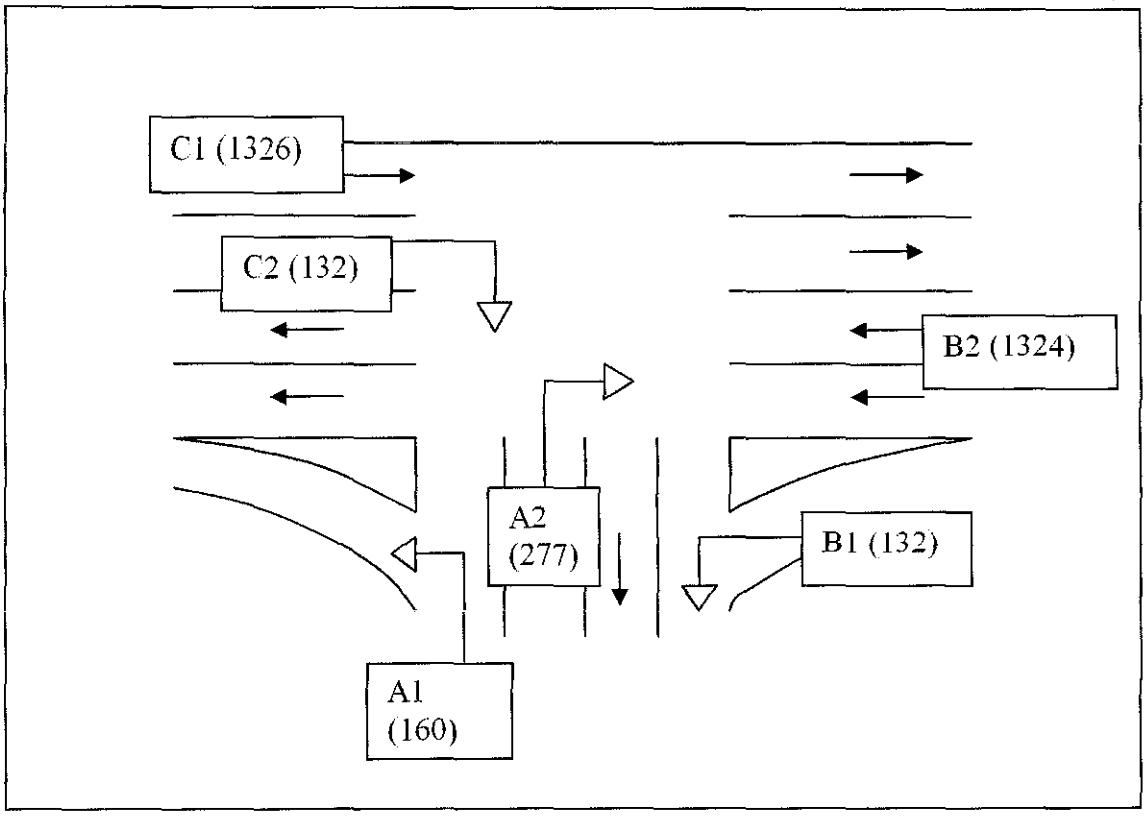

Figure 12: Intersection volume at traffic Light at L4

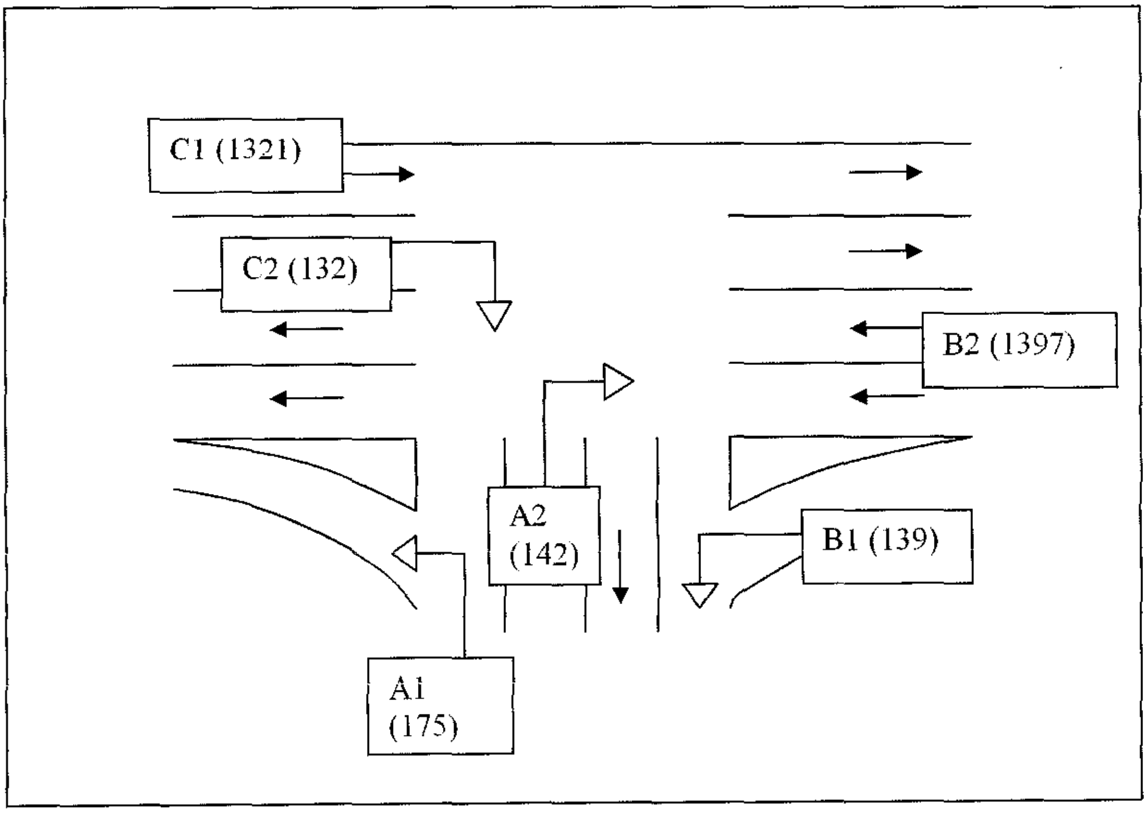

Figure 13: Intersection volume at traffic Light at L5

Results of traffic analysis are done by using aaSIDRA software and below are the result of the total capacity at each intersection:

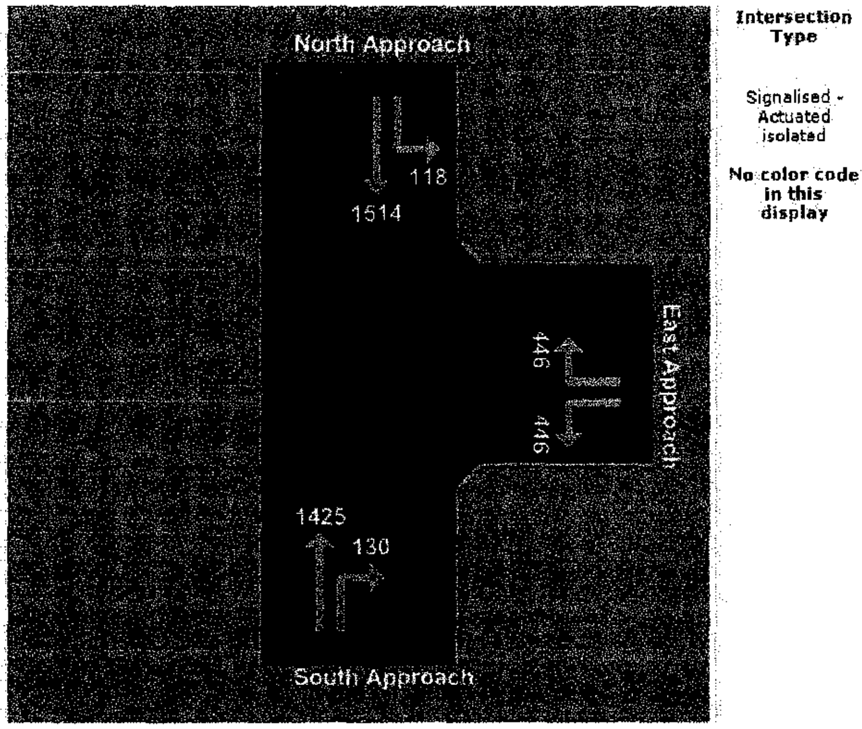

Figure 14: Total Capacity veh/h for traffic intersection L1

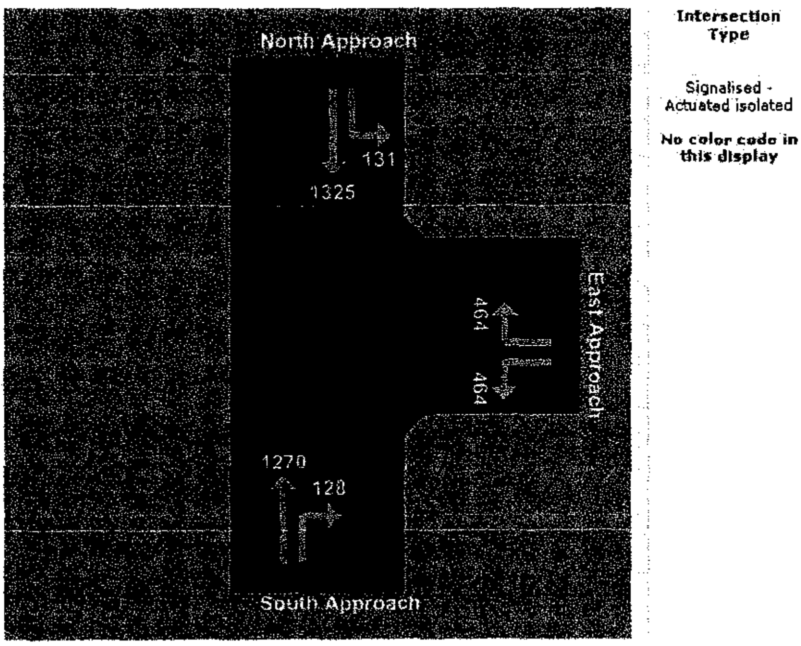

Figure 15: Total Capacity veh/h for traffic intersection L2

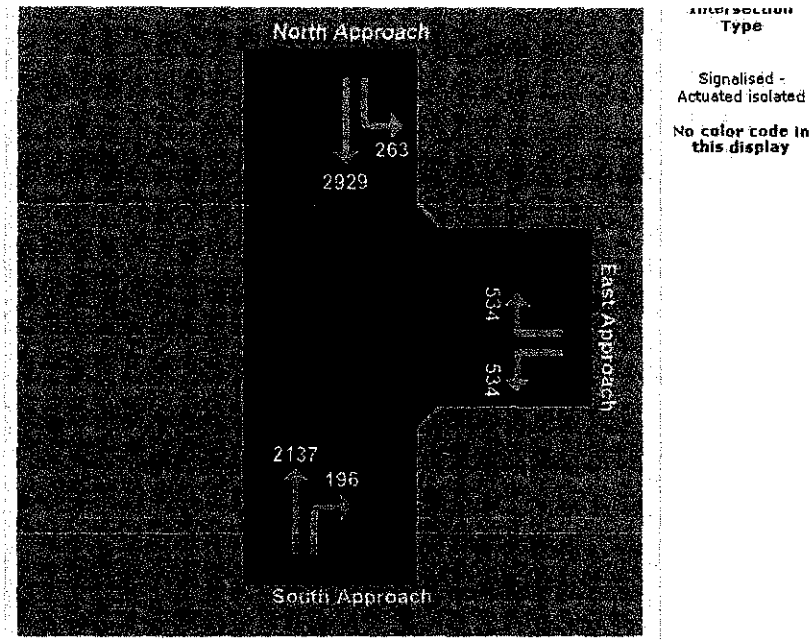

Figure 16: Total Capacity veh/h for traffic intersection L3

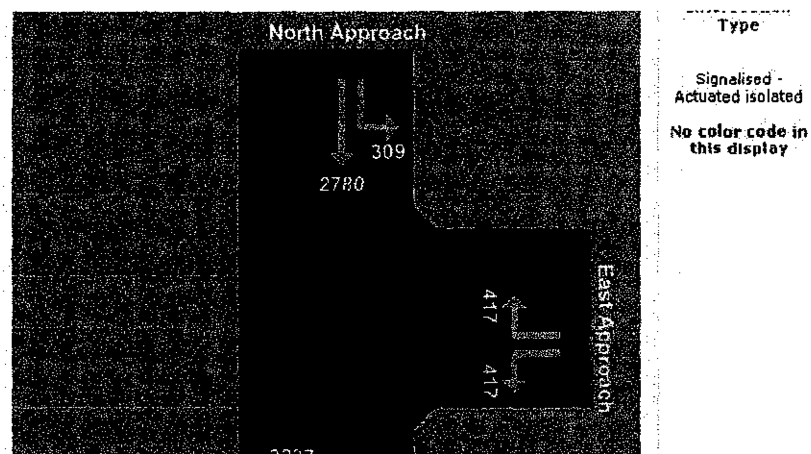

Figure 17: Total Capacity veh/h for traffic intersection L4

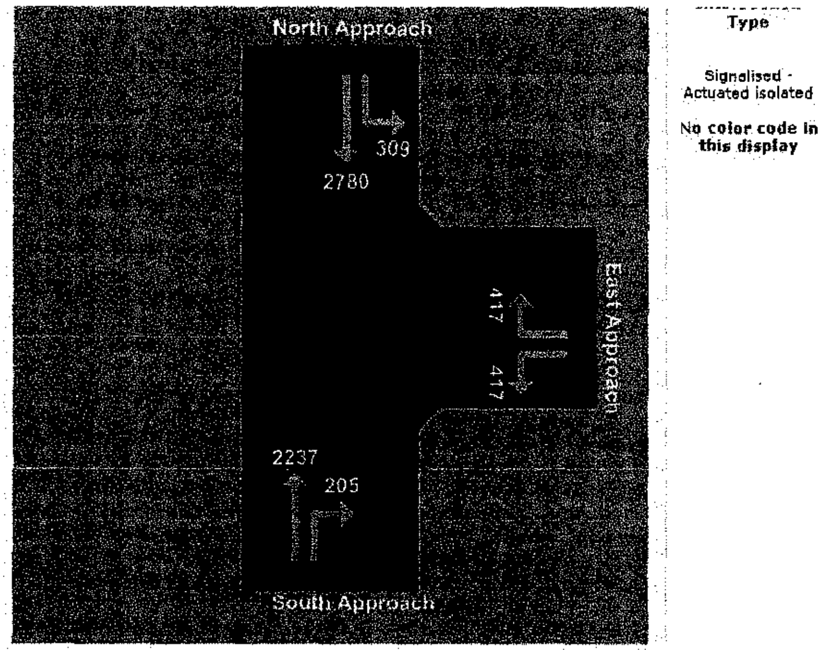

Figure 18: Total Capacity veh/h for traffic intersection L5

Below are the degree of saturation at each intersection which are also computed using the aaSIDRA:

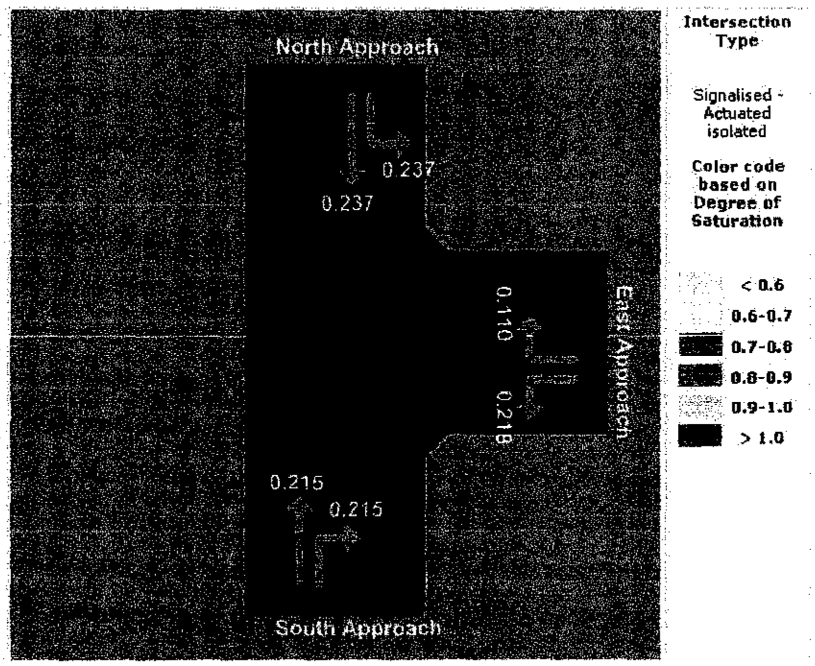

Figure 19: Degree of saturation V/C for traffic intersection L1

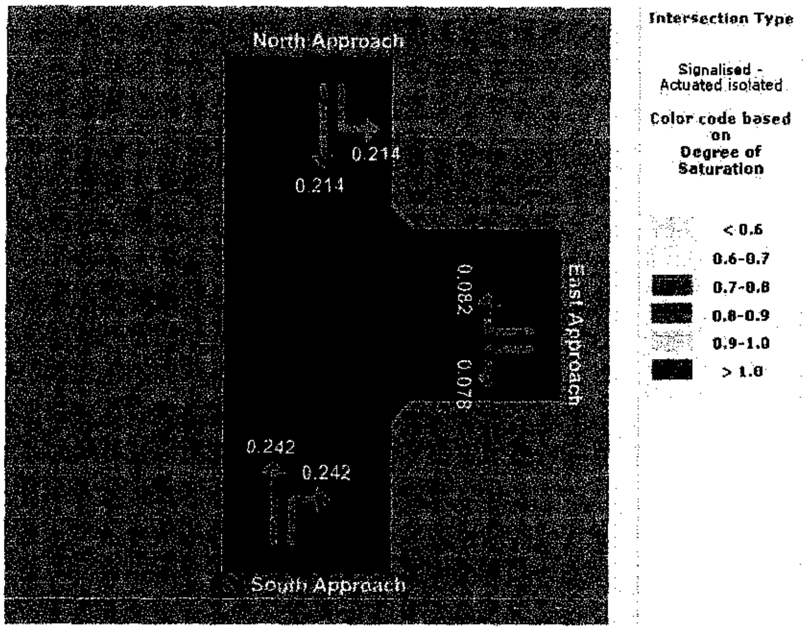

Figure 20: Degree of saturation V/C for traffic intersection L2

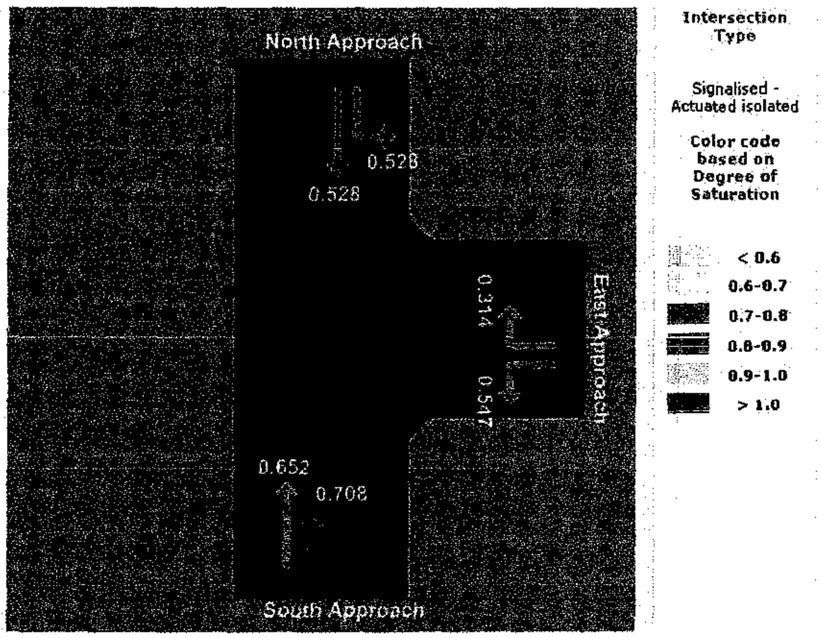

Figure 21: Degree of saturation V/C for traffic intersection L3

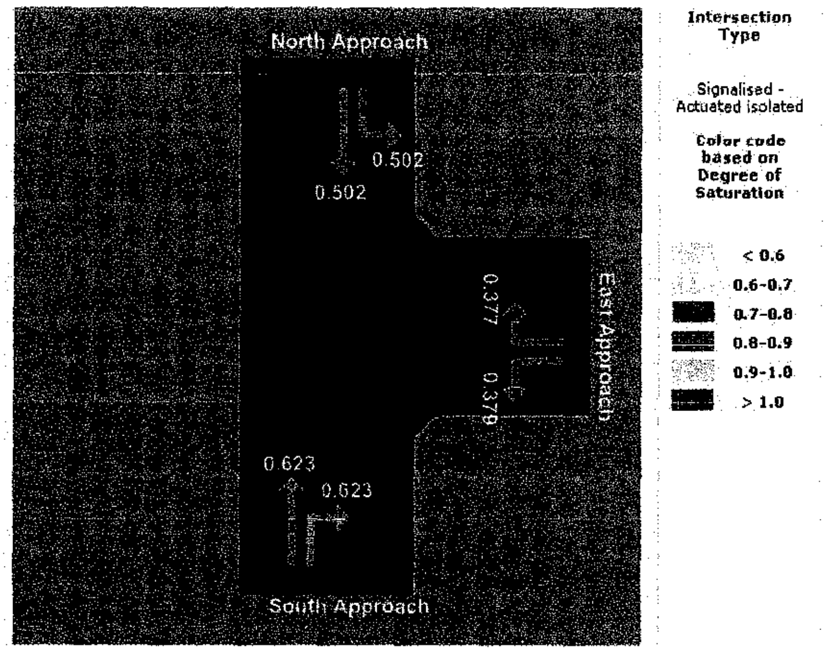

Figure 22: Degree of saturation V/C for traffic intersection L4

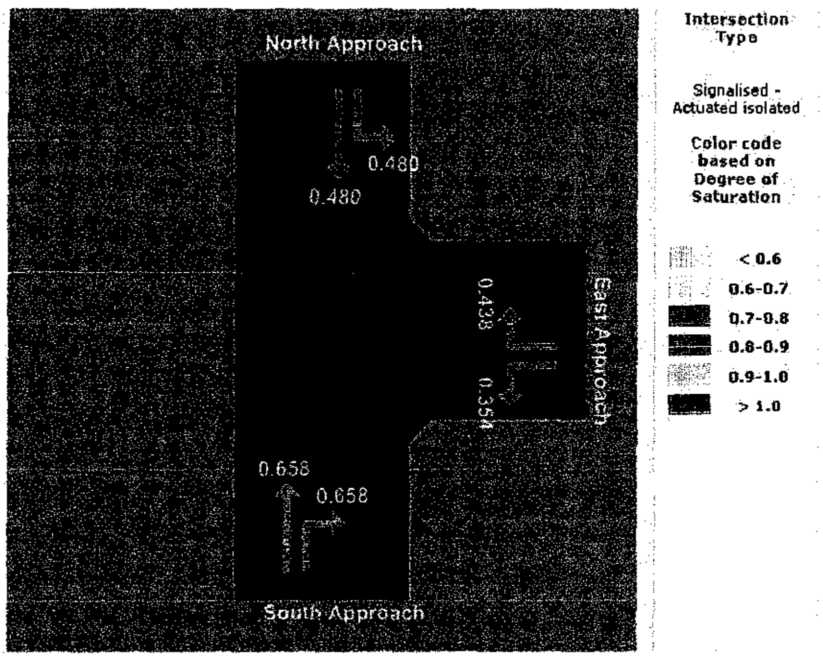

Figure 23: Degree of saturation V/C for traffic intersection L5

Below are the results of LOS at each intersection. This shows the effectiveness of the junction. The intersection summaries are enclosed in the appendix.

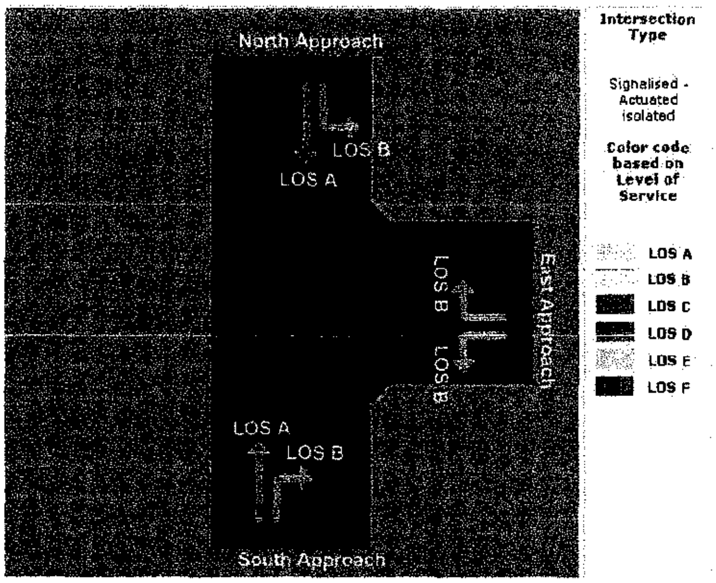

Figure 24: LOS of junction for traffic intersection L1

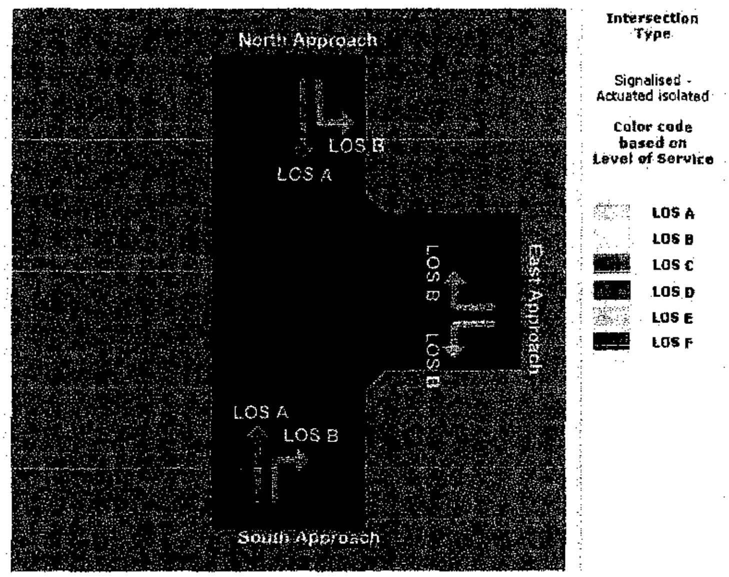

Figure 25: LOS of junction for traffic intersection L2

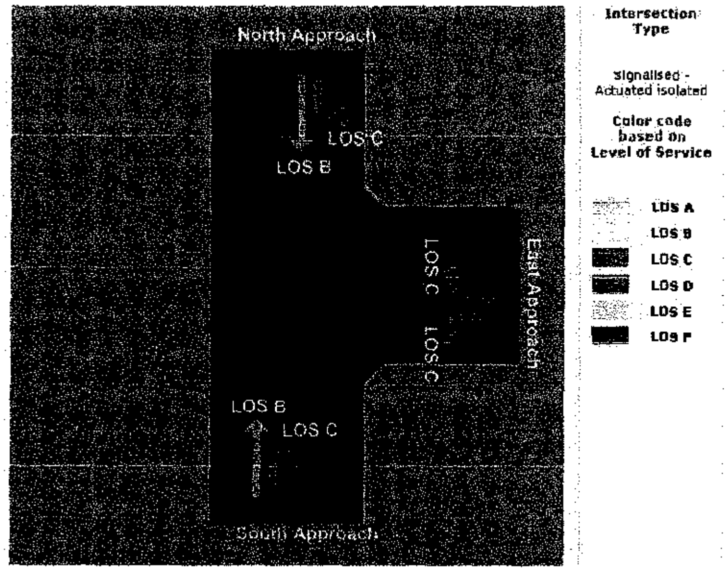

Figure 26: LOS of junction for traffic intersection L3

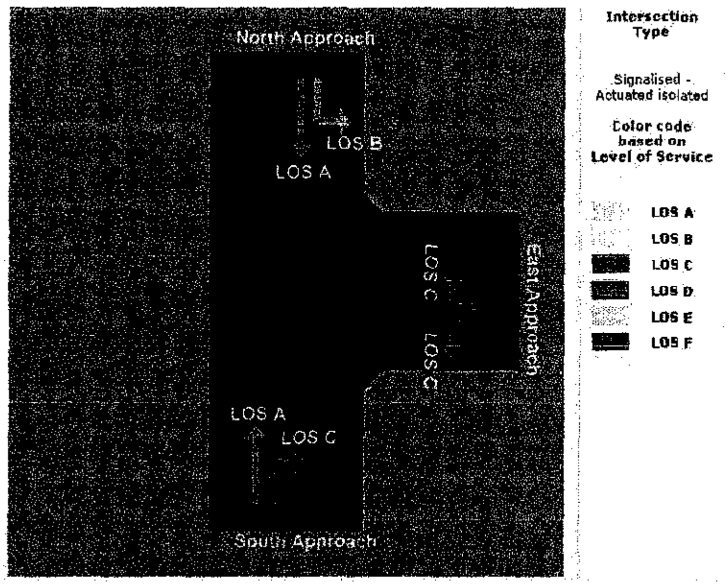

Figure 27: LOS of junction for traffic intersection L4

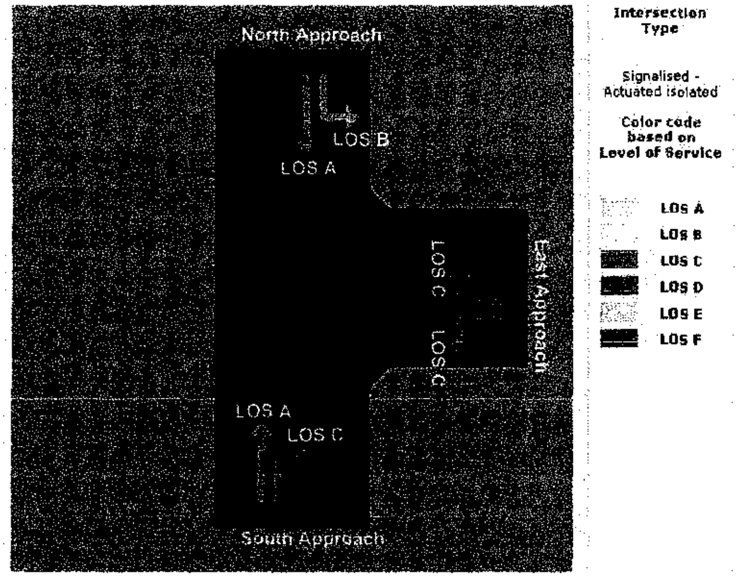

Figure 28: LOS of junction for traffic intersection L5

4.3.1 Forecasting future growth of the traffic light intersection

After obtaining the current LOS, future LOS also can be obtained from aaSIDRA. This future growth is estimated up to 10 year (assumed no development). Figure below shows the forecast future LOS at each intersection:

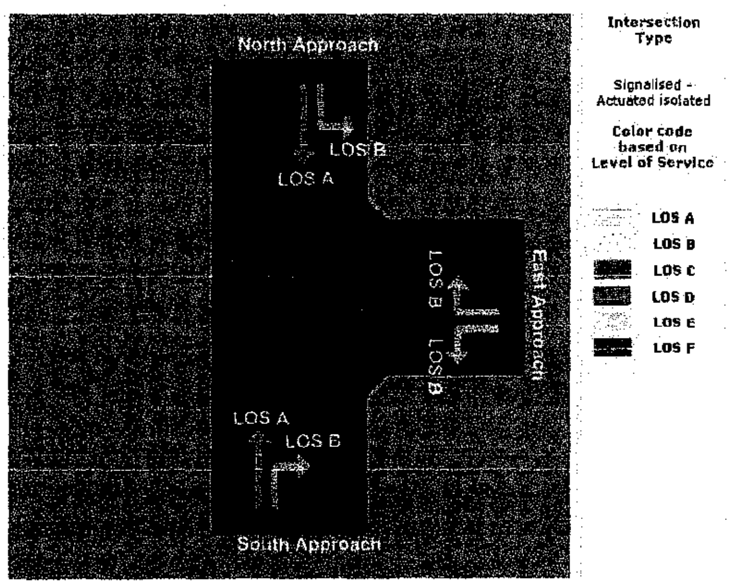

Figure 29 : Forecast LOS for 10 years at intersection L1

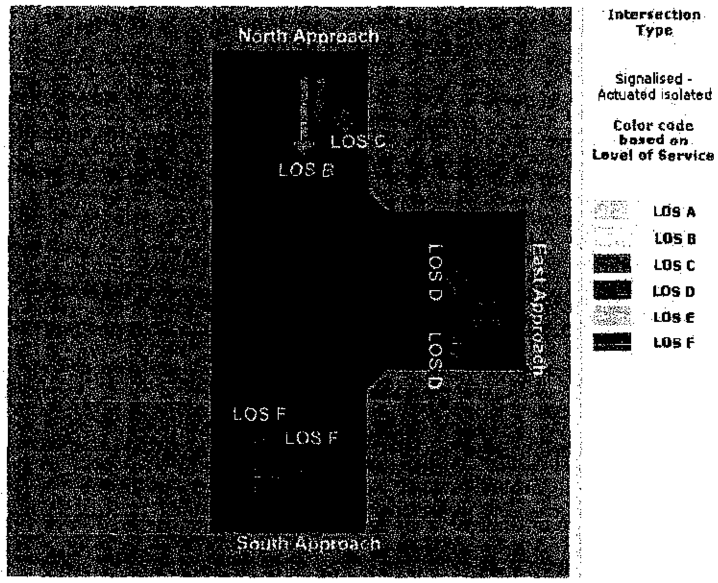

Figure 31 : Forecast LOS for 10 years at intersection L3

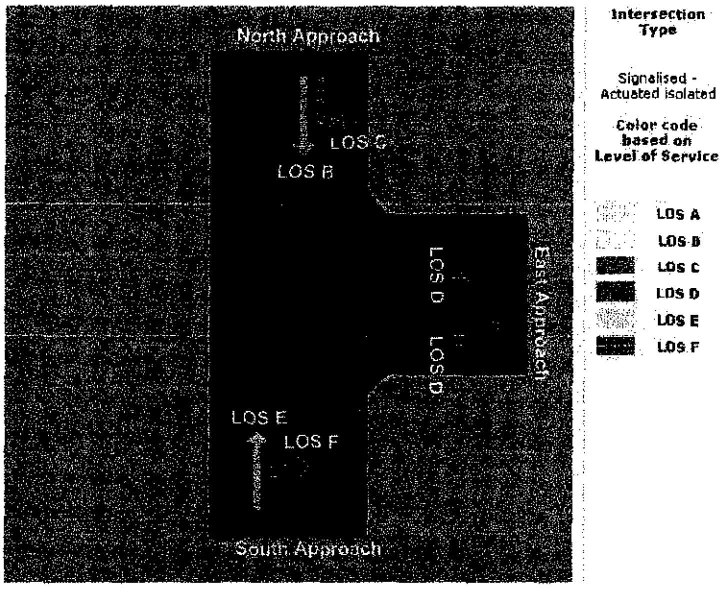

Figure 32 : Forecast LOS for 10 years at intersection L4

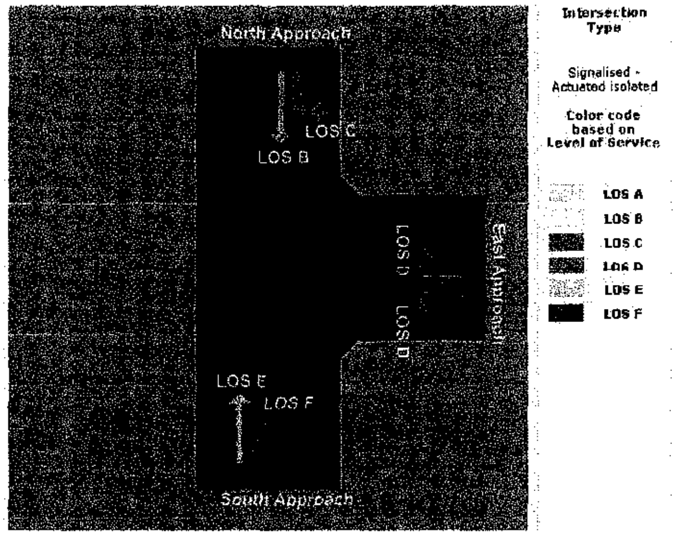

Figure 33 : Forecast LOS for 10 years at intersection L5

4.4 LOS of segment of the project site

From the data obtained from the volume studies and spot speed studies, the Percent Time Spent Following (PTSF) and average travel time (ATS) at each segment were calculated and Level of Service can be define from the value obtained from PTSF and ATS. At each segment, the passenger-car equivalent for heavy vehicle is equal to 1.1(table 9.5 Garber and Hoel, 2001). The grade adjustment factor is 1.0 (table 9.5 Garber and Hoel, 2001). The percentage of directional split is 50-50 for both ways. The peak hour factor is 0.95.

4.4.1 Percent Time Spent Following (PTSF) for segment 1

The percent time spent following (PTSF) is 60.67%. By using the standards in table 2, the LOS obtained is LOS C.

4.4.2 Percent Time Spent Following (PTSF) for segment 2

The percent time spent following (PTSF) is 60.53%. By using the standards in table 2, the LOS obtained is LOS C.

4.4.3 Percent Time Spent Following (PTSF) for segment 3

The percent time spent following (PTSF) is 61.23%. By using the standards in table 2, the LOS obtained is LOS C

4.4.4 Percent Time Spent Following (PTSF) for segment 4

The percent time spent following (PTSF) is 58.66%. By using the standards in table 2, the LOS obtained is LOS C

4.4.5 Percent Time Spent Following (PTSF) for segment 5

The percent time spent following (PTSF) is 58.7%. By using the standards in table 2, the LOS obtained is LOS C

4.4.6 Percent Time Spent Following (PTSF) for segment 6

The percent time spent following (PTSF) is 58.66%. By using the standards in table 2, the LOS obtained is LOS C

4.4.7 Percent Time Spent Following (PTSF) for segment 7

The percent time spent following (PTSF) is 58.66%. By using the standards in table 2, the LOS obtained is LOS C

4.4.8 Average Travel Speed (ATS) for segment 1

The Average Travel Speed is 68.99 km/h or 42.87 mi/h. By using the standards in table 1, the LOS obtained is LOS D.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 1 is LOS D.

4.4.9 Average Travel Speed (ATS) for segment 2

The Average Travel Speed is 68.61 km/h or 42.63 mi/h. By using the standards in table 1, the LOS obtained is LOS D.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 2 is LOS D.

4.4.10 Average Travel Speed (ATS) for segment 3

The Average Travel Speed is 68.59 km/h or 42.62 mi/h. By using the standards in table 1, the LOS obtained is LOS D.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 3 is LOS D.

4.4.11 Average Travel Speed (ATS) for segment 4

The Average Travel Speed is 84.20 km/h or 52.31 mi/h. By using the standards in table 1, the LOS obtained is LOS B.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 3 is LOS C.

4.4.12 Average Travel Speed (ATS) for segment 5

The Average Travel Speed is 83.30 km/h or 51.76 mi/h. By using the standards in table 1, the LOS obtained is LOS B.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 3 is LOS C.

4.4.13 Average Travel Speed (ATS) for segment 6

The Average Travel Speed is 83.69 km/h or 52 mi/h. By using the standards in table 1, the LOS obtained is LOS B.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 3 is LOS C.

4.4.14 Average Travel Speed (ATS) for segment 7

The Average Travel Speed is 83.40 km/h or 51.82 mi/h. By using the standards in table 1, the LOS obtained is LOS B.

Since the value of ATS and PTSF does not correspond to the same value, the lower value will be used. Therefore, LOS for segment 3 is LOS C.

4.5 Discussion of the results

The LOS for segment 1 to segment 7 are mostly LOS C and LOS D. This is expected since the passing opportunity is nearly zero. As the passing desire is increasing, it is natural that it will form a platoon that consists of five to ten consecutive vehicles in length especially when a heavy vehicle with heavy loads moves with a slow speed leads the platoon. The road is design with speed limit of 90 km/h but 50% of the vehicles traveling at 69 km/h to 72km/h (taken from median speed)

Contributors to the LOS value of the segment:

1) high volume of heavy vehicle using the highway.
2) vehicles tends to move slower when the roads are not smooth or rough.
3) some sections with 1 lane only.
4) lightning facilities.

For traffic intersection, it shows that all the intersections are able to handle the traffic since most of the LOS obtained varies from LOS A to LOS C. However, for future forecasting at 10 years, some of the intersection reaches LOS E and LOS F. This will cause heavy congestion. This maybe because the road is now currently is the main road for the traveler from Jelapang to Lumut and vice versa. If this analysis is correct, the specified intersections need to be upgrade within 10 years time. However, detail researches are required before launching any improvements.

4.6 Proposal to increase the LOS

As the result shows, the LOS of the segment mostly are LOS C and LOD D. LOS C shows that the segment is still capable handling the current traffic volume. However, as time goes by, a lot of development may increase the volume of the traffic. In the future, the LOS of the segment may fall to LOS D or LOS E which is not preferable. Furthermore, sudden congestion may occur when the festival seasons approaching, such as Hari Raya, Chinese New Year, Deepavali etc. Accident also may cause congestion since the driver will tend to slow down and look at the accident. Under these circumstances, the LOS may fall to LOS F.

To increase the Level of Sevice, additional lane may be one of the solutions since there are some of the segments are 1 lane for both directions. Under some circumstances, adding more lanes may invites more traffic, and further investigation is needed to justify it. Adding proper lighting also can be used to improve the Level of Service since some of the segment has no lighting and this cause the driver to drive slower at night. Some of the roads are not smooth with some holes on the road. By repairing the damaged road may also increase the LOS. As for the intersection, the traffic light duration may need to be calculate again and need to be adjust from time to time according to the traffic volume.

The road currently can cater the daily traffic and there's no need to rush to improve the road. Furthermore, to make major improvement to the road, a lot of things need to be considered and procedures to be followed.

CHAPTER 5 : CONCLUSION

The level of service is taken as a good indication of how well the particular segment is operating. It is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/or passengers, in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

In particular, the geometric characteristics, traffic conditions, and signal characteristics must be used in determining its LOS. This study will be focusing on the characteristics of the road and how it affects the Level of Service of the studied road.

As a conclusion, the current road segment can cater the traffic capacity and it still can manage to handle the future growth of traffic volume for at least in 10 years time. As for the intersection, the current intersections are able to cater the traffic capacity, but in 10 years time, some of the intersection may not be able to cater the capacity of the traffic. Therefore, proper improvement is needed to ensure the motorist can use the road efficiently and increase the road safety.

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[8]http://www.ctre.iastate.edu/PUBS/traffichandbook/2SpotSpeed.pdf

[9]http://www.ctre.iastate.edu/PUBS/traffichandbook/3TrafficCounts.pdf

[10]Jabatan Kerja Raya(JKR) IPOH, National Traffic Count 2004 on road AR307

[11]http://www.sidrasolutions.com/sidra/

APPENDIXES

Future traffic flow estimation (without development) calculation for Traffic Light Intersection

using average Malaysia urban growth rate, r = 5%
n projection of years = 10 years

use equation $V (1 + r)^n$

intersection 1

	V	$V (1 + r)^n$
A1	92	150
A2	47	77
B1	27	44
B2	341	556
C1	272	443
C2	27	44

Due Lumut = 706
Due Ipoh = 88
Due Jelapang = 521

intersection 2

	V	$V (1 + r)^n$
A1	36	59
A2	34	55
B1	29	47
B2	292	476
C1	276	450
C2	27	44

Due Lumut = 506
Due Jelapang = 535
Due Suburb = 92

Intersection 3

	V	$V (1 + r)^n$
A1	149	243
A2	150	245
B1	122	199
B2	1324	2158
C1	1471	2398
C2	147	240

Due Lumut = 439
Due Jelapang = 2643
Due Chemor = 2306

Intersection 4

	V	V $(1+r)^n$
A1	160	261
A2	277	452
B1	1324	2158
B2	132	215
C1	1326	2161
C2	132	215

Due Suburb = 347
Due Jelapang = 2613
Due Chemor = 2373

Intersection 5

	V	V $(1+r)^n$
A1	175	285
A2	142	231
B1	1397	2277
B2	139	227
C1	1321	2153
C2	132	215

Due Suburb = 442
Due Jelapang = 2384
Due Chemor = 2562

Calculation for PTSF for segment 1

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.907194

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$ where PHF = 0.95 and $f_{HV} = 1.0$

Vp = 711 veh/h

note: 711 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

$BPTSF = 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*711)})$
$= 46.47$

$PTSF = PTSF + f_{d/np}$
$= 60.67$

Calculation for PTSF for segment 2

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.91083

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 708 veh/h

note: 708 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

BPTSF $= 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*708)})$
$= 46.33$

PTSF $=$ PTSF $+ f_{d/np}$
$= 60.53$

Calculation for PTSF for segment 3

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

f_{HV} = 0.892937

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 723 veh/h

note: 723 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

$BPTSF = 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*723)})$
$= 47.03$

$PTSF = PTSF + f_{d/np}$
$= 61.23$

Calculation for PTSF for segment 4

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.964972

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 669 veh/h

note: 669 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

$BPTSF = 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*669)})$
$= 44.46$

$PTSF = PTSF + f_{d/np}$

$= 58.66$

Calculation for PTSF for segment 5

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.962927

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 670 veh/h

note: 670 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

$BPTSF = 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*670)})$
$= 44.5$

$PTSF = PTSF + f_{d/np}$
$= 58.7$

Calculation for PTSF for segment 6

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.963948

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 669 veh/h

note: 669 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

BPTSF $= 100(1-e^{-0.000879Vp})$

$= 100(1-e^{(-0.000879*669)})$
$= 44.46$

PTSF $=$ PTSF $+ f_{d/np}$
$= 58.66$

Calculation for PTSF for segment 7

adjustment factor for heavy vehicle, f_{HV}

$1 / (1 + P_T (E_T))$

$f_{HV} =$ 0.964972

Passenger-car equivalent flow rate for the peak 15-min period, Vp

$Vp = V/(PHF \times 1.0 \times f_g \times f_{HV})$

Vp = 669 veh/h

note: 669 < 3200; this section is operating below capacity

Base Percent Time Spent Following for both direction, BPTSF:

$BPTSF = 100(1\text{-}e^{-0.000879Vp})$

$= 100(1\text{-}e^{(-0.000879*669)})$
$= 44.46$

$PTSF = PTSF + f_{d/np}$
$= 58.66$

Calculation For ATS for segment 1

Mean speed of traffic measured in the field, S_{FM} = 70.8 km/h (from spot speed data calculation)

S_{FM} = 70.8

Obeserved flow rate, V_f = 613

f_{HV} = 0.907194

Vp = 711

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:

Field measurement at volumes > 200 veh/h

Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 76.04 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 68.99 km/h

= 42.87 mi/h

Calculation For ATS for segment 2

Mean speed of traffic measured in the field, S_{FM} = 70.8 km/h (from spot speed data calculation)

S_{FM} = 70.8

Obeserved flow rate, V_f = 568

f_{HV} = 0.91083

Vp = 708

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:

Field measurement at volumes > 200 veh/h

Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 75.64 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 68.61 km/h

= 42.63 mi/h

Calculation For ATS for segment 3

Mean speed of traffic measured in the field, S_{FM} = 70.8 km/h (from spot speed data calculation)

S_{FM} = 70.8

Obeserved flow rate, V_f = 568

f_{HV} = 0.89293

Vp = 723

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:
Field measurement at volumes > 200 veh/h
Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 75.74 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 68.59 km/h
= 42.62 mi/h

Calculation For ATS for segment 4

Mean speed of traffic measured in the field, S_{FM} = 68.46 km/h (from spot speed data calculation)

S_{FM} = 68.46

Obeserved flow rate, V_f = 2795

f_{HV} = 0.965

Vp = 669

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:
Field measurement at volumes > 200 veh/h
Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 90.94 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 84.20 km/h
= 52.31 mi/h

Calculation For ATS for segment 5

Mean speed of traffic measured in the field, S_{FM} = 68.46 km/h (from spot speed data calculation)

S_{FM} = 68.46

Obeserved flow rate, V_f = 2678

f_{HV} = 0.963

Vp = 670

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:

Field measurement at volumes > 200 veh/h
Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 90.04 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 83.30 km/h
= 51.76 mi/h

Calculation For ATS for segment 6

Mean speed of traffic measured in the field, S_{FM} = 68.46 km/h (from spot speed data calculation)

S_{FM} = 68.46

Obeserved flow rate, V_f = 2728

f_{HV} = 0.964

Vp = 669

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:

Field measurement at volumes > 200 veh/h
Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 90.42 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 83.69 km/h
= 52 mi/h

Calculation For ATS for segment 7

Mean speed of traffic measured in the field, S_{FM} = 68.46 km/h (from spot speed data calculation)

S_{FM} = 68.46

Obeserved flow rate, V_f = 2692

f_{HV} = 0.964

Vp = 669

adjustment for the percentage of no-passing zones, f_{np} = 1.65
(interpolation of table 9.6 Garber and Hoel textbook)

Find FFS under the following conditions:
Field measurement at volumes > 200 veh/h
Field data are available

Free Flow Speed, (FFS) = $S_{FM} + 0.00776(V_f/f_{HV})$

= 90.13 km/h

Average Travel Speed, ATS = FFS - 0.0076Vp - fnp

= 83.40 km/h
= 51.82 mi/h

Intersection Summary for Intersection 1 (L1)

Title

Performance Measure	Vehicles	Persons
Demand Flow	868 veh/h	1302 pers/h
Degree of Saturation	0.237	
Capacity (Total)	4079 veh/h	
95% Back of Queue (m)	12 m	
95% Back of Queue (veh)	1.7 veh	
Control Delay (Total)	2.52 veh-h/h	3.78 pers-h/h
Control Delay (Average)	10.5 s/veh	10.5 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS B	
Total Effective Stops	561 veh/h	841 pers/h
Effective Stop Rate	0.65 per veh	0.65 per pers
Travel Distance (Total)	525.7 veh-km/h	788.5 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	11.3 veh-h/h	16.9 pers-h/h
Travel Time (Average)	46.8 secs	46.8 secs
Travel Speed	46.6 km/h	46.6 km/h
Operating Cost (Total)	272 $/h	272 $/h
Fuel Consumption (Total)	55.4 L/h	
Carbon Dioxide (Total)	138.5 kg/h	
Hydrocarbons (Total)	0.235 kg/h	
Carbon Monoxide (Total)	11.24 kg/h	
NOX (Total)	0.337 kg/h	

Intersection Summary for Intersection 2 (L2)

Title

Performance Measure	Vehicles	Persons
Demand Flow	723 veh/h	1085 pers/h
Degree of Saturation	0.242	
Capacity (Total)	3783 veh/h	
95% Back of Queue (m)	11 m	
95% Back of Queue (veh)	1.5 veh	
Control Delay (Total)	2.05 veh-h/h	3.07 pers-h/h
Control Delay (Average)	10.2 s/veh	10.2 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS B	
Total Effective Stops	469 veh/h	703 pers/h
Effective Stop Rate	0.65 per veh	0.65 per pers
Travel Distance (Total)	438.0 veh-km/h	657.0 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	9.3 veh-h/h	14.0 pers-h/h
Travel Time (Average)	46.5 secs	46.5 secs
Travel Speed	46.9 km/h	46.9 km/h
Operating Cost (Total)	224 $/h	224 $/h
Fuel Consumption (Total)	46.1 L/h	
Carbon Dioxide (Total)	115.3 kg/h	
Hydrocarbons (Total)	0.196 kg/h	
Carbon Monoxide (Total)	9.44 kg/h	
NOX (Total)	0.282 kg/h	

Intersection Summary for Intersection 3 (L3)

Title

Performance Measure	**Vehicles**	**Persons**
Demand Flow	3480 veh/h	5220 pers/h
Degree of Saturation	0.658	
Capacity (Total)	6486 veh/h	
95% Back of Queue (m)	105 m	
95% Back of Queue (veh)	15.0 veh	
Control Delay (Total)	11.61 veh-h/h	17.42 pers-h/h
Control Delay (Average)	12.0 s/veh	12.0 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS C	
Total Effective Stops	2269 veh/h	3404 pers/h
Effective Stop Rate	0.65 per veh	0.65 per pers
Travel Distance (Total)	2108.4 veh-km/h	3162.6 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	46.8 veh-h/h	70.1 pers-h/h
Travel Time (Average)	48.4 secs	48.4 secs
Travel Speed	45.1 km/h	45.1 km/h
Operating Cost (Total)	1126 $/h	1126 $/h
Fuel Consumption (Total)	218.1 L/h	
Carbon Dioxide (Total)	545.2 kg/h	
Hydrocarbons (Total)	0.920 kg/h	
Carbon Monoxide (Total)	41.79 kg/h	
NOX (Total)	1.290 kg/h	

Intersection Summary for Intersection 4 (L4)

Title

Performance Measure	Vehicles	Persons
Demand Flow	3388 veh/h	5082 pers/h
Degree of Saturation	0.623	
Capacity (Total)	6365 veh/h	
95% Back of Queue (m)	90 m	
95% Back of Queue (veh)	12.9 veh	
Control Delay (Total)	10.93 veh-h/h	16.39 pers-h/h
Control Delay (Average)	11.6 s/veh	11.6 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS C	
Total Effective Stops	2219 veh/h	3329 pers/h
Effective Stop Rate	0.66 per veh	0.66 per pers
Travel Distance (Total)	2052.6 veh-km/h	3079.0 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	45.1 veh-h/h	67.7 pers-h/h
Travel Time (Average)	48.0 secs	48.0 secs
Travel Speed	45.5 km/h	45.5 km/h
Operating Cost (Total)	1087 $/h	1087 $/h
Fuel Consumption (Total)	212.3 L/h	
Carbon Dioxide (Total)	530.7 kg/h	
Hydrocarbons (Total)	0.895 kg/h	
Carbon Monoxide (Total)	40.94 kg/h	
NOX (Total)	1.261 kg/h	

Intersection Summary for Intersection 5 (L5)

Title

Performance Measure	Vehicles	Persons
Demand Flow	3480 veh/h	5220 pers/h
Degree of Saturation	0.658	
Capacity (Total)	6486 veh/h	
95% Back of Queue (m)	105 m	
95% Back of Queue (veh)	15.0 veh	
Control Delay (Total)	11.61 veh-h/h	17.42 pers-h/h
Control Delay (Average)	12.0 s/veh	12.0 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS C	
Total Effective Stops	2269 veh/h	3404 pers/h
Effective Stop Rate	0.65 per veh	0.65 per pers
Travel Distance (Total)	2108.4 veh-km/h	3162.6 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	46.8 veh-h/h	70.1 pers-h/h
Travel Time (Average)	48.4 secs	48.4 secs
Travel Speed	45.1 km/h	45.1 km/h
Operating Cost (Total)	1126 $/h	1126 $/h
Fuel Consumption (Total)	218.1 L/h	
Carbon Dioxide (Total)	545.2 kg/h	
Hydrocarbons (Total)	0.920 kg/h	
Carbon Monoxide (Total)	41.79 kg/h	
NOX (Total)	1.290 kg/h	