The Effectiveness of The Implementation of ITACA System to Traffic Light Junction in Putrajaya

by

Nurul Huda Mohd Sahri

Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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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 the original work contained herein have not been taken or done by unspecified sources or persons.

NURUL HUDA MOHD SAHRI

ABSTRACT

Since Putrajaya was officially proclaimed as the new Federal Administrative Centre of Malaysia, Perbadanan Putrajaya has been given a great responsibility to structure, organize and implement a development for this city for the convenience of its resident. To ensure that Putrajaya will be a modern and organized city, Perbadanan Putrajaya has introduced a traffic light system that is Intelligent Traffic Adaptive Control Agent (ITACA) System that will enable the traffic to be fully controlled by computer.

It is noted as the best way in traffic management system to minimize the congestion level at urban city as well as the best computerized traffic control in Asia. Implementation of ITACA allows the traffic at the implemented junction to flow smoothly and road user doesn't have to rush and cut queues while queuing at junction. When the traffic light system using a fully computerized control system, all the system will be integrate to be one central dynamic traffic control system that will be able to control from the Perbadanan Putrajaya Headquarters building as the control centre.

This report described the detailed step and analysis regarding measure in determining the junction performance for both with and without ITACA system operation. The problem statement has been stated, the scope has been identified, and also the objectives have been listed out in order to be achieved in the final steps of this project. By conducting traffic survey and traffic analysis, it was determined that junctions with the implementation of ITACA system has a better performance compared to junctions without the system. This report also gives a better overview of ITACA system, the architecture of ITACA system, an overview of aaSIDRA software and also its applications which are applied and used in conducting traffic analysis.

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Besides that, I would like to express the special thanks other Civil Engineering lecturers, technicians especially En. Zaini and En. Johan that gives me advice and help regarding the project. Special thanks to Mohd Zaki Othman who always been there when needed, as well as all my friends and all the final year Civil Engineering for their great ideas, help, courage and support for me to complete this project. Thank you for all their full cooperation. Last but not least, thank you to everyone else that involve directly or indirectly in providing a big contribution and supports to this project. I owe everything to you.

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ABBREVIATION AND NOMENCLATURES

ATMS	Area Traffic Management Control
ATCS	Area Traffic Control System
aaSIDRA	Signalised & unsignalised Intersection Design and Research Aid
CBD	Centre Business District
CCTV	Close Circuit Television
ERL	Express Rail Link
ITACA	Intelligent Traffic Adaptive Control Agent
ITMC	Intersection Turning Movement Count
ITS	Intelligent Traffic System
LRT	Light Rail Transit
LT	Left Turn
OPTIMUS	Urban Traffic Control System
PCU	Passenger Car Unit
RT	Right Turn
SCOOP	Split Cycle Offset Optimization Technique
SCAT	Sydney Coordinated Adaptive Traffic System
TCP/IP	Transmission Control Protocol/Internet Protocol
VMS	Variable Message Sign

CHAPTER 1
INTRODUCTION

1.1 Background of Study Area

Putrajaya was officially proclaimed as the new Federal Administrative Centre of Malaysia on 1st February 2001. It is situated 25km south of Kuala Lumpur and to have a full fledge population of 330,000 people with 254,000 job opportunities in year 2012 when the development of Putrajaya is fully completed. The site covers an area of 4,932 hectares. It was vision as a prime city with combination of high quality environment and advanced technology, which befits a capital for the 21st century. This includes having a minimal access to the central core area (precincts) from a few road and bridge links and the use of private vehicles is discouraged.

Several studies including those specific to transportation have been commissioned for Putrajaya and its vicinity since the conceptualization of the new federal capital. The development of Putrajaya is demarcated into 20 planning zones called precincts. The Structure Plan for Putrajaya and parts of Sepang District was prepared in 1995. This Plan provides for a broad planning framework for Putrajaya. Further refinement was prepared in the Putrajaya Master Plan and the local plans of all the precincts in Putrajaya. The physical development of Putrajaya was based on a Master Plan approved in February 1995 and its subsequent reviewed published in March 1997. The local Plans interpreted the policies and strategies in the Structure Plan and the Master Plan into physical development forms that is more detailed and practical.

The Master Plan has also set out transport objectives as follows:

- To provide an attractive built environment, free of congestion, and with minimal environmental pollution.
- To achieve a target of 70% of all travel to the precincts by public transport.
- To give priority to public transport and to encourage preference for this mode.
- To provide a clear and efficient hierarchy of roads with good links to external areas, development sites and the precincts.
- To ensure sufficient flexibility to cater for phasing out and for evolving needs in the future.

One of the measures taken to achieve the Master Plan transport objectives is by the implementation of Area Traffic Management Systems (ATMS). This study only concentrated on the implementation of Area Traffic Management Systems (ATMS) of Putrajaya which is based on the Intelligent Traffic Adaptive Control Agent (ITACA) Expert System. The ability of the system to provide expert decisions on best traffic flow for precinct traffic management is based on consolidation of information from a centralized expert system and the success of this system is based on collective information from precinct traffic. Currently apart from 9 junctions that function as an integrated system, implementation at other precincts has been as a stand alone system.

The ATMS also shall provide an interface to Area Traffic Control System (ATCS) in Putrajaya based on ITACA system. The interface is a service that allows the two systems to exchange messages. These messages consist of alarms, requests and responses. This service is TCP/IP based.

ATCS functions to centrally monitor and control traffic signals within a given road network. The objectives of the ATCS are as follows:

i. To minimize overall stops, delay and congestion levels below that achieved by the best fixed-time within a designated area.

ii. To operate in real-time, adjusting signal timings throughout the system in response to variations in traffic demand and system capacity automatically and also allowing human intervention to override under certain circumstances.

iii. To provide information for traffic management purposes. Users can be informed of alternative routes available or less congested links based on real-time data provided by the system.

1.2 Problem Statement

Putrajaya was proclaimed as the new Federal Administrative of Malaysia. This means that shifting the government centre from Kuala Lumpur to Putrajaya in order to control the overflow of Kuala Lumpur development. This will make Putrajaya become the new Centre Business District (CBD) by year 2012 when the development of Putrajaya is fully completed. This will also lead to congestion and other traffic problems as experienced by other CBD before such as Kuala Lumpur, Penang and Seremban (just to name a few).

In order to overcome or at least minimize the negative effect of this development (congestion), Putrajaya has came out with an initiative to implement Intelligent Traffic System (ITS) to its traffic management system which will be integrated with ITACA system, the traffic management control at traffic light. This research is basically to study the effectiveness of implementing ITACA system at traffic light junctions in Putrajaya.

Intelligent Traffic System (ITS) in recent years has provided a powerful tool to mitigate traffic congestion on road network. This included the deployment of many traffic management systems all over the world such as Split Cycle Offset Optimization Technique (SCOOP), Sydney Coordinated Adaptive Traffic System (SCAT) and the Intelligent Traffic Adaptive Control Agent (ITACA) System. ITACA System is chosen to be implemented at Putrajaya because the road network at Putrajaya is mostly suitable to be managed by ITACA System, i.e. the junctions are located close to each other.

1.3 Objectives of Study

From this study, it was hope to finds out how ITACA System effectively minimizes duration and effects of nonrecurring congestion on road networks in Putrajaya. Besides, it was also to satisfy the stated objective of this study:-

- To compare and measure the effectiveness of junctions operation with and without ITACA System
- To develop skills in junction analysis process using aaSIDRA software, traffic survey and traffic forecasting.
- To know how traffic management system is implement and develop in Malaysia especially in Putrajaya.

The purpose of Final Year Project (FYP) paper is to develop a framework, which will enhance students' skills in the process of applying knowledge, expanding thoughts, solving problems independently and presenting findings through minimum guidance and supervision. Other objectives of FYP are:

- To integrate theory with practice
- To familiarized students with research and/or design works
- To develop skills in project management, communications, teamwork spirit, etc.
- To use the undertaken project as basis for job employment

CHAPTER 2
LITERATURE REVIEW

2.1 ITACA System

ITACA is an intelligent traffic control adaptive system which works in real time. Its main function is to adjust with a certain frequency the control parameters (cycle, split and offset) of traffic plans so as to minimize the amount of stops and delays all throughout the network, centralized by means of the real time data obtained from the detectors. It is aimed at keeping an overall traffic flow smooth and ease in each intersection. ITACA consists of two different subsystems; Adaptive System and Expert System(optional).

2.1.1 Adaptive System

This is a means of traffic control which works out the different components of a traffic plan: cycle, split and offset, using an algorithmic method. Its main characteristics are:

- gathering and processing of data each 5 seconds
- local application of its results, done separately for each intersection (gathering information from every nearby intersection, of which there's precise knowledge of its location in the network)
- action, once every several cycles, in each sub area to adjust the cycle time , as a result of calculations carried out

- action, several times per cycle, over the same intersection distributing adequately the green time between stages, as a result of calculations carried out
- action, once per cycle, in each intersection to adjust the relative start time of the cycle, as a result of calculations carried out.

2.1.2 Expert System

This system can take any data from the adaptive system to work out a more global solution for the traffic. It can only be used when the Control System is working in an Adaptive Mode, since the information produced by the Adaptive System is the source of Expert System's decisions. This system also is an intended as supplement to the traffic engineer, where he/she has introduced his/her knowledge in an understandable way (rules) and from which the Expert System is able to take decisions.

This is done on a basis of a set of rules stated by the user to adjust the importance of certain traffic movements. The Adaptive System uses those critical facts for its calculation every 5 seconds. Therefore they're instantly implemented. Those rules are suitable for habitual traffic jams, or for specific situations, being only called for only when the traffic needs. In short, the Expert system implements any course of action described by the user in the set of rules where the Traffic Rules Editor allows the user to define the rules in a traffic language.

Traffic Rules Editor is the door to the inside of the Expert System by which its knowledge base is defined with the help of the Rules Editor. The optimum benefit from the Expert System depends on the quality of the rules and actions they contain.

Besides the preceding subsystems, there is another plan selection method which is timetable. The main functions which are performed in urban traffic centralization are as follows:

- Communications with masters and controllers
- Obtaining data
- Data Processing

- Control Strategy
- Plan calculation or selection modes
- Database storage of data
- Database data processing
- Automatic operator warnings
- User interface

2.1.3 ITACA System's Function

ITACA provides real time urban traffic control by computing the best solution for every intersection and continuously adapting signal sequences to match traffic demand. Frequent changes the ITACA uses real time traffic flow data, obtained from detectors located in the field, to model traffic line-ups at every stop line (Figure 2.1). The detectors use is loop detectors which installed on the road in a distance of 5 meters to every stop line at traffic lights.

Figure 2.1: Loop Detectors

Integration with field equipment ITACA does not require prepared traffic plans because it dynamically computes the best plan, thereby optimizing, in real time, traffic movement throughout the network. ITACA's operation is tightly coupled with RMY traffic controllers. RMY traffic controllers' functions to collect data obtained from detectors and transmit or send it to Master Controller before it is sending to Application System (Control Centre) through CMY communications network. Master Controller functions to collect all traffic flow data from all RMY traffic controllers at every junction within ITACA system's control. The current CMY communications network is only temporary, because upon full completion of Putrajaya in year 2012, this communication network will be change to wireless communications network called Putranet using TCP/IP protocol for both communications network.

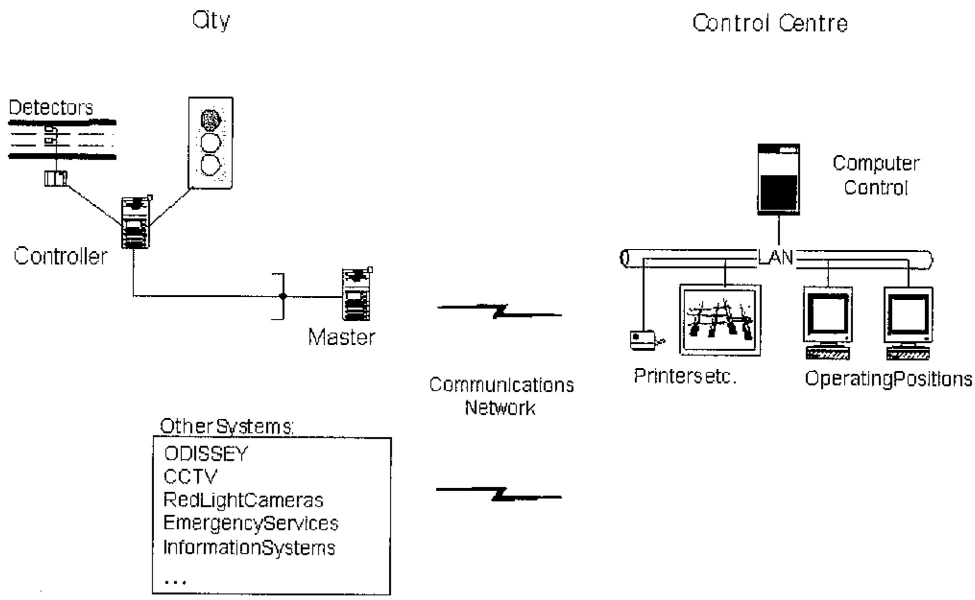
Application System which located at control centre using OPTIMUS Urban Traffic Control System. OPTIMUS is like software for urban traffic control system that can grow according to the needs of the city. Minimizing traffic congestion, Adaptive control must be supervised by an intelligent system that can analyze networkwide data. The most flexible tool for this kind of supervision is an Expert System. It can take advantage of the adaptive system's ability to dynamically implement plans by directing control processes during recognized conditions such as congestion or precongestion. The Expert System integrates the real time data from the adaptive system (raw traffic data, simulation model, queue estimation, current control status etc.), and local knowledge (unique to each network) built up from the experience of the local engineer. This enables the most appropriate solutions for each network to be produced in real time.

ITACA, the core of the OPTIMUS Urban Traffic Control System, can be complemented by many sub-systems such as:

- CCTV System (Close Circuit Television)
- Variable Message Sign Systems (VMS)
- Priority Bus System
- Enforcement System
- Reversible Lane Management System
- Internet based traffic information dissemination

However, these sub-systems are not going to be implemented yet because it was planned to be fully complemented in year 2012, when Putrajaya development is fully completed. Figure 2.2 shows the diagram of how the ITACA System works.

Figure 2.2: System Architecture of ITACA



2.2 aaTraffic SIDRA (Signalised & unsignalised Intersection Design and Research Aid)

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

- signalised intersections (fixed-time / pretimed and actuated),
- roundabouts,
- two-way stop sign control,
- all-way stop sign control, and
- 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 allow to perform 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 US HCM version of aaSIDRA is based on the calibration of model parameters against the US Highway Capacity Manual.

The analyses that can be done by aaSIDRA software are:

- 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;
- Analyse many design alternatives to *optimise* the intersection geometry, signal phasing and timings specifying different strategies for optimisation;
- 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;
- Determine *signal timings* (fixed-time / pretimed and actuated) for any intersection geometry allowing for simple as well as complex phasing arrangements;
- Carry out a *design life analysis* to assess impact of traffic growth;
- Carry out a *parameter sensitivity analysis* for optimisation, evaluation and geometric design purposes;
- Design intersection geometry including *lane use arrangements* taking advantage of the unique *lane-by-lane* analysis method of aaSIDRA;
- Design *short lane lengths* (turn bays, lanes with parking upstream, and loss of a lane at the exit side);
- Analyse effects of heavy vehicles on intersection performance;
- Analyse complicated cases of shared lanes and opposed turns (e.g. permissive and protected phases, slip lanes, turns on red);
- Analyse oversaturated conditions making use of aaSIDRA's *time-dependent* delay, queue length and stop rate formulae.

In using aaSIDRA, we also can:

- Prepare data and inspect output with ease due to the graphical nature of aaSIDRA input and output;
- 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;

- Control the amount of output by selecting individual output tables, with options for summary and full output;
- Present data and results in picture and graphs form in reports;
- Carry out sensitivity analyses to evaluate the impact of changes on parameters representing intersection geometry and driver behaviors;
- 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;
- Compare alternative (gap-acceptance and "empirical") capacity estimation methods for roundabouts;
- 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.

2.3 Traffic in Putrajaya

Putrajaya is a well-planned and organized city including the development of their road network. The infrastructure and facilities of their road network are projected to be able to cater for traffic growth upon its completion and in the future years. Besides, Perbadanan Putrajaya also has come out with traffic management system in order to control traffic growth in and into Putrajaya such as Road Pricing Scheme, Park and Ride facilities at ERL (Express Rail Link) and LRT (Light Rail Transit) stations, etc. This to ensure that upon its completion and even in the future, congestion wouldn't exist and bring a problem for Putrajaya city as experienced by many developed city before.

Currently, most of road network in Putrajaya are still in construction process for most precincts except Precinct 1 which has fully completed and utilized. Implementation of traffic management system and facilities (such as pedestrian crossing, public transport facilities, etc.) for all road networks are still in development process for all precincts, but some of the facilities has already been used but not at its full performance.

Traffic flow at Putrajaya has a peak hour flow at 7.00am to 9.00am in the morning and at 4.00pm to 6.00pm in the evening especially at Precinct 1, 2 and 3 because Government Complex and Offices are located here. This type of land use will generate much traffic before office hour in the morning and after office hour in the evening. But this condition creates only a minimum congestion level which still within acceptable limit.

CHAPTER 3
METHODOLOGY / PROJECT WORK

Methodology is a collection of procedures, techniques, tools and documentation aids that is used in conducting and completing this study. It was determined earlier at the proposal stage in order to give an overall understanding on what the expectation of this project and to identify the most systematic method so that progress can be effectively monitored. Three major steps undertaken by this study are survey, traffic forecasting and traffic analysis.

3.1 Survey

3.1.1 Reconnaissance Survey

Two types of survey were conducted for this project; reconnaissance survey and traffic survey. 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:-

- location of the junctions
- junction configuration
- road hierarchy (function)
- land use (locality) of the nearby area

Two types of junctions determined are junctions with the implementation of ITACA system at Putrajaya and junctions that is not operate under this system which identified to be junctions at Cyberjaya. Both types of junction need to have the same junction configuration, road hierarchy (function) and land use (locality) of the nearby area for comparison of the effectiveness.

3.1.2 Traffic Survey

For this project, volume studies will be the main concerns as the survey involve is Intersection Turning Movement Counts (ITMC). Traffic counts are the most basic of traffic studies and are the primary measure of demand; virtually all aspects of traffic engineering require volume as an input, including highway planning and design, decisions on traffic control and operations, detailed signal timing, and others. There are numbers of survey methodologies available to help understand traffic movement. The main techniques are described below, with their principal applications. All traffic count methodologies are noninterventionalist that is they do not affect the traffic flow being measured.

- ***Equipment***

Other than note-taking materials, video camera (with its tripod stand) and a watch, no special equipment required. If a manual or electronic turning-movement count board is available, it should be used. A calculator or laptop computer can be programmed to ease the counting task. Because the observer was least experience in collecting this type of data, it was required two or three members of the data collection team working together.

- ***Data Collection***

Before going to the field, the observer had earlier known how the data is going to be used. The following procedure is for gathering data to identify the peak-hour traffic volume and how it varies at the peak-hour period.

i) *<u>Visited the site and choose a location and time to collect the data.</u>*

It is important to visit the site at or near the time of day when data will be collected as it was done almost twice fore this project. This is to get familiar with the junction and traffic flow conditions. Because the purpose is to determine the peak-hour traffic at the intersection for use in later analysis, then the previous traffic data for the intersection to indicate what time of day the peak-hour traffic is likely to occur need to be determine first.

From the report of *Putrajaya Transport Action Plan Study*; Technical Note No. 11, ITS Strategy for Putrajaya, it was stated that traffic flow at Putrajaya has a peaking flow at 7.00am to 9.00am in the morning and at 4.00pm to 6.00pm in the evening especially at Precinct 1, 2 and 3 because Government Complex and Offices are located here. It is assumed the same peaking traffic flow at Cyberjaya junction (Junction 1C (J1C) and Junction 2C (J2C)). So it was required to do traffic survey at four junction altogether, two at Putrajaya and two at Cyberjaya. Therefore it was critical to plan and organized for the ITMC survey as proper as possible.

ii) Record the traffic flow

Unlike a spot speed study, the person conducting the ITMC survey does not need to be invisible to the drivers. It is unusual for traffic volumes to be affected by the presence of people counting traffic, so the observer and the equipment (video camera) can be placed at a vantage point that gives a clear view of the intersection and all of its approaches where turning vehicles do not block the view of the road. The best place to put the video camera is at a high elevation such as at the buildings nearby but unfortunately didn't get the buildings' owner permission.

The traffic flow was recorded for one hour from 8.00am to 9.00am in the morning and 4.30pm to 5.30pm in the evening. During recording the traffic flow, need to always check on the video camera condition such as its battery, angle of the captured view, etc.

iii) Checked work done before leaving the field.

Before leaving the field, it was checked that all the relevant and useful data was collected and recorded such as the location of the junction, streets names, etc. Any unusual observations that affect this survey also should be noted and recorded.

iv) Collect and record the data

This can be done by replaying the tape and start counting the traffic. To get a clear and better picture of the recorded traffic flow, a projector and a large display screen are used. Data collection form are a major component in controlling the quality of data, it was designed to meet the specific needs of the study and are intended to foster easy transfer of data in a consistent fashion. The data collection form is as shown in *Appendix II*. Certain items must be verified in this form such as the junction name, approach name, the time of the survey and then there is a column to fill the traffic volume for each turning for that specified approach.

During the traffic count, there are several assumptions are made:

- Do not count for motorcycle because the effect of the presence of motorcycle to junction performance is negligible as its only contributed 20% from total traffic flow.
- Do not consider the classification of vehicles (car and taxi, heavy goods vehicles, bus).
- Neglect U-turn movement.

3.2 Traffic Forecasting

Traffic Forecasting is done to forecast future volume of the junctions by using average annual growth. The value of average annual growth before the completion of Putrajaya in year 2012 will be taken from the percentage of completed development in the study year by taking 2005 as the base year. For traffic forecasting of year 2012, using the average annual growth of urban area in Malaysia

(3% to 6% p.a) based on the current volume. This forecasting is done for both junctions with and without ITACA System by using the formula below:-

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

With V = current traffic volume

r = traffic growth

n = number of forecast year

Taken r is the annual traffic growth of urban area in Malaysia is in the range of 3% to 6% p.a which we take the average of 5% while n would be number of forecast years taken as 7 years.

3.3 Traffic Analysis

Traffic Analysis is done using aaSIDRA software to determine Level of Service (LOS), Queue, Delay, Saturation, etc for both current and forecast traffic volumes. It is necessary to defined most of the variables for each lane group before proceed with the signalized intersection analysis. Table 3.1 summarizes all of the input data needed to conduct a full analysis of signalized intersection. By using aaSIDRA software, most of the variable's value is set as default value. However caution should be exercised in using these, as the accuracy of volume over capacity ratio (*v/c*), delay, and level of service predictions is influenced.

Table 3.1 : Data Requirements for Each Lane Group in Signalized Intersection Analysis

Type of Condition	Parameter
Geometric Conditions	Area Type (CBD, Other) Number of Lanes Average Lane Width Grade (%) Existence of LT or RT Lanes Length of Storage Bay for LT or RT Lane Parking Conditions (Yes/No)

Traffic Conditions	Demand Volume by Movement (veh/h) Base Saturation Flow Rate (pc/hg/ln) Peak Hour Factor Percent Heavy Vehicles (%) Pedestrian Flow in Conflicting Crosswalk (peds/h) Local Buses Stopping at Intersection (buses/h) Parking Activity (maneuvers/h) Arrival Type Proportion of Vehicles Arriving on Green Approach Speed (mi/h)
Signalization Conditions	Cycle Length (s) Green Time (s) Yellow Plus All-Red Interval (s) Type of Operation (Pretimed, Semi-Actuated, Full Actuated) Pedestrian Push Button Minimum Pedestrian Green (s) Phase Plan Analysis Period (h)

(Modofied from *Highway Capacity Manual,* 4th Edition, Transportation Research Board, National Research Council, Washington DC, 2000. Exhibit 16-3, pg. 16-3.)

CHAPTER 4
RESULT AND DISCUSSION

4.1 Survey Data

4.1.1 Reconnaissance Survey

The location for identified traffic light junction that operates under ITACA system is shown in Figure 4.1 below. There altogether 9 junctions (named Junction 1 (J1), Junction 2 (J2), Junction 3 (J3), Junction 4 (J4), Junction 8 (J8), Junction 9 (J9), Junction 10 (J10), Junction 11 (J11) and Junction 12 (J12)) located at Precinct 1 and Precinct 8.

But for this study, it was only considered for Intersection of Lebuh Perdana Barat with Persiaran R7B (Junction 3 (J3)) and Intersection of Lebuh Wawasan with Persiaran R7B (Junction 4 (J4)). As for junction at Cyberjaya, it was identified that Intersection between Persiaran Multimedia with Persiaran Apec (Junction 1C(J1C)) and Intersection of Persiaran Multimedia with Persiaran HSBC (Junction 2C(J2C)) has the similar junction configuration (Figure 4.6) and road hierarchy system (Table 4.1). As shown in Table 4.1, even the land use for both type of junction are different, it was assumed that this land use type will generate the same or almost the same amount of traffic. *Appendix I* lists the details and criteria of Road Hierarchy system.

Figure 4.1: Location of Traffic Light Junction with ITACA System

Figure 4.2: Intersection of Persiaran Multimedia with Persiaran Apec (Junction 1C)

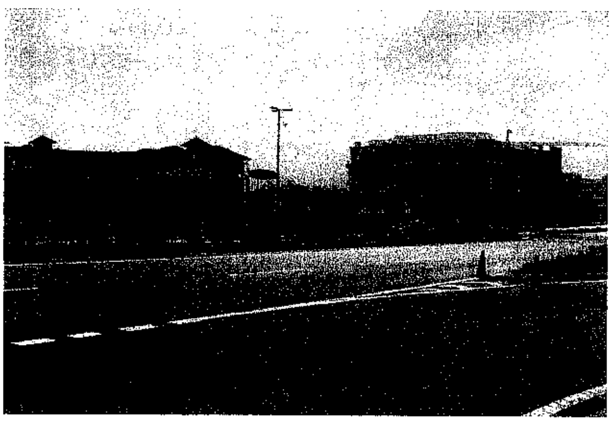


Figure 4.3: Intersection of Persiaran Multimedia with Persiaran HSBC (Junction 2C)

Figure 4.4: Intersection of Lebuh Perdana Barat with Persiaran R7B (Junction 3)

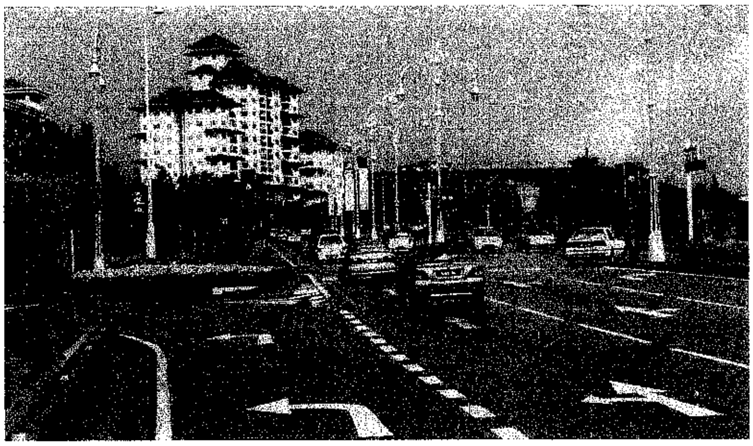


Figure 4.5: Intersection of Lebuh Wawasan with Persiaran R7B (Junction 4)

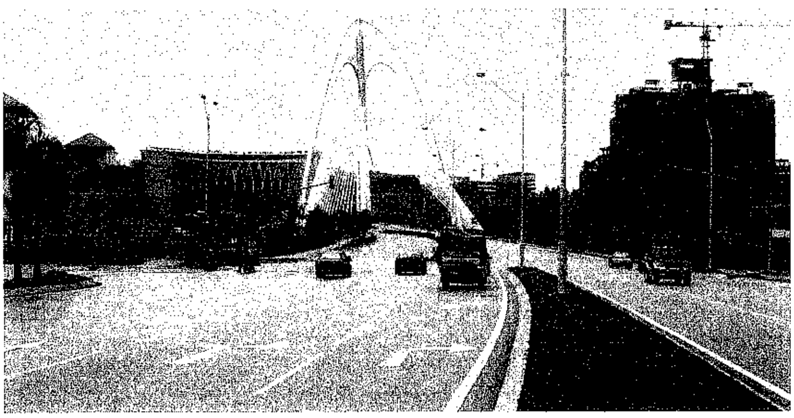
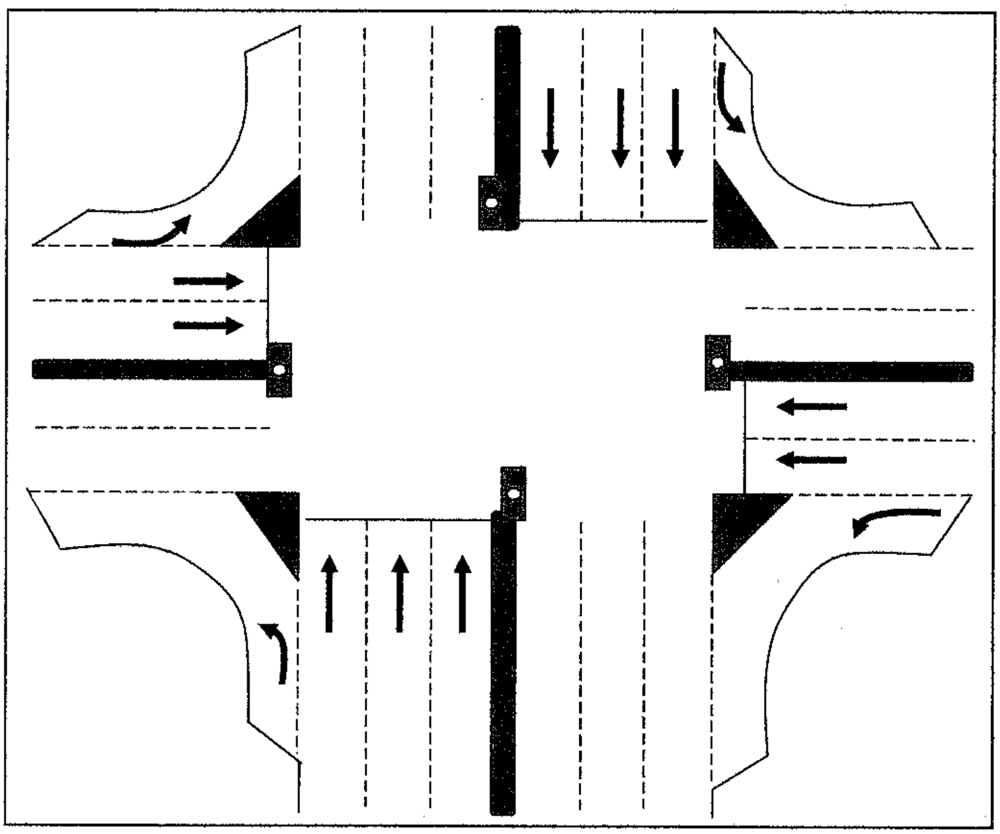


Table 4.1: Description of Junction with and without ITACA System

Junction	Approach	ITACA System	Road Hierarchy	Land Use
J1C	Persiaran Multimedia	No	Local Road (4 Lane)	Offices / Commercial
	Persiaran Apec		Spine Road (4 Lane)	
J2C	Persiaran Multimedia	No	Local Road (4 Lane)	Offices / Residential
	Persiaran HSBC		Spine Road (4 Lane)	
J3	Lebuh Perdana Barat	Yes	Local Road (4 Lane)	School / Residential
	Persiaran R7B		Spine Road (4 Lane)	
J4	Lebuh Wawasan	Yes	Local Road (4 Lane)	Residential
	Persiaran R7B		Spine Road (4 Lane)	

Figure 4.6: Junction Configuration for J1C, J2C, J3 and J4



It was also identified that, Intersection of Persiaran Multimedia with Persiaran Apec (Junction 1C) and Intersection of Persiaran Multimedia with Persiaran HSBC (Junction 2C) at Cyberjaya is pretimed traffic signal controls. As of Intersection of Lebuh Perdana Barat with Persiaran R7B (Junction 3 (J3)) and Intersection of Lebuh Wawasan with Persiaran R7B (Junction 4 (J4)) at Putrajaya has been identified as fully actuated traffic signal controls.

4.1.2 Intersection Turning Movement Count (ITMC) Survey

Data collected were recorded in the data collection form as shown in *Appendix II*, the example of data collection for Junction 2C (J2C). This data do not consider the vehicle classification.

Later, when the survey data are presented as Passenger Car Unit (PCU) it is assume that there are 5% of heavy goods vehicle and bus for traffic volume of each approach. Then, the 5% percent volume will convert to PCU using the passenger car equivalent factor as shown in Table 4.2 produce by Highway Planning Unit (HPU) and added to volume count.

Using the formula below and Table 4.2;

Traffic count (PCU) = [(Traffic count x 5%) x PCU Factor] + Traffic count

Table 4.2: Equivalent Passenger Car Value

VEHICLE TYPE	PASSENGER CAR EQUIVALENT
Car and Taxi	1.00
Heavy goods vehicle	2.25
Bus	2.25

The survey data in PCU for current and forecast traffic volume is shown in the Graphic Summary of Vehicle Movement in *Appendix III* and the summary of junction volume for comparison are listed in Table 4.3.

Table 4.3: Summary of Junction Volume

Junction	Current Volume (Year 2005) pcu/hr		Forecast Volume (Year 2012) pcu/hr	
	AM	PM	AM	PM
J1C	2521	1673	3558	2354
J2C	1681	1919	2371	2699
J3	1606	1434	2261	2018
J4	1538	1074	2165	1512

It was required to determine the comparison of the total junction volume for both junctions with and without implementation of ITACA system to have almost the same junction volume. This is to ensure that the traffic analysis done is valid and comparable for both junctions. Figure 4.7 and Figure 4.8 shows the histogram of volume comparison for year 2005 and 2012 respectively and it is shown that there's only a significant difference between J1C and J2C (without implementation of ITACA system at Cyberjaya) with J3 and J4 (with implementation of ITACA system at Putrajaya)

Figure 4.7: Total Junction Volume (Year 2005)

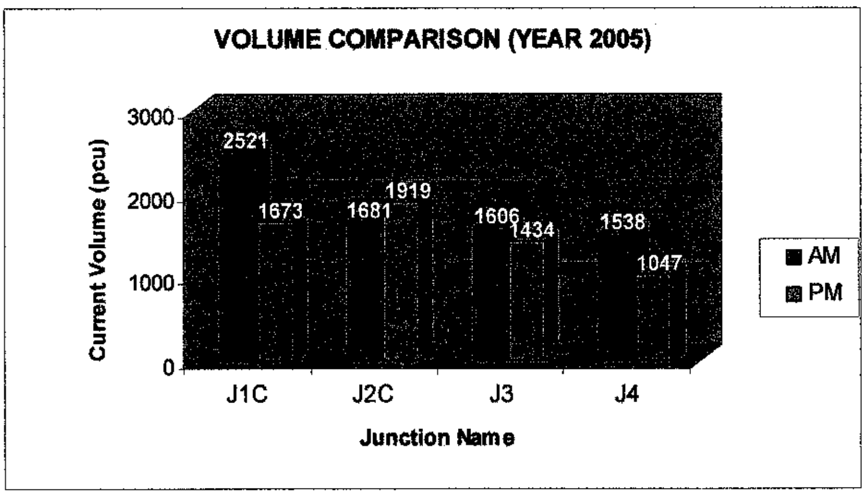
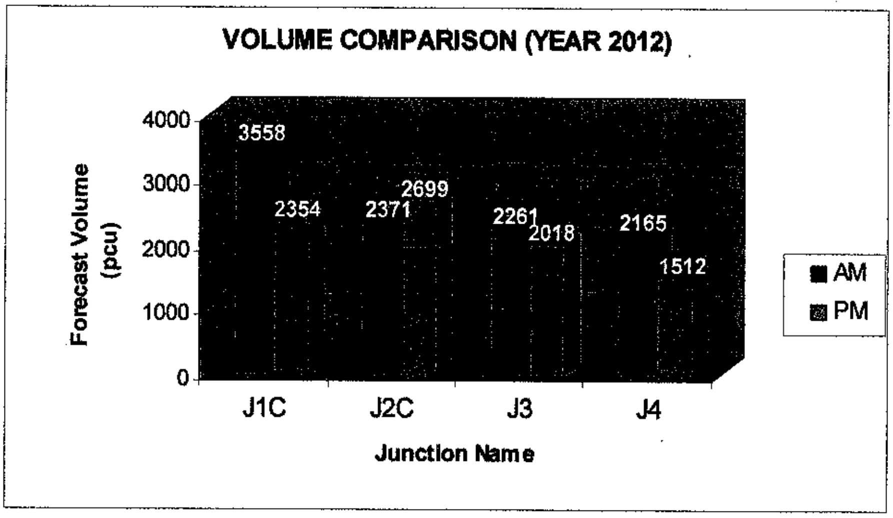


Figure 4.8: Total Junction Volume (Year 2012)



4.2 Result of Traffic Analysis

The result of traffic analysis done by running aaSIDRA software can be summarized in the Table 4.4 and Table 4.5 below. Parameters that are critical for the analysis of junction performance are control delay (s), queue length (m) and level of service (LOS). From this we can determine the effectiveness of junction with ITACA system (J3 and J4) by comparing with the junction without ITACA system (J1C and J2C). All the Intersection Summary results from the aaSIDRA software are listed in *Appendix IV*.

As shown in the Table 4.5, it is clearly shown that J3 and J4 has a better results for junction performance compared to J1C and J2C which both experienced the worst performance even in year 2005. In contrast, J3 and J4 have a better performance even in year 2012 (completion year of Putrajaya development). It can be said that this is prove the effectiveness of ITACA system in reducing traffic congestion and give better junction performance.

Table 4.4 : Summarized of Junctions Performance for AM and PM

INTERSECTION	2005						2012					
	Control Delay (s)		Queue (m)		LOS		Control Delay (s)		Queue (m)		LOS	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
J1C	36.1	25.7	377	81	D	C	262.4	37.9	2198	173	F	D
J2C	31.1	35.3	67	86	C	D	45.7	56.4	141	192	D	E
J3	19.7	23.2	44	59	B	C	21.6	24.4	68	82	C	C
J4	20.9	20.1	111	77	C	D	24.7	21.9	190	122	D	C

Table 4.5 : Overall Junctions Performance

INTERSECTION	2005			2012		
	Control Delay (s)	Queue (m)	LOS	Control Delay (s)	Queue (m)	LOS
J1C	36.1	377	D	262.4	2198	F
J2C	35.3	86	D	56.4	192	E
J3	23.2	59	C	24.4	82	C
J4	20.9	111	D	24.7	190	D

CHAPTER 5
CONCLUSION AND RECOMMENDATION

ITACA's operation is the core of the OPTIMUS Urban Traffic Control System. Basically it was supported with the Detectors (Loop Detectors), RMY traffic controllers, Master traffic controller, communication network (CMY or Putranet) and Application System (Control Center) which integrated to be the system architecture of ITACA.

This study is determined whether this system is able to reduce and minimize traffic congestion as well as fulfilling the objectives of the implementation of Area Traffic Control System (ATCS) at Putrajaya. So, traffic analysis exercise is to prove that this system is effective and able to reduce congestion level at Putrajaya upon its completion.

Before proceed with traffic analysis, traffic survey and analyses of the survey data was conducted. Survey include visited to the junctions that operate under ITACA system at Putrajaya and junctions that not operate under ITACA system at Cyberjaya which has been identified earlier. By conducting Intersection Turning Movement Count (ITMC) survey, it has determined the value of traffic flow for each direction of every approach.

The method use to determine the effectiveness of ITACA System was by comparison of analysis output using aaSIDRA Software between junctions that operates with and without ITACA based on current and forecast traffic flow. It was determined that junctions with ITACA system implementation (J3 and J4) have a better performance which also proved the effectiveness of the implemented system. Even by the completion year of Putrajaya development, year 2012 where traffic will increase and the implementation of ITACA system will be fully completed and utilized, the performance of both junction are still at the convenience level.

It is also recommend for Putrajaya Holding Berhad to implement ITACA system to other traffic light junction that has a potential of congestion to occur in Putrajaya area. Besides, as this system was proved able to reduce traffic congestion, it is also suitable to be implemented to other urban area in Malaysia.

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APPENDICES

APPENDIX I ROAD HIERARCHY SYSTEM

Table of Road Hierarchy (Function) Description:

Road Hierarchy (Function)	**Allowable/Estimated Speed (km/hr)**	**Road Capacity (pcu/hr/lane)**
Expressway, U6	100	1650
Primary Distributor, U5	80	1400
Secondary Distributor, U4	70	1260
Local Distributor, U3	50	1100
Spine Road, U2	40	1000
Local Road, U1	40	700
Access Road Not Cul-De-Sac	30	400
Boulevard U3/U2	50	1100

APPENDIX II

INTERSECTION TURNING MOVEMENT COUNT (ITMC) SURVEY FORM

INTERSECTION MOVEMENT SURVEY

(INTERSECTION COUNT)

Junction : ______________________________

Approach : ______________________________

Time : ______________________________

Left	Trough	Right
Total :	**Total :**	**Total :**

INTERSECTION MOVEMENT SURVEY
(INTERSECTION COUNT)

Junction : JUNCTION 2 (J2C) Time : 8.00AM - 9.00AM

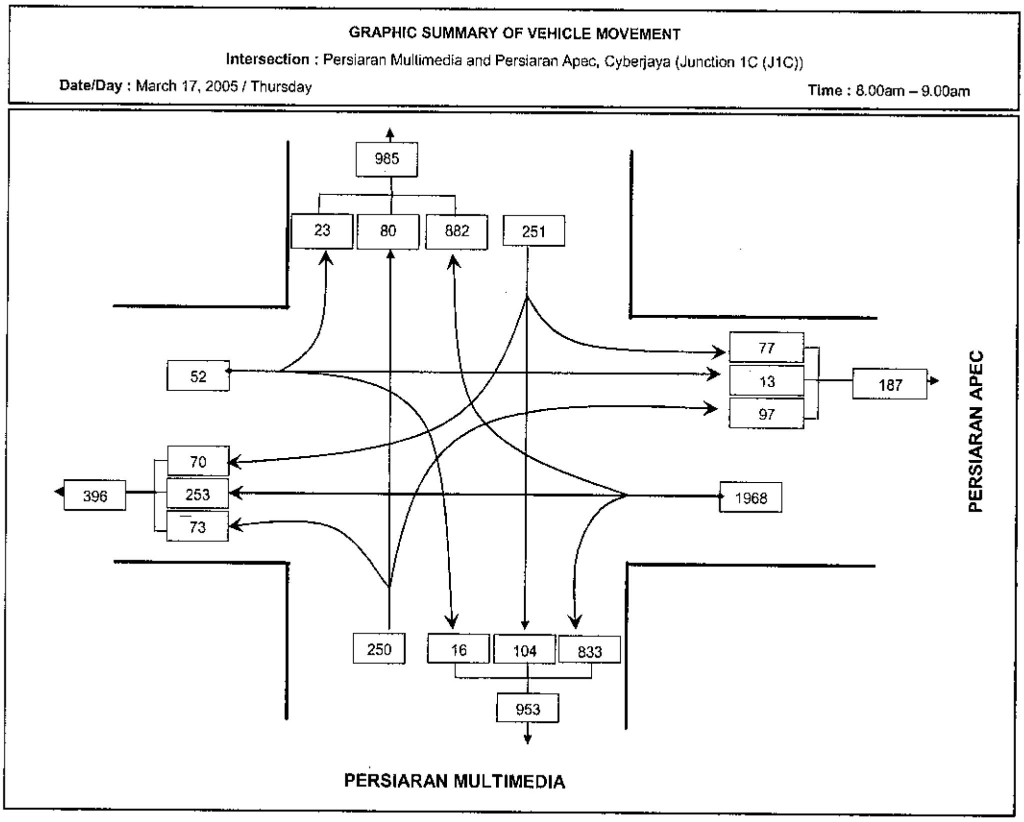
Approach : NORTHBOUND (PERSIARAN MULTIMEDIA)

Left	Trough	Right
1 1	5 8 3 9 4	3 1 2 1
1 1	4 12 4 11 1	2 3 2 6
1 1	5 1 10 9 4	1 4 2 4
1 1	1 8 9	1 2 4 2
1	6 2 4 3 1	2 2 2 4
1	2 8 4 4 5	1 2 4 4
1	11 1 12 9	1 2 2
1	3 1 1 10	3 4 2
1	3 1 8 1	1 2 3
1	3 1 6 11	1 4 3
1	11 1 11 12	2 2 4
1	5 1 2 7	5 2 5
1	1 2 5	5 2 2
1	4 1 10	3 3 1
1	6 6 5	2 3 2
1	6 9 6	2 4 2
1		5 2 5
2		1 2 4
Total : 23	**Total :** 370	**Total :** 118

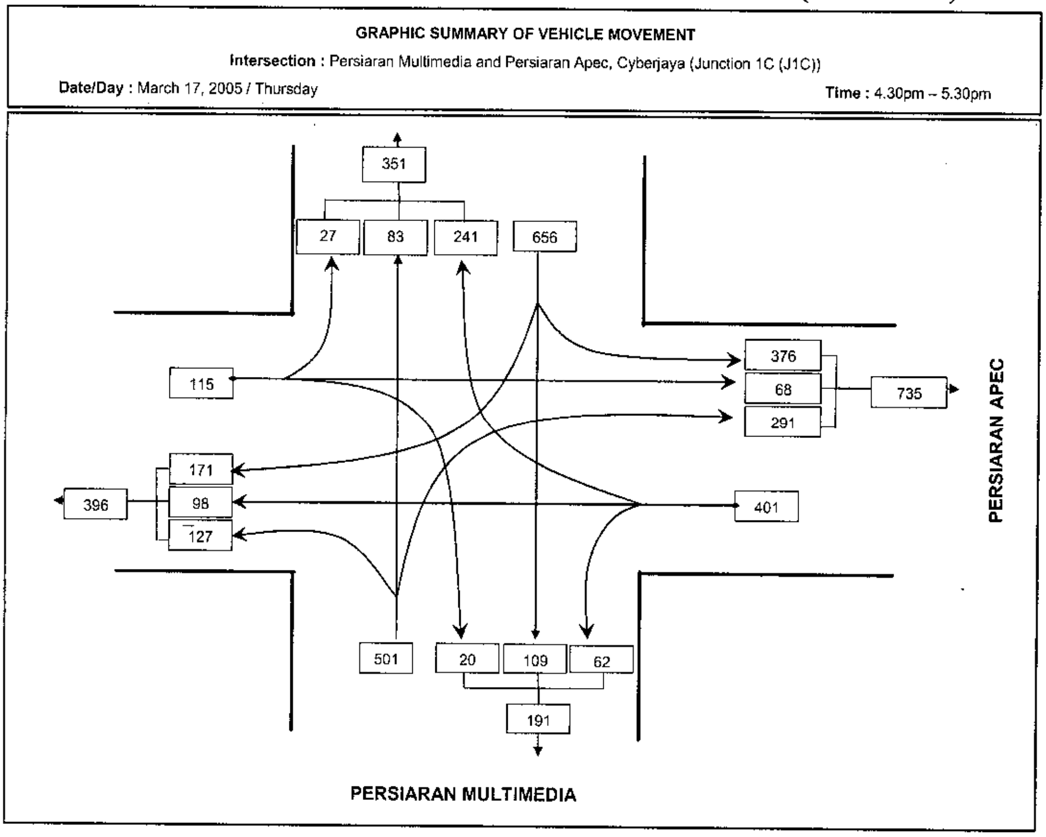
APPENDIX III

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

1. Graphic Summary of Vehicle Movement J1C – AM Peak (Year 2005)



2. Graphic Summary of Vehicle Movement J1C – PM Peak (Year 2005)

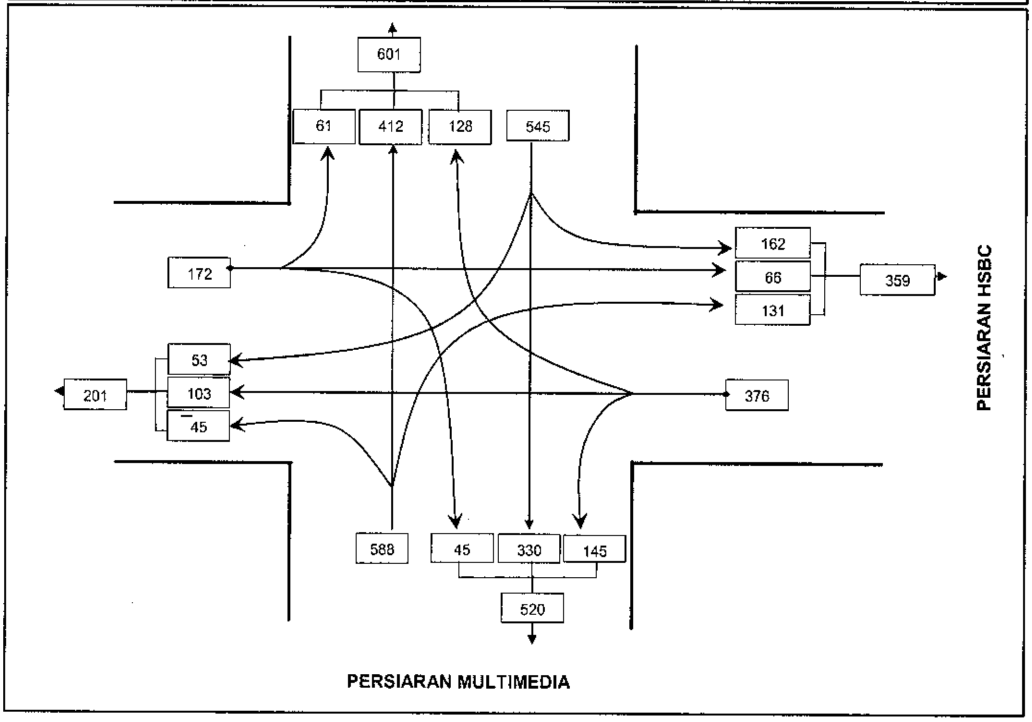


3. Graphic Summary of Vehicle Movement J2C – AM Peak (Year 2005)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Persiaran Multimedia and Persiaran HSBC, Cyberjaya (Junction 2C (J2C))

Date/Day : March 17, 2005 / Thursday **Time** : 8.00am – 9.00am

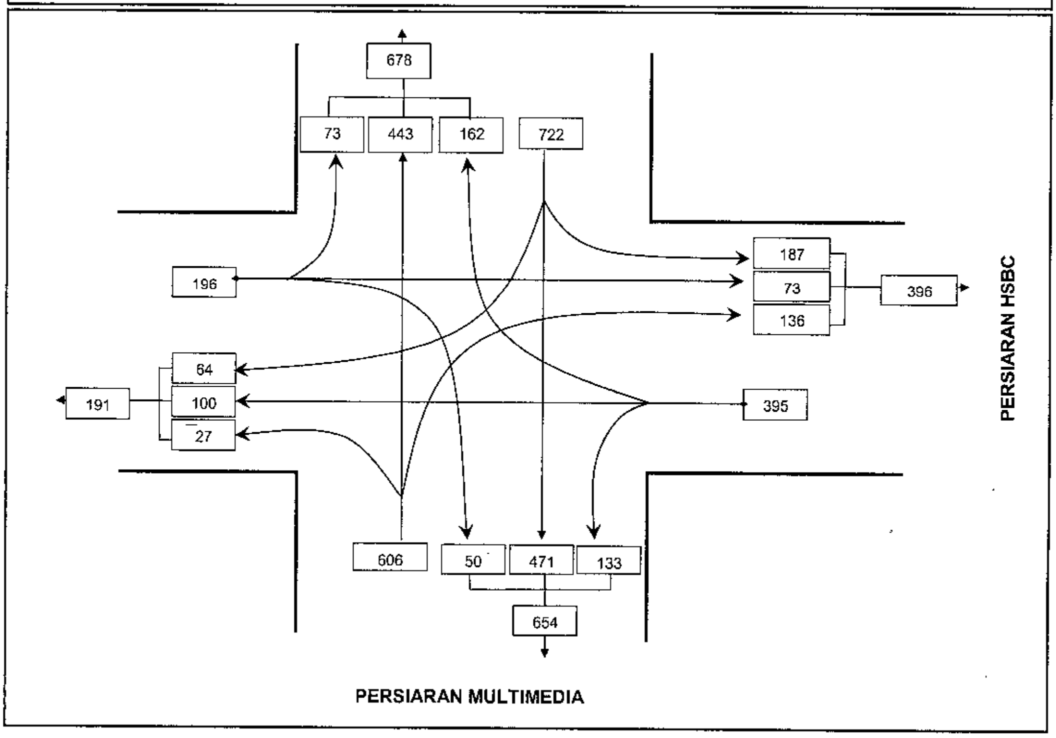


4. Graphic Summary of Vehicle Movement J2C – PM Peak (Year 2005)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Persiaran Multimedia and Persiaran HSBC, Cyberjaya (Junction 2C (J2C))

Date/Day : March 17, 2005 / Thursday **Time** : 4.30pm – 5.30pm

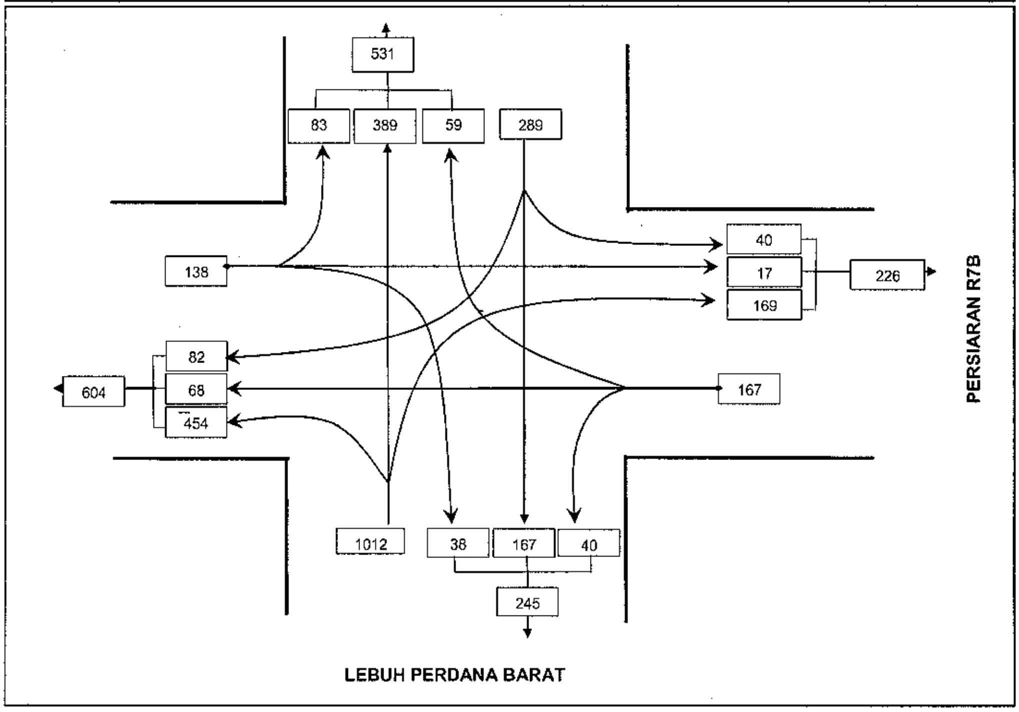


5. Graphic Summary of Vehicle Movement J3 – AM Peak (Year 2005)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Perdana Barat and Persiaran R7B, Putrajaya (Junction 3 (J3))

Date/Day : March 18, 2005 / Friday **Time :** 8.00am – 9.00am

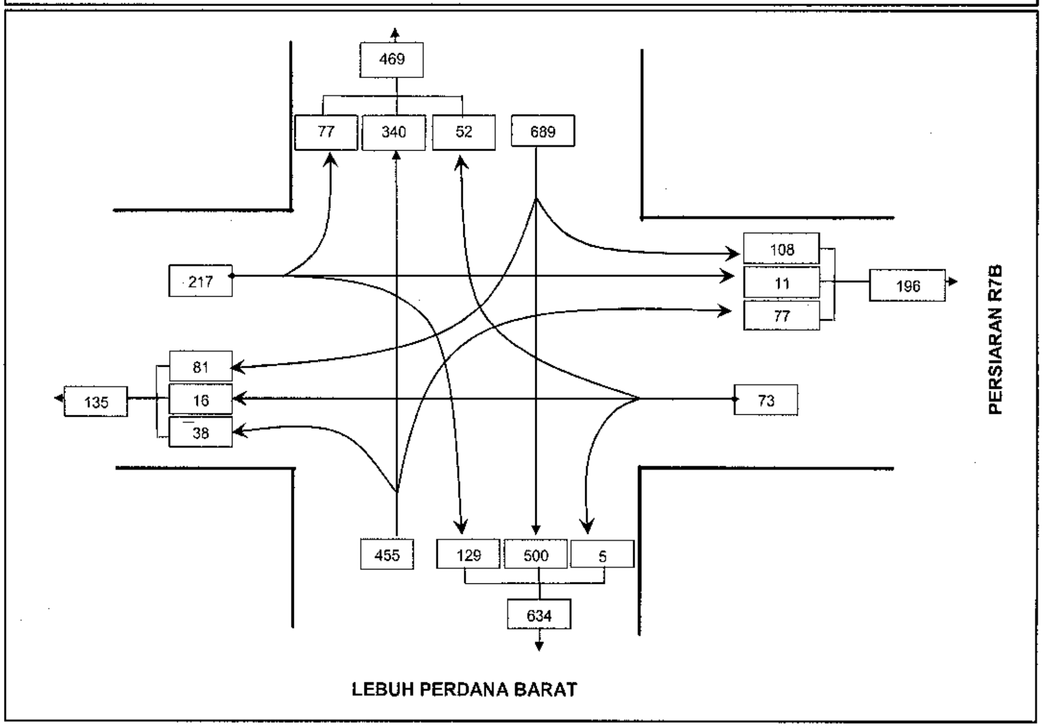


6. Graphic Summary of Vehicle Movement J3 – PM Peak (Year 2005)

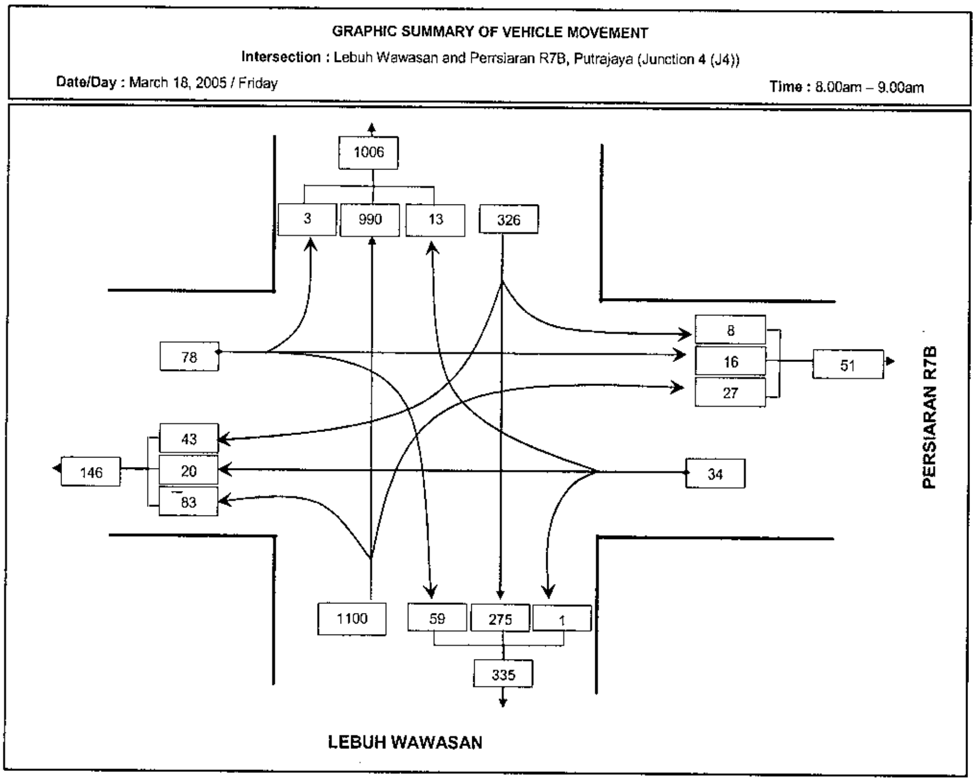
GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Perdana Barat and Persiaran R7B, Putrajaya (Junction 3 (J3))

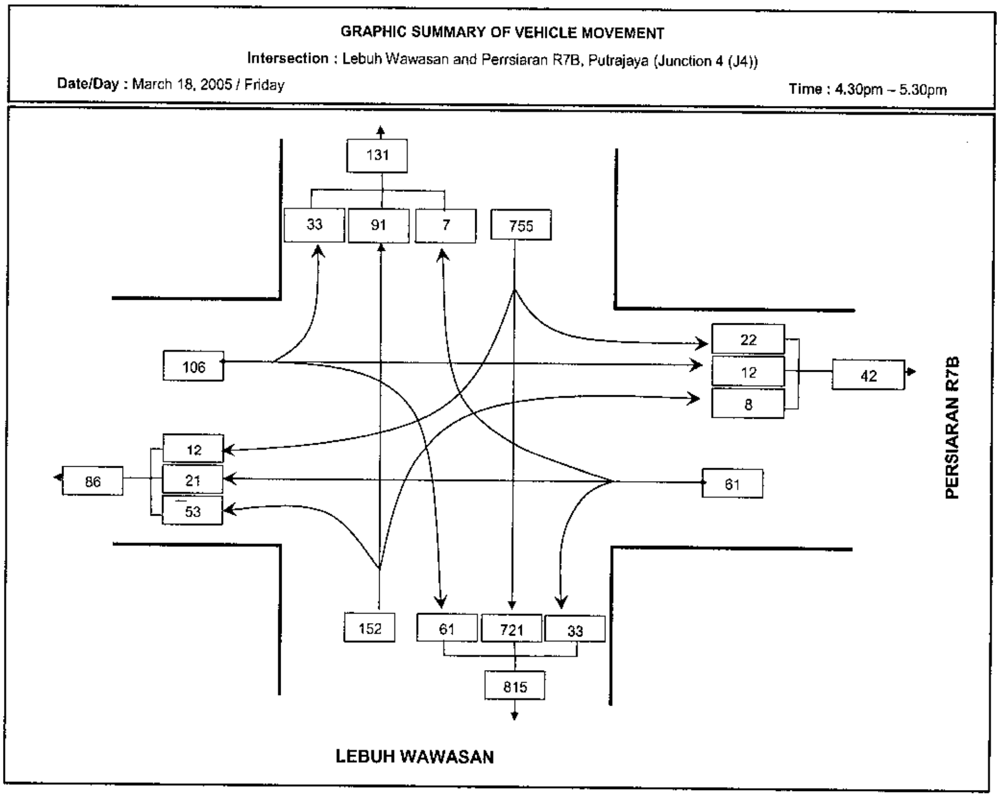
Date/Day : March 18, 2005 / Friday **Time :** 4.30pm – 5.30pm



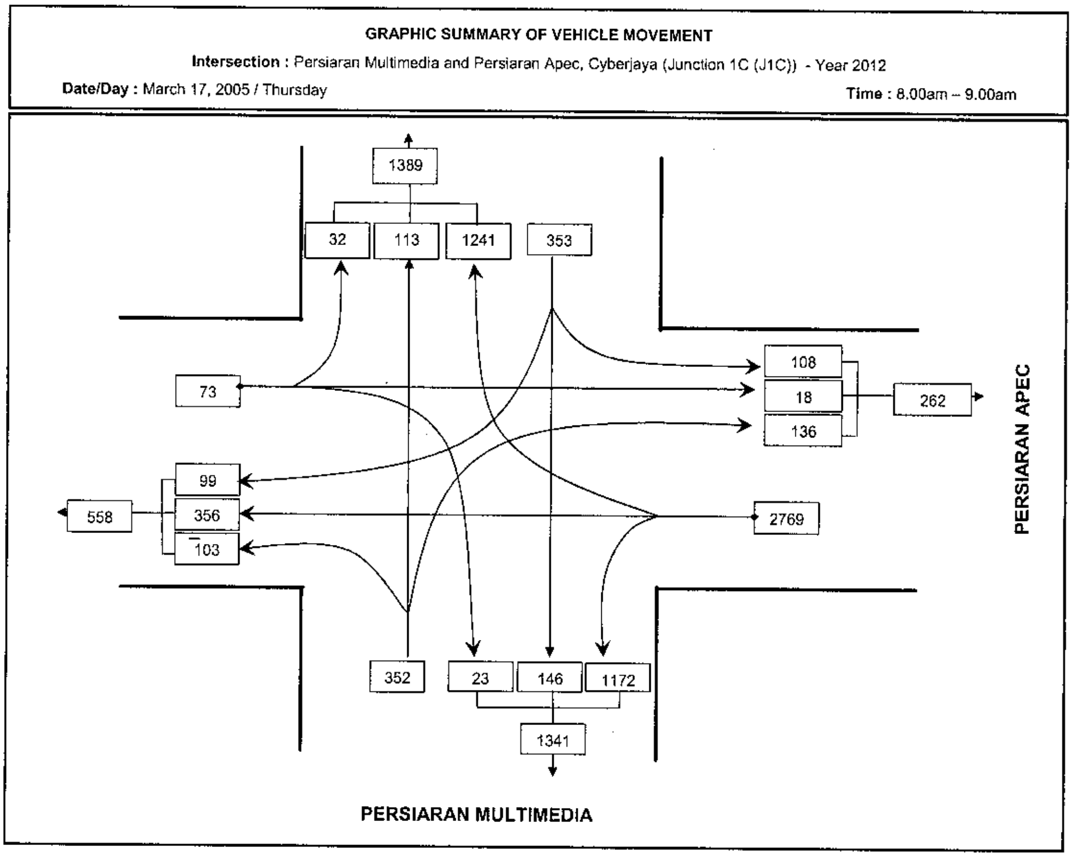
7. Graphic Summary of Vehicle Movement J4 – AM Peak (Year 2005)



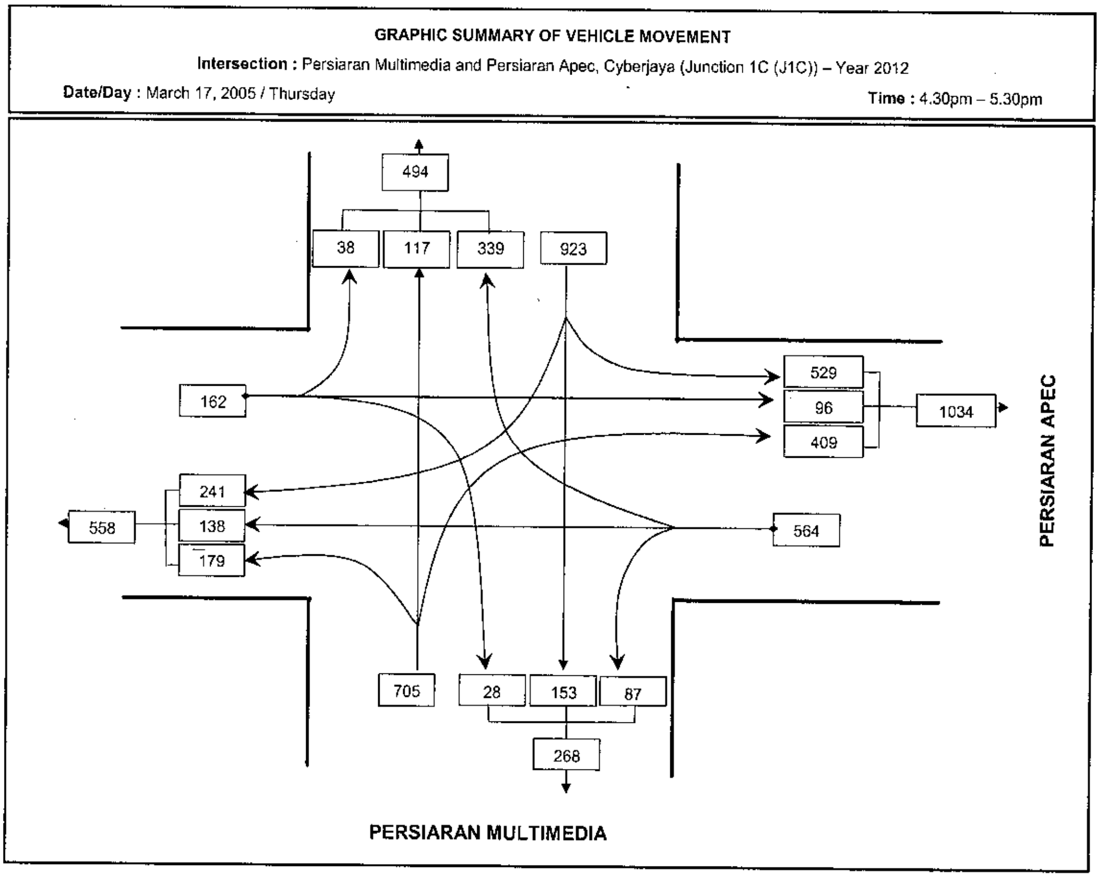
8. Graphic Summary of Vehicle Movement J4 – PM Peak (Year 2005)



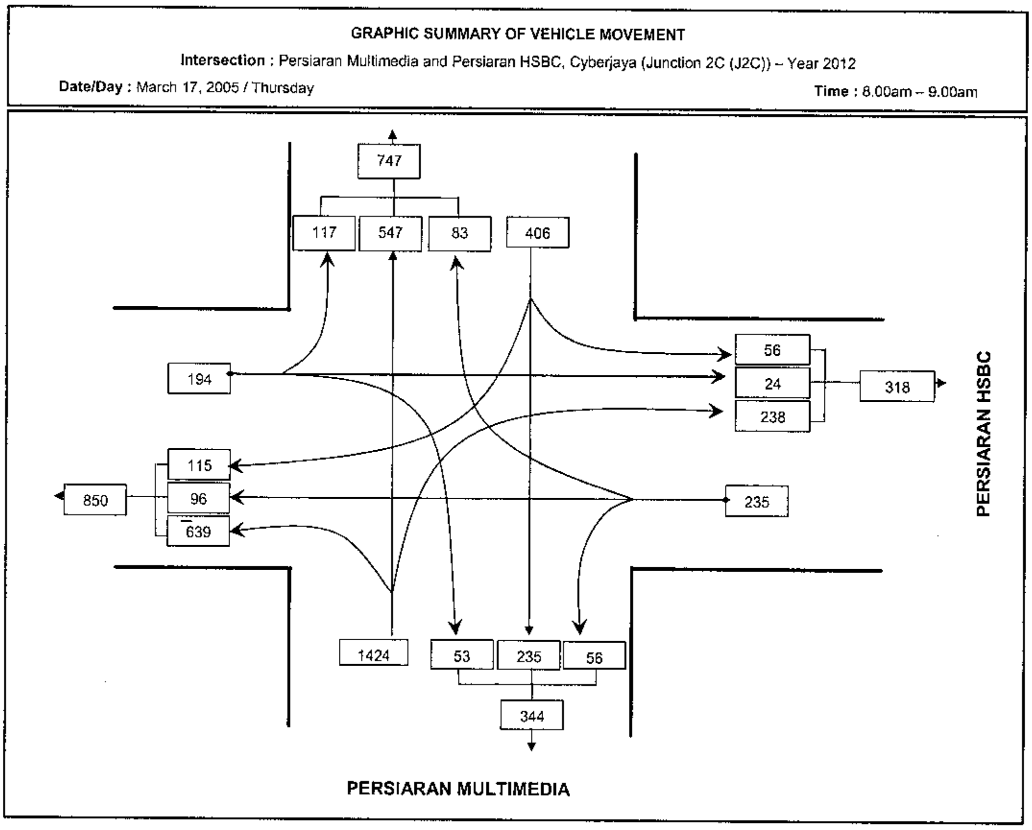
9. Graphic Summary of Vehicle Movement J1C – AM Peak (Year 2012)



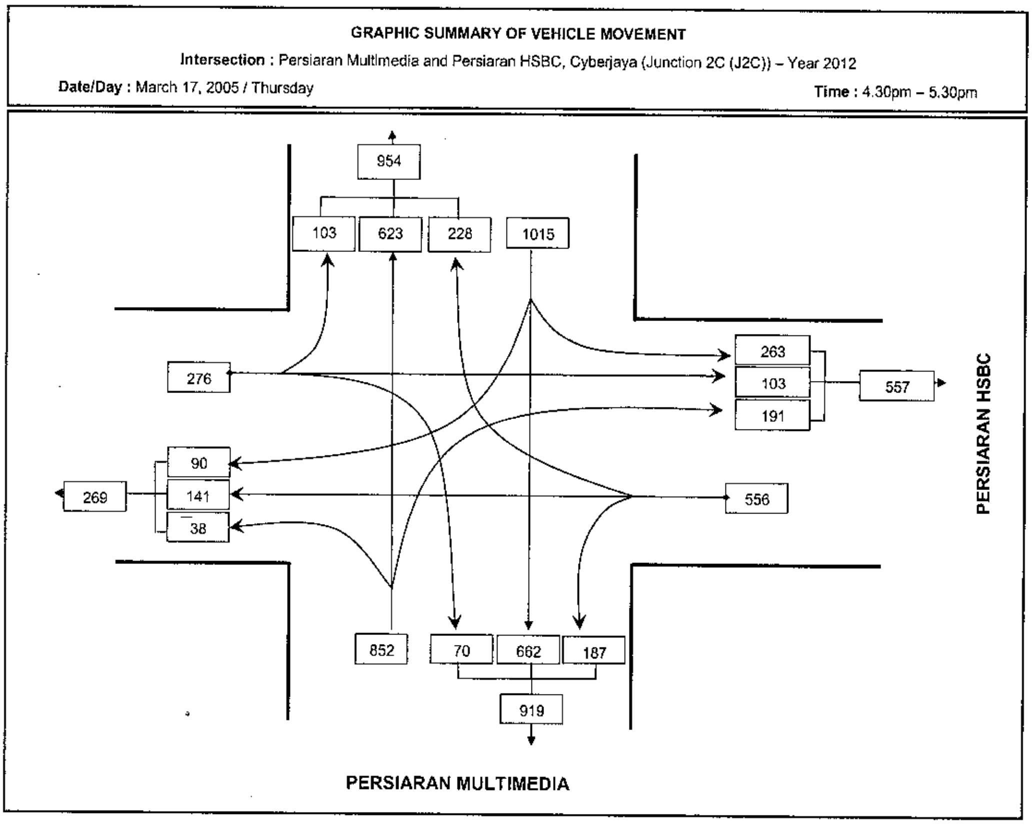
10. Graphic Summary of Vehicle Movement J1C – PM Peak (Year 2012)



11. Graphic Summary of Vehicle Movement J2C – AM Peak (Year 2012)



12. Graphic Summary of Vehicle Movement J2C – PM Peak (Year 2012)

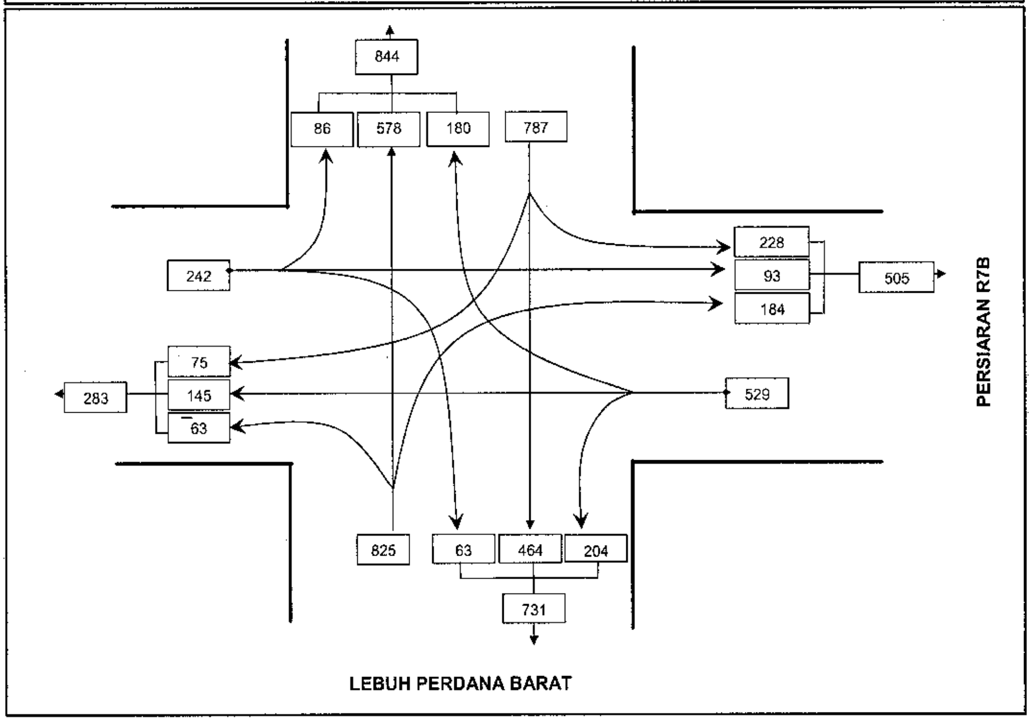


13. Graphic Summary of Vehicle Movement J3 – AM Peak (Year 2012)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Perdana Barat and Perrsiaran R7B, Putrajaya (Junction 3 (J3)) – Year 2012

Date/Day : March 18, 2005 / Friday **Time** : 8.00am – 9.00am

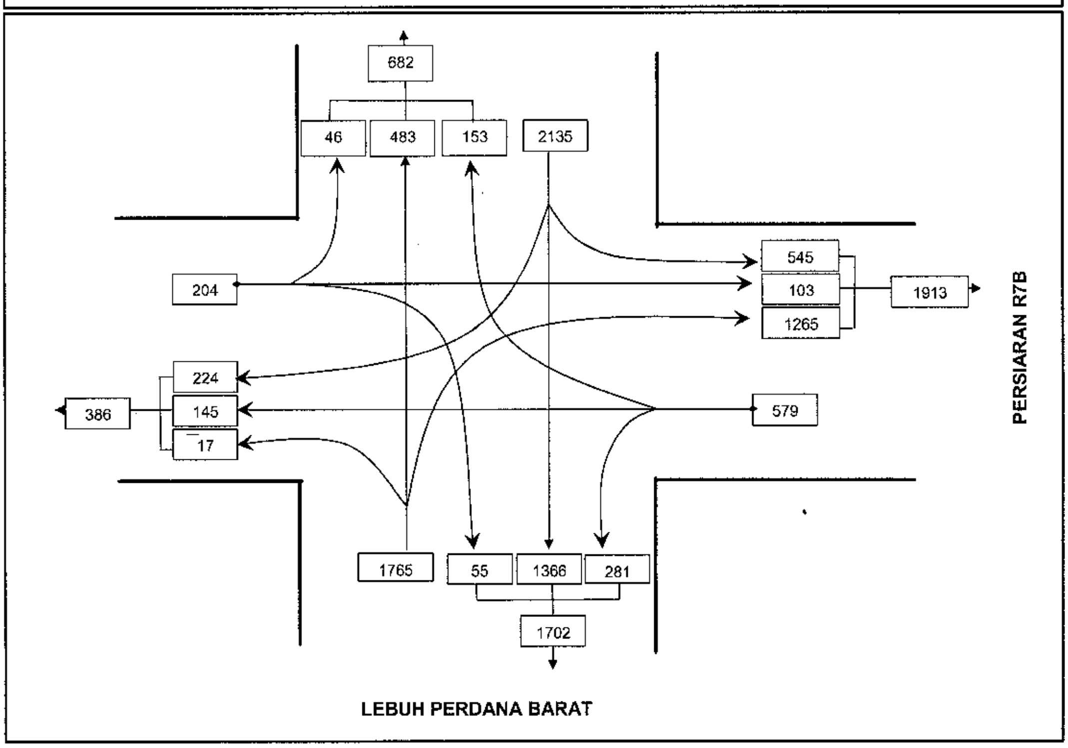


14. Graphic Summary of Vehicle Movement J3 – PM Peak (Year 2012)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Perdana Barat and Perrsiaran R7B, Putrajaya (Junction 3 (J3)) – Year 2012

Date/Day : March 18, 2005 / Friday **Time** : 4.30pm – 5.30pm

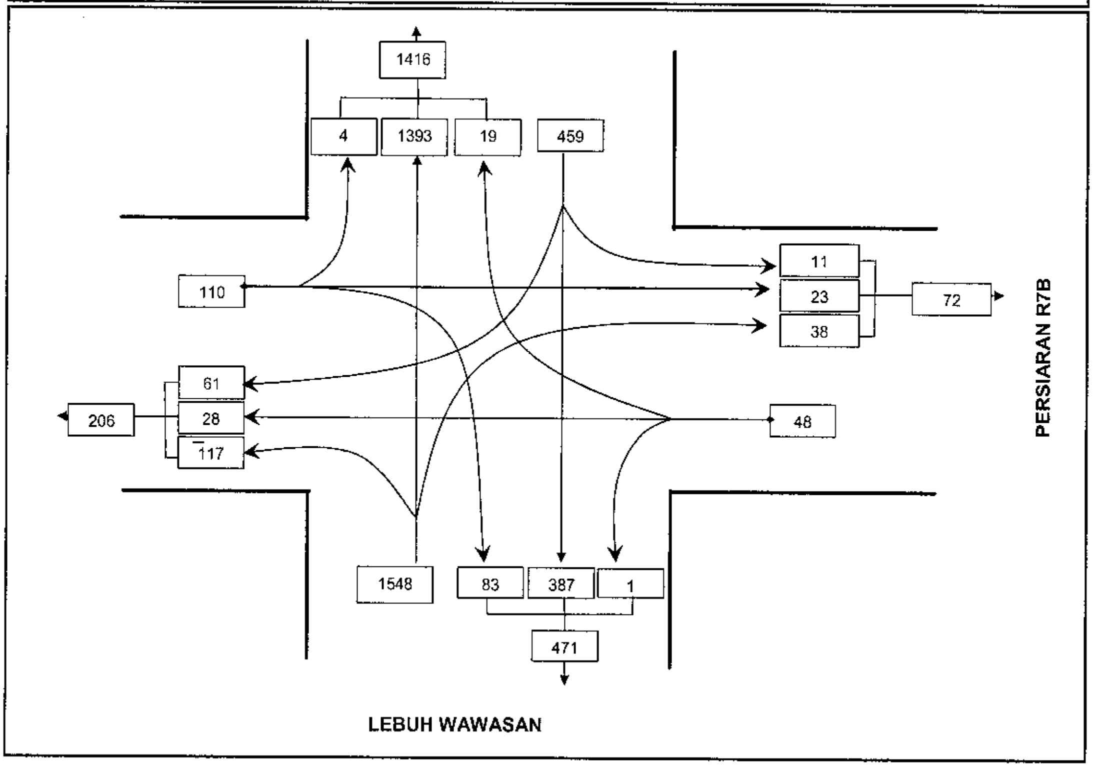


15. Graphic Summary of Vehicle Movement J4 – AM Peak (Year 2012)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Wawasan and Perrsiaran R7B, Putrajaya (Junction 4 (J4)) – Year 2012

Date/Day : March 18, 2005 / Friday   **Time** : 8.00am – 9.00am

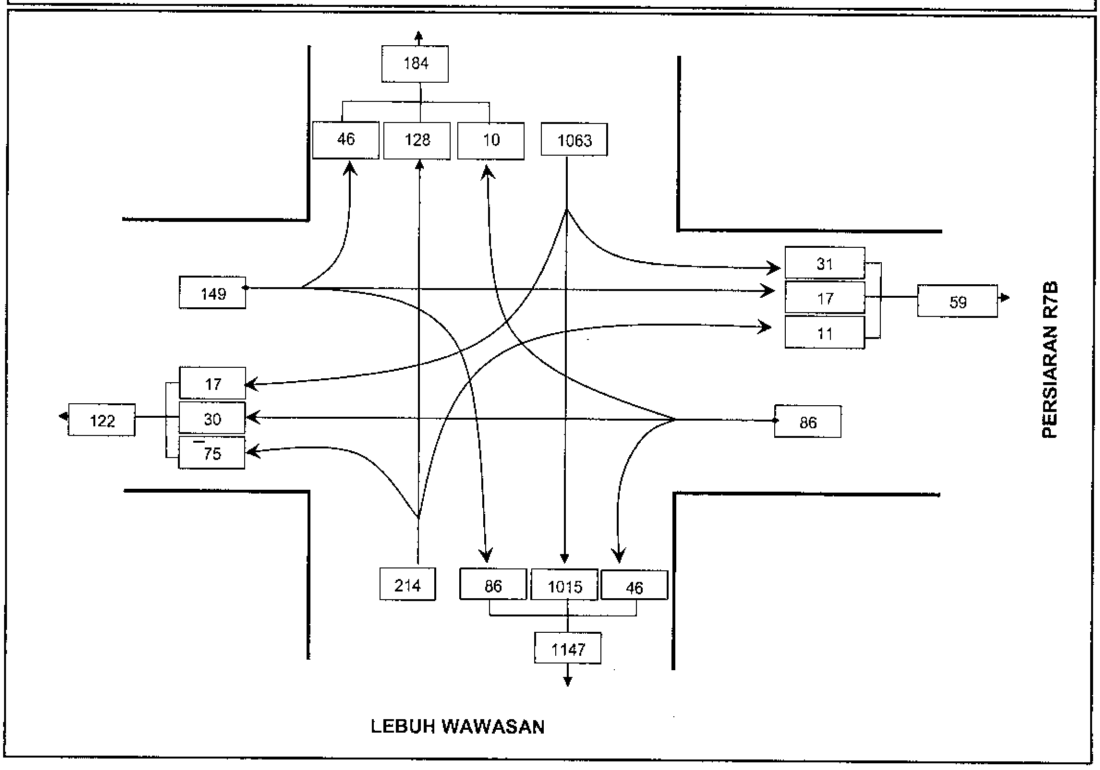


16. Graphic Summary of Vehicle Movement J4 – PM Peak (Year 2012)

GRAPHIC SUMMARY OF VEHICLE MOVEMENT

Intersection : Lebuh Wawasan and Perrsiaran R7B, Putrajaya (Junction 4 (J4)) - Year 2012

Date/Day : March 18, 2005 / Friday   **Time** : 4.30pm – 5.30pm



APPENDIX IV

INTERSECTION SUMMARY (aaSIDRA SOFTWARE OUTPUT)

Intersection Summary

aaTraffic SIDRA

J1C (AM Peak) Year 2005

Performance Measure	Vehicles	Persons
Demand Flow	2521 veh/h	3782 pers/h
Degree of Saturation	0.894	
Capacity (Total)	8146 veh/h	
95% Back of Queue (m)	377 m	
95% Back of Queue (veh)	53.9 veh	
Control Delay (Total)	25.28 veh-h/h	37.92 pers-h/h
Control Delay (Average)	36.1 s/veh	36.1 s/pers
Level of Service	LOS D	
Level of Service (Worst Movement)	LOS F	
Total Effective Stops	2103 veh/h	3154 pers/h
Effective Stop Rate	0.83 per veh	0.83 per pers
Travel Distance (Total)	1529.6 veh-km/h	2294.3 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	50.9 veh-h/h	76.3 pers-h/h
Travel Time (Average)	72.6 secs	72.6 secs
Travel Speed	30.1 km/h	30.1 km/h
Operating Cost (Total)	1260 $/h	1260 $/h
Fuel Consumption (Total)	198.3 L/h	
Carbon Dioxide (Total)	495.7 kg/h	
Hydrocarbons (Total)	0.905 kg/h	
Carbon Monoxide (Total)	38.48 kg/h	
NOX (Total)	1.111 kg/h	

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Intersection Summary

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aaTraffic SIDRA

J1C (PM Peak) Year 2005

Performance Measure	Vehicles	Persons
Demand Flow	1673 veh/h	2510 pers/h
Degree of Saturation	0.840	
Capacity (Total)	8285 veh/h	
95% Back of Queue (m)	81 m	
95% Back of Queue (veh)	11.6 veh	
Control Delay (Total)	11.95 veh-h/h	17.93 pers-h/h
Control Delay (Average)	25.7 s/veh	25.7 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1340 veh/h	2010 pers/h
Effective Stop Rate	0.80 per veh	0.80 per pers
Travel Distance (Total)	1014.9 veh-km/h	1522.3 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	28.9 veh-h/h	43.4 pers-h/h
Travel Time (Average)	62.2 secs	62.2 secs
Travel Speed	35.1 km/h	35.1 km/h
Operating Cost (Total)	716 $/h	716 $/h
Fuel Consumption (Total)	123.3 L/h	
Carbon Dioxide (Total)	308.2 kg/h	
Hydrocarbons (Total)	0.553 kg/h	
Carbon Monoxide (Total)	24.90 kg/h	
NOX (Total)	0.718 kg/h	

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Intersection Summary

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J2C (AM Peak) 2005

Performance Measure	Vehicles	Persons
Demand Flow	1681 veh/h	2522 pers/h
Degree of Saturation	0.489	
Capacity (Total)	9222 veh/h	
95% Back of Queue (m)	67 m	
95% Back of Queue (veh)	9.6 veh	
Control Delay (Total)	14.51 veh-h/h	21.76 pers-h/h
Control Delay (Average)	31.1 s/veh	31.1 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1214 veh/h	1821 pers/h
Effective Stop Rate	0.72 per veh	0.72 per pers
Travel Distance (Total)	1019.6 veh-km/h	1529.3 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	31.5 veh-h/h	47.3 pers-h/h
Travel Time (Average)	67.5 secs	67.5 secs
Travel Speed	32.3 km/h	32.3 km/h
Operating Cost (Total)	769 $/h	769 $/h
Fuel Consumption (Total)	134.2 L/h	
Carbon Dioxide (Total)	335.5 kg/h	
Hydrocarbons (Total)	0.554 kg/h	
Carbon Monoxide (Total)	25.58 kg/h	
NOX (Total)	0.818 kg/h	

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Intersection Summary

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aaTraffic SIDRA

J2C (PM Peak) 2005

Performance Measure	Vehicles	Persons
Demand Flow	1919 veh/h	2879 pers/h
Degree of Saturation	0.537	
Capacity (Total)	9330 veh/h	
95% Back of Queue (m)	86 m	
95% Back of Queue (veh)	12.3 veh	
Control Delay (Total)	18.84 veh-h/h	28.26 pers-h/h
Control Delay (Average)	35.3 s/veh	35.3 s/pers
Level of Service	LOS D	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1413 veh/h	2120 pers/h
Effective Stop Rate	0.74 per veh	0.74 per pers
Travel Distance (Total)	1163.8 veh-km/h	1745.7 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	38.3 veh-h/h	57.4 pers-h/h
Travel Time (Average)	71.8 secs	71.8 secs
Travel Speed	30.4 km/h	30.4 km/h
Operating Cost (Total)	929 $/h	929 $/h
Fuel Consumption (Total)	157.8 L/h	
Carbon Dioxide (Total)	394.5 kg/h	
Hydrocarbons (Total)	0.651 kg/h	
Carbon Monoxide (Total)	29.67 kg/h	
NOX (Total)	0.956 kg/h	

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Intersection Summary

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aaTraffic SIDRA

J3 (AM Peak) Year 2005

Performance Measure	Vehicles	Persons
Demand Flow	1606 veh/h	2409 pers/h
Degree of Saturation	0.662	
Capacity (Total)	8098 veh/h	
95% Back of Queue (m)	44 m	
95% Back of Queue (veh)	6.3 veh	
Control Delay (Total)	8.81 veh-h/h	13.21 pers-h/h
Control Delay (Average)	19.7 s/veh	19.7 s/pers
Level of Service	LOS B	
Level of Service (Worst Movement)	LOS C	
Total Effective Stops	1199 veh/h	1798 pers/h
Effective Stop Rate	0.75 per veh	0.75 per pers
Travel Distance (Total)	974.5 veh-km/h	1461.8 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	25.1 veh-h/h	37.7 pers-h/h
Travel Time (Average)	56.4 secs	56.4 secs
Travel Speed	38.8 km/h	38.8 km/h
Operating Cost (Total)	618 $/h	618 $/h
Fuel Consumption (Total)	113.1 L/h	
Carbon Dioxide (Total)	282.8 kg/h	
Hydrocarbons (Total)	0.500 kg/h	
Carbon Monoxide (Total)	23.19 kg/h	
NOX (Total)	0.673 kg/h	

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Intersection Summary

akcelik & associates
aaTraffic SIDRA

J3 (PM Peak) Year 2005

Performance Measure	Vehicles	Persons
Demand Flow	1434 veh/h	2151 pers/h
Degree of Saturation	0.792	
Capacity (Total)	8185 veh/h	
95% Back of Queue (m)	59 m	
95% Back of Queue (veh)	8.5 veh	
Control Delay (Total)	9.24 veh-h/h	13.87 pers-h/h
Control Delay (Average)	23.2 s/veh	23.2 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS C	
Total Effective Stops	1167 veh/h	1750 pers/h
Effective Stop Rate	0.81 per veh	0.81 per pers
Travel Distance (Total)	869.6 veh-km/h	1304.4 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	23.8 veh-h/h	35.7 pers-h/h
Travel Time (Average)	59.7 secs	59.7 secs
Travel Speed	36.6 km/h	36.6 km/h
Operating Cost (Total)	571 $/h	571 $/h
Fuel Consumption (Total)	103.5 L/h	
Carbon Dioxide (Total)	258.8 kg/h	
Hydrocarbons (Total)	0.459 kg/h	
Carbon Monoxide (Total)	21.37 kg/h	
NOX (Total)	0.616 kg/h	

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Intersection Summary

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J4 (AM Peak) 2005

Performance Measure	Vehicles	Persons
Demand Flow	1538 veh/h	2307 pers/h
Degree of Saturation	0.672	
Capacity (Total)	9478 veh/h	
95% Back of Queue (m)	111 m	
95% Back of Queue (veh)	15.8 veh	
Control Delay (Total)	8.95 veh-h/h	13.42 pers-h/h
Control Delay (Average)	20.9 s/veh	20.9 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1098 veh/h	1647 pers/h
Effective Stop Rate	0.71 per veh	0.71 per pers
Travel Distance (Total)	932.6 veh-km/h	1398.9 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	24.5 veh-h/h	36.7 pers-h/h
Travel Time (Average)	57.3 secs	57.3 secs
Travel Speed	38.1 km/h	38.1 km/h
Operating Cost (Total)	589 $/h	589 $/h
Fuel Consumption (Total)	113.5 L/h	
Carbon Dioxide (Total)	283.8 kg/h	
Hydrocarbons (Total)	0.455 kg/h	
Carbon Monoxide (Total)	21.98 kg/h	
NOX (Total)	0.713 kg/h	

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Intersection Summary

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J4 (PM Peak) 2005

Performance Measure	Vehicles	Persons
Demand Flow	1074 veh/h	1611 pers/h
Degree of Saturation	0.575	
Capacity (Total)	9336 veh/h	
95% Back of Queue (m)	77 m	
95% Back of Queue (veh)	11.0 veh	
Control Delay (Total)	6.00 veh-h/h	9.00 pers-h/h
Control Delay (Average)	20.1 s/veh	20.1 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	755 veh/h	1133 pers/h
Effective Stop Rate	0.70 per veh	0.70 per pers
Travel Distance (Total)	651.4 veh-km/h	977.2 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	16.9 veh-h/h	25.3 pers-h/h
Travel Time (Average)	56.6 secs	56.6 secs
Travel Speed	38.6 km/h	38.6 km/h
Operating Cost (Total)	416 $/h	416 $/h
Fuel Consumption (Total)	84.9 L/h	
Carbon Dioxide (Total)	212.2 kg/h	
Hydrocarbons (Total)	0.318 kg/h	
Carbon Monoxide (Total)	16.38 kg/h	
NOX (Total)	0.561 kg/h	

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Intersection Summary

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J1C (AM Peak) Year 2012

Performance Measure	Vehicles	Persons
Demand Flow	3558 veh/h	5337 pers/h
Degree of Saturation	1.247	
Capacity (Total)	7743 veh/h	
95% Back of Queue (m)	2198 m	
95% Back of Queue (veh)	314.0 veh	
Control Delay (Total)	259.32 veh-h/h	388.98 pers-h/h
Control Delay (Average)	262.4 s/veh	262.4 s/pers
Level of Service	LOS F	
Level of Service (Worst Movement)	LOS F	
Total Effective Stops	6673 veh/h	10010 pers/h
Effective Stop Rate	1.88 per veh	1.88 per pers
Travel Distance (Total)	2158.7 veh-km/h	3238.1 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	295.5 veh-h/h	443.2 pers-h/h
Travel Time (Average)	299.0 secs	299.0 secs
Travel Speed	7.3 km/h	7.3 km/h
Operating Cost (Total)	7297 $/h	7297 $/h
Fuel Consumption (Total)	724.2 L/h	
Carbon Dioxide (Total)	1810.4 kg/h	
Hydrocarbons (Total)	3.740 kg/h	
Carbon Monoxide (Total)	108.31 kg/h	
NOX (Total)	3.059 kg/h	

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Intersection Summary

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J1C (PM Peak) Year 2012

Performance Measure	Vehicles	Persons
Demand Flow	2354 veh/h	3531 pers/h
Degree of Saturation	0.898	
Capacity (Total)	8227 veh/h	
95% Back of Queue (m)	173 m	
95% Back of Queue (veh)	24.7 veh	
Control Delay (Total)	24.80 veh-h/h	37.20 pers-h/h
Control Delay (Average)	37.9 s/veh	37.9 s/pers
Level of Service	LOS D	
Level of Service (Worst Movement)	LOS E	
Total Effective Stops	2011 veh/h	3016 pers/h
Effective Stop Rate	0.85 per veh	0.85 per pers
Travel Distance (Total)	1428.0 veh-km/h	2142.0 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	48.6 veh-h/h	73.0 pers-h/h
Travel Time (Average)	74.4 secs	74.4 secs
Travel Speed	29.4 km/h	29.4 km/h
Operating Cost (Total)	1196 $/h	1196 $/h
Fuel Consumption (Total)	186.8 L/h	
Carbon Dioxide (Total)	466.9 kg/h	
Hydrocarbons (Total)	0.855 kg/h	
Carbon Monoxide (Total)	36.27 kg/h	
NOX (Total)	1.044 kg/h	

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Intersection Summary

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J2C (AM Peak) 2012

Performance Measure	Vehicles	Persons
Demand Flow	2371 veh/h	3557 pers/h
Degree of Saturation	0.645	
Capacity (Total)	9548 veh/h	
95% Back of Queue (m)	141 m	
95% Back of Queue (veh)	20.2 veh	
Control Delay (Total)	30.08 veh-h/h	45.13 pers-h/h
Control Delay (Average)	45.7 s/veh	45.7 s/pers
Level of Service	LOS D	
Level of Service (Worst Movement)	LOS E	
Total Effective Stops	1781 veh/h	2672 pers/h
Effective Stop Rate	0.75 per veh	0.75 per pers
Travel Distance (Total)	1438.1 veh-km/h	2157.1 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	54.1 veh-h/h	81.1 pers-h/h
Travel Time (Average)	82.1 secs	82.1 secs
Travel Speed	26.6 km/h	26.6 km/h
Operating Cost (Total)	1300 $/h	1300 $/h
Fuel Consumption (Total)	202.8 L/h	
Carbon Dioxide (Total)	507.1 kg/h	
Hydrocarbons (Total)	0.862 kg/h	
Carbon Monoxide (Total)	36.88 kg/h	
NOX (Total)	1.179 kg/h	

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Intersection Summary

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J2C (PM Peak) 2012

Performance Measure	Vehicles	Persons
Demand Flow	2699 veh/h	4049 pers/h
Degree of Saturation	0.693	
Capacity (Total)	9659 veh/h	
95% Back of Queue (m)	192 m	
95% Back of Queue (veh)	27.4 veh	
Control Delay (Total)	42.27 veh-h/h	63.41 pers-h/h
Control Delay (Average)	56.4 s/veh	56.4 s/pers
Level of Service	LOS E	
Level of Service (Worst Movement)	LOS E	
Total Effective Stops	2078 veh/h	3117 pers/h
Effective Stop Rate	0.77 per veh	0.77 per pers
Travel Distance (Total)	1636.8 veh-km/h	2455.3 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	69.6 veh-h/h	104.3 pers-h/h
Travel Time (Average)	92.8 secs	92.8 secs
Travel Speed	23.5 km/h	23.5 km/h
Operating Cost (Total)	1658 $/h	1658 $/h
Fuel Consumption (Total)	243.9 L/h	
Carbon Dioxide (Total)	609.8 kg/h	
Hydrocarbons (Total)	1.047 kg/h	
Carbon Monoxide (Total)	42.96 kg/h	
NOX (Total)	1.385 kg/h	

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Intersection Summary

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J3 (AM Peak) Year 2012

Performance Measure	Vehicles	Persons
Demand Flow	2261 veh/h	3392 pers/h
Degree of Saturation	0.693	
Capacity (Total)	8494 veh/h	
95% Back of Queue (m)	68 m	
95% Back of Queue (veh)	9.7 veh	
Control Delay (Total)	13.55 veh-h/h	20.33 pers-h/h
Control Delay (Average)	21.6 s/veh	21.6 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1738 veh/h	2608 pers/h
Effective Stop Rate	0.77 per veh	0.77 per pers
Travel Distance (Total)	1372.0 veh-km/h	2058.0 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	36.5 veh-h/h	54.8 pers-h/h
Travel Time (Average)	58.2 secs	58.2 secs
Travel Speed	37.5 km/h	37.5 km/h
Operating Cost (Total)	897 $/h	897 $/h
Fuel Consumption (Total)	161.0 L/h	
Carbon Dioxide (Total)	402.6 kg/h	
Hydrocarbons (Total)	0.714 kg/h	
Carbon Monoxide (Total)	32.79 kg/h	
NOX (Total)	0.951 kg/h	

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Intersection Summary

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J3 (PM Peak) Year 2012

Performance Measure	Vehicles	Persons
Demand Flow	2018 veh/h	3027 pers/h
Degree of Saturation	0.713	
Capacity (Total)	8677 veh/h	
95% Back of Queue (m)	82 m	
95% Back of Queue (veh)	11.7 veh	
Control Delay (Total)	13.68 veh-h/h	20.51 pers-h/h
Control Delay (Average)	24.4 s/veh	24.4 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1598 veh/h	2397 pers/h
Effective Stop Rate	0.79 per veh	0.79 per pers
Travel Distance (Total)	1223.5 veh-km/h	1835.2 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	34.1 veh-h/h	51.2 pers-h/h
Travel Time (Average)	60.8 secs	60.8 secs
Travel Speed	35.9 km/h	35.9 km/h
Operating Cost (Total)	817 $/h	817 $/h
Fuel Consumption (Total)	145.3 L/h	
Carbon Dioxide (Total)	363.1 kg/h	
Hydrocarbons (Total)	0.645 kg/h	
Carbon Monoxide (Total)	29.48 kg/h	
NOX (Total)	0.856 kg/h	

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Intersection Summary

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J4 (AM Peak) 2012

Performance Measure	Vehicles	Persons
Demand Flow	2165 veh/h	3248 pers/h
Degree of Saturation	0.841	
Capacity (Total)	9749 veh/h	
95% Back of Queue (m)	190 m	
95% Back of Queue (veh)	27.2 veh	
Control Delay (Total)	14.86 veh-h/h	22.29 pers-h/h
Control Delay (Average)	24.7 s/veh	24.7 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1683 veh/h	2525 pers/h
Effective Stop Rate	0.78 per veh	0.78 per pers
Travel Distance (Total)	1312.8 veh-km/h	1969.2 pers-km/h
Travel Distance (Average)	606 m	606 m
Travel Time (Total)	36.7 veh-h/h	55.1 pers-h/h
Travel Time (Average)	61.1 secs	61.1 secs
Travel Speed	35.7 km/h	35.7 km/h
Operating Cost (Total)	879 $/h	879 $/h
Fuel Consumption (Total)	165.2 L/h	
Carbon Dioxide (Total)	412.9 kg/h	
Hydrocarbons (Total)	0.671 kg/h	
Carbon Monoxide (Total)	32.25 kg/h	
NOX (Total)	1.032 kg/h	

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Intersection Summary

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J4 (PM Peak) 2012

Performance Measure	Vehicles	Persons
Demand Flow	1512 veh/h	2268 pers/h
Degree of Saturation	0.713	
Capacity (Total)	9592 veh/h	
95% Back of Queue (m)	122 m	
95% Back of Queue (veh)	17.4 veh	
Control Delay (Total)	9.18 veh-h/h	13.78 pers-h/h
Control Delay (Average)	21.9 s/veh	21.9 s/pers
Level of Service	LOS C	
Level of Service (Worst Movement)	LOS D	
Total Effective Stops	1115 veh/h	1673 pers/h
Effective Stop Rate	0.74 per veh	0.74 per pers
Travel Distance (Total)	917.1 veh-km/h	1375.7 pers-km/h
Travel Distance (Average)	607 m	607 m
Travel Time (Total)	24.5 veh-h/h	36.7 pers-h/h
Travel Time (Average)	58.3 secs	58.3 secs
Travel Speed	37.5 km/h	37.5 km/h
Operating Cost (Total)	601 $/h	601 $/h
Fuel Consumption (Total)	121.0 L/h	
Carbon Dioxide (Total)	302.4 kg/h	
Hydrocarbons (Total)	0.457 kg/h	
Carbon Monoxide (Total)	23.43 kg/h	
NOX (Total)	0.797 kg/h	

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