Study on the level of service (LOS) and performance of the Jelapang- Seri Iskandar route (a section of the Ipoh-Lumut highway)

By

Imran Bin Khalid (2207)

DESSERTATION REPORT

Submitted to the
Civil Engineering Programme
Universiti Teknologi Petronas
in Partial Fulfillment of the Requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

December 2005

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

(Assoc. Prof. Dr. Madzlan Napiah)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2005

CERTIFICATION OF ORIGINALITY

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

(IMRAN BIN KHALID)

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ABSTRACT

Traffic engineering studies were carry out to find the level of service (LOS) for the propose section of the Ipoh-Lumut highway. Spot speed studies, volume studies, traffic flow and travel time and delay studies were established for the analysis. Two sections of the highway were studied for speed trend analysis that represents different traffic conditions for basic data collection. Three intersections were also studied for performance measure. The result of the study concluded the LOS of the section of the highway and intersections. Proposal was made for solution to improve the LOS.

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CHAPTER 1: INTRODUCTION

1.1 Background of Project

The Ipoh-Lumut highway is one of the busiest routes in Perak. It functions as a lifeline, from the Lumut port to Jelapang- Chemor, near Ipoh. The establishment of institutions such as Universiti Teknologi PETORNAS (UTP), Universiti Teknologi Mara (UiTM) Seri Iskandar branch, naval communication center, the booming township of Bandar Seri Iskandar, and the proposed Commonwealth University; add to the increase in traffic volume and flow on the highway.

The 2-lane 2-way highway starts at Jelapang and ends at the shores of Lumut, about 70 km apart. It connects vital locations such as the outskirts of Ipoh, detour to Batu Gajah, Tronoh, Bandar Sri Iskandar, Bota, Parit and the port of Lumut. As it is a federal route, it is maintained under Jabatan Kerja Raya (JKR).

The highway subjects to partial or very limited access control. With traffic lights functioning as it's only access control measure. There're no toll houses, concrete divider on road shoulder and limited steel railing. Design speed is 100 km/h with only a few sharp horizontal alignments. Only a few steep slopes exist primarily near the entrance to the outskirts of Ipoh City. Passing/climbing lane exists on the steep gradient but only limited to short passes. Solid and double lines exist on steep gradients, upgrade, near traffic light intersection and horizontal curve. Road lights focus primarily on populated areas and important intersections, mainly near Ipoh. Some steep gradients and curvature remain unlit.

The project site is limited due to project constraints such as time, resource, man power and financial constraints. The site is from the Traffic light controlled T-junction on Jalan Jelapang to the traffic light controlled T-junction in Falim. This study was carried out over 2 semesters. During semester one (Jan-June 2005), studies were conducted on segment 1 (L1 to L2) and traffic light intersection L1.For semester two (July-Dec 2005), studies were conducted on segment 2(L2 to L3) of the project site and traffic light intersections L2 and L3.

1.1.1 Traffic in project site

The Ipoh- Lumut highway is one of the most busiest and major highway in Perak. It is designated as a federal route. The infrastructure and facilities of the road network consist of class I 2 way 2 lane highway, traffic lights, steel railing, feeder roads and rat runs. Specifically, the project site consists of 3 traffic light intersection, covered by 8.5 km of highway length. The first segment is 5.2 km in length and the second segment covers 3.3 km. The lane width is standardized at 350cm.

Currently, most of road network are fully completed and utilized. Except for a stretch in segment 1, this is undertaking road upgrading under JKR. Facilities such as pedestrian crossing, public transport facilities, etc. are at a minimum, due to the highway purpose of catering high demand of traffic.

Traffic flow at the highway approaching the traffic light intersection at Jelapang (L1, L2, and L3) has a peak hour flow at 8.00am to 9.30am in the morning and at 4.30pm to 6.00pm in the evening due to people going to and from work. Traffic flow during off peak is constant as commuters travel from the Plus Highway to destinations approaching Lumut, vice versa.

As the highway is a two lane two way, with nearly 80% no passing zone, travel speed is nearly constant. This is also due to heavy vehicle traveling at lower speeds creating platoons of vehicle behind it.

1.2 Problem Statement

Increase in traffic flow due to population rise, partial to limited access control and limited lanes has resulted in poor level of service (LOS) along the route. Solid lines, double lines/ no passing zones on numerous stretches also contribute to the increase of time needed to reach a final destination. Sight distance is also limited when traveling during night time due to lack of lighting along the route. Figure 1 illustrates the project site undertaken for performance studies.

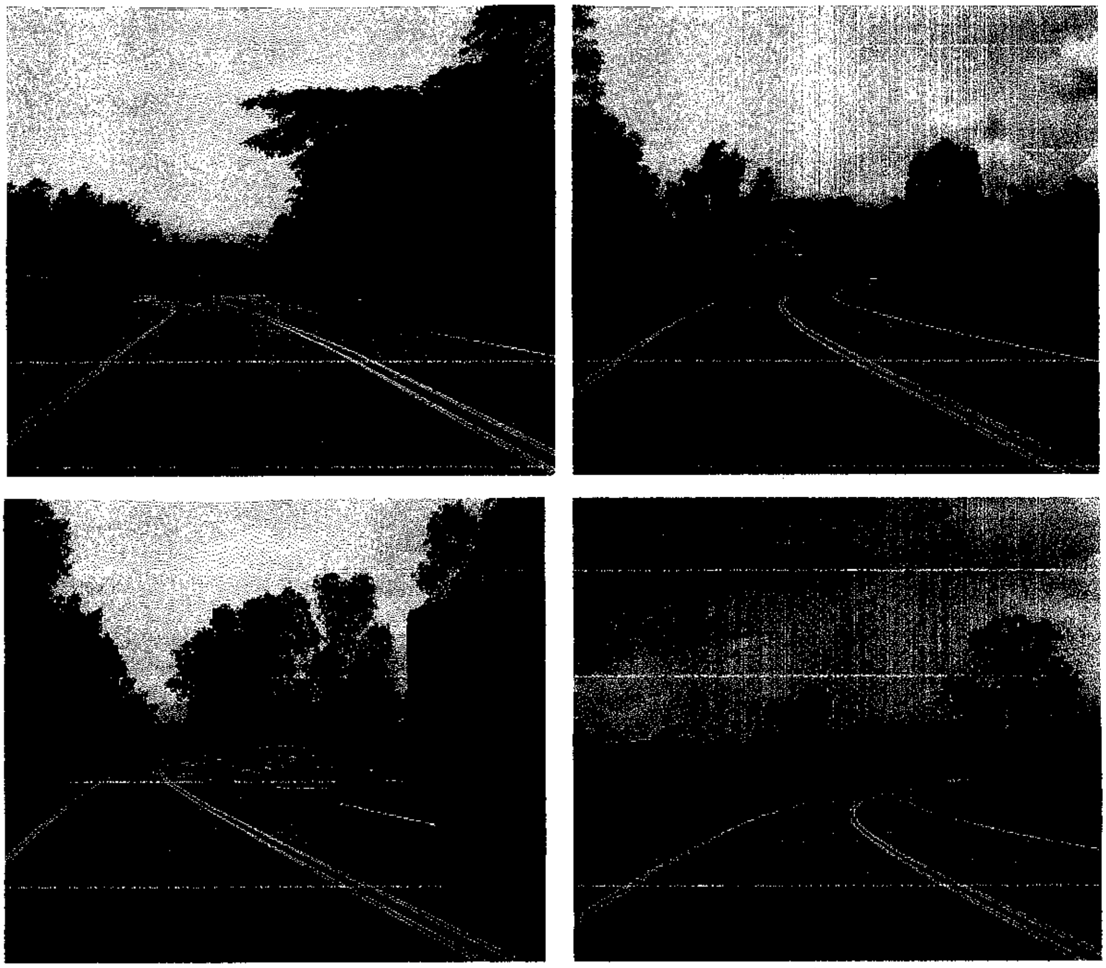


Figure 1: The project site. A two-lane two way class I highway.

1.3 Objectives and Scope of Study

The highway design will eventually exhaust in catering the needs of the commuters commuting the route. Upgrading the route will ensure the continuity of the development of the area. The objectives are stated as below:

1) To study the current LOS of the mention stretch, and contributing factors of the LOS.
2) To propose a solution to increase the LOS. This has to be justified by data, calculations and analysis.

1.3.1 The Relevancy of the Project

This project is related to study the current travel demand and level of service of the site. It is based on traffic and highway engineering principals and methodology. Even though the current LOS (visibly observed) still being able to cater the volume demand, it is necessary to evaluate it in order to determine which level it belongs to, hence take steps to increase it for future demand trends.

1.3.2 Feasibility of the Project within the Scope and Time Frame

This project took about two semesters for completion. In the time frame given, this project needs to propose a solution to increase the LOS.

For this reason, this project requires gaining data and information on the highway segment. It took about one semester for the data and information gathering period. Traffic studies were conducted to evaluate the LOS and travel demand. This resulted in a conclusion of the LOS and related proposal.

CHAPTER 2: LITERATURE REVIEW

2.1 Level of Service

The Level of Service (LOS) expresses the performance of a highway at traffic volumes less than capacity. LOS for class I highway (project site) is based on two measures which is Percent Time Spent Following (PTSF) and the Average Travel Speed (ATS). At an operational level of analysis, LOS is determined based on existing or future traffic conditions and specific roadway characteristics.

Highway Capacity Manual (HCM) will be used to calculate the LOS. The HCM procedure puts the project site as a Class I highway. This is a two-lane highway that functions as primary arterials, daily commuter routes, and links to other arterial highways. Motorist' expectations are that travel will be at relatively high speeds. The procedure will analyze two-lane highway with two way traffic. The grade is considered less then 3% for the whole span.

Level of service (LOS) is a quality measure, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience. A given LOS (A, B, C, D, E, and F) comprises or describes a *range* of conditions or values always given from the perspective of the facility user. [1]

2.2 LOS class definitions

According to the definition (Garber and Hoel, 2001, p.379)

LOS A

Free-flow conditions with unimpeded maneuverability. Stopped delay at signalized intersection is minimal.

LOS B

Reasonably unimpeded operations with slightly restricted maneuverability. Stopped delays are not bothersome.

LOS C

Stable operations with somewhat more restrictions in making mid-block lane changes than LOS B. Motorists will experience appreciable tension while driving.

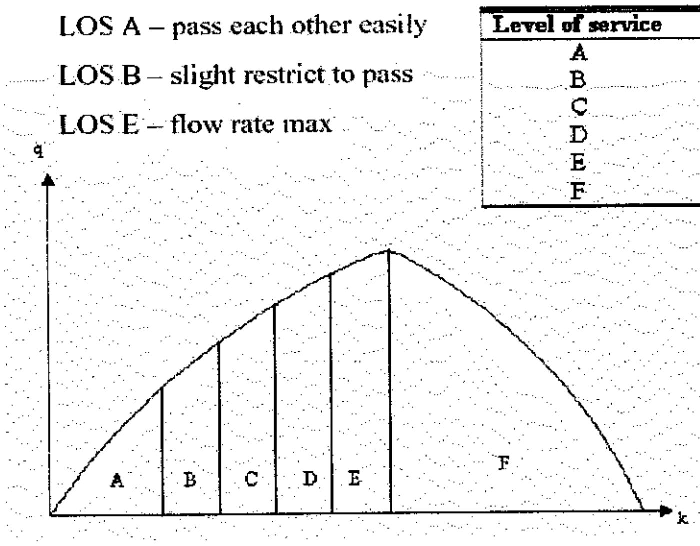
LOS D

Approaching unstable operations where small increases in volume produce substantial increases in delay and decreases in speed.

LOS E

Operations with significant intersection approach delays and low average speeds.

Figure 2 illustrates the flow rate against density curve for highway level of service.



Level of service	Density, pc/km/ln
A	0-7
B	>7-11
C	>11-16
D	>16-22
E	>22-28
F	>28

Figure 2 : Highway level of service

2.3 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 of slower vehicles requires use of the opposing lane. As volumes or geometric constraints increase, the ability to pass decreases and platoons of vehicles are formed. The delay experienced by motorists also increases. The LOS for two-lane highways is based on mobility. [2]

The Highway Capacity Manual (HCM) standards were used to calculate the LOS. The HCM procedure puts the project site as a **Class I highway**. This is a two-lane highway that functions as primary arterials, daily commuter routes, and links to other arterial highways. Motorist' expectations are that travel will be at relatively high speeds. The procedure analyzed two-lane highway with two way traffic. The grade is considered lest then 3% for the whole span.

2.4 Traffic light intersection

Intersection counts are used for timing traffic signals, designing channelization, planning turn prohibitions, computing capacity, analyzing high crash intersections, and evaluating congestion. The manual count method is usually used to conduct an intersection count. A single observer can complete an intersection count only in very light traffic conditions. The intersection count classification scheme must be understood by all observers before the count can begin. Each intersection has 12 possible movements. The intersection movements are through, left turn, and right turn.[3]

Figure 3 refers to the traffic light intersection L1. The observer records the intersection movement for each vehicle that enters the intersection.

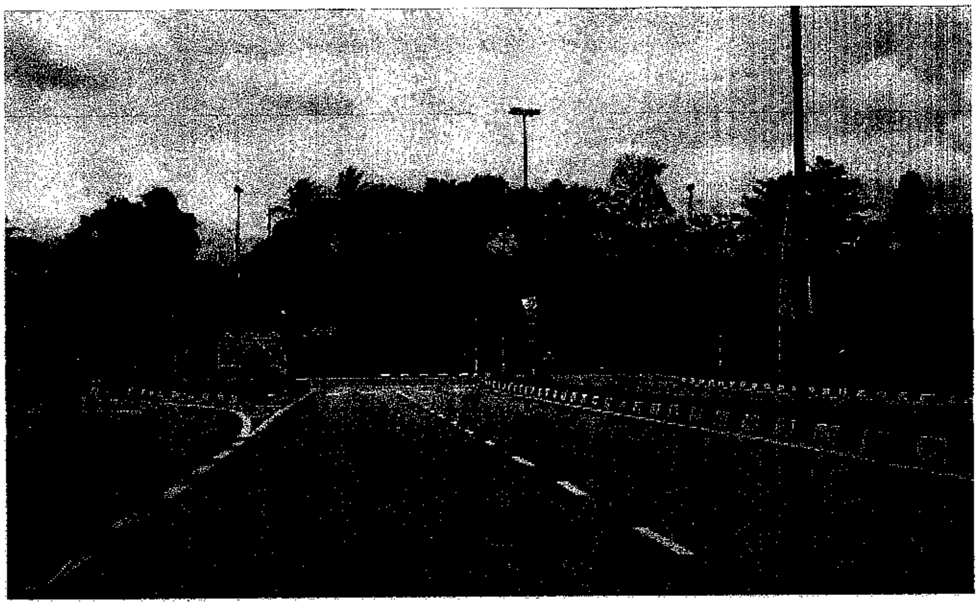


Figure 3 : Traffic light intersection, at project site designated L1

2.5 Traffic engineering studies

2.5.1 Spot speed studies

Spot speed studies are used primarily to determine the distribution of traffic speeds, or vehicle speed percentiles, at a specific location. (Garber and Hoel, 2001, p.84)

These data help traffic engineers determine and/or evaluate traffic operations and traffic control practices at specific locations; establish design elements for roadways, pedestrian walkways, and bikeways; assess roadway safety questions; and make other traffic safety-related analyses.

For spot speed studies, a sample size of at least 50 and preferably 100 vehicles should be obtained. (Using multiples of 100 for the sample size simplifies calculations.) [4]

"Data for weekday speeds should be not be collected on Mondays or Fridays because of potential differences in traffic patterns on those days" (Garber and

Hoel,2001, p.84) unless, of course, an agency wants to conduct a spot speed study during a special event or other activity occurring on either Monday or Friday. The site to be observed should be documented with an accurate sketch and local law enforcement and other officials should be contacted if staff will be on location collecting data or installing equipment.

Spot speed data can be gathered by any of three methods:

- stopwatch (least expensive)
- radar meter
- pneumatic road tubes (most expensive)

2.5.1.1 Stopwatch method

This method consists of timing vehicles with a hand-held stop watch as they travel between two predetermined reference points that are a specific distance apart. Using the distance between reference points and the recorded times, staff can calculate each vehicle's speed. The stop watch method is the quickest and easiest but also the least accurate data collection method. Speeds must be calculated manually, and staff must be physically present to collect data. [5]

Figure 4 shows the layout of the study. Timers will need two stopwatches (one for backup), manual data collection forms (samples are included in handbook), measuring tape, two brightly colored reference posts, and a hardhat and safety vest.

Staff should select the appropriate time of day for collecting data. For analyzing peak traffic flows, of course, speeds should be measured during peak traffic times. For assessing general speed trends or setting speed limits, off-peak measurements are more appropriate.

The reference posts should be set up according to the layout sketch. Staff needs to select an observation point, according to the layout sketch, that provides a clear view of the reference posts and traffic.

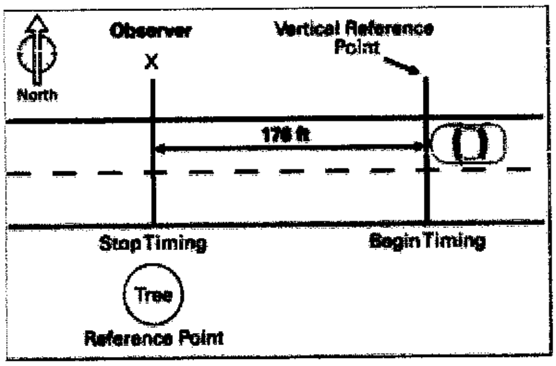


Figure 4 : Example stop watch spot speed study layout

2.5.1.2 Radar meter method

This method uses a radar meter that can be hand-held or mounted on a vehicle or tripod. The meter is easily operated by one person and automatically displays vehicle speed. A staff member simply pulls the trigger or points the meter at a vehicle and, as the meter displays the vehicle's speed, records the speed on the data collection sheet. Agency staff must be physically on site to collect data. They will need a radar meter, backup batteries, a tripod (optional), manual data collection forms (again, sample forms are included in the handbook), and a hardhat and safety vest. Again, staff should select the appropriate time of day for collecting data. They will also need to determine a strategy for targeting vehicles randomly (for example, every fifth vehicle). The traffic observation location should be out of sight of motorists; if driver see the radar meter, they may slow down, skewing study results. [5]

2.5.1.3 Pneumatic road tube method

This method is normally used for more extensive, long-term data collection. Pneumatic tubes are placed in the travel lanes, attached to the pavement, and connected to recorders on the side of the road. As vehicles pass over the tubes, the recorders gather vehicle data that is used to calculate vehicle speeds. The automatic recorders can collect large amounts of data, which can be downloaded to a disk or computer. For this type of study, agency staff does not have to be on location during data collection. However, the pneumatic equipment is more expensive and the setup more extensive. The recorders cannot automatically collect vehicle classification data, so that information, if needed, has to be collected by other means. [6]

2.5.1.4 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). That is, half of the vehicles observed are going faster than the 50th percentile speed, and half are going slower. The 85th percentile represents the speed at or below which 85 percent of the observed motorists are traveling. It is normally considered to be the highest safe speed for a roadway section, and speed limits are generally set using the 85th percentile speed. (Garber and Hoel, 2001, p.85)

2.5.2 Volume studies

Traffic volume studies are conducted to determine the 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. (Garber and Hoel, 2001, p.99)

2.5.2.1 Using count period to determine study method

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.
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.The study methods for short duration counts are described in this chapter in order from least expensive (manual) to most expensive (automatic), assuming the user is starting with no equipment.[5]

2.5.2.2 Manual count method

Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available. Manual counts are typically used for periods of less than a day. Normal intervals for a manual count are 5, 10, or 15 minutes. Traffic counts during a Monday morning rush hour and a Friday evening rush hour may show exceptionally high volumes and are not normally used in analysis; therefore, counts are usually conducted on a Tuesday, Wednesday, or Thursday. [5]

Manual Count Recording Methods

Manual counts are recorded using one of three methods: tally sheets, mechanical counting boards, or electronic counting boards, as below:

1) Tally Sheets

Recording data onto tally sheets is the simplest means of conducting manual counts. The data can be recorded with a tick mark on a pre-prepared field form. A watch or stopwatch is necessary to measure the desired count interval.

2) Mechanical Counting Boards

Mechanical count boards consist of counters mounted on a board that record each direction of travel. Common counts include pedestrian, bicycle, vehicle classification, and traffic volume counts. Typical counters are push button devices with three to five registers. Each button represents a different stratification of type of vehicle or pedestrian being counted. The limited number of buttons on the counter can restrict the number of classifications that can be counted on a given board. A watch or a stopwatch is also necessary with this method to measure the desired count interval.

3) Electronic Counting Boards

Electronic counting boards are battery-operated, hand-held devices used in collecting traffic count data. They are similar to mechanical counting boards, but with some important differences. Electronic counting boards are lighter, more compact, and easier to handle. They have an internal clock that automatically separates the data by time interval. Special functions include automatic data reduction and summary. The data can also be downloaded to a computer, which saves time.

Manual Count Study Preparation Checklist is as below:

1) Obtain tally sheet or counting board
2) Obtain watch
3) Obtain hardhat and safety vest
4) Select location
5) Select time and day
6) Determine availability of recorders

2.5.2.3 Automatic count method

The automatic count method provides a means for gathering large amounts of traffic data. Automatic counts are usually taken in 1-hour intervals for each 24-hour period. The counts may extend for a week, month, or year. When the counts are recorded for each 24-hour time period, the peak flow period can be identified. Automatic counts are recorded using one of three methods: portable counters, permanent counters, and videotape. As this method won't be use in the survey, no further elaboration will be given.

2.5.3 Travel time and delay studies

The purpose of a Travel Time and Delay Study is to evaluate the quality of traffic movement along a route and determine the locations, types, and extent of traffic delays by using a moving test vehicle. This study method can be used to compare operational conditions before and after roadway or intersection improvements have been made. It can also be used as a tool to assist in prioritizing projects by comparing the magnitude of the operational deficiencies (such as delays and stops) for each project under consideration. [5]

The Travel Time and Delay Study can also be used by planners to monitor level of service for local government comprehensive plans. The methodology presented herein provides the engineer with quantitative information with which he can develop recommendations for improvements such as traffic signal retiming, safety improvements, turn lane additions, and channelization enhancements.

2.5.3.1 Definitions

(Defined by the Manual on Uniform Traffic Studies, 2000)

Acceleration Noise (AN) - Represents the degree of driver discomfort due to acceleration and deceleration. It is computed (approximately) as the root mean square value of acceleration (meter per second squared) considering each second of operation separately (The Theory of Road Traffic Flow). Stopped times (e.g., speeds less than 8kph) are excluded from the computations.

Control Point (CP) - A node at the beginning or end of a link, usually the stop line at a signalized intersection, but can be any physical feature, i.e., power pole. The stop line or physical feature selected within the intersection must be located in the same direction of travel. The control point may be different for each direction of travel. However, once a control point is chosen it shall be used for each run in that particular direction.

Delay (D) - The elapsed time (in seconds) spent driving at a speed less than 8 kph.

Distance - The length of a link or the length of a run .

Running Speed (RS) - The test vehicle's average speed (in kilometers per hour) while the vehicle is in motion (does not include delay time) it can be calculated by the formula:

RS = Distance of TT - D

Running Time (RT) - The elapsed time (in seconds) excluding delay spent driving a distance.

Special Control Points (SCP) - Beginning and end points of the study route. They shall be located outside the influence of a signalized intersection or other highway feature which might cause delay. The vehicle must be at normal operating speed for the route when passing these points.

Stop (S) - The average number of times per link or run that the test vehicle's speed falls below 8 kph. After a stop, an additional stop will not be recorded unless the speed first exceeds 40 kph.

Travel Speed (TS) or Average Speed (AS) - The test vehicle's average speed (in kilometers per hour) over a distance.

Travel Time (TT). The total elapsed time (in seconds) spent driving a specified distance.

2.5.3.2 Study procedures

1) To conduct a Travel Time and Delay Study, one must first define the study area by selecting all control points before beginning the study. The time periods recommended for studies are A.M. and P.M. peak hours as well as off peak hours in the direction of heaviest traffic movements.

2) These studies should be made during reasonably good weather so that unusual conditions do not influence the study. Also, since crashes or other unusual delays will produce erroneous results, any runs made during such an occurrence should be terminated and another run conducted. These studies should be conducted during average or typical weekday traffic conditions.

3) When conducting a Travel Time and Delay Study, the floating car technique should be used. In using the floating car technique, the driver floats with traffic by passing as many vehicles as pass the test car. The idea is to emulate an average driver

for each section of roadway. Engineering judgment should also be used in applying this procedure to fit the purpose of the study. [7]

2.6 LOS Analysis

To obtain a LOS value, in reference with the HCM 2000, a Percent Time Spent Following **(PTSF)** value must be obtained first.

$$PTSF = BPTSF + f_{d/np} \qquad (2.1)$$

BPTSF = the base percent time spent following for both directions and is computed using Eq. 2.2

$$BPTSF = 100[1-e^{-0.000879vp}] \qquad (2.2)$$

$f_{d/np}$ = adjustment in PTSF to account for the combined effect of 1) percent of directional distribution of traffic and 2) percent of passing zones (table 9.3 Garber/Hoel).

V_p = passenger car equivalent flow rate for the peak 15-min period and is computed using Eq. 2.3

$$V_p = \frac{V}{(PHF)(f_g)(f_{HV})} \qquad (2.3)$$

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 Eq. 2.4.

$$f_{HV} = \frac{1}{1+P_T(E_T-1)+P_R(E_R-1)} \qquad (2.4)$$

P_T and P_R = the decimal portion of trucks (and busses) and RVs in the traffic stream.

E_T and E_R = the passenger car equivalent for trucks and RV/s respectively. Values are provided in table 9.5 (Garber and Hoel)

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

Average Travel Speed, ATS = FFS – $0.00776V_p$ - f_{np} (2.5)

FFS = free flow speed, the mean speed at low flow when volumes are, 200pc/h

f_{np} = Adjustment for the percentage of no-passing zones. (Refer to table 9.6 Garber and Hoel, 2001, p.302).

V_p = Passenger-car equivalent flow rate for the peak 15-min period.

To find FFS with the following conditions:

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

Free flow speed, (FFS) = $S_{FM} + 0.00776(V_f / f_{HV})$ (2.6)

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

V_f = Observed flow rate

f_{HV} = Adjustment factor for heavy vehicle

From the values of PTSF and ATS, it will be use to determine the LOS from the HCM manual or table 9.1, 9.2 of the Garber and Hoel Text. If values of PTSF and ATS do not correspond to the same LOS, the lower value is used (Garber and Hoel, 2001). Table 1 and Table 2 are reprinted from Highway Capacity Manual, HCM 2000.

LOS	Percent time spent following	Average travel speed (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 I

LOS	Percent time spent following
A	≤ 40
B	$> 40\text{-}55$
C	$> 55\text{-}70$
D	$> 70\text{-}85$
E	> 85

Table 2 : Level- of- service for two-lane highways

2.7 aaSidra Software

The aaSIDRA, or aaTraffic SIDRA (Signalised & unsignalised Intersection Design and Research Aid) software an aid for design and evaluation of the following intersection types (aaSidra user manual):

1) Signalized intersections (fixed-time / pretimed and actuated).
2) Roundabouts.
3) Two-way stop sign control.
4) All-way stop sign control.
5) Give-way (yield) sign-control.

aaSIDRA uses detailed analytical traffic models coupled with an iterative approximation method to provide estimates of capacity and performance statistics (delay, queue length, stop rate, etc). Although aaSIDRA is a single intersection analysis package, this software also allows performing traffic signal analysis as an isolated intersection (default) or as a coordinated intersection by specifying platoon arrival data. aaSIDRA traffic models can be calibrated for local conditions.

The analyses that can be done by aaSIDRA software are:

1. Obtain estimates of capacity and performance characteristics such as delay, queue length, stop rate as well as operating cost, fuel consumption and pollutant emissions for all intersection types;
2. Analyze many design alternatives to *optimize* the intersection geometry, signal phasing and timings specifying different strategies for optimization;
3. Handle intersections with up to 8 legs, each with one-way or two-way traffic, one-lane or multi- lane approaches, and short lanes, slip lanes, continuous lanes and turn bans as relevant;
4. Determine *signal timings* (fixed-time / pre-timed and actuated) for any intersection geometry allowing for simple as well as complex phasing arrangements;
5. Carry out a design life analysis to assess impact of traffic growth;
6. Carry out a parameter sensitivity analysis for optimization, evaluation and geometric design purposes;

7. Design intersection geometry including lane use arrangements taking advantage of the unique *lane-by-lane* analysis method of aaSIDRA;
8. Design short lane lengths (turn bays, lanes with parking upstream, and loss of a lane at the exit side);
9. Analyze effects of heavy vehicles on intersection performance;
10. Analyze complicated cases of shared lanes and opposed turns (e.g. permissive and protected phases, slip lanes, turns on red);
11. Analyze oversaturated conditions making use of aaSIDRA's time-dependent delay, queue length and stop rate formulae.

In using aaSIDRA, we also could:

1. Prepare data and inspect output with ease due to the graphical nature of aaSIDRA input and output;
2. Obtain output including capacity, timing and performance results reported for individual lanes, individual movements (or lane groups), movement groupings (such as vehicles and pedestrians), and for the intersection as a whole;
3. Control the amount of output by selecting individual output tables, with options for summary and full output;
4. Present data and results in picture and graphs form in reports;
5. Carry out sensitivity analyses to evaluate the impact of changes on parameters representing intersection geometry and driver behaviors;
6. Calculate annual sums of statistics such as operating cost, fuel consumption, emissions, total person delay, stops and so on, and present demonstrate benefits of alternative intersection treatments in a more powerful way;
7. Compare alternative (gap-acceptance and "empirical") capacity estimation methods for roundabouts;
8. Calibrate the parameters of the operating cost model for local conditions allowing for factor such as the value of time and resource cost of fuel.

CHAPTER 3: METHODOLOGY

3.1 Procedure Identification

The methodology and procedure that was used in the research of finding the performance of the highway and traffic light intersection is divided into four parts:

3.1.1 Literature Review and Information Gathering

During this phase, all relevant information was gathered from various books, internets, journals, encyclopedia and thesis that have been developed earlier by internal and external parties. The information will be useful in the analysis phase.

3.1.2 Site survey

Two types of survey were conducted for this project; reconnaissance survey and traffic survey (traffic survey will be further elaborated). Reconnaissance survey is basically to identify the appropriate and potential junctions for this study. Besides that, this survey also to determine some data that might be useful for traffic analysis such as:-

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

Type of junction determined is non-actuated traffic light intersection.

3.1.3 Data Analysis

The data obtain was then manually calculated to gain the final LOS of the segment put into consideration. To gain the LOS, other calculations for the survey such as volume in the east/west bound direction, average travel time east/west, arithmetic mean speed, modal speed, pace, median speed, 85^{th} percentile and standard deviation. The traffic light intersection data, such as traffic and junction volume were put into the aaSidra software to calculate its LOS and other relevant output such as flow rate and capacity.

3.1.4 Report writing

The final phase of this research is report writing where all the finding and result of this project were collected and gathered as a part of the course requirements. Besides that, the report also possibly serves as a reference for further development of the respective field of study.

3.2 Equipments

Equipments are required during the phase of project site survey to obtain data for analysis. Video recording camera, laser gun (Figure 5), stop watch and manual counter (Figure 6) and data sheet were needed.

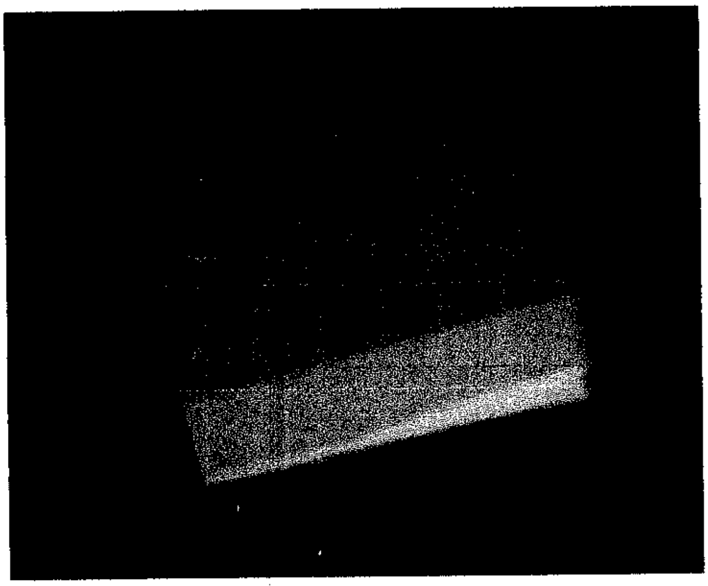


Figure 5 : Laser gun for spot speed studies (0.01 accuracy)

Figure 6 : stop watch and manual counter for travel time study

3.3 Engineering Traffic survey

Basically there are 4 types of study that was conducted at each of the highway segment and three traffic light intersections. This is stated below:

1) Spot speed studies
2) Volume studies
3) Junction movement
4) Travel time delay

For the spot speed studies, manual method using a laser gun was conducted. 100 speed readings were collected for each spot speed study. From this a frequency distribution table was produced (Table 3 and Table 4) for the set of speed data for analysis. This is then converted into graphs (Figure 9 and Figure 10). An arithmetic mean speed can then be calculated from the table. A histogram (Figure 7, and Figure 8) and a cumulative distribution graph (Figure 11 and Figure 12) were also produced for further understanding of the travel speed at the site, for both segments respectively.

Volume studies were conducted next. To collect data on the number of vehicles that passes a point on the highway. The traffic volume studies were done manually using a counter. The count will started at 2.45 pm and ends at 3.45 pm. This was divided on 15 minutes basis. From this, a differentiation between heavy and passenger vehicles was recorded. This is for the heavy vehicle adjustment factor. This factor corrects for the additional delay and reduction in saturation flow due to the presence of heavy vehicles in the traffic stream. The additional delay and reduction in saturation flow are due mainly to the difference between the operational capabilities of the heavy vehicles and passenger cars and the additional space taken up by heavy vehicles.

Travel time and delay studies determine the amount of time required to travel from one point to another on a given route. Data obtained give a good indication of the level of service on the study section. The "moving vehicle technique" method was used. This technique requires making round trips on the test section, where it is assumed that the road runs east-west. 3 rounds were made on each direction to obtain average for travel time, number of vehicles traveling in opposite direction, number of vehicles that overtook the test vehicle and the number of vehicles overtaken by the test vehicle. This was plug into an equation to find the average travel time in east and west direction.

Then, a junction movement study was conducted at the traffic light intersection. This was be done by stationing a recording camera for a period from 2.45 pm to 3.45 pm on a Wednesday. From the recording, the number of vehicles entering and exiting an intersection was counted manually. This data was then transferred into the aaSidra software to calculate the Level of Service of the traffic light intersection. (Figure 16, 17, 18)

The length of the segment and length of no-passing zone was obtained from test vehicle's odometer readings. From all the relevant data obtained, the calculation for percent time spent following (PTSF) for the two-way segment and average travel speed (ATS) was calculated. The value of the PTSF and ATS was use to find the level of service (LOS) of the road. It is to be noted that the LOS value indication is taken from the US Highway Capacity Manual (HCM) 2000. This is in reference with the class-I table. As the two-lane highway functions as primary arterials.

3.3.1 Spot speed studies survey

The survey was conducted on a Wednesday at 10.30 am to 12.30 pm. The day and time chosen reflects median flow rate of the week. (Garber and Hoel, 2001). A straight section was chosen on the L1-L2, and L2-L3 segment for constant vehicular speed readings. 100 speed readings were taken using the laser gun. Every reading was recorded on a data sheet.

3.3.2 Volume studies survey

The survey was conducted on a stretch approaching the traffic light intersection L1, L2 and L3. The student uses manual counter to count the number of vehicles entering and exiting the highway via the L1, L2 and L3 traffic light. Number of passenger vehicle and heavy vehicle is counted on a different table. The volume count was recorded on a Wednesday at 10.30 am to 11.30 am.

3.3.3 Junction movement survey

The survey was conducted on traffic light intersection L1, L2, L3. The vehicular movements into various junctions were recorded using a video recording camera. The recordings are from 2.45 pm – 3.45 pm. The data are divided into 15-minutes intervals, with heavy and passenger vehicles are put in a different table. During the traffic count, there are several assumptions made:

1. Do not count for motorcycle because the effect of the presence of motorcycle to junction performance is negligible.
2. Neglect U-turn movement.

3.3.4 Travel time and delay survey

The survey was conducted using the moving vehicle technique. The segment was designated into eastward and westward run directions. 3 numbers of runs were performed in each direction to obtain its average travel time, number of vehicles traveling in opposite direction, number of vehicles that overtook test vehicle and number of vehicles overtaken by the test vehicle. During the survey, the length of the segment and also the length of no passing zones were recorded.

3.4 Analysis of traffic light intersection using aaSidra

Traffic Analysis is done using aaSIDRA software to determine Level of Service (LOS), Queue, Delay, Saturation, etc for both current and forecasted traffic volumes (Figure 18, 19, 20, 21, 22, 23, 24). It is necessary to defined most of the variables for each lane group before proceed with the signalized intersection analysis. The variables are number of Lanes, average Lane width, grade (%), parking Conditions (Yes/No), demand volume by movement (veh/h), peak hour factor, percent Heavy Vehicles (%), approach Speed (km/h), cycle length and green time.

By using aaSIDRA software, most of the variable's value is set as default value. However caution was exercised in using these, as the accuracy of volume over capacity ratio (*v/c*), delay, and level of service predictions is influenced.

From the input of data, the LOS and other readings was presented into graphical presentation.

3.4.1 Traffic light intersection forecasting

Traffic Forecasting is done to forecast future volume of the junctions by using average annual growth. The volume in 10 years was forecasted. For traffic forecasting of year 2015, using the average annual growth of urban area in Malaysia (3% to 6% p.a); a value of 5% was used.

This forecasting is done for the junction assuming no development in the area of study using the formula below:-

$$\text{Forecast Traffic} = V\,(1+r)^{n}$$

With V = current traffic volume

r = traffic growth

n = number of forecast year

The assumption is due to constraints on population and traffic data availability. The forecasted LOS is then presented in graphical presentations by the software (Figure 25 and Figure 26). The presentations were then being compared between current and forecasted LOS for discussion.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Spot Speed Study result

The data collected will determine the speed characteristics of the whole population of vehicles traveling on the study site. It is necessary to use statistical methods in analyzing this data. The raw data has been converted into a frequency distribution table (table 3 and table 4) and the arithmetic mean speed derived.

Speed Class (km/h)	Class `Midvalue,ui	Class Frequency,fi	fiui	% of observation in class	Cumulative % of observations	f(ui-Ū)2
45-46.9	46	1	46	1	1	590.49
47-48.9	48	2	96	2	3	994.58
49-50.9	50	1	50	1	4	412.09
51-52.9	52	3	156	3	7	1004.67
53-54.9	54	3	162	3	10	797.07
55-56.9	56	3	168	3	13	613.47
57-58.9	58	5	290	5	18	756.45
59-60.9	60	4	240	4	22	424.36
61-62.9	62	3	186	3	25	206.67
63-64.9	64	5	320	5	30	198.45
65-66.9	66	9	594	9	39	166.41
67-68.9	68	5	340	5	41	26.45
69-70.9	70	5	350	5	46	0.45
71-72.9	72	7	504	7	53	20.23
73-74.9	74	9	666	9	62	123.21
75-76.9	76	10	760	10	72	324.9
77-78.9	78	3	234	6	78	177.87
79-80.9	80	6	480	6	86	564.54
81-82.9	82	3	246	3	89	410.67
83-84.9	84	4	336	4	91	750.76
85-86.9	86	3	258	3	94	739.47
87-88.9	88	1	88	1	95	313.29
89-90.9	90	2	180	2	97	776.18
91-92.9	92	1	92	1	98	470.89
93-94.9	94	1	94	1	99	561.69
95-96.9	96	1	96	1	100	660.49
Totals		100	7032	100		12085.8

Table 3 : Frequency distribution table for segment 1

From Table 3, the **Arithmetic mean speed,** $\bar{U} = \sum f_i u_i / \Sigma fi$

= 70.30 km/h is obtained for segment 1

Speed Class (km/h)	Class `Midvalue,ui	Class Frequency,fi	fiui	% of observation in class	Cumulative % of observations	f(ui-Ū)2
49-50.9	50	2	100	2	2	507.15
51-52.9	52	1	52	1	3	421.07
53-54.9	54	3	162	3	6	342.99
55-56.9	56	3	168	3	9	272.91
57-58.9	58	2	116	2	11	210.83
59-60.9	60	6	360	6	17	156.75
61-62.9	62	8	496	8	25	110.67
63-64.9	64	3	192	3	28	72.59
65-66.9	66	6	396	6	34	42.51
67-68.9	68	3	204	3	37	20.43
69-70.9	70	6	420	6	43	6.35
71-72.9	72	5	360	5	48	0.27
73-74.9	74	9	666	9	57	2.19
75-76.9	76	5	380	5	62	12.11
77-78.9	78	6	468	6	68	30.03
79-80.9	80	12	960	12	80	55.95
81-82.9	82	4	328	4	84	89.87
83-84.9	84	3	252	3	87	131.79
85-86.9	86	4	344	4	91	181.71
87-88.9	88	2	176	2	93	239.63
89-90.9	90	2	180	2	95	305.55
91-92.9	92	1	92	1	96	379.47
93-94.9	94	2	188	2	98	461.39
95-96.9	96	2	192	2	100	551.31
Totals		100	7252	100		4605.52

Table 4 : Frequency distribution table for segment 2

From Table 4, the **Arithmetic mean speed, Ū=** $\sum f_i u_i / \Sigma$ fi

= 72.52 km/h is obtained for segment 2

The histogram of observed vehicle's speeds, frequency distribution, and cumulative distribution graph were also derived from the frequency distribution table. From Figure 7, the modal speed obtained is 77 km/h for segment 1. For segment 2, referring to Figure 8, the modal speed is 80 km/h.

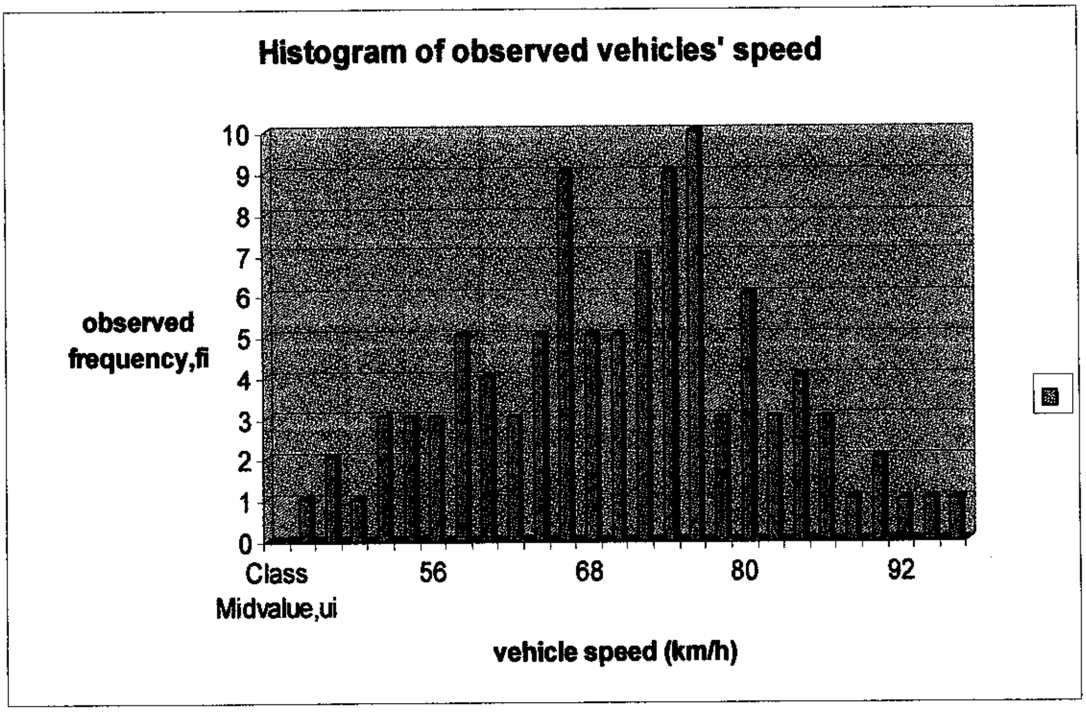


Figure 7: Histogram of observed vehicles' speed for segment 1

Speed corresponding to the highest point, **Modal speed** = 77 km/h (segment 1)

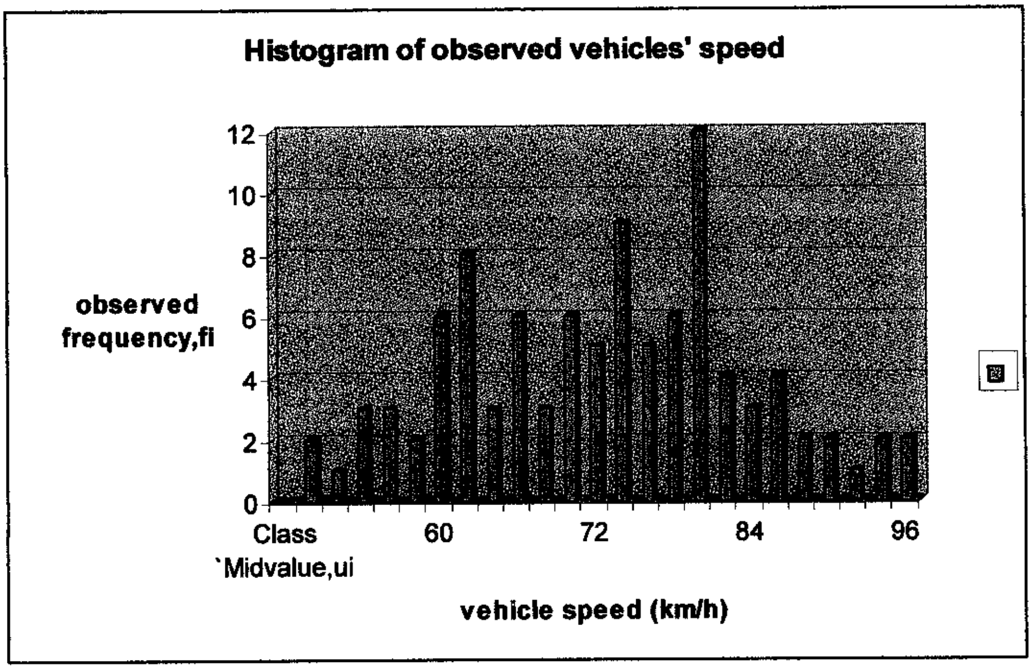


Figure 8: Histogram of observed vehicles' speed for segment 2

Speed corresponding to the highest point, **Modal speed** = 80 km/h (segment 2)

The pace range was obtain from the frequency distribution graphs. Figure 9 shows the pace between 67-75 km/h for segment 1. Figure 10 shows the pace between 65-82 km/h.

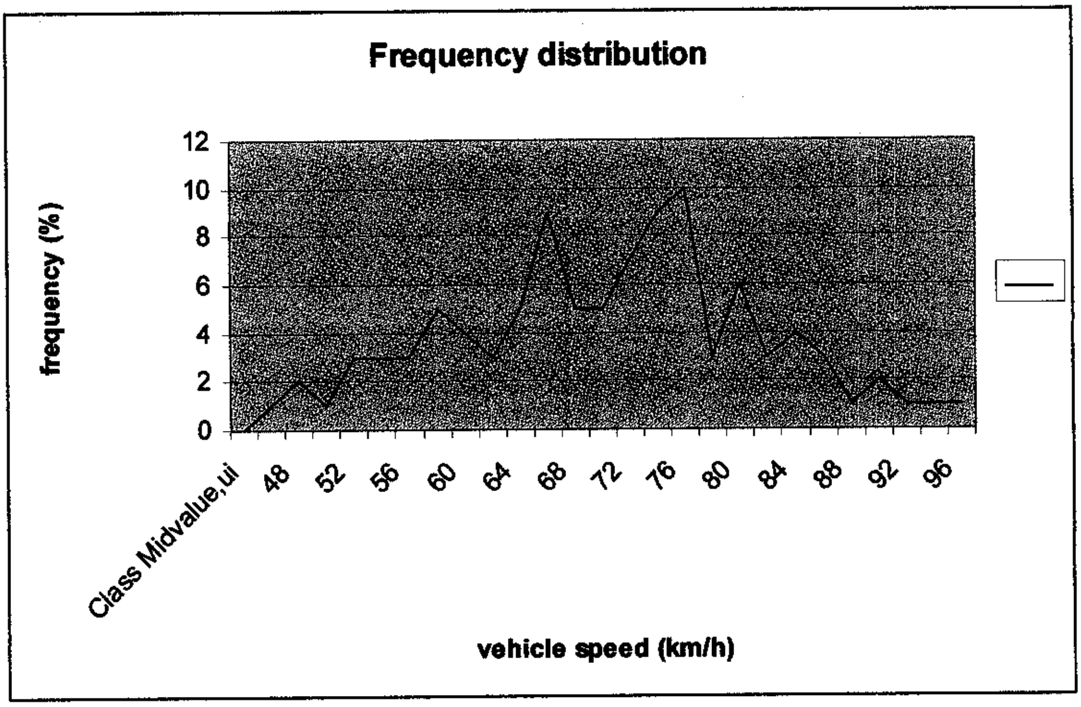


Figure 9 : Frequency distribution graph for segment 1

The **pace** is = 67-75 km/h

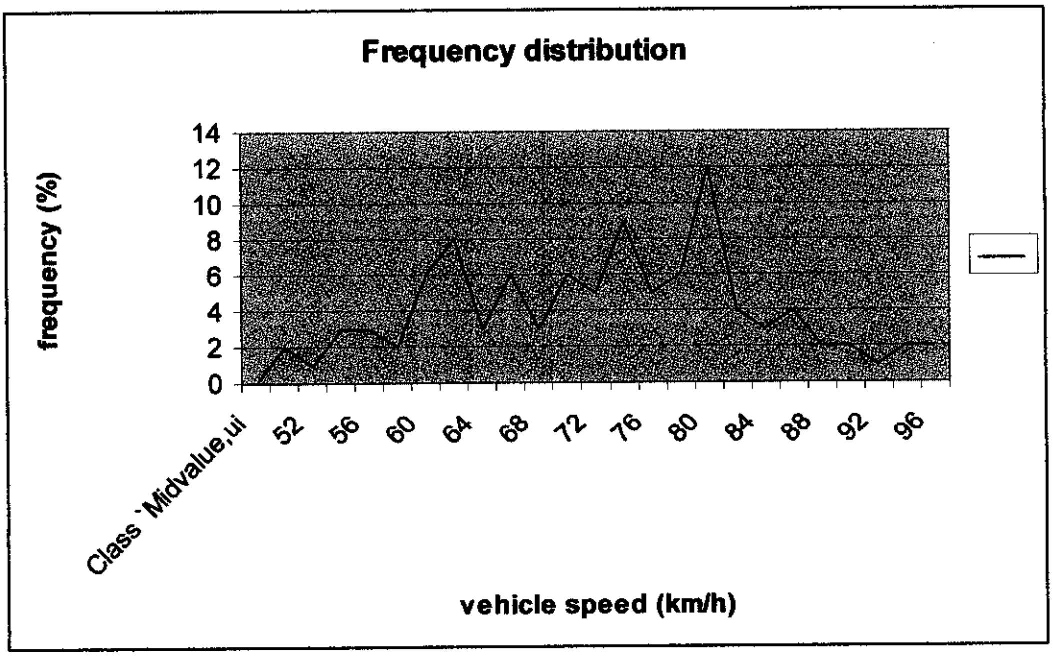


Figure 10 : Frequency distribution graph for segment 2

The **pace** is = 65-82 km/h

For segment 1, the **Median Speed** is 71.5 km/h, **85th percentile** is 80.8 km/h and its **Standard deviation, S** = 11.05 km/h. (Derived from Figure 11).

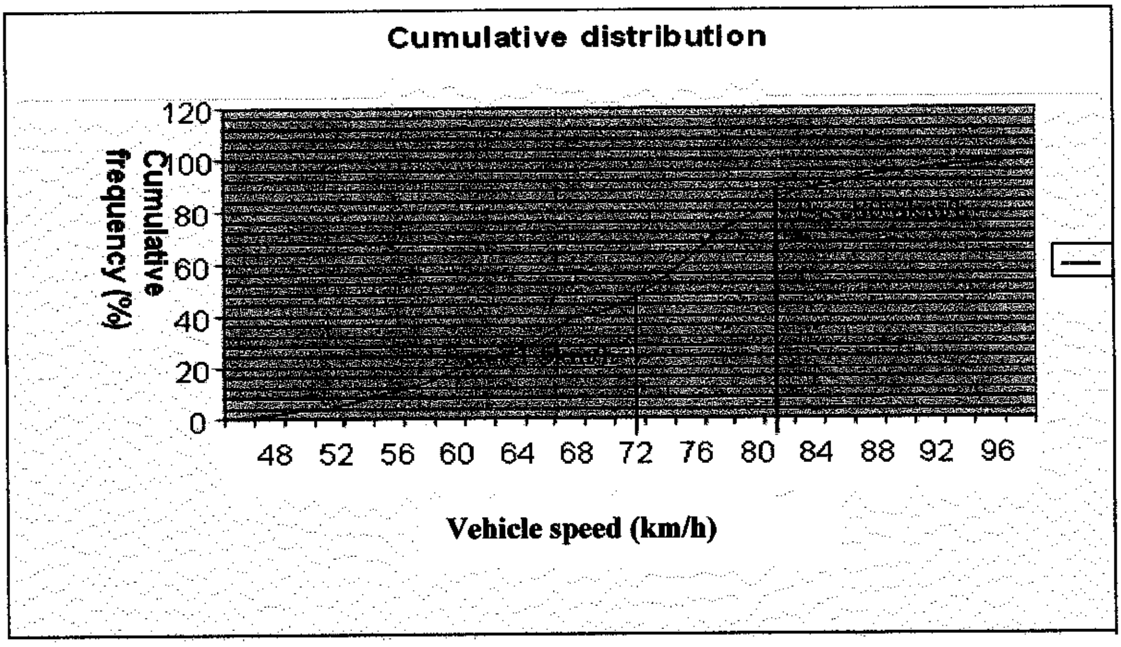


Figure 11 : Cumulative distribution graph for segment 1

For segment 2, the **Median Speed** is 73.7 km/h, **85th percentile** is 83.2 km/h and its **Standard deviation, S** = 6.82 km/h. (Derived from Figure 12).

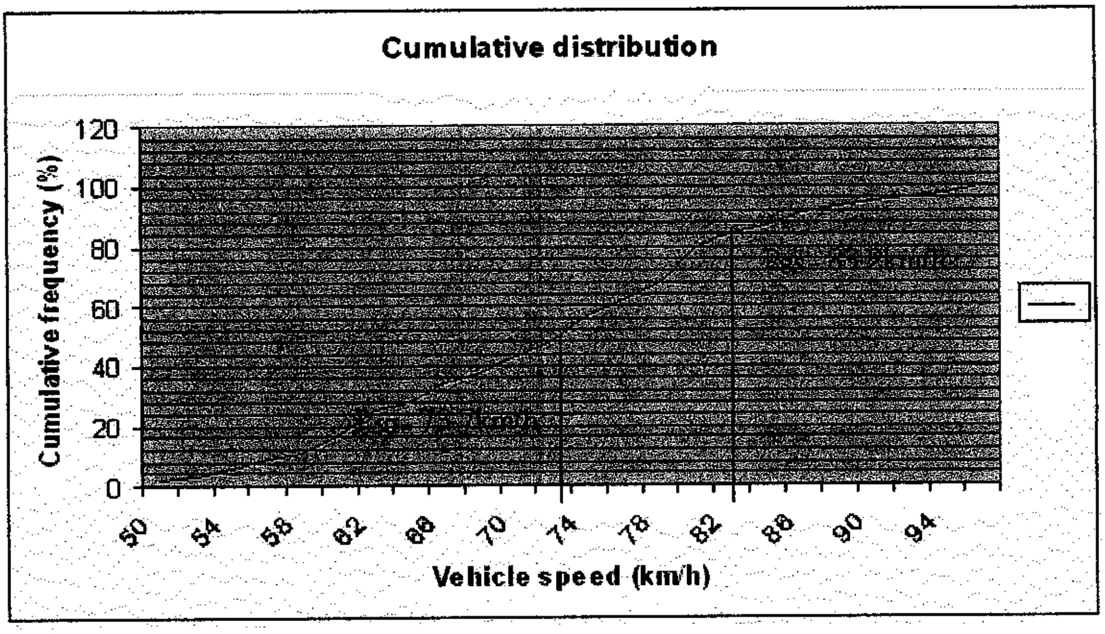


Figure 12 : Cumulative distribution graph for segment 2

4.2 Volume study results

From the volume study results, it is counted that total vehicular volume on intersection L1 per hour is 468 veh/h. For intersection L2 is 548 veh/h and for intersection L3 is 864 veh/h.

4.3 Junction movement results

Vehicular count from the video recordings is illustrated in the figure below. Figure 13 shows the junction movement of traffic volumes at traffic light intersection L1. Figure 14 shows the junction movement of traffic volumes at traffic light intersection L2. And figure 15 shows the junction movement of traffic volumes at traffic light intersection L3.

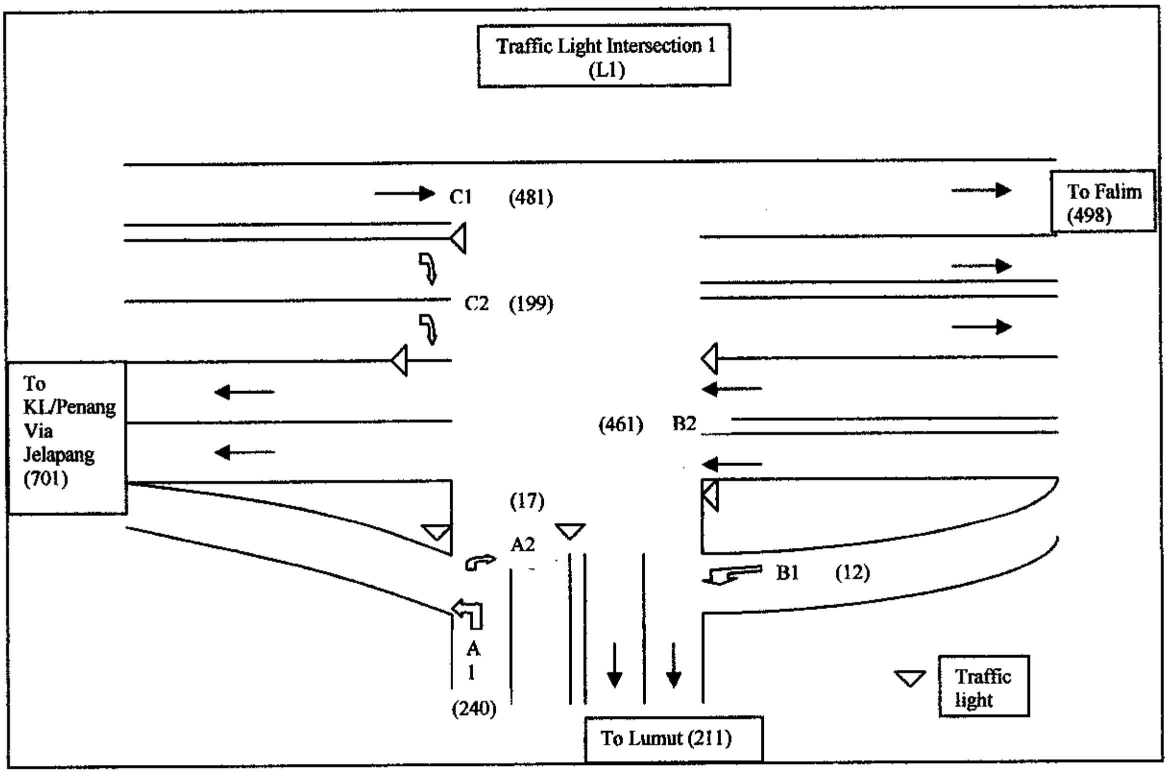


Figure 13: Intersection volume at Traffic Light designated L1

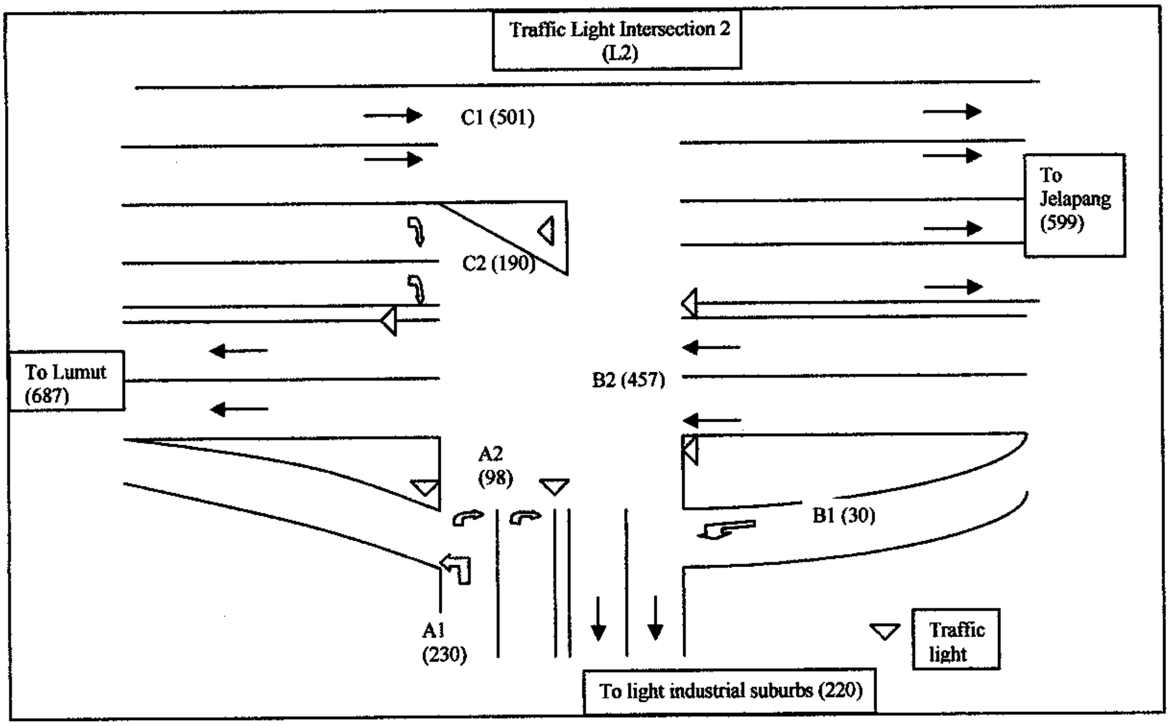


Figure 14: Intersection volume at Traffic Light designated L2

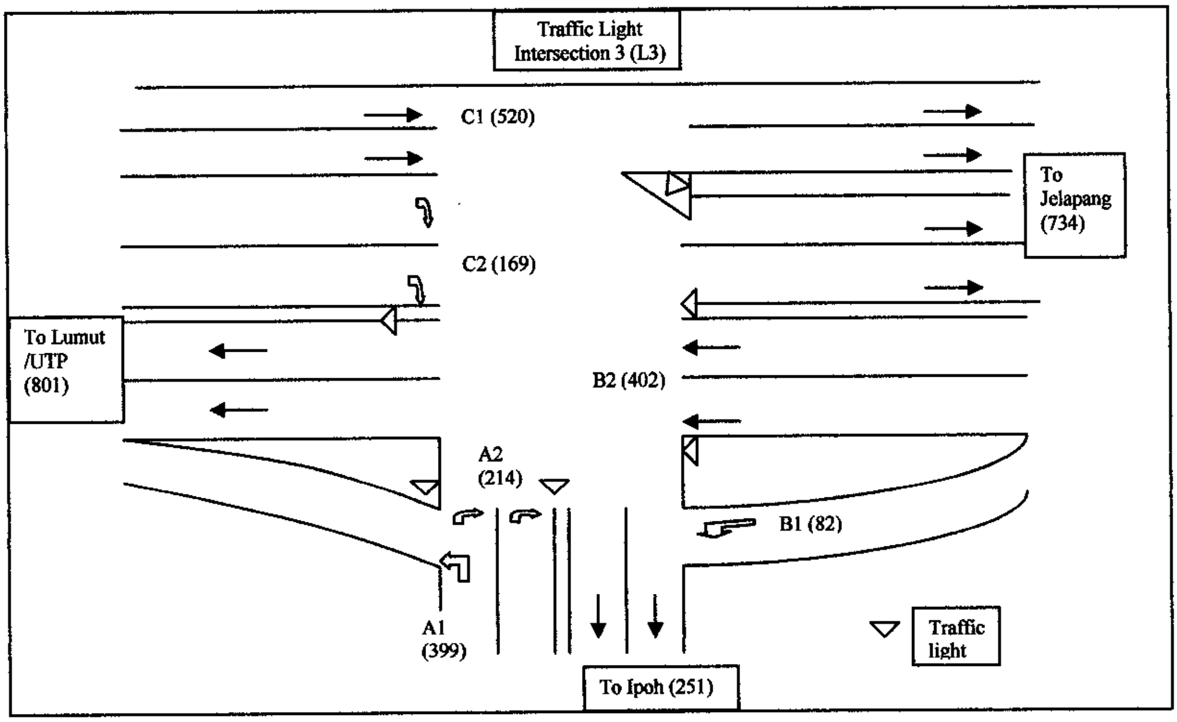


Figure 15: Intersection volume at Traffic Light designated L3

The result of traffic analysis done by running aaSIDRA software can be summarized in the figures below. Parameters that are critical for the analysis of junction performance are control delay (s), queue length (m) and level of service (LOS). From that, the effectiveness of the junction would be determined. All the Intersection Summary results from the aaSIDRA software are listed in the APPENDIX. Figure 16, 17 and 18 are the LOS of traffic light intersections of L1, L2, and L3 respectively.

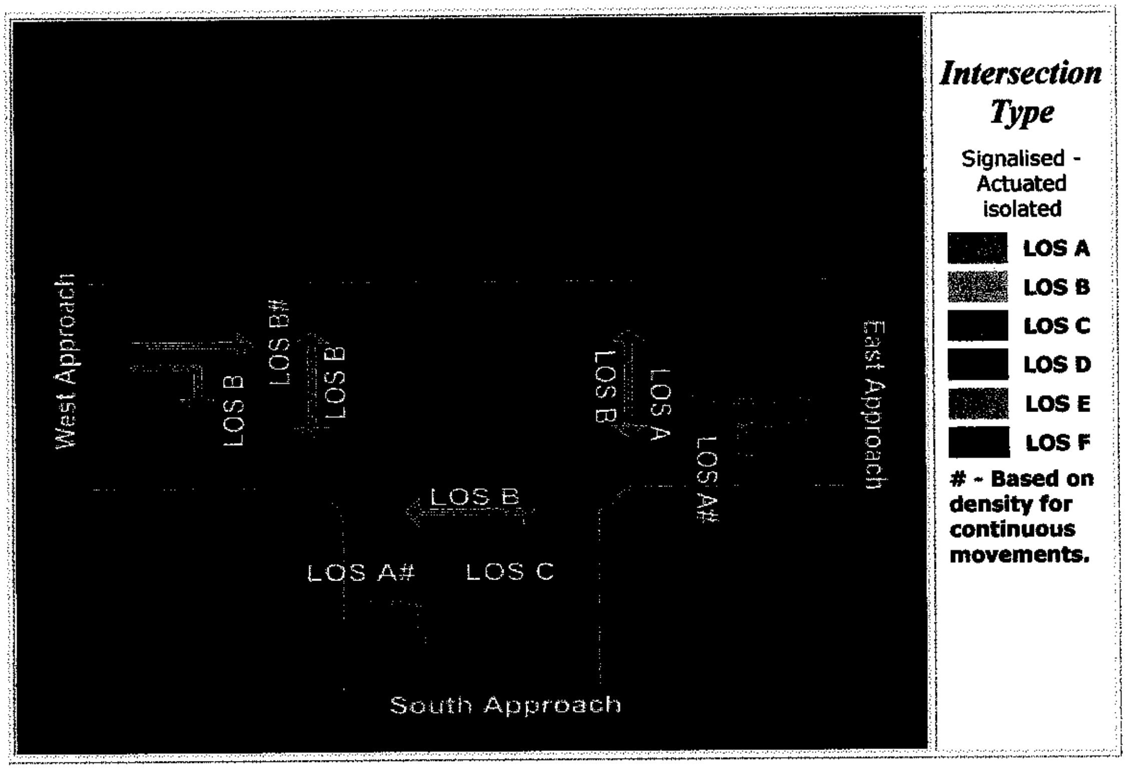


Figure 16: LOS of traffic light intersection L1

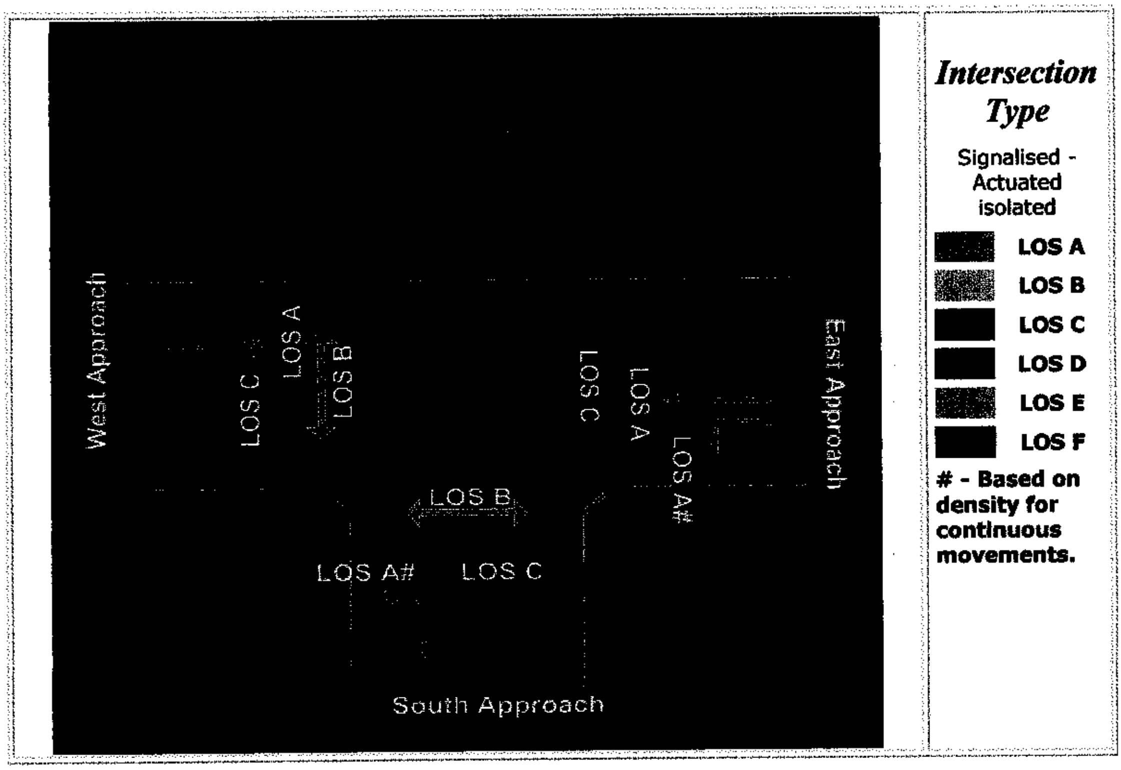


Figure 17: LOS of traffic light intersection L2

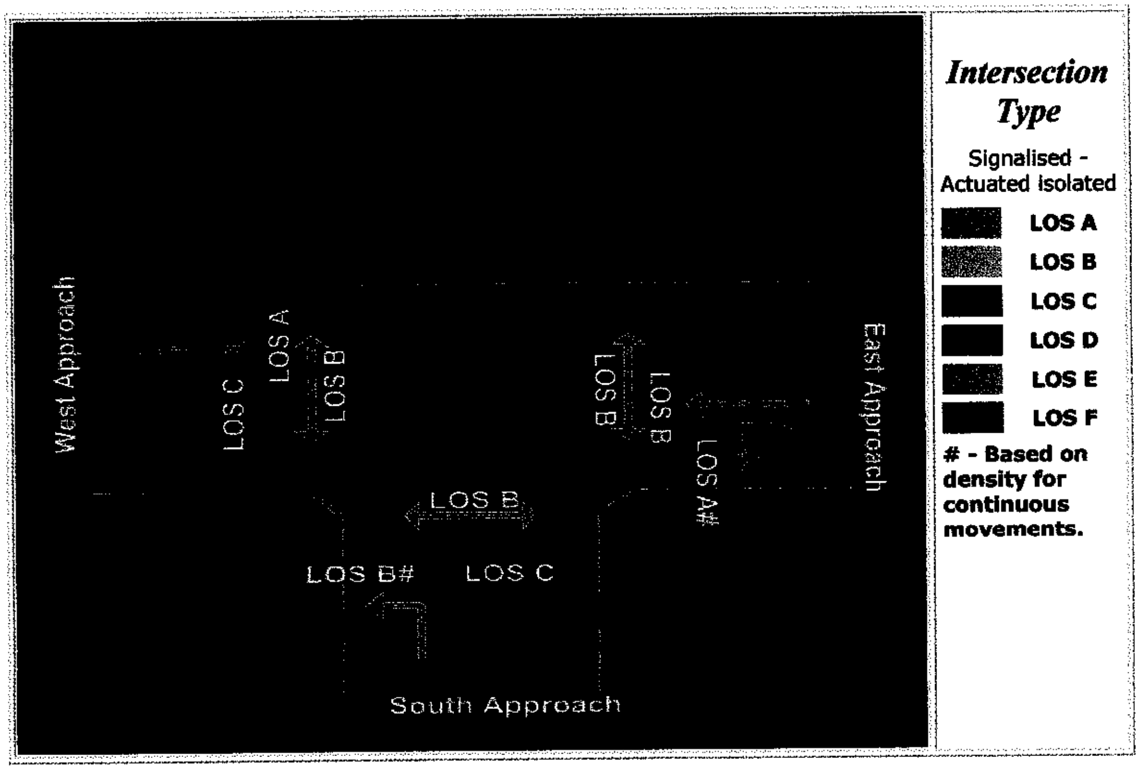


Figure 18: LOS of traffic light intersection L3

The degree of saturation was also computed using the aaSidra software. Figure 19, 20, 21 illustrates for intersections L1, L2, and L3 respectively.

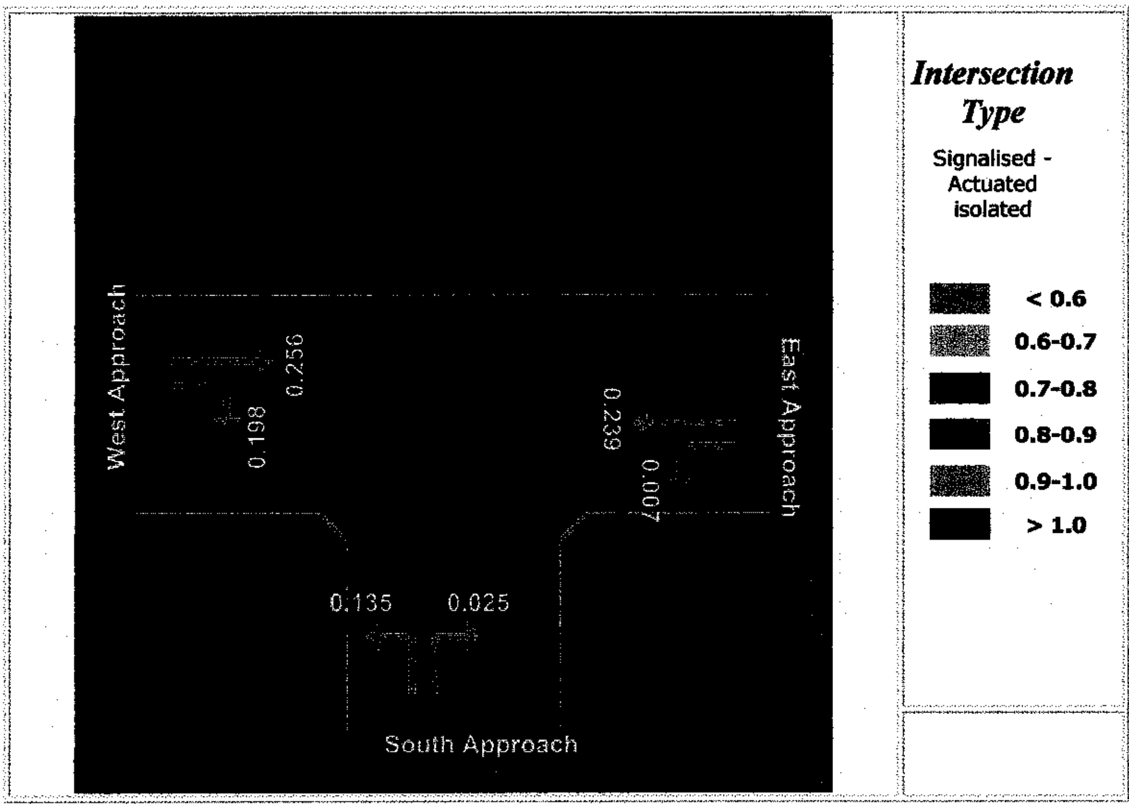


Figure 19: Degree of saturation V/C for traffic light intersection L1

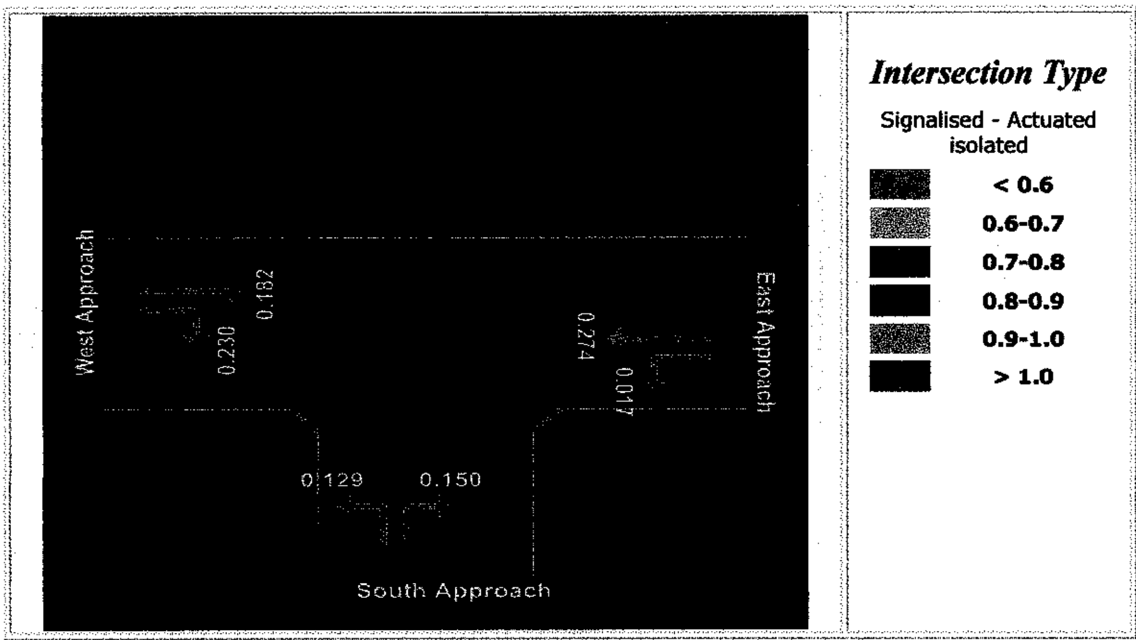


Figure 20: Degree of saturation V/C for traffic light intersection L2

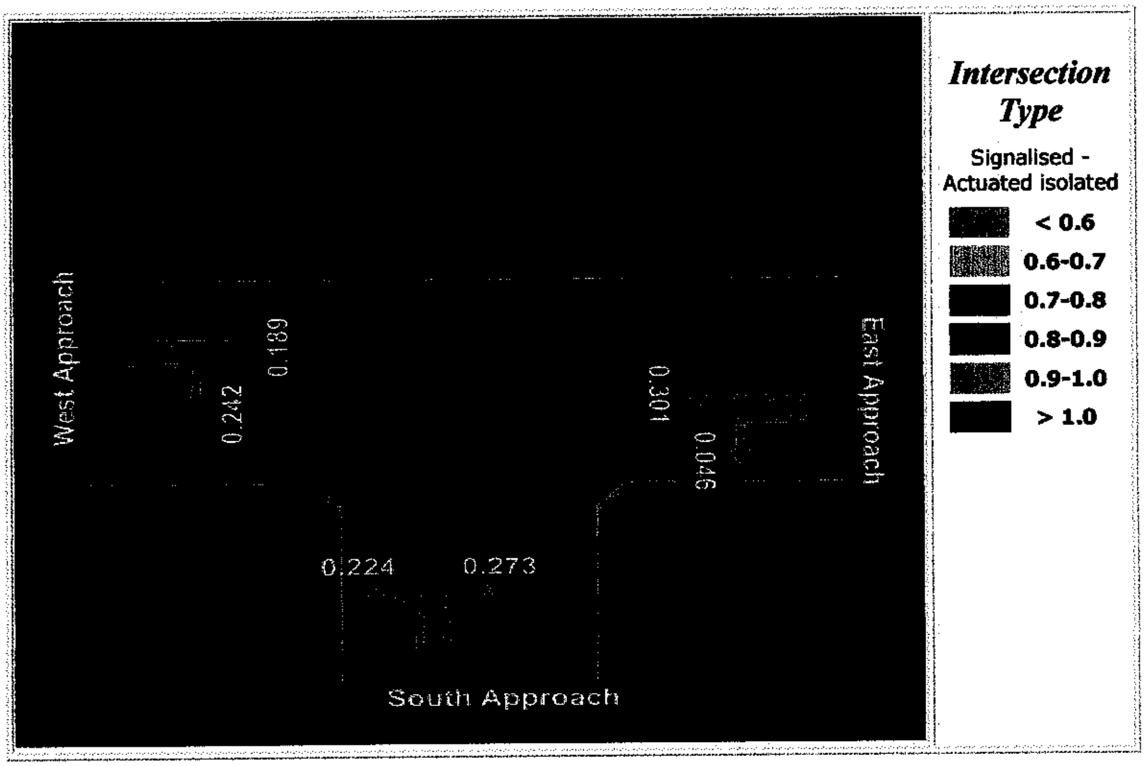


Figure 21: Degree of saturation V/C for traffic light intersection L3

Another important parameter to examine is the total capacity for each junction movement on an intersection. This is calculated using the aaSidra software. Figure 22, 23, and 24 illustrated total capacity for traffic light intersection L1, L2 and L3 respectively.

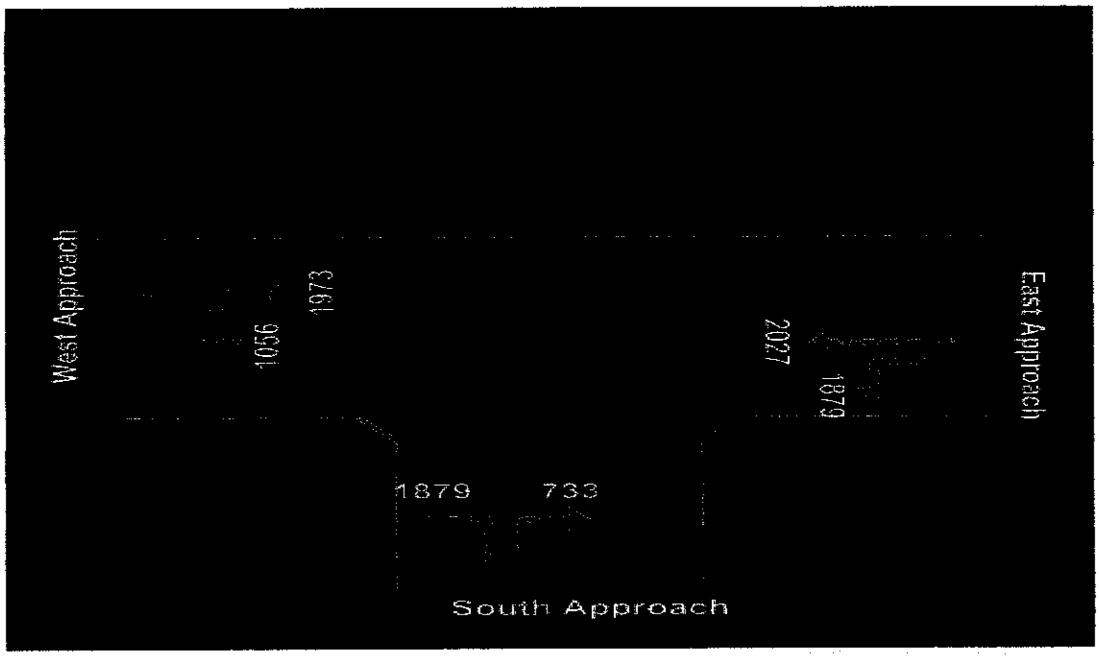


Figure 22: Total capacity veh/h for traffic intersection L1

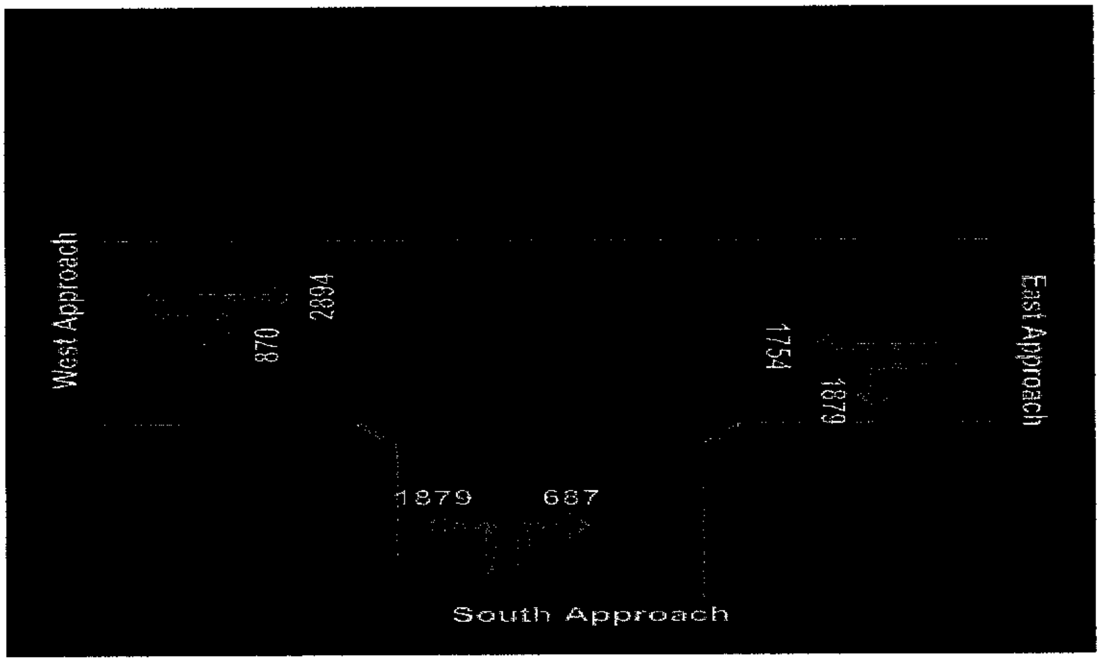


Figure 23: Total capacity veh/h for traffic intersection L2

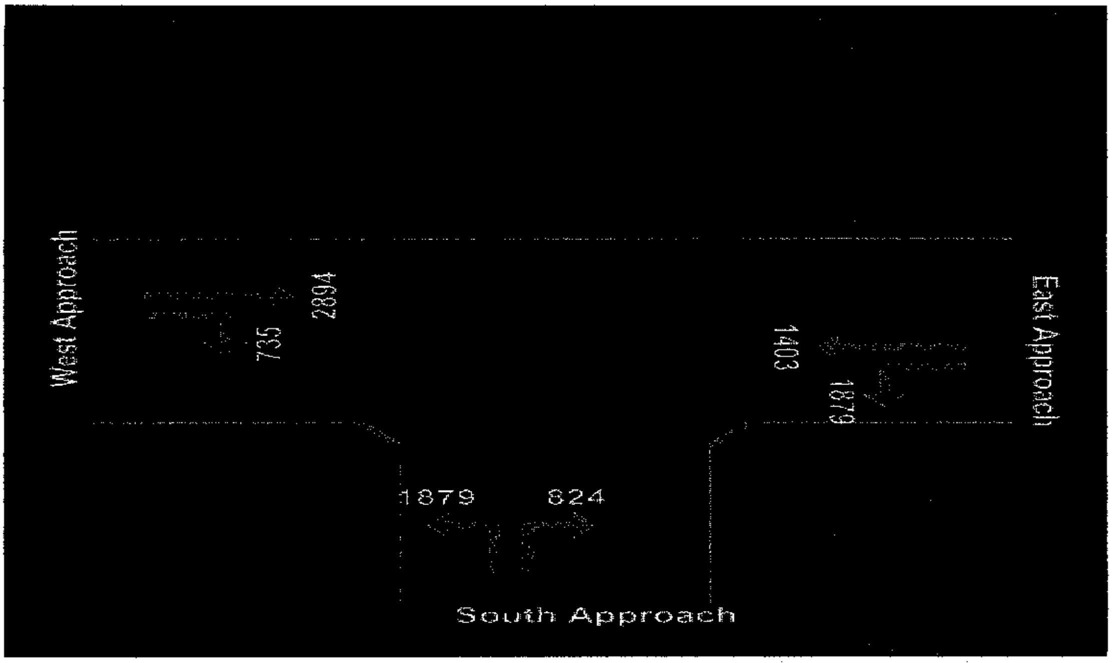


Figure 24: Total capacity veh/h for traffic intersection L3

4.3.1 Future growth forecasting of traffic light intersections

Future traffic flow estimation (without development) is calculated using aaSidra. The number of year predicted is 10. Figure 25, 26, and 27 illustrates the future LOS prediction for intersection L1, L2, and L3 respectively.

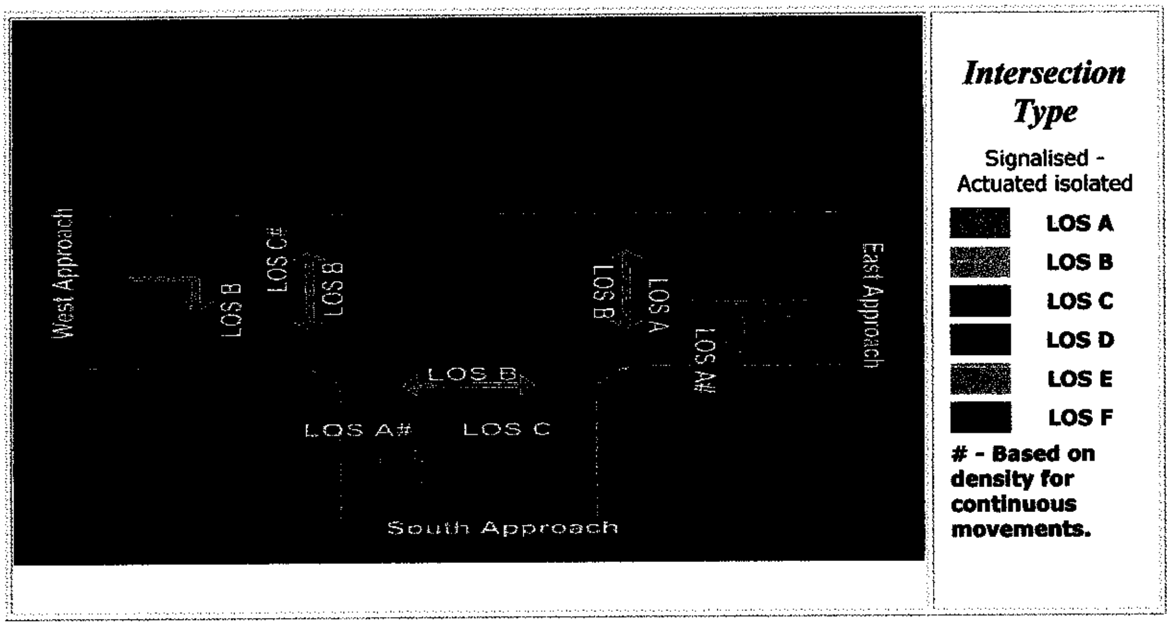


Figure 25: Future LOS for 10 years for Traffic Light Intersection L1

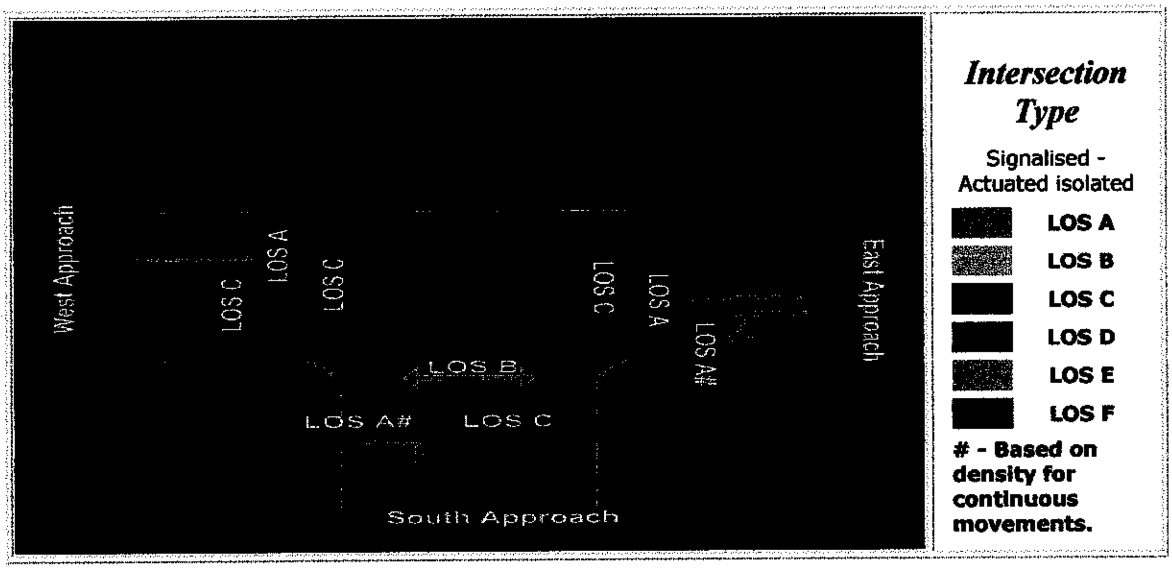


Figure 26: Future LOS for 10 years for Traffic Light Intersection L2

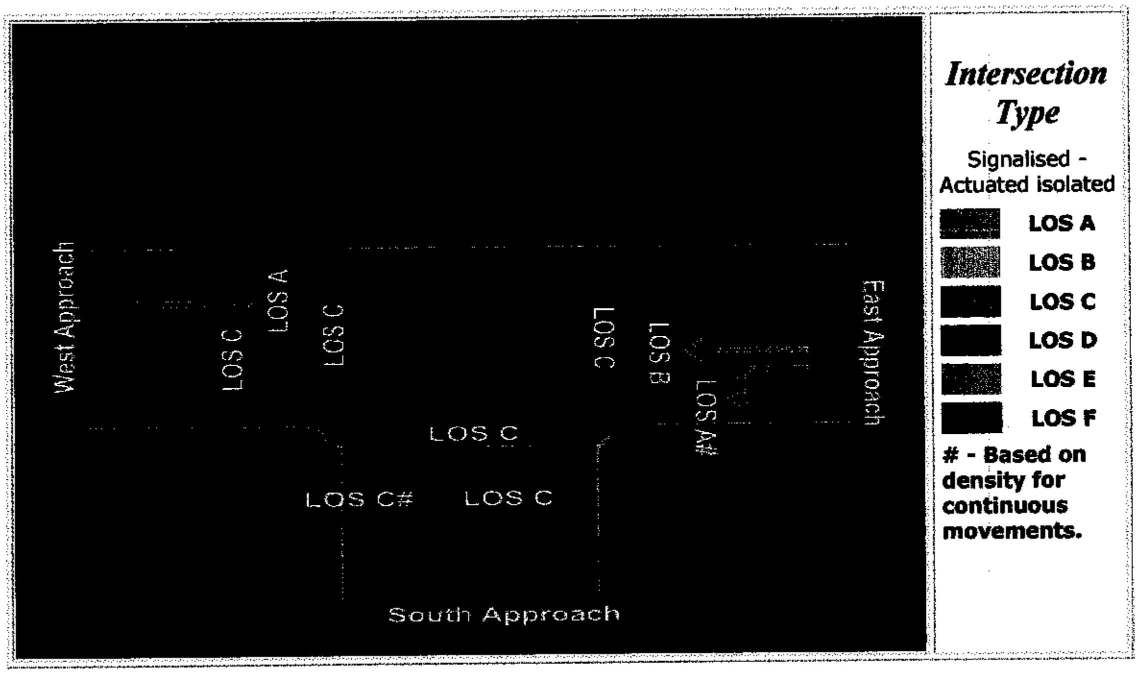


Figure 27: Future LOS for 10 years for Traffic Light Intersection L3

4.4 Travel time study results

Information obtained from the study was use for the final LOS calculations for both segments. From Table 5, the following findings were obtained for segment 1 of the studied section. Volume in the westbound direction is 310 veh/h. Volume in the westbound direction is 333 veh/h. Average travels time in the westbound direction is 4.61min and average travel time in the eastbound direction is 4.37 min.

Run direction /number	Travel time (min)	No. of vehicle traveling in opposite direction	No. of vehicle that overtook test vehicle	No. of vehicle overtaken by test vehicle
Eastward				
1	4.06	41	1	0
2	4.35	54	0	3
3	4.30	42	4	0
Average	4.23	45.67	1.67	1
Westward				
1	4.29	43	1	0
2	5.00	48	0	2
3	4.19	52	0	1
Average	4.49	47.67	0.33	1

Table 5: Data from travel time study using the moving- vehicle technique for segment 1

From Table 6, the following findings were obtained for segment 2 of the studied section. Volume in the westbound direction is 813 veh/h. Volume in the westbound direction is 930 veh/h. Average travels time in the westbound direction is 2.30 min and average travel time in the eastbound direction is 2.75 min.

Run direction /number	Travel time (min)	No. of vehicle traveling in opposite direction	No. of vehicle that overtook test vehicle	No. of vehicle overtaken by test vehicle
Eastward				
1	3.26	80	1	2
2	2.50	69	0	1
3	2.42	55	2	1
Average	2.73	68	1	1.33
Westward				
1	2.21	80	0	1
2	2.27	72	0	1
3	2.18	79	1	2
Average	2.22	77	0.33	1.33

Table 6: Data from travel time study using the moving- vehicle technique for segment 2

4.5 LOS of segment of the project site

From all the tables and readings obtained above, both from reconnaissance survey and traffic survey; the relevant input for LOS calculations were summarized. Percent time spent following (PTSF) and average travel time (ATS) were then concluded from those input.

4.5.1 Input for Segment 1 (L1-L2)

For Segment 1 (L1-L2) the segment length is 5.2km and the total no passing length is 4.4km. The Peak Hourly Volume is 628 veh/h (2-way) and the peak 15-minutes volume is 167 veh/h.

The Passenger car equivalent for heavy vehicle is equal to 1.1 (Table 9.5 Garber and Hoel, 2001, p.381). The grade adjustment factor is equal to 1.0 (table 9.4 Garber and Hoel, 2001, p.381). The percentage of directional split is 50-50 for both ways and the percent of no passing zones is 84.62%. Hence the percent of passing zones is 15.38%.

Adjustment in PTSF to account for combined effect of percent directional distribution of traffic and percent of passing zones is 19.88% (interpolation of Table 9.3 Garber and Hoel, 2001, p.380). The decimal portion of heavy vehicles is 0.3425. The Peak Hour Factor is 0.94 and the design flow is 668 veh/h.

4.5.2 Input for Segment 2 (L2-L3)

For Segment 2 (L2-L3) the segment length is 3.3km and the total no passing length is 0.57km. The Peak Hourly Volume is veh/h (2-way) and the peak 15-minutes volume is 185 veh/h.

The Passenger car equivalent for heavy vehicle is equal to 1.1 (Table 9.5 Garber and Hoel, 2001, p.381). The grade adjustment factor is equal to 1.0 (table 9.4 Garber and Hoel, 2001, p.381). The percentage of directional split is 50-50 for both ways and the percent of no passing zones is 17.27%. Hence the percent of passing zones is 82.73%.

Adjustment in PTSF to account for combined effect of percent directional distribution of traffic and percent of passing zones is 7.77% (interpolation of Table 9.3 Garber and Hoel, 2001, p.380). The decimal portion of heavy vehicles is 0.3722. The Peak Hour Factor is 0.96 and the design flow is 740 veh/h.

4.5.3 Percent time spent following (PTSF) for Segment 1 (L1-L2)

The Percent time spent following (PTSF) is **75.34%.** According to the values in Table 2, to determine class I LOS, the result obtained is **LOS D.**

4.5.4 Percent time spent following (PTSF) for Segment 2 (L2-L3)

The Percent time spent following (PTSF) is **67.79%.** According to the values in Table 2, to determine class I LOS, the result obtained is **LOS D.**

4.5.5 Average travel speed (ATS) for segment 1(L1-L2)

The Average Travel Speed, ATS is **73.55km/h** or 45.7 mi/h. According to the values in Table 1, to determine class I LOS, the result obtained is **LOS C.**

The values of PTSF and ATS do not correspond to the same LOS, so the lower value will be use. Hence, the level of service for segment 1 (L1-L2) of the study area is **LOS D**. "If value of PTSF and ATS do not correspond to the same LOS, the lower value is used." (Garber & Hoel, 2001, p.334)

4.5.6 Average travel speed (ATS) for segment 2(L2-L3)

The Average Travel Speed, ATS is **84.43km/h** or 52.46 mi/h. According to the values in Table 1, to determine class I LOS, the result obtained is **LOS B.**

The values of PTSF and ATS do not correspond to the same LOS, so the lower value will be use. Hence, the level of service for segment 2 (L2-L3) of the study area is **LOS D**.

4.6 Discussion of results

The LOS for segment 1 (L1-L2) and segment 2 (L2-L3) of the study area was found to be **LOS D**. Flow is unstable and passing maneuvers are difficult, if not impossible to complete. Since the number of passing opportunities is approaching zero as passing desire increase, each lane operates essentially independently of the opposing lane. It is common that platoons will form that are five to ten consecutive vehicles in length. Although posted speed limit is 90 km/h, the average travel speed is only 70-85 km/h.

Contributors to the LOS value of the segment are as follows:

1) High percentage of no passing zones, 84.62% (segment 1).
2) Only one lane for each direction.
3) Existence of a section with 4% grade.
4) No climbing lane for heavy vehicles.
5) Posted speed limit at 90 km/h.
6) High number of heavy vehicle traveling the highway.

For traffic light intersection L1, L2, and L3 as shown, it is clearly that all junctions have satisfactory results for junction performance having a minimum value of LOS C. For future forecasting of 10 years, assuming without development, all junctions have at least LOS C. This indicates the current intersection performance is capable to cater present and future volume demands. In Malaysia, it is satisfactory for a minimum LOS C for intersections.

4.7 Proposal to increase the LOS

As mentioned above, the LOS of both the segment of the highway being studied is LOS D. This will eventually fall to LOS E in a decade due to increase in the surrounding development, which will result in increase volume of the highway. Unexpected events such as accident, or even peak festive seasons can possibly result the LOS to fall to LOS E or even F. Assuming cost aside, with the result obtain, it is **justified** to propose the 2-lane 2-way highway being upgraded into a multilane highway. With 2 lanes on each direction, making it a four lane undivided/divided highway. The calculations to determine a new LOS value for the proposed multilane highway has been conducted. The calculations are based on present data results, but with additional lane on each direction and using density as an indication of LOS. The results are as follows:

Segment 1: LOS A

Segment 2: LOS A

LOS A for multilane highway translates into a free flow travel condition. The only constraint on the operation of vehicles lies in the geometric features of the roadway and individual driver preferences. Maneuverability within the traffic stream is good, and minor disruptions to traffic are easily absorbed without an effect on travel speed.

An additional lane also serves for passing lane to overtake slower heavy vehicles. Heavy vehicles are identified as a major factor reducing the traveling speed of passenger cars. This become even more significant on 4% grades as passenger cars would be safely overtaking slower vehicles without illegally crossing the no passing (solid) line.

It is to be stated that the proposal is not an urgent matter as the highway is still able to cater for the near future traffic volume. Factors such as government budget, pace of development, the nation/state political and financial scenario, and local/national/structure plan should be seriously taken into consideration before any upgrading should take place.

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 of motorist perceptions of the operational conditions existing on the facility. A primary objective in traffic engineering is to provide facilities that operate at level of service acceptable to the users of those facilities. Regular evaluation of the level of service at the facilities will help in determining whether acceptable conditions exist and to identify those locations where improvements may be necessary. The different level of operating conditions is related to the volume of traffic that relates to the capacity of the facility.

The complexity of signalized intersection requires that several factors be considered when its LOS is being evaluated. In particular, the geometric characteristics, prevailing traffic conditions, and signal characteristics must be used in determining its LOS. This requirement makes the determination and improvement of LOS at the signalized intersection much more complex. Since the geometry of a highway segment is usually fixed, the capacity of a highway segment can be improved by improving the highway geometry if consideration is given to some variations over time in traffic composition. However, this cannot be done easily at signalized intersection because of the added factor of green time allocation to the different traffic streams, which has significant impact on the operations of the intersection.

As a conclusion, the traffic light intersections would not have to face major upgrades as its current performance can cater present and future demands. A different case for the segments studied. As the LOS is going to deteriorate within the decade, it is best to upgrade it by converting into a multilane highway. Studies and calculations clearly show that an investment to upgrade the studied highway will result in maximum level of service to cater for future growth and development. The cost to upgrade will be justified by the maximum return in terms of LOS improvements.

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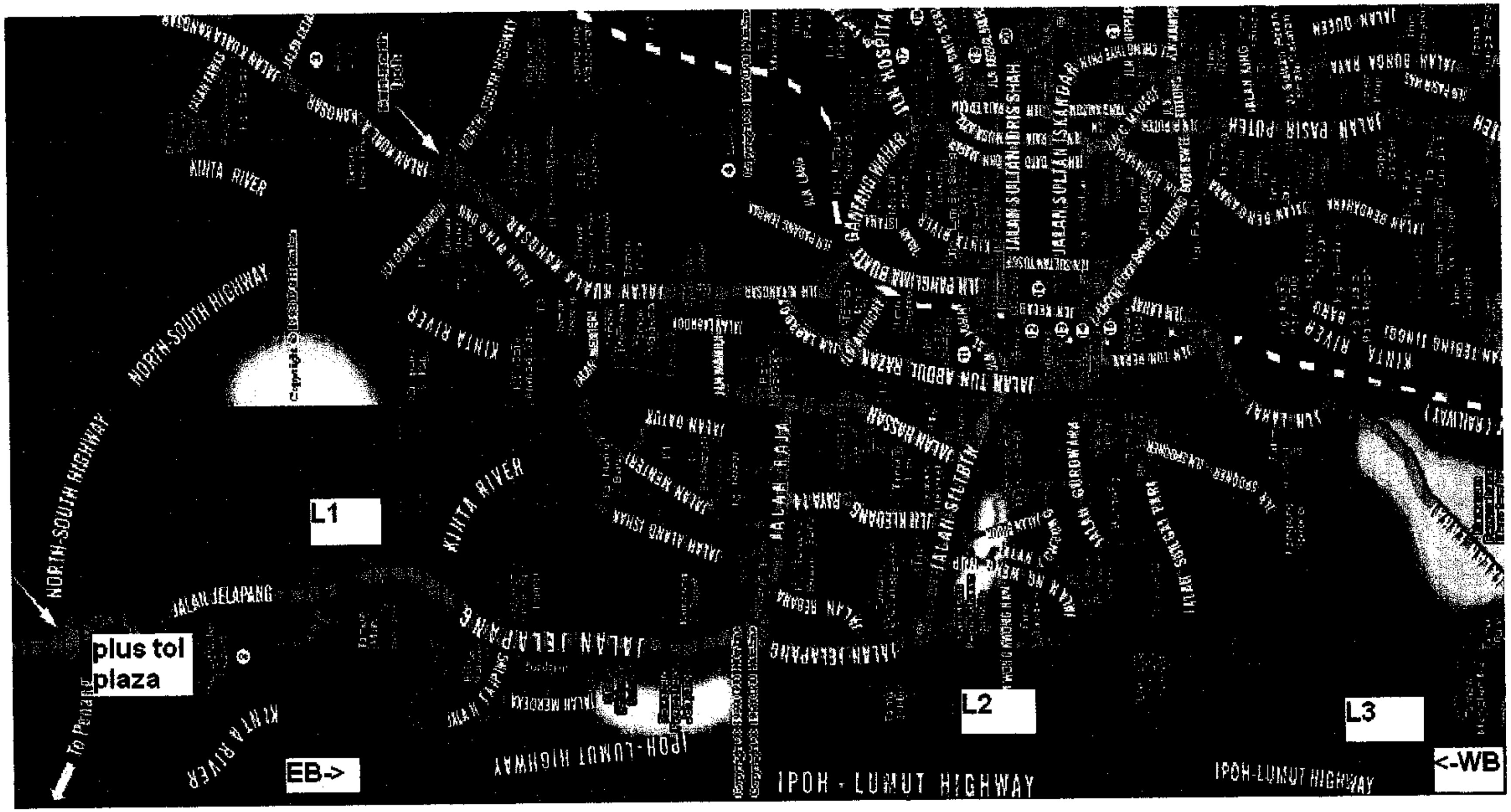
Online Resources:

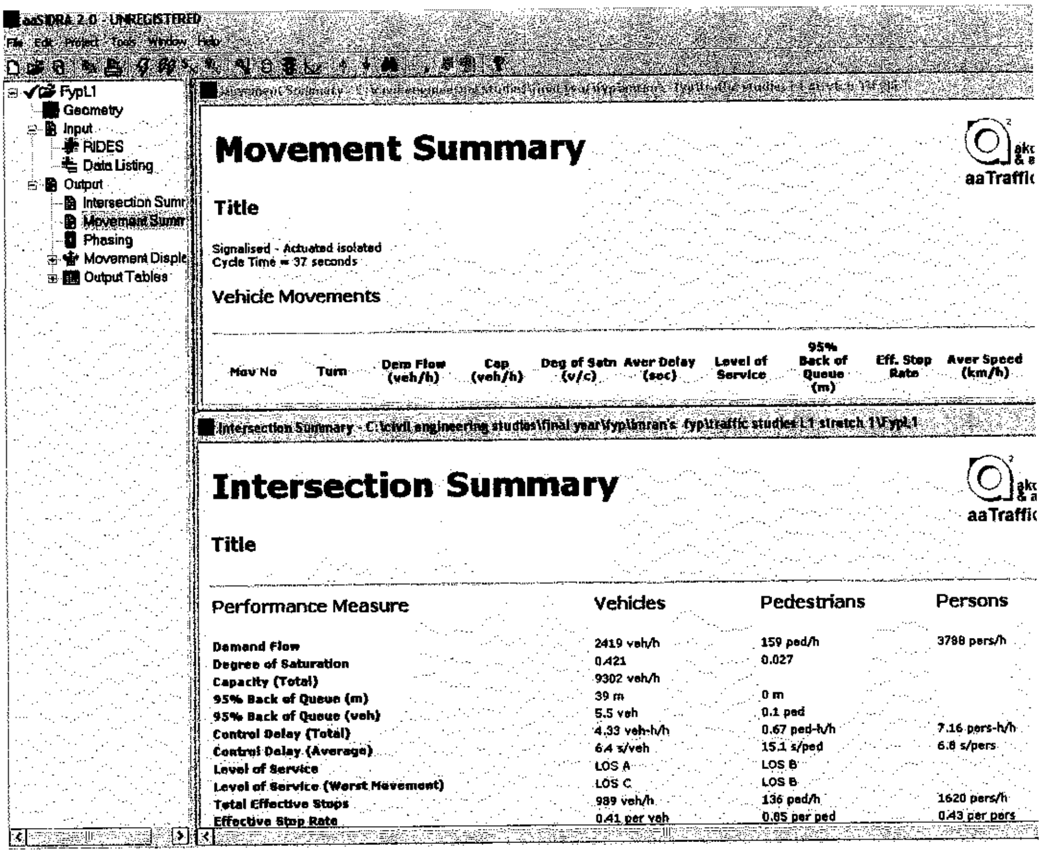
a. www.ctre.iastate.edu/pubs/Tech_News/2004/sep-oct/spot_speed.htm
b. www.dot.state.fl.us/trafficoperations/muts/Chapter14.pdf
c. www.webs1.uidaho.edu/niatt_labmanual/Chapters/signaltimingdesign/exampleproblems/PeakHourVolumeDesignFlowPHF.htm
d. www.vbt.bme.hu/phdsymp/2ndphd/proceedings/styevola.pdf
e. www.ipohonline.com.my
f. www.jkr.gov.my/jln/hari-jkr/Road1.htm
g. http://cee.engr.ucdavis.edu/classes/classweb/ECI161/Capacity_and_Level_of_Service.pdf

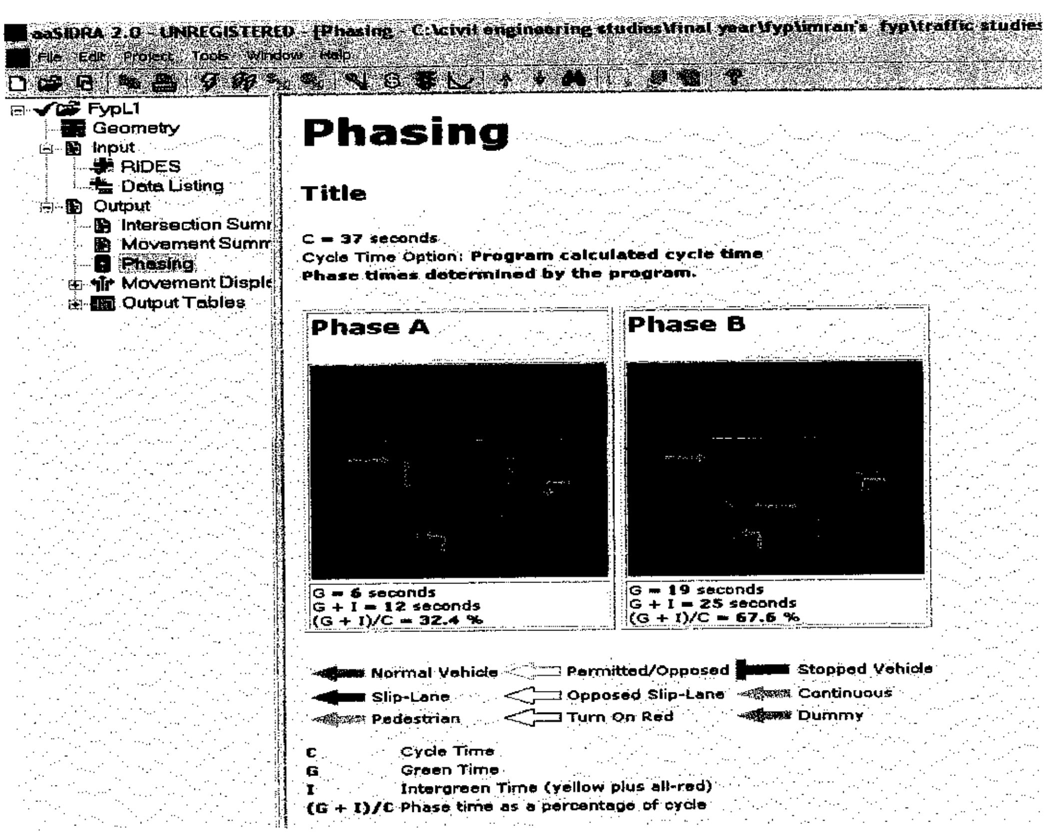
APPENDIX

TITLE: MAP OF PROJECT SITE



TITLE: aaSIDRA INTERFACE





TITLE: Speed Data Obtained on segment 1 (L1-L2)

Car No.	Speed (km/h)		Car No.	Speed(km/h)
1	75.8		50	63.6
2	66.2		51	85.7
3	68.8		52	80.5
4	64.9		53	59.6
5	64.6		54	55.1
6	74		55	74
7	68.4		56	90.2
8	54		57	85.5
9	59.9		58	66.2
10	57.3		59	81.8
11	84.2		60	77.4
12	66.1		61	73.9
13	45.5		62	59
14	75.7		63	55
15	59.2		64	74.7
16	57.2		65	67.6
17	61.8		66	70.6
18	67.8		67	66.8
19	52.8		68	62.4
20	66.3		69	66.2
21	91.6		70	50.6
22	70.7		71	68.4
23	57.1		72	70.4
24	74.5		73	87.6
25	70.5		74	47.5
26	58.1		75	70.8
27	54		76	65.7
28	52.9		77	52.6
29	56.6		78	48.9
30	74.7		79	73.2
31	61.2		80	83.2
32	63.4		81	71.3
33	93.1		82	79.1
34	71.1		83	79.7
35	82.6		84	76.9
36	77		85	53.1
37	86.7		86	75.9
38	63.3		87	73
39	65.8		88	71.6
40	82.5		89	58.8
41	81.1		90	80.5
42	76.6		91	79
43	74.8		92	69.3
44	72.3		93	83.3
45	75.1		94	84.9
46	90.4		95	72.7
47	95.2		96	69.3
48	76.5		97	76.8
49	66.7		98	77.4
			99	80.7
			100	76.5

TITLE: Speed Data Obtained on segment 1 (L2-L3)

Car No.	Speed (km/h)		Car No.	Speed(km/h)
1	61.8		50	74.8
2	62.9		51	65.1
3	76.8		52	96.1
4	95.6		53	94.0
5	82.1		54	83.3
6	58.3		55	84.3
7	64.2		56	80.1
8	76.7		57	85.2
9	69.9		58	49.1
10	73.3		59	76.3
11	96.0		60	68.8
12	80.2		61	79.2
13	73.3		62	70.3
14	90.1		63	85.3
15	54.8		64	65.1
16	74.1		65	72.9
17	93.2		66	60.2
18	72.6		67	80.3
19	88.7		68	76.0
20	65.4		69	51.2
21	61.3		70	60.7
22	61.2		71	74.4
23	73.7		72	73.8
24	54.3		73	53.8
25	59.1		74	63.0
26	59.4		75	86.7
27	69.4		76	89.8
28	65.1		77	65.5
29	77.3		78	49.4
30	68.5		79	91.2
31	80.2		80	72.0
32	88.9		81	84.1
33	62.4		82	81.6
34	55.6		83	81.5
35	73.3		84	73.0
36	82.3		85	77.8
37	82.2		86	62.8
38	79.6		87	57.3
39	71.0		88	61.9
40	66.0		89	69.2
41	78.9		90	79.9
42	80.9		91	61.8
43	96.8		92	78.9
44	69.8		93	67.0
45	78.8		94	63.6
46	82.0		95	71.4
47	71.9		96	59.2
48	60.5		97	78.0
49	76.8		98	85.2
			99	79.9
			100	79.7

TITLE: Volume study results on intersections L1, L2, L3

Intersection L1

A1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	54	25	79
3.00-3.15 pm	52	24	76
3.15-3.30 pm	53	24	77
3.30-3.45 pm	57	27	84
Total 1 hour	216	100	**316**
% heavy vehicle, HV = 31.65 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.76			
Adjusted volume = (0.76)(316) = **240** vehicle/hour			

A2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	3	1	4
3.00-3.15 pm	4	0	4
3.15-3.30 pm	5	0	5
3.30-3.45 pm	5	1	6
Total 1 hour	17	2	**19**
% heavy vehicle, HV = 10.53 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.90			
Adjusted volume = (0.90)(19) =**17** vehicle/hour			

B1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	3	1	4
3.00-3.15 pm	5	0	5
3.15-3.30 pm	1	0	1
3.30-3.45 pm	3	0	3
Total 1 hour	12	1	**13**
% heavy vehicle, HV = 7.69 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.93			
Adjusted volume = (0.93)(13) = **12** vehicle/hour			

C2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	34	30	64
3.00-3.15 pm	41	27	68
3.15-3.30 pm	47	27	74
3.30-3.45 pm	46	28	74
Total 1 hour	168	112	**280**
% heavy vehicle, HV = 40.0 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.71			
Adjusted volume = (0.71)(280) = **199** vehicle/hour			

Total vehicular volume on intersection L1 per hour is 468 veh/ h.

Intersection L2

A1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	49	28	77
3.00-3.15 pm	50	30	80
3.15-3.30 pm	47	29	76
3.30-3.45 pm	51	31	82
Total 1 hour	197	118	**315**
% heavy vehicle, HV = 37.46 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.73			
Adjusted volume = (0.73)(315) = **230** vehicle/hour			

A2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	21	11	32
3.00-3.15 pm	24	9	33
3.15-3.30 pm	19	14	33
3.30-3.45 pm	22	11	33
Total 1 hour	86	45	**131**
% heavy vehicle, HV = 34.35 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.74			
Adjusted volume = (0.74)(131) =**98** vehicle/hour			

B1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	7	3	10
3.00-3.15 pm	5	1	6
3.15-3.30 pm	4	4	8
3.30-3.45 pm	9	7	16
Total 1 hour	25	15	**40**
% heavy vehicle, HV = 37.5 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.73			
Adjusted volume = (0.73)(40) = **30** vehicle/hour			

C2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	31	16	95
3.00-3.15 pm	27	20	47
3.15-3.30 pm	36	14	50
3.30-3.45 pm	33	18	51
Total 1 hour	168	68	**243**
% heavy vehicle, HV = 28.0 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.78			
Adjusted volume = (0.78)(243) = **190** vehicle/hour			

Total vehicular volume on intersection L2 per hour is 548 veh/ h.

Intersection L3

A1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	92	32	124
3.00-3.15 pm	101	21	122
3.15-3.30 pm	89	37	126
3.30-3.45 pm	95	25	120
Total 1 hour	377	115	**492**
% heavy vehicle, HV = 23.37 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.81			
Adjusted volume = (0.81)(492) = **399** vehicle/hour			

A2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	45	23	68
3.00-3.15 pm	51	19	70
3.15-3.30 pm	39	28	67
3.30-3.45 pm	53	30	83
Total 1 hour	188	100	**288**
% heavy vehicle, HV = 34.72 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.74			
Adjusted volume = (0.74)(288) =**214** vehicle/hour			

B1

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	21	6	27
3.00-3.15 pm	15	9	24
3.15-3.30 pm	16	11	27
3.30-3.45 pm	22	7	29
Total 1 hour	74	33	**107**
% heavy vehicle, HV = 30.84 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.76			
Adjusted volume = (0.76)(107) = **82** vehicle/hour			

C2

Time	Passenger Vehicles Volume	Heavy Vehicles Volume	Total volume
2.45-3.00 pm	31	11	42
3.00-3.15 pm	45	9	54
3.15-3.30 pm	41	13	54
3.30-3.45 pm	44	11	55
Total 1 hour	161	44	**205**
% heavy vehicle, HV = 21.46 Heavy vehicle adjustment factor f_{HV} = 100/100+ HV(E_T-1) = 0.82			
Adjusted volume = (0.82)(205) = **169** vehicle/hour			

Total vehicular volume on intersection L3 per hour is 864 veh/ h.

TITLE: Future traffic flow estimation (without development) calculation for Traffic Light Intersections

Using average Malaysia urban growth rate,r = 5.00%
n projection of years = 10

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

Intersection L1

A1 = 240 $(1+0.05)^{10}$ = 391
A2 = 17 $(1+0.05)^{10}$ = 28
B1 = 12 $(1+0.05)^{10}$ = 20
B2 = 461 $(1+0.05)^{10}$ = 751
C1 = 481 $(1+0.05)^{10}$ = 784
C2 = 199 $(1+0.05)^{10}$ = 324
Due Falim = 498 $(1+0.05)^{10}$ = 812
Due Kl/Penang = 701 $(1+0.05)^{10}$ = 1143
Due Lumut = 211 $(1+0.05)^{10}$ = 344

Intersection L2

A1 = 230 $(1+0.05)^{10}$ = 375
A2 = 98 $(1+0.05)^{10}$ = 160
B1 = 30 $(1+0.05)^{10}$ = 49
B2 = 457 $(1+0.05)^{10}$ = 745
C1 = 501 $(1+0.05)^{10}$ = 817
C2 = 190 $(1+0.05)^{10}$ = 310
Due Lumut = 687 $(1+0.05)^{10}$ = 1120
Due Jelapang = 599 $(1+0.05)^{10}$ = 977
Due suburbs = 220 $(1+0.05)^{10}$ = 359

Intersection L3

A1 = 399 $(1+0.05)^{10}$ = 651
A2 = 214 $(1+0.05)^{10}$ = 349
B1 = 82 $(1+0.05)^{10}$ = 134
B2 = 402 $(1+0.05)^{10}$ = 656
C1 = 520 $(1+0.05)^{10}$ = 848
C2 = 169 $(1+0.05)^{10}$ = 276
Due Lumut/UTP = 801 $(1+0.05)^{10}$ = 1306
Due Jelapang = 734 $(1+0.05)^{10}$ = 1197
Due Ipoh = 251 $(1+0.05)^{10}$ = 410

TITLE: CALCULATIONS FOR TRAVEL TIME STUDY FOR SEGMENT 1 (L1-L2)

Average number of vehicles traveling eastward when test vehicle is traveling westward (N_w) = 47.67

Average number of vehicles that overtake test vehicle while it's traveling westward (O_w) = 0.33

Average number of vehicle that overtake test vehicle while it is traveling eastward (O_e) = 1.67

Average number of vehicle the test vehicle passes while traveling westward (P_w) = 1

Average number of vehicle the test vehicle passes while traveling eastward (P_e) = 1

Volume in the westbound direction, V_w

$$= \frac{(N_e + O_w - P_w)\,60}{T_e + T_w}$$

$$= \frac{(45.67 + 0.33 - 1)\,60}{4.23 + 4.49}$$

= 309.6

= 310 veh/h

Volume in the westbound direction, V_e

$$= \frac{(N_w + O_e - P_e)\,60}{T_e + T_w}$$

$$= \frac{(47.67 + 1.67 - 1)\,60}{4.23 + 4.49}$$

= 332.6

= 333 veh/h

Average travel time in the westbound direction

$$\check{T}_w = 4.49 - \frac{(0.33 - 1)\,60}{310}$$

= 4.61 min

Average travel time in the eastbound direction

$$\check{T}_e = 4.49 - \frac{(1.67 - 1)\,60}{333}$$

= 4.37 min

TITLE: CALCULATIONS FOR TRAVEL TIME STUDY FOR SEGMENT 2 (L2-L3)

Average number of vehicles traveling eastward when test vehicle is traveling westward (N_w) = 77

Average number of vehicles that overtake test vehicle while it's traveling westward (O_w) = 0.33

Average number of vehicle that overtake test vehicle while it is traveling eastward (O_e) = 1

Average number of vehicle the test vehicle passes while traveling westward (P_w) = 1.33

Average number of vehicle the test vehicle passes while traveling eastward (P_e) = 1.33

Volume in the westbound direction, V_w

$$= \frac{(N_e + O_w - P_w)\,60}{T_e + T_w}$$

$$= \frac{(68 + 0.33 - 1.33)\,60}{2.73 + 2.22}$$

= 812.12

= 813 veh/h

Volume in the westbound direction, V_e

$$= \frac{(N_w + O_e - P_e)\,60}{T_e + T_w}$$

$$= \frac{(77 + 1 - 1.33)\,60}{2.73 + 2.22}$$

= 929.33

= 930 veh/h

Average travel time in the westbound direction

$$\check{T}_w = 2.22 - \frac{(0.33 - 1.33)\,60}{813}$$

= 2.30 min

Average travel time in the eastbound direction

$$\check{T}_e = 2.73 - \frac{(1 - 1.33)\,60}{930}$$

= 2.75 min

TITLE: CALCULATIONS FOR PTSF FOR SEGMENT 1 (L1-L2)

Adjustment factor for heavy vehicle, f_{HV}

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

$f_{HV} = 1/(1+(0.3425)(1.1)$
$= 0.726$

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

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

$V_p = 628/(0.94 \times 1.0 \times 0.726)$
$= 920.23$ veh/h

920 < 3200; this section is operating below capacity.

Base percent time spent following for both direction, BPTSF

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

$= 100(1-e^{-0.000879(920.23)})$

$= 55.46$

Percent time spent following (PTSF) = BPTSF + $f_{d/np}$
$= 55.46 + 19.88$
$= \mathbf{75.34\%}$

TITLE: CALCULATIONS FOR PTSF FOR SEGMENT 2 (L2-L3)

Adjustment factor for heavy vehicle, f_{HV}

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

$f_{HV} = 1/(1+(0.3722)(1.1)$
$= 0.710$

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

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

$V_p = 711/(0.96 \times 1.0 \times 0.710)$
$= 1043.13$ veh/h

1044 < 3200; this section is operating below capacity.

Base percent time spent following for both direction, BPTSF

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

$= 100(1-e^{-0.000879(1043.13)})$

$= 60.02$

Percent time spent following (PTSF) = BPTSF + $f_{d/np}$
$= 60.02 + 7.77$
= 67.79%

TITLE: CALCULATIONS FOR ATS FOR SEGMENT 1 (L1-L2)

Mean speed of traffic measured in the field, S_{FM} = 70.3 km/h (from spot speed data calculation)

Observed flow rate, V_f= 643 veh/h (from travel time study)

f_{HV} = 0.726 (see above)

V_p= 920.23 veh/h (see above)

Adjustment for the percentage of no-passing zones, f_{np} = 3.516 (interpolation of table 9.6 Garber and Hoel text)

To find FFS with the following conditions:

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

Free flow speed, (FFS) = $S_{FM} + 0.00776(V_f / f_{HV})$
= 70.3 + 0.00776 (643 / 0.726)
= 77.17 km/h

Average Travel Speed, ATS = FFS – $0.00776V_p$ - f_{np}

= 77.17- 0.00776(920.23) – 3.516
= 73.55km/h = 45.7 mi/h

TITLE: CALCULATIONS FOR ATS FOR SEGMENT 2 (L2-L3)

Mean speed of traffic measured in the field, S_{FM} = 72.52 km/h (from spot speed data calculation)

Observed flow rate, V_f = 1743 veh/h (from travel time study)

f_{HV} = 0.710 (see above)

V_p= 1043.13 veh/h (see above)

Adjustment for the percentage of no-passing zones, f_{np} = 0.95 (interpolation of table 9.6 Garber and Hoel text)

To find FFS with the following conditions:

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

Free flow speed, (FFS) = S_{FM} + $0.00776(V_f / f_{HV})$
= 72.52 + 0.00776 (1743 / 0.710)
= 91.57 km/h

Average Travel Speed, ATS = FFS – $0.00776V_p$ - f_{np}

= 91.57- 0.00776(1043.13) – 0.95
= 84.43 km/h = 52.46 mi/h

TITLE: CALCULATIONS ON LOS FOR SEGMENT 1 (L1-L2) FOR MULTILANE HIGHWAY

Hourly peak volume, V = 628 veh/h
Peak Hour Factor, PHF = 0.94
Number of travel lanes in one direction, N = 2
Driver population factor, f_p=1.00
Heavy vehicle adjustment factor, f_{HV} = 0.726
Free flow speed, FFS,S = 77.17km/h = 48.0mi/h

15-minute passenger-car eq. flow rate, $v_p = \dfrac{V}{(PHF)(N)(f_p)(f_{HV})}$

$$= \frac{628}{(0.94)(2)(1)(0.726)}$$

$$= 460.11 \text{ pc/h/ln}$$

Density, $D = v_p / S$

$$= 460.11 / 48$$

$$= 9.59 \text{ pc/mi/ln}$$

Referring table 9.24 (Garber & Hoel text); the obtain LOS for segment 1 is **LOS A.**

TITLE: CALCULATIONS ON LOS FOR SEGMENT 2 (L2-L3) FOR MULTILANE HIGHWAY

Hourly peak volume, V = 711 veh/h
Peak Hour Factor, PHF = 0.96
Number of travel lanes in one direction, N = 2
Driver population factor, f_p=1.00
Heavy vehicle adjustment factor, f_{HV} = 0.710
Free flow speed, FFS,S = 91.57km/h = 56.86mi/h

15-minute passenger-car eq. flow rate, $v_p = \dfrac{V}{(PHF)\,(N)\,(f_p)\,(f_{HV})}$

$$= \frac{711}{(0.96)(2)(1)(0.710)}$$

$$= 521.57 \text{ pc/h/ln}$$

Density, $D = v_p / S$

$= 521.57/\ 56.86$

$= 9.17$ pc/mi/ln

Referring table 9.24 (Garber & Hoel text); the obtain LOS for segment 2 is **LOS A.**

TITLE: VEHICLES MOVEMENT SUMMARY FOR L1

aaSIDRA 2.0 - UNREGISTERED - [Movement Summary - C:\civil engineering studies\final year\fyp\imran's fyp\traffic studies L1 stretch 1\FypL1]

File Edit Project Tools Window Help

Signalised - Actuated isolated
Cycle Time = 37 seconds

Vehicle Movements

Mov No	Turn	Dem Flow (veh/h)	Cap (veh/h)	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Aver Speed (km/h)	Oper Cost ($/h)
South Approach										
1	L	412	1879	0.219	8.3	LOS A#	7#	0.62	48.9	140
3	R	29	733	0.040	23.9	LOS C	2	0.68	36.1	12
Approach		**441**	**2612**	**0.219**	**9.3**	**LOS A**	**2**	**0.63**	**47.8**	**152**
East Approach										
4	L	21	1879	0.011	8.3	LOS A#	0#	0.62	48.9	7
5	T	791	2027	0.390	6.3	LOS A	39	0.54	51.1	225
Approach		**812**	**3906**	**0.390**	**6.3**	**LOS A**	**39**	**0.54**	**51.1**	**233**
West Approach										
11	T	825	1973	0.418	0.1	LOS C#	14#	0.00	59.9	218
12	R	341	810	0.421	18.4	LOS B	21	0.79	39.8	132
Approach		**1166**	**2783**	**0.421**	**5.4**	**LOS A**	**21**	**0.23**	**52.2**	**350**
All Vehicles		**2419**	**9302**	**0.421**	**6.4**	**LOS A**	**39**	**0.41**	**51.0**	**735**

Pedestrian Movements

Mov No	Dem Flow (veh/h)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Oper Cost ($/h)
51	53	13.0	LOS B	0	0.84	4
53	53	16.4	LOS B	0	0.86	5
57	53	15.9	LOS B	0	0.86	5
All Peds	**159**	**15.1**	**LOS B**	**0**	**0.85**	**15**

TITLE: VEHICLES MOVEMENT SUMMARY FOR L2

aaSIDRA 2.0 - UNREGISTERED - [Movement Summary - C:\civil engineering studies\final year\fyp\IMRAN'S FYP\traffic studies L1 segment L1-L2\FypL2]

File Edit Project Tools Window Help

Signalised - Actuated isolated
Cycle Time = 45 seconds

Vehicle Movements

Mov No	Turn	Dem Flow (veh/h)	Cap (veh/h)	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Aver Speed (km/h)	Oper Cost ($/h)
South Approach										
1	L	242	1879	0.129	8.3	LOS A#	4#	0.62	48.9	82
3	R	103	687	0.150	22.9	LOS C	8	0.75	36.8	43
Approach		**345**	**2566**	**0.150**	**12.6**	**LOS B**	**8**	**0.66**	**44.5**	**125**
East Approach										
4	L	32	1879	0.017	8.3	LOS A#	1#	0.62	48.9	11
5	T	481	1754	0.274	9.0	LOS A	30	0.54	48.1	145
Approach		**513**	**3634**	**0.274**	**9.0**	**LOS A**	**30**	**0.55**	**48.1**	**156**
West Approach										
11	T	527	2894	0.182	1.1	LOS A	8	0.12	55.8	143
12	R	200	870	0.230	20.1	LOS C	14	0.77	38.6	80
Approach		**727**	**3765**	**0.230**	**6.3**	**LOS A**	**14**	**0.30**	**49.7**	**223**
All Vehicles		**1585**	**9964**	**0.274**	**8.5**	**LOS A**	**30**	**0.46**	**48.0**	**504**

Pedestrian Movements

Mov No	Dem Flow (veh/h)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Oper Cost ($/h)
51	53	16.9	LOS B	0	0.87	5
53	53	20.8	LOS C	0	0.89	6
57	53	19.4	LOS B	0	0.88	6
All Peds	**159**	**19.0**	**LOS B**	**0**	**0.88**	**17**

TITLE: VEHICLES MOVEMENT SUMMARY FOR L3

aaSIDRA 2.0 - UNREGISTERED - [Movement Summary - C:\civil engineering studies\final year\fyp\IMRAN'S FYP\traffic studies L1 segment L1-L2\FypL3]

File Edit Project Tools Window Help

Signalised - Actuated isolated
Cycle Time = 45 seconds

Vehicle Movements

Mov No	Turn	Dem Flow (veh/h)	Cap (veh/h)	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Aver Speed (km/h)	Oper Cost ($/h)
South Approach										
1	L	420	1879	0.224	8.3	LOS B#	7#	0.62	48.9	143
3	R	225	824	0.273	21.1	LOS C	17	0.77	37.9	91
Approach		**645**	**2703**	**0.273**	**12.7**	**LOS B**	**17**	**0.68**	**44.4**	**234**
East Approach										
4	L	86	1879	0.046	8.3	LOS A#	1#	0.62	48.9	29
5	T	423	1403	0.301	12.0	LOS B	30	0.61	45.1	134
Approach		**509**	**3283**	**0.301**	**11.4**	**LOS B**	**30**	**0.61**	**45.7**	**164**
West Approach										
11	T	547	2894	0.189	1.1	LOS A	9	0.12	55.8	149
12	R	178	735	0.242	23.3	LOS C	14	0.77	36.5	74
Approach		**725**	**3629**	**0.242**	**6.5**	**LOS A**	**14**	**0.28**	**49.4**	**223**
All Vehicles		**1879**	**9616**	**0.301**	**10.0**	**LOS A**	**30**	**0.51**	**46.6**	**621**

Pedestrian Movements

Mov No	Dem Flow (veh/h)	Aver Delay (sec)	Level of Service	95% Back of Queue (m)	Eff. Stop Rate	Oper Cost ($/h)
51	53	16.9	LOS B	0	0.87	5
53	53	18.9	LOS B	0	0.88	6
57	53	17.4	LOS B	0	0.87	5
All Peds	**159**	**17.7**	**LOS B**	**0**	**0.87**	**16**

TITLE: INTERSECTION SUMMARY FOR L1

Intersection Summary - C:\civil engineering studies\final year\fyp\IMRAN'S FYP\traffic studies L1 segment L...

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flow	2419 veh/h	159 ped/h	3788 pers/h
Degree of Saturation	0.421	0.027	
Capacity (Total)	9302 veh/h		
95% Back of Queue (m)	39 m	0 m	
95% Back of Queue (veh)	5.5 veh	0.1 ped	
Control Delay (Total)	4.33 veh-h/h	0.67 ped-h/h	7.16 pers-h/h
Control Delay (Average)	6.4 s/veh	15.1 s/ped	6.8 s/pers
Level of Service	LOS A	LOS B	
Level of Service (Worst Movement)	LOS C	LOS B	
Total Effective Stops	989 veh/h	136 ped/h	1620 pers/h
Effective Stop Rate	0.41 per veh	0.85 per ped	0.43 per pers
Travel Distance (Total)	1466.4 veh-km/h	1.6 ped-km/h	2201.1 pers-km/h
Travel Distance (Average)	606 m	10 m	581 m
Travel Time (Total)	28.8 veh-h/h	1.1 ped-h/h	44.2 pers-h/h
Travel Time (Average)	42.8 secs	24.1 secs	42.0 secs
Travel Speed	51.0 km/h	1.5 km/h	49.8 km/h
Operating Cost (Total)	735 $/h	15 $/h	750 $/h
Fuel Consumption (Total)	136.0 L/h		
Carbon Dioxide (Total)	339.9 kg/h		
Hydrocarbons (Total)	0.549 kg/h		
Carbon Monoxide (Total)	22.09 kg/h		
NOX (Total)	0.756 kg/h		

TITLE: INTERSECTION SUMMARY FOR L2

Intersection Summary - C:\civil engineering studies\final year\fyp\IMRAN'S FYP\traffic studies L1 segment L...

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flow	1585 veh/h	159 ped/h	2537 pers/h
Degree of Saturation	0.274	0.033	
Capacity (Total)	9964 veh/h		
95% Back of Queue (m)	30 m	0 m	
95% Back of Queue (veh)	4.2 veh	0.1 ped	
Control Delay (Total)	3.76 veh-h/h	0.84 ped-h/h	6.48 pers-h/h
Control Delay (Average)	8.5 s/veh	19.0 s/ped	9.2 s/pers
Level of Service	LOS A	LOS B	
Level of Service (Worst Movement)	LOS C	LOS C	
Total Effective Stops	728 veh/h	140 ped/h	1232 pers/h
Effective Stop Rate	0.46 per veh	0.88 per ped	0.49 per pers
Travel Distance (Total)	960.8 veh-km/h	1.6 ped-km/h	1442.8 pers-km/h
Travel Distance (Average)	606 m	10 m	569 m
Travel Time (Total)	20.0 veh-h/h	1.2 ped-h/h	31.3 pers-h/h
Travel Time (Average)	45.5 secs	28.0 secs	44.4 secs
Travel Speed	48.0 km/h	1.3 km/h	46.2 km/h
Operating Cost (Total)	504 $/h	17 $/h	521 $/h
Fuel Consumption (Total)	94.8 L/h		
Carbon Dioxide (Total)	237.0 kg/h		
Hydrocarbons (Total)	0.393 kg/h		
Carbon Monoxide (Total)	16.91 kg/h		
NOX (Total)	0.544 kg/h		

TITLE: INTERSECTION SUMMARY FOR L3

Intersection Summary - C:\civil engineering studies\final year\fyp\IMRAN'S FYP\traffic studies L1 segment L...

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flow	1879 veh/h	159 ped/h	2978 pers/h
Degree of Saturation	0.301	0.033	
Capacity (Total)	9616 veh/h		
95% Back of Queue (m)	30 m	0 m	
95% Back of Queue (veh)	4.3 veh	0.1 ped	
Control Delay (Total)	5.21 veh-h/h	0.78 ped-h/h	8.60 pers-h/h
Control Delay (Average)	10.0 s/veh	17.7 s/ped	10.4 s/pers
Level of Service	LOS A	LOS B	
Level of Service (Worst Movement)	LOS C	LOS B	
Total Effective Stops	953 veh/h	139 ped/h	1568 pers/h
Effective Stop Rate	0.51 per veh	0.87 per ped	0.53 per pers
Travel Distance (Total)	1139.3 veh-km/h	1.6 ped-km/h	1710.5 pers-km/h
Travel Distance (Average)	606 m	10 m	574 m
Travel Time (Total)	24.5 veh-h/h	1.2 ped-h/h	37.9 pers-h/h
Travel Time (Average)	46.8 secs	26.7 secs	45.8 secs
Travel Speed	46.6 km/h	1.3 km/h	45.2 km/h
Operating Cost (Total)	621 $/h	16 $/h	637 $/h
Fuel Consumption (Total)	116.1 L/h		
Carbon Dioxide (Total)	290.3 kg/h		
Hydrocarbons (Total)	0.489 kg/h		
Carbon Monoxide (Total)	21.43 kg/h		
NOX (Total)	0.671 kg/h		