DYNAMIC TRAFFIC LIGHT FLOW CONTROL SYSTEM USING ON-ROAD SENSOR TECHNOLOGY

MOHAMED IRFAN

FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY
UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

DYNAMIC TRAFFIC LIGHT FLOW CONTROL SYSTEM USING ON-ROAD SENSOR TECHNOLOGY

MOHAMED IRFAN

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF COMPUTER SCIENCE

2017

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Mohamed Irfan

Registration/Matric No: WGA120051

Name of Degree: Master of Computer Science

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

Dynamic Traffic Light Flow Control System using On-Road Sensor Technology

Field of Study: Sensors

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;

(2) This Work is original;

(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;

(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;

(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;

(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate"s Signature Date: 20 March 2017

Subscribed and solemnly declared before,

Witness"s Signature Date: 20 March 2017

Name:

Designation:

ABSTRACT

The increasing number of vehicular traffic around the world has resulted in congestion, especially in large urban areas. This has become a major concern among transportation specialists & related decision makers. Traffic congestion at cross-roads is a huge problem since precious time and resources are wasted when vehicles have to wait in the queue for a long period of time. The most common traffic light systems that are currently installed have a fixed time interval for changing the signals. These systems remain this way until further resetting is done to change the signal time. The timing of these standard traffic light systems are based on their default setup which basically considers normal traffic flow. The existing methods and proposed methods for intelligent traffic management and control are not adequately efficient in terms of performance and decision making. In this research, a system is proposed that utilizes and manages traffic light controllers; more specifically an algorithm is presented which dynamically changes the traffic control system based on the vehicular flow data generated by on-road sensor technology. The sensors are used as a tool to measure the volume of vehicles, while a dynamic traffic controller is developed to control the operation of the traffic light system which is supported by these sensors. The controller uses Traffic Light Signal Manipulation Algorithm (TLSMA) to dynamically change in the traffic signals by using the data generated by the sensors. Simulation has been carried out using SUMO to solve traffic congestion by measuring the average speed and the vehicular flow on a single intersection.

ABSTRAK

Peningkatan jumlah lalu lintas kenderaan di seluruh dunia telah menyebabkan kesesakan, terutama di kawasan bandar besar. Ini telah menjadi kebimbangan utama di kalangan pakar pengangkutan & pembuat keputusan yang berkaitan. kesesakan lalu lintas di persimpangan jalan adalah satu masalah yang besar kerana masa berharga dan sumber-sumber yang sia-sia apabila kenderaan perlu menunggu dalam barisan untuk tempoh masa yang panjang. Sistem lampu isyarat yang paling biasa yang kini dipasang mempunyai selang masa yang tetap untuk menukar isyarat. Sistem ini kekal dengan cara ini sehingga terpasang semula lanjut dilakukan untuk menukar masa isyarat. Masa ini sistem lampu isyarat standard adalah berdasarkan kepada persediaan lalai mereka yang pada asasnya menganggap aliran trafik normal. Kaedah-kaedah yang sedia ada dan kaedah yang dicadangkan untuk pengurusan trafik pintar dan kawalan tidak cukup cekap dari segi prestasi dan membuat keputusan. Dalam kajian ini, kami mencadangkan satu sistem yang menggunakan dan menguruskan pengawal lampu isyarat, lebih khusus kami membentangkan satu algoritma yang dinamik berubah sistem kawalan lalu lintas berdasarkan data aliran kenderaan yang dihasilkan oleh teknologi sensor di jalan. Sensor yang digunakan sebagai alat untuk mengukur jumlah kenderaan, manakala pengawal trafik dinamik dibangunkan untuk mengawal operasi sistem lampu isyarat yang disokong oleh sensor. Pengawal ini menggunakan Traffic Light Signal Manipulasi Algoritma (TLSMA) untuk secara dinamik berubah dalam isyarat lalu lintas dengan menggunakan data yang dihasilkan oleh sensor. Simulasi telah dijalankan menggunakan SUMO untuk menyelesaikan masalah kesesakan lalu lintas dengan mengukur kelajuan purata dan aliran kenderaan di persimpangan tunggal.

ACKNOWLEDGEMENT

First and foremost I would like to offer my sincerest gratitude to my supervisor, Dr Rafidah Md Noor, who has supported me continuously throughout my thesis with her patience and encouragement during my Masters study. She taught me how to find research issues and how to solve problems. Her knowledge, along with her vision, professional spirit and attitude towards the research inspired me. Without her help and support, this research would not have been possible. Apart from being a good researcher, I have also learned and experienced that the time I spent on this research will always help and encourage me in the future.

Second, I would like to thank fellow students who have given their support during this research. I would like to express my heartfelt gratitude to them for their insightful and illuminative suggestions on my research. Their acuminous insight and guidance is invaluable to the accomplishment of this thesis. Furthermore, I would like to thank all my teachers at the faculty from whom I have learned so much during my long journey in this course.

Third, I would like to take this opportunity to thank my sponsor IDB for giving me the chance to pursue the study in this Masters course, without them none of this would be possible. I would also like to thank my family for their support during the time of my study.

Last but not least, I thank my wife and my son for being there for me through the entire period of my study. Without their continuous love, support, trust, and encouragement, none of this would have been possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Overview

Traffic congestion is becoming a critical issue across the world these days due to the increase in the number of vehicles. The traffic congestion occurs when too many vehicles attempt to use the transportation foundation with restricted limit. This increase in vehicles cause traffic congestions, this causes many issues such as delayed transportation, consumption of unnecessary energy, pollution in the environment, traffic safety and the effectiveness of the transportation framework. The problems involved with this subject have leaded the researchers to mainly focus their consideration in the region of Intelligent Transport Systems (ITS). This research contemplates the technologies and the scientific aspects with the purpose of developing a new system that is capable of solving some of the mentioned problems. In order to provide a solution for traffic congestion it is important to identify the capabilities of an intelligent transportation system for road-vehicles and implement this technology that can provide a much safer, environment friendly and an efficient traffic system (Papageorgiou et al., 2003).

Intelligent Transportation Systems is an advanced traffic control mechanism that has taken the attention of transportation experts, automobile manufacturers and political decision makers. ITS can be applied to solve transportation problems such as traffic congestion and the efficiency of the traffic along with traffic safety by using its advanced communication and information technology. Traffic light systems play a key role in improving the road transportation throughput by reducing delays. Standard traffic lights which are currently installed in many junctions are based on predetermined timing schemes, which are fixed during the installation and remain this way until further resetting can be done (Figueiredo et al., 2001).

To control the normal traffic, most traffic light systems have default setup with a given set of timing. However, every road requires different traffic control mechanism to manage the traffic at a given time based on the conditions in the traffic flow. Due to this, collecting real-time data is very important to solve the traffic problem. Traditional methods have its own shortcomings which include maintenance and cost of implementation. The coverage of the sensors is limited because these sensors are installed at fixed locations and cable-based communication methods are used to transmit traffic information which is identified during traffic jams. Overcoming these drawbacks using technologies such as wireless sensor networks and various other forms of traffic sensing methods are increasing in an Intelligent Transport System (Mimbela, 2007).

These sensors can dynamically identify traffic information and then transfer traffic data through ITS at a low cost. Therefore, this research will focus on using sensors to implement a dynamic traffic light system; by obtaining real-time traffic data gathered by these sensors to design an algorithm in order to solve traffic congestion. Drivers and passengers are not the only ones who suffers from a traffic congestion, according to Malaysian transport ministry, traffic issues have produced huge losses in terms of productivity. In order to succeed from this problem, the aim is to build more roads. However, the cost of development and environmental issues which will have a huge impact in building more roads have reached a certain level which cannot be further enhanced (Tong, 2014).

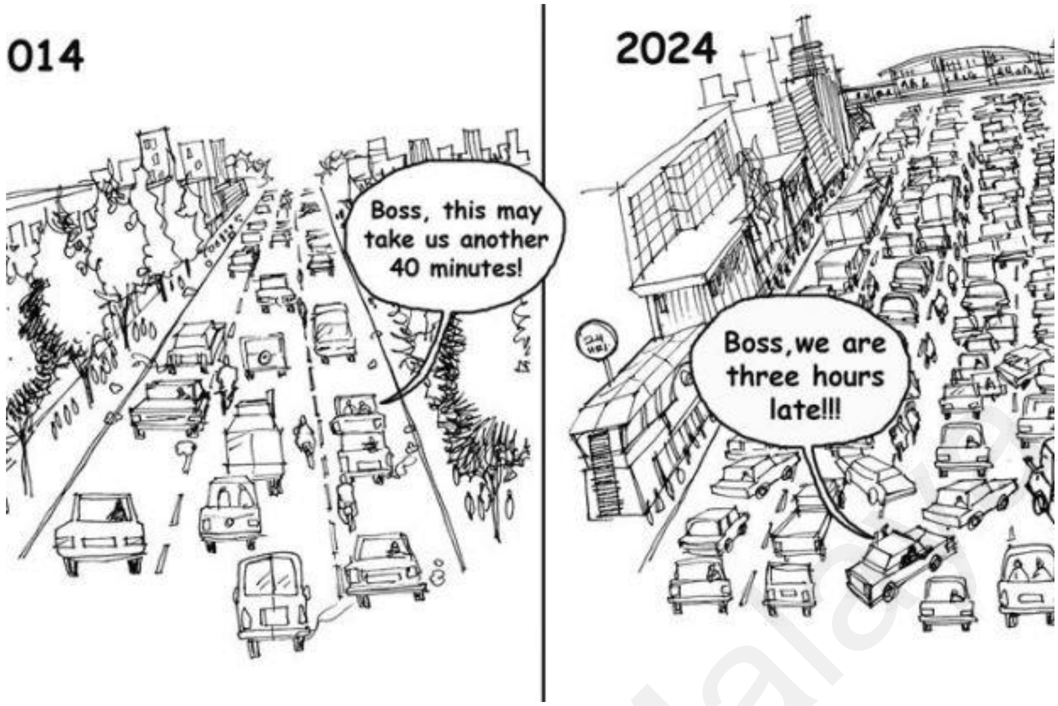


Figure 1.1: Traffic Congestion (Tong, 2014)

Newly-released data from the Malaysian Automotive Association (MAA) shows that the growth of car sales is increasing every year, an amount that is more than country's population growth of about 1.5%. Vehicles sold in 2013 have also increased 4.5% compared to the year before that and this amount will increase year after year according to the current rate. Let's assume that around 800,000 cars are added to existing roads every year. The infrastructure of the roads will never be able to keep up with the growth of cars even with the help of the road expansion. Suburban areas can be expanded but not the city and this is an area where most people will go and where the traffic will begin to build up.

In terms of development, Malaysia‟s public transportation system has not been able to achieve road enhancement that they desire. Since 88% of their population relies on private vehicles and 12% uses public transport, private vehicles have become an important method of transportation and this has led to an increasing number of traffic jams across all the major cities.

The Malaysian economy is facing a huge price in terms of efficiency and productivity due to heavy traffic jams. According to Tong (2014), "people are wasting an average of two hours in traffic jams every day, 100,000 people will be wasting 200,000 hours or 8,333 days, equivalent to 22.8 years. If one million people were to be stuck in traffic jams for two hours per day, that would be 2 million hours wasted, which is 83,333 hours or 228 years. If we further divide this into 8 working hours per day, it equals to the wastage of 10,416 man-days, solely due to an average of two hours traffic jam per day. That is how much time we are wasting on the road every day depending on the number of vehicles and people trapped in the jams. The situation will become worse as the number of vehicles increase".

Valuable time is wasted during traffic congestion, apart from the cost of time, health costs should also be taken into consideration. Drivers may suffer from panic and stress since they have to rush to work in order to attend an important meeting or an appointment. Likewise, people are likely to get stress since they are forced to cancel an appointment or important meeting because they are stuck in a traffic jam (Tong, 2014).

Traffic jam leads to the unnecessary cost of fuel emission for the vehicles and this is a cost the government has to deal with because of fuel subsidies. According to the data mentioned in the Establishment Post; in 2013 alone, the Malaysian government had a fuel subsidy bill that amounted to RM28.9 billion (US$9 billion). Due to the increase in the number of vehicles, this bill has certainly increased. The cost of fuel subsidies in 2004 was around RM4.8 billion (US$1.5 billion). This means that the subsidy bill has increased by 500 percent in 10 years.

Due to these issues, the government decided to build new highways to help the traffic congestions in urban areas. However, due to the cost and time needed to build these places, it is necessary to find a quick solution to the increase congestion problem. Therefore, it is important for transport experts and technology engineers to find a better solution to relieve the traffic congestion by carrying out necessary procedures. One of the main areas is road junctions where traffic is heavy during rush hours. These areas require utmost importance to smoothen the flow since valuable time and resources are wasted at these junctions (Lim, 2015).

1.2 Intelligent Transportation System

Intelligent transportation system (ITS) is an automatic traffic management systems that manages road traffic. The main goal of this system is to improving safety, optimizing the speed of the flow of traffic, and minimizing the energy consumption of vehicles. ITS uses different kinds of technologies to enhance the performance of transportation network, however their primary objective is the same; that is to save valuable time for the drivers and reduce the cost and energy consumption along with the environmental impacts. ITS increases the safety and efficiency of the drivers by using its communication and management technology and enhancing transportation systems.

Commission for Global Road Safety (2006) reported that in 1999, the number of deaths due to road accidents were recorded at 750,000 to 880,000. This amount is increasing every year at an estimated rate of about 1.25 million deaths per year. Critical changes to the transportation infrastructure have to be made to decrease these appalling figures or this amount is probably going to increment essentially. Giving the right training for the drivers and improving the road infrastructure can help the drivers feel safe for some extent, however it will not be enough to challenge this issue. Safety is also one of the most important aspects of an Intelligent Transportation System.

ITS can improve the mobility and safety of a transportation infrastructure while enhancing the global connectivity. By integrating advanced communications technology into the vehicles and transportation infrastructure; ITS can improve the productivity as well. ITS consists of wide range wireless and wired communication technologies to control traffic and enhance the existing transportation infrastructure. As mentioned before ITS improves the driving experience, safety, capacity of road systems, reduces risks in transportation, relieves traffic congestion, improves transportation efficiency and reduces pollution (Mathew, 2010).

Intelligent transportation systems use different kinds of technologies to enhance the performance of a transportation network. The main outcome of the ITS is to provide safety, save valuable time, reducing the cost, energy and the environment impacts. (Ezell, 2010).

1.2.1 Applications

ITS was first proposed to solve the traffic congestion problem. However, this technology made advancement in different areas such as safety, security, weather information and traffic management (Chen, Jin, & Regan, 2010). In Figure 1.2 illustrates the different applications in an Intelligent Transportation System.

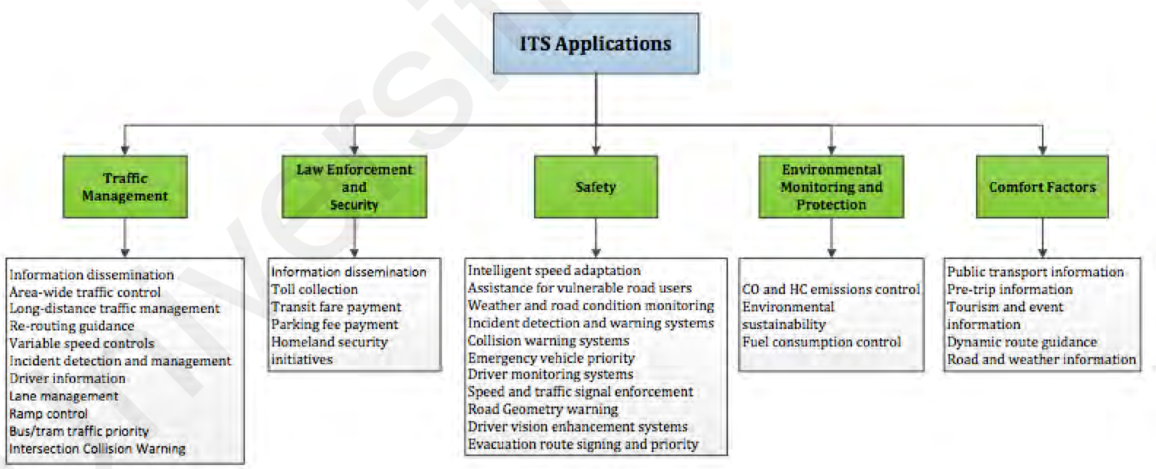


Figure 1.2: The applications of ITS (Amini, 2013)

1.2.2 Advantages of ITS Deployment

ITS offers a lot of advantages that are basically not available in traditional transportation systems. Primarily, ITS provides two kinds of advantages. One is the rectification of traffic problems, like congestion, air pollution, and accidents. The other is increased services and efficiency for the users and its operators of the transportation infrastructure.

The introduction of ITS can bring about the following advantages:

Mobility

In an adaptable economy, when travelling between their homes and their workplaces; people need the ability to do it conveniently, reliably, and affordably such as schools, shops, offices and recreational facilities. Changing demographics, urbanization, and changes in the places where people live, work, shop, and relax can make providing mobility a more complex task. The quality of life and their ability to contribute to the economy can improve with better mobility rather than just to depend on it.

There are many approaches to enhance the mobility of drivers and vehicles in all transportation modes in an ITS. Traveler Information can help travelers to avoid traffic congestion and can help improve these conditions by choosing different lanes. Managing the traffic effectively by controlling the timing of traffic signals can help increase traffic efficiency. Demand Management such as road and access pricing can help relieve heavy congestion in urban areas (Yokota, 2004).

Traffic Congestion

Traffic congestion is a serious problem around the world and this issue is growing rapidly in developing countries where there is a rapid increase in the use of motorized vehicles. Overcrowding of vehicles can cause so many issues such as delays, uncertainty, unnecessary fuel consumption, greater air pollution, and accidents. ITS provides a platform to alleviate traffic congestion by helping the drivers to travel better by suggesting alternate routes, travel times and by keeping the drivers always informed by such changes.

Environmental Impact

For developed countries, air quality maintenance was once regarded as a great comfort. To keep the emissions under control they could easily bear the cost of technology. However, the consequences of poor air quality are now recognized as a larger cost to all national economies especially on health and productivity. By optimizing the travels, reducing congestion, minimizing accidents, improving vehicle and driver performance can help to manage the transportation system well.

Reducing Fatalities and Crash Severity

Traffic accidents claim thousands of lives and cause millions of injuries around the world every year. The personal tragedy of each death is increased by the economic and social costs of these losses. ITS can help by providing safety and minimizing the magnitude of these accidents by making use of the technology to make crashes less severe and to avoid them all together.

Managing the Transportation Infrastructure

Modern transportation systems are more complex systems which require effective management and control tools for a better and faster system to provide a complete information about the current and future state of the system. One of the main reasons for an ITS is to help provide information and tools for sensors which are built into the infrastructure and sensors which are installed automobiles that can help continuously monitor pavement conditions. As a result of doing this, pavement development issues can be spotted at an early stage and repaired before they become worse since it will become expensive to fix later. Effectively allocating and scheduling more maintenance resources, infrastructure management systems can also help contain costs.

Reducing Travel Uncertainty

Another interesting perception identified by transportation administrators in recent years is that major benefits of their programs have not just been to get more people to their destinations faster but to provide greater reliability and predictability in transportation. Due to extreme weather conditions, demand, traffic incidents, or a large number of other external factors, it is an unfortunate aspect that most of the current transportation systems travel times differ vastly day to day. This uncertainty allows drivers to allow extra time for worst case circumstances or risk being late at least some of the time. However, ITS can help to ease travel uncertainty by resolving traffic (and therefore reducing travel time variance). ITS can also provide improved the real-time and predictive information to plan shipments better. Navigation systems in vehicles can install real-time traffic information to dynamically adjust driving routes to optimize trips based on current traffic information.

Increasing Security

Security of the transportation system (vehicles and infrastructure) is another concern which has grown significantly in the last few years. Freight containers which contain dangerous materials such as explosives or biohazards might be used to cause harm in another country if they are improperly managed. Likewise, drivers and passengers are potentially at risk of getting exposed to hazardous materials as well since travel terminals (bus and train stations) are high-occupancy vehicles as well. GPS allows to address these concerns in an ITS.

Improved sensors and information systems can monitor the location of the containers and the contents it carries via wired and wireless communications. Monitoring the cargo and routes taken by the vehicles can simplify and increase the visibility of transport logistics. This is also an area in ITS in which improved security can help facilitate increased efficiency and productivity (Yokota, 2004).

Increasing Efficiency for Operators

Electronic Toll Collection (ETC) is another way ITS can enhance the operational efficiency of the transportation system. Drivers can claim an electronic transponder that identifies their vehicle and their account by registering with a toll agency. When the vehicles which are equipped with transponder passes a toll collection point, the system automatically deducts the toll amount from the driver‟s account. In the long run, ETC opens the option to create more flexible tolls that can vary based on time of day, the congestion level and many other factors as well. In general, ITS can provide transportation system operators with better tools to plan, operate, and maintain the system in order to gain current information about the status of the transportation system.

Increasing efficiency for users

According to Yokota (2004), ITS can also provide a more efficient platform for the travelers. For example, the ETC systems mentioned above have advantages for drivers as well as system operators. Hence, the advantage to the driver is that they don't have to stop for toll collection, the toll will be paid while the car is moving. Another advantage is that the overall delays at toll barriers decrease for all vehicles. A similar process that can help other travelers is by using smart cards to pay a variety of fees. In various parts of the world, the smart card can be used for public transport fares, for parking, and for other purposes.

For the government, smart cards are a convenient way to provide travel subsidies by electronically storing money on the smart card.

The in-vehicle navigation system is a very popular element in an ITS application in developed countries because it computes and delivers the correct driving directions to a destination in which the driver has set to reach. This system includes the database of the map, location sensors, a computer, and a user interface (e.g., a touch screen). The UI of the system lets the driver identify a destination and let the system deliver directions needed to reach the destination. Navigation systems generate efficient traffic routes that can help drivers well informed without getting lost.

Navigation systems will most likely receive information about the traffic in real-time traffic and it will adjust routes dynamically based on current conditions in the near future. The cost of these navigation systems are decreasing gradually and ITS can provide drivers with better and more current information about the state of the transportation system. This information will provide a healthy platform for the travelers to arrange their trips efficiently and by making better connections which will reduce the uncertainty of travelling (Yokota, 2004).

1.2.3 ITS Function

ITS functions are divided into three interrelated areas, they are data collection, data processing, and information dissemination. Figure 3 illustrates their function and their inter-relationships. According to Farradyne (2001):

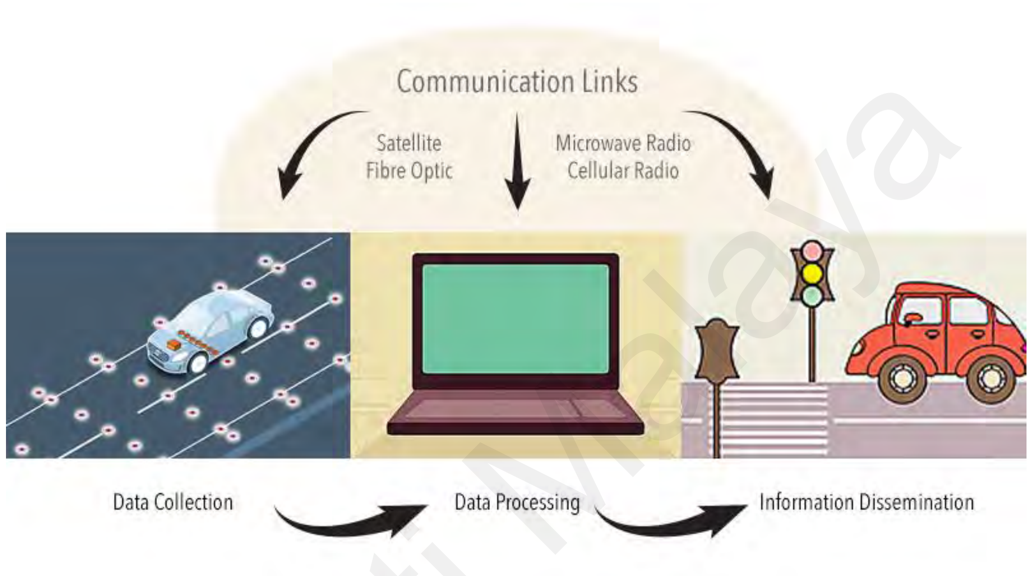


Figure 1.3: Concept - How ITS Function

Data Collection: Gathering data from various types of sources including field devices such as cameras and vehicle detectors. For example, magnetic sensors can detect movement of vehicles and record the necessary information.

Data Processing: This involves making the most of the data collected usable to support or perform specific functions. For example, the collected sensor data can be processed to allocate more time for traffic light systems.

Information Dissemination: In this phase information will be made available to end users. It can be a transportation service provider that needs to make operational decisions like adjusting traffic signal timings (Farradyne, 2001).

1.2.4 Justification

The main reason Intelligent Transportation System is used in this study is because the cost of deploying the system is fairly straightforward. The primary functions are simple and the maintaining it is relatively effortless. The applications are easily adaptable to handle with rapid growth and urban development.

Traffic congestion is a huge problem in developing countries where vehicles are increasing rapidly. Since ITS provides a platform to reduce congestion, this research will be focusing on ITS to help minimize traffic congestion. Delays, fuels consumption, air pollution and accidents are various problems of traffic congestion. ITS can help to reduce this by creating a more efficient mechanism for traffic light control system, by suggesting alternate routes and travel times, by keeping travelers well informed and by helping to respond to and attending incidents swiftly.

1.3 Magnetic Sensors

Vehicle detection is an important factor in an Intelligent Transportation System. This involves collecting and processing important vehicular data like speed, their presence, and density etc., using vehicle detection sensors. Magnetic sensors are one of the most popular methods for vehicle detection since vehicles are mostly made up from metals and vehicle movement can disrupt earth magnetic fields. This distortion of the magnetic fields by a moving vehicle can be easily detected and measured on the road (Daubaras, & Zilys, 2012).

Vehicle detection technologies have evolved in the last couple decades. From air hoses to inductive loops, most of the legacy detection methods were focused on getting information about vehicles presence to make the decision with a set of control systems. Almost all the vehicles have metals in their chassis (Iron, steel, nickel, cobalt, etc.), due to this magnetic sensors are a great device to detect vehicles. Most magnetic sensor technologies are fairly small in size nowadays thanks to solid state technology. Integrating these sensors has become relatively easy since both its size and the electrical interfacing have improved. Figure 1.4 illustrates magnetic field distortions made by a moving car which can be easily detected and measured on the road.

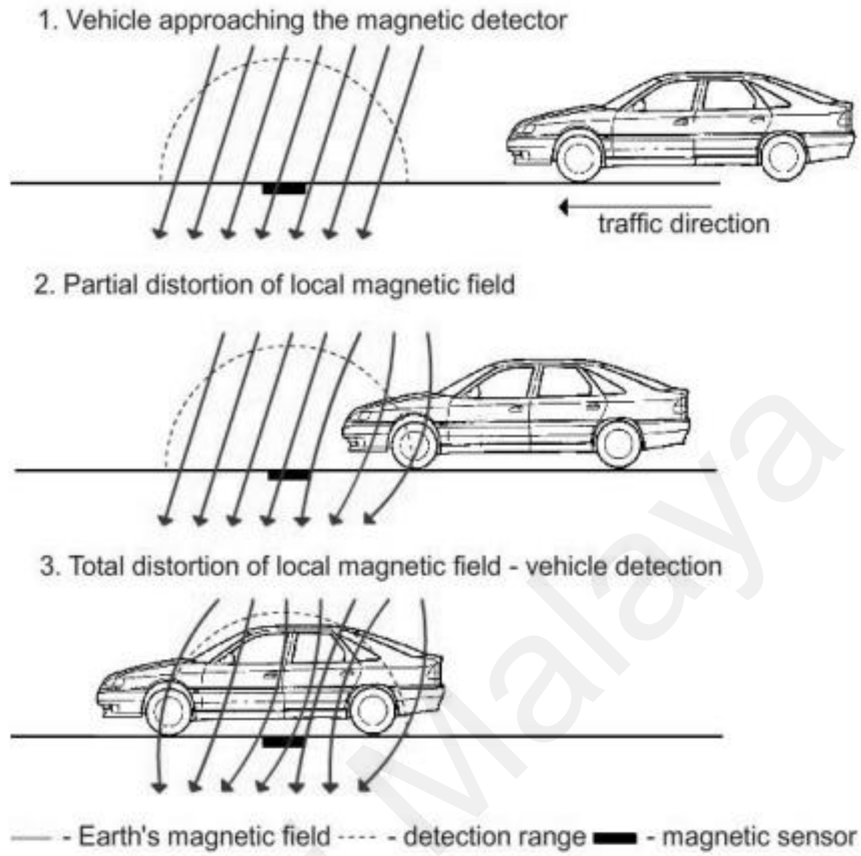


Figure 1.4: Magnetic field distortion by a moving vehicle (Bugdol et al., 2014)

Magnetic sensors are fixed in the roadway at intersections equipped with traffic lights. As the vehicle approaches, the magnetic field around the detector makes distortions which are detected by an electronic sensor. It is possible to detect the size and speed of the moving vehicle by identifying the noise level. This will allow the system to differentiate the type of vehicle and optimize decisions about how to control the traffic lights. For example, an ambulance which is moving at a fast speed will have a higher priority than a car, which can be stopped and re-accelerated with lower costs. Valuable time might be lost if an ambulance had to be stopped just like a normal car during rush hours. In order for the system to properly operate, depending on the intersection it might require installing at least several detectors. The data collected from the detectors will be transmitted to the controller, which analyses the traffic from every direction and controls the lights on various intersections.

Using magnetic sensors for vehicle detection is not a new concept around the world. Various researches have been conducted based on the devices operating with the same principle. However, it should also be noted although this is not totally a new concept and previously implemented systems have had its flaws. The problems are mostly linked with complicated setup procedures and due to suspended detectors. Magnetic sensors can be applied to numerous potential applications because of its variety in function and flexibility in development. Although magnetic sensors are difficult to use, they provide the most reliable and accurate data without physical contact.

Compared to other detection systems, magnetic sensors have an important advantage because detectors are cheap and it offers simplicity to install and system maintenance is cheaper and convenient as well. Magnetic sensors are not vulnerable to weather conditions, unlike other detection methods. Taking all these factors into account, magnetic sensors are applicable for the intelligent traffic control systems in the future and it can also be deployed into transportation infrastructure in order to enhance safety and mobility (Bugdol et al., 2014).

1.3.1 Loop Detectors

Induction loop sensors were first introduced in the early 1960s, since then it has become the most utilized sensor in a traffic control system because of its reliability and cost effectiveness. It is also classified as the most effective detection method available. The inductive loop has a coil of wire embedded in the road's surface which includes three main components:

- Insulated loop wire inserted in the pavement.
- Lead-in cable from the pavement pull box to the intersection controller cabinet.
- A controller cabinet with an electronics unit.

Inductive-loop system operates as a tuned electrical circuit in which the loop wire and lead-in cable are the inductive elements. When a vehicle passes or stops over the loop, the vehicle induces eddy currents in the wire loops, which decreases their inductance.

The reduced inductance activates the electronics unit output relay which sends a pulse to the controller indicating the presence of a vehicle. Conventional inductive loop detectors supplied data such as vehicle movement, presence, count, and occupancy. In spite the fact that loops cannot directly measure speed, by using a two-loop speed trap or a single loop detector and an algorithm which involves loop length, average vehicle length, time over the detector, and by counting the number of vehicles, the speed can be determined. Latest versions of inductive loop support vehicle classification by containing electronics units that excite the wire loop at a higher frequency that distinguishes particular metal segments under the vehicle (Klein, Mills & Gibson, 2006).

Traffic light systems which are based on Inductive-loop sensors operate by observing disruptions inside the electromagnetic field over a coil of wire built into the roadway as shown in Figure 1.5.

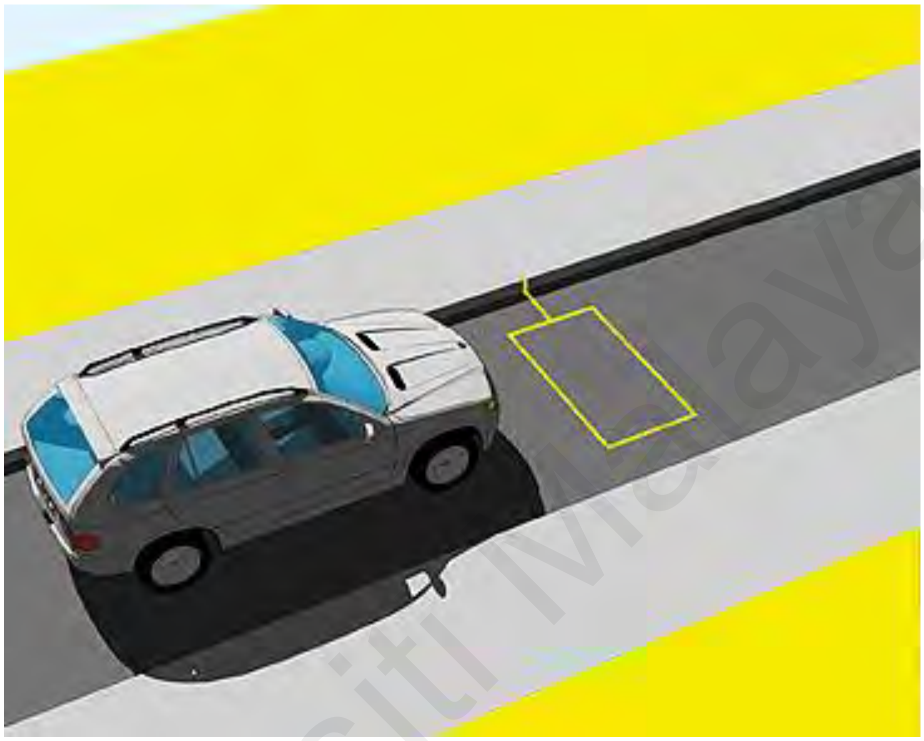


Figure 1.5: Dual Channel Loop Detector. (n.d.).

Vehicles are normally made of metal and when these vehicles enter the wire loop area, the magnetic field generated by the alternating electrical current in the signal detector circuit induces weak electrical currents in the conductive object. According to Daubaras and Zilys (2012), “the electrical currents are induced in the object to generate their own magnetic field that works in opposition to the magnetic field generated by the sensor coil.

This opposition changes the resonant frequency of the sensor circuit by reducing the effective inductance of the sensor coil. This change in resonant frequency (an increase in frequency as the inductance decreases) is detected by the circuit instrumentation in the signal controller cabinet, which then tells the signal control electronics that a vehicle is present". Traffic light systems which use loop sensors are constantly monitoring the inductive loops on the lane. These sensors can identify vehicles presence when an inductance rises and collects this data to perform necessary functions to adjust traffic signal. Induction loop sensors can also be used to actuate traffic control devices and detect congestion and incident.

Induction loop sensors are used in this study because it provides basic traffic parameters (volume, presence, occupancy, speed, headway, and gap) and since its application is identified as a mature technology. When installed and maintained properly, Induction loop sensors are considered as the best for many applications. In terms of vehicle counts, it is also the most consistently accurate detector. Also, the equipment cost of inductive loop sensors may be low when compared to over-roadway sensors. Induction loop sensors operate well in different weather conditions as well as both high and low volume traffic conditions. Due to its flexible design, inductive loop sensors can be sustained for a large variety of applications (Daubaras, & Zilys, 2012).

1.4 Traffic Light Systems

Traffic light control which is also known as traffic control signals is a device that is used by traffic lights to control the movement of traffic at intersections in the road. The main purpose of the traffic lights is to ensure that the vehicles pass through an intersection safely and to allow a large amount of traffic to pass through the channel with minimal delay.

A high-quality traffic control strategy can enhance the safety of the traffic and reduce energy consumption. However, a low-quality control strategy would cause considerable delays in traffic because of the inaccuracies in scheduling and frequent changes in the traffic lights. There are many issues which need to be examined when designing a control strategy for the traffic lights, such as increasing size of a large traffic network, limited coverage of traffic detection, and various unpredictable changes which are difficult to measure, like traffic accidents (Zhou, 2010).

In a traffic light operation, there are four factors which influence the traffic conditions; they are stage specification, split, cycle time and offset. These factors are important to keep in mind when designing control strategies according to U.S. Department of Transportation, Federal Highway Administration.

Stage specification: Complicated road junctions include a large number of streams, the specification for the most favorable number and the structure of stages is a nontrivial task that can have a significant effect on an intersection limit and efficiency.

Split: This is the most applicable green signal time of each stage (part of the cycle time) that needs to be optimized based on the demand of the involved lanes.

Cycle time: Since the proportion of the constantly lost times becomes accordingly smaller, longer cycle times typically increases the intersection capacity. However, longer cycle times could increase vehicle delays in an undersaturated intersection due to longer waiting times during the red phase.

Offset: This is the time difference between the traffic lights green phases of adjacent intersections for a smooth flow of traffic at multiple intersections, which is also defined as a „green wave‟; clearly, the specification of offset should ideally take into account the possible existence of vehicle queues (Koonce et al., 2008).

1.4.1 Signal Timing

Traffic signals are scheduled to improve the traffic flow and to make the traffic system as safe as possible for all users. Every traffic signal controller is programmed and set with different timing settings depending on the time of day such as rush hours or according to the situation that is occurring at an intersection at that very moment.

According to National Transportation Operations Coalition (Traffic Signals 101, 2014), there are three basic types of signal timing:

- Fixed time
- Actuated
- Coordinated

Fixed time: In this signal control the signal cycles are same every time despite the volume of traffic since this signal control uses a pre-set time intervals. Based on the information gathered from the past events, they allocate the most green-time to the most congested traffic movement. Some fixed-time systems use different pre-set time intervals for morning rush hour, evening rush hour, and other busy times.

Actuated: Signal timing interchanges the information collected from the detectors. Signal controller is able to change and manipulate the amount of green time for each cycle. Actuated signals are best utilized in traffic scenarios where there is a large number of traffic which varies considerably during the day, when interruptions to the traffic flow must be minimized, or when there is very light side-street traffic.

Coordinated: Apart from timing the traffic signals individually, some of the signals are timed as an adaptive or coordinated network. The signal coordination‟s purpose is to help the traffic flow through a series of signals which is set at a predetermined speed to minimize or avoid stops. Traffic signals cannot always turn green once the vehicles reaches the intersection because of the need to provide the flow for more than one direction. Due to this reason traffic engineers use computer programs to determine the best compromise among all the competing directions of traffic (Koonce et al., 2008).

By taking these issues into consideration, the existing traffic light control strategies that vary in complexity can be classified based on different structures of traffic scenarios; isolated intersection control, arterial coordination control, and network control. These control strategies are classified in Table 1.

Table 1.1: Traffic Light Control Strategies

	Control Scope		
Control Logic	**Isolated Intersection**	**Arterial Coordination**	**Network Control**
Fixed-time	✓	✓	✓
Actuated	✓	✓	✓
Adaptive	✓	✓	✓

Arterial coordination: When the road consists of multiple adjacent intersections in the same direction then this control strategy is implemented. The possible available movements and number of phases of this strategy are similar to an isolated intersection traffic light control strategy. Since this type of control considers coordination between two adjacent intersections, the offset adjustment cannot usually be ignored. The probable movement which are available and number of phases are similar to traffic light control in an isolated intersection. The common measurement of performance includes maximum intersection throughput, minimum average delay for vehicles, and the minimum number of vehicle stops.

Isolated intersection: This is a control strategy that is used in a traffic architecture consisting of multiple intersecting roads. Because of these lanes, this strategy is regarded as a branch of arterial coordination control. Measurements such as the number of phases, optimization elements, possible available movements, and performance are similar to traffic light control in arterial coordination control. Isolated intersection control means to manage the traffic lights at a single intersection, by taking local traffic conditions such as the traffic volume, waiting time, occupancy, vehicle speed, and other factors into consideration.

Network control: When there are multiple interconnecting roads, then this strategy is used to manage the traffic network. This strategy is considered as extensions of arterial coordination control because of intercrossing roads. The number of phases, optimization elements, possible available movements and performance measurement are similar to traffic light control in arterial coordination control (Zhou, Cao, Zeng, & Wu, 2010).

1.5 Problem Statement

The most common traffic light systems that are installed have a fixed time signal timing to change the signals. These systems remain this way until further resetting can be done to change the time frame. The allocation of time of these standard traffic light systems are based on their default setup which basically considers normal traffic flow. The problem of fixed time traffic light systems is that signal allocation cannot be dynamically set based on the volume of vehicles in a particular lane. Since the time is fixed, a lane which needs more time for green signal gets the same priority as a lane with few vehicles or no vehicles at all. This causes traffic congestion, accidents and so on.

The problem with the existing solutions is that although it provides a way for the incoming vehicles, they do not provide a way to determine the corresponding lanes congestion when allocating time for the signals. Existing solutions only provide a method based on the incoming vehicles which arrive on a junction. They do not check if the vehicles that are departing to are free of congestion. By taking the problem at hand, the system will provide an algorithm to dynamically change the signal timing using data collected by the sensors. These sensors will calculate the vehicle flow at the arrival of a traffic junction and will also check if the corresponding lanes in order to change the timing to minimize traffic congestion.

1.6 Objectives

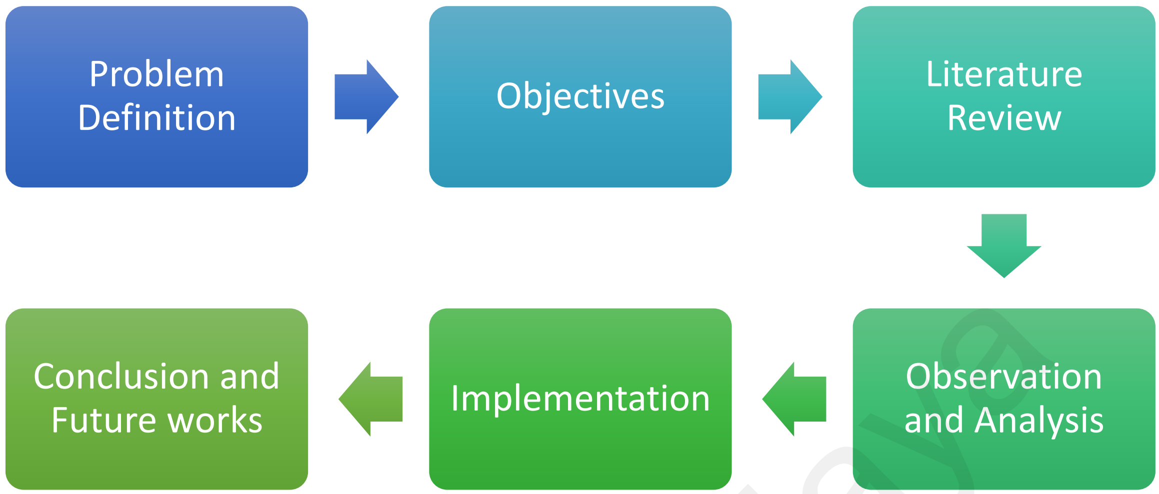
The aim of this research is to develop a dynamic traffic light system using on-road sensor technology. The aim of this research is divided into 3 objectives:

To investigate the existing traffic light control systems, including the basic concepts and different types of control strategies.

To develop a new algorithm that is capable of changing the traffic light signal based on real-time traffic flow data generated by the on-road sensor technology.

To evaluate the performance of the system, by using SUMO simulator that makes use of the traffic data generated by the sensors.

1.7 Methodology



Problem Definition

The research process begins with identifying the problem which is the first step towards its solution, in this case, the signal allocation in traffic light systems. Refer to the problem statement to find out more about the problem of this research.

Objectives

After identifying the problem, the main objectives of this research are mentioned in the objectives. It determines which tasks are needed to be accomplished in order to successfully complete this research.

Literature Review

After finding out the research problem, a literature review will be conducted to know about the previous studies carried out to solve these issues. Chapter 2 will provide more information on the literature review.

Observation and Analysis

During this stage, an observation will be carried out based on the information gathered from the literature review. The objectives will be refined further by studying the observation and analyzing the data that is collected. Based on the analysis this research will identify if the mentioned problem in Chapter 2 is worth finding a solution.

Implementation

This stage will be divided into three separate stages.

1. Dynamic traffic control algorithm using real-time sensor data

Through a network simulator, the traffic will be calculated to develop a dynamic traffic light system. The sensors will regulate the amount of vehicles that arrive and depart using the utilization rate. It will check whether the flow density is oversaturated, under saturated or saturated based on the utilization rate before passing the information to adjust the signal timing. Based on the data collected by the sensors, the traffic control algorithm will be created to allocate more time for the green signal based on the volume of traffic provided by the sensors.

2. Creating a realistic traffic scenario using SUMO simulator

In order to create a dynamic traffic light system, a traffic scenario will be built to test the algorithm. Using SUMO, a realistic traffic scenario will be created to test the traffic control algorithm based on the data provided by the sensors. The simulation will be designed based on a four-way junction. Vehicles from each lane will move straight or right as shown in figure 1.

3. Testing and Evaluation

The performance of this proposed method will be evaluated after the simulation has been carried out by SUMO. The system will determine if the proposed method is much more reliable than existing fixed time methods or better than an actuated model.

Conclusion and future works

After the implementation and evaluation, this research will be concluded by highlighting some of the factors that can still improve this study further.

1.8 Thesis Outline

An introduction to this research is given in Chapter 1 and the research problem is highlighted; in this case the signal allocation in traffic light systems. Since the existing traffic light systems do not provide an ideal solution to allocate more time for green light signal if there is an increase in vehicles in a particular lane.

In Chapter 2 a literature review was done and discussion about the previous works has been explained on traffic light control systems and what are the possible issues in those systems. Also, some of the existing methods and how it fits the problem that is being addressed in the study that was highlighted.

In Chapter 3 an observation was carried out and an analysis was done for the existing problem based on the findings from the literature review. This chapter also focuses on how the mentioned problem affects the existing methods and justification has been made for the findings.

In Chapter 4 the architectural design was presented for the traffic light system after conducting the observation and analysis from Chapter 3. In this chapter implementation, the system was conducted using data gathered by the sensors. These sensors will measure a number of vehicles reaching a traffic junction. After gaining the information from the sensors, Traffic Light Signal Manipulation Algorithm (TLSMA) will allocate the necessary green signal time needed for a particular lane.

The results generated were presented after the method was carried out on the simulator and discussion about the findings was highlighted. Tests will be carried in SUMO simulator and the results will be evaluated, to check whether traffic control using WSN is a better solution than the current solutions which are used in traffic light systems.

Chapter 5 will conclude the research with a discussion on future works and what factors can still improve this study further.

1.9 Summary

In this chapter, an introduction about this research is given. A brief discussion about the current state of traffic problems was mentioned as well. Importance of an Intelligent Transportation System was highlighted in this research because ITS is necessary to solve the existing traffic problems.

The sensor which is used in this study is discussed briefly along with the traffic light systems and its signal timing. The problem statement and objectives has also been stated in this chapter along with how the research will be structured.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Traffic optimization using traffic light controls in an intelligent transportation system has been attracting a lot of interest and attention in the past decade. Since this research will be focused on dynamic traffic light control, this chapter will review the existing works that has been carried out.

Traffic cannot be optimized without gathering traffic data and using it effectively to schedule the traffic. Meaning, traffic flow data of vehicles which are moving on the road needs to be collected; this includes speed, traffic volume, delays etc. Traffic flow is different at each intersection so to effectively schedule the signal timing to solve the problem of traffic congestion, these data are vital to schedule the timing based on the current traffic flow.

ITS have seen a lot of growth in terms of development, but for this system to work real-time traffic data is required. Various methods of traffic light control have been carried out and the next section will provide the details of these existing approaches to controlling traffic lights at road intersections (Zhou, Cao, Zeng, & Wu, 2010).

2.2 Collection methods

Different types of collection methods such as inductive loops detection, video recognition, ultrasonic, microwave radar etc. have been used to gather real-time traffic information. These methods use some kind of sensor which is embedded in the road or alongside the road to detect traffic flow. Real-time traffic information is collected and calculated based on the traffic flow. This data is then transmitted to the control center to make changes to the signal control.

This section will investigate both wired and wireless based systems which are used to detect real-time traffic flow to improve traffic congestions.

2.2.1 Wired based methods

Wired based methods involve collecting traffic flow data using a wired technology such as inductive loop detection, video recognition, microwave radar etc. The sensors detect movement of vehicles using this technology and the data collected is transmitted through the wire.

The most common technology used in an ITS is the inductive loops detection. The sensors in an inductive loop are implemented on the road to create a magnetic field to detection vehicles movement. When the vehicle passes the sensor, real-time traffic information such as speed, length, space between two vehicles is collected and calculated. Inductive loops detection provides better accuracy compared to other wired based detection methods. However, this method is vulnerable to sever weather conditions such fog, snow, rain etc. Due to the sensors being implemented at fixed location, the coverage area is limited. Deploying sensors can be expensive and the lifetime of the pavement is reduced since the pavement needs to be cut in order to implement the sensors (Mimbela & Klein, 2007; Leduc, 2008).

Just like inductive loops, video recognition is also widely used in traffic light control systems to gain information regarding traffic flow. Rather than installing the sensors in the road itself, video recognition sensors are deployed in polls to watch/record the movement of the vehicles. When the vehicles passes these cameras, information about vehicles speed, type, amount etc. are recorded and analyzed to track the changes in the images which is then calculated. An advantage of this method is that it can track multiple lanes at once and its flexible installation process can make it easy to extend the coverage area by adding more cameras. However, the drawback of this method is that it is vulnerable to weather conditions and it is easy affected during night time hence requiring street lights to detect traffic data (Rhodes, Bullock, & Sturdevant, 2006).

Another wired based method is microwave radar; this technology uses radar sensing to monitor traffic flow. The sensors are installed over the roadway just like video recognition detection. Microwave radar sensors use an antenna to transmit energy to detect movement in an area and when the vehicle passes by the energy is transmitted back to determine the speed, amount and type of the vehicles. This method has no vulnerability to weather conditions and can be used simultaneously at multiple lanes without any interference. However, this method cannot detect vehicles which are not moving (Leduc, 2008).

2.2.2 Wireless based methods

Wireless-based methods collect real-time traffic data using sensor nodes which then transmits these data wirelessly to calculate and make changes to signal timing according to the traffic congestion.

Passive infrared detection is a wireless based method to detect traffic conditions by determining the infrared energy emitting from the detection area. This detection method uses passive infrared (PIR) sensors which are usually installed over the road. This method can collect data like the amount of vehicles, speed, type etc. However, in severe weather conditions the sensors have difficulty in detecting vehicles. Also the coverage area is limited because the sensors are installed at fixed locations.

Active infrared detection uses laser radar to collect real-time traffic data based on the infrared energy received. These sensors are installed over the road, which collects data such as amount of vehicles, speed, length etc. This method can detect multiple lanes without any interruptions. However, it is expensive to install and maintain, also sensors do not perform well in bad weather conditions.

Ultrasonic detection and Passive acoustic detection are two methods which can detect real-time traffic data by measuring the sound waves emitted by the vehicles. Both of these use sensors which are installed over the road. Although this method can identify multiple lanes concurrently without any interference, both of these methods do not perform well under bad weather conditions (Mimbela & Klein, 2007).

2.3 Intelligent traffic control systems

Intelligent traffic control systems make use of wired or wireless based collection method to improve the traffic flow during congestion. This section will investigate various studies focused on this topic which optimizes signal timing based on the flow of traffic.

SCOOT and SCATS are the earliest form of intelligent traffic control used when controlling traffic based of intelligent methods began in 1990. Both of these methods help optimize signal cycle time by detecting real-time traffic data. However, SCOOT is mainly designed to respond to long-term and slow changes to traffic demand. SCATS do not have a traffic model and it selects the most appropriate pre-specified control mechanism based on the real-time traffic condition (Sims, & Dobinson, 1980; Robertson, & Bretherton, 1991).

Fuzzy logic systems are another type of intelligent traffic control system which is based on fuzzy technique. Several studies have been made on applying fuzzy logic to control traffic light at intersections.

Chou and Teng (2002) have proposed a traffic junction signal controller which is based on fuzzy logic (FTJSC). The authors simulated this model in an environment which consists of number of junctions, lanes, the length of the vehicles and the width of the lanes. The proposed method was applicable to use on multiple lanes and junctions without any modification to the system.

Hegyi et al. (2001) presented system that can be used in traffic control center to control the traffic. The system uses traffic control measures for a given traffic situation by providing a limited list of appropriate combinations. This system is based on a fuzzy decision support system. However, this method might be difficult to control if the number of inputs and control measures increases which can only be dealt by multilevel decision support architecture.

Zeng et al. (2007) have proposed a two-layer fuzzy control algorithm which is capable for controlling traffic which involves a network of large traffic flow and high possibility of congestion. First part of this method is to monitor real-time traffic flow using fuzzy based estimation method. The second part of the controller is used to minimize the average delay of the vehicles under the condition that no congestion would occur using the boundary intersections. However, this method is only for intersections that are oversaturated.

Tubaishat et al. [2007] proposed a new idea of decentralized traffic light control system that makes use of the wireless sensor network. The architecture of their system is divided into three layers; the first layer includes the wireless sensor network, the second layer is for the localized traffic flow model policy, and the third layer is the higher level coordination of the traffic lights agents. The sensors used in this system are installed on the road which goes in and out of an intersection. These sensors detect vehicular data like speed, amount etc. and transfer it to the nearest Intersection Control Agent (ICA). This will determine the flow model of the intersection depending on the data that is generated by the sensors. However, this model does not provide information on the flow policy used.

Yousef et al. (2010) have presented an adaptive traffic control system based on a novel traffic infrastructure. This method also makes use of the Wireless Sensor Network (WSN). The techniques they have used are dynamically adaptive to traffic conditions and it can be used on both single and multiple intersections. To control the traffic signals they make use of WSN. The intelligent traffic controller is created to manage the operation of the traffic infrastructure. The controller includes traffic system communication algorithm

(TSCA) and the traffic signals time manipulation algorithm (TSTMA). Both of these algorithms have provided an adaptive system that can estimate traffic efficiently. The dynamic change in the traffic signals flow sequence represents this along with the traffic variation. However, they have not discussed about security of communication or the kind of sensor that is being used in the system.

Royani et al. (2010) proposed a traffic light controller which is based on fuzzy neural network. This method can be used to control the changing traffic volume at oversaturated or unusual load conditions. The objective of this method is to improve the vehicular throughput and minimize delays. However, this system is only based on heavy traffic intersections.

Zhou et al. (2010) have presented an adaptive traffic light control algorithm that can adjust both the length and the sequence of the traffic lights according to the real time traffic detected. Their algorithm takes factors like traffic volume, waiting time, vehicle density, etc., to regulate green light sequence and the ideal green light span. The objective of this method is to increase the throughput of the network, shrink the average delay and average number of stops. However, they have not mentioned anything about the communication scheme or the sensors used.

Kosenan (2003) presented a traffic signal control system called HUTSIG in which the simulation is based on real-time, multi-agent control scheme, and fuzzy inference. The HUTSIM simulation model is used both for off-line evaluation of the signal control scheme and for on-line modeling of traffic situations during actual control. However, they have failed to specify the type of sensor used.

Ferreira et al. (2010) have designed a virtual traffic light protocol that can optimize the traffic flow dynamically at the road intersections without requiring any infrastructure at roadside. The vehicles act as mobile traffic state sensors and it uses vehicle-to-vehicle communications with DSRC. The main problem of this method is that it requires all vehicles to be equipped with DSRC devices and all vehicles to share the same digital road map in order to perform successfully.

Chen et al. (2006) proposed a system which contains three types of nodes to gather and transfer traffic information. These nodes are in-vehicle unit, roadside unit on both road sides and the intersection unit on the intersection. The vehicle unit collects vehicular information like speed, type etc and transfers this information to roadside unit which is then passed to the intersection unit to be analyzed and passed to the strategy sub-system. This sub-system calculates an optimized scheme to control and/or guide the execution sub-system. However, they have failed to propose an algorithm for interconnected intersections.

Hull et al. (2006) have proposed a mobile sensor computing system called CarTel. This system collects and processes the data gathered by sensors which are installed on vehicles which are considered as mobile units. A CarTel node includes of a set of sensors which is coupled and known as a mobile embedded computer. Each of these nodes will gathers and processes sensor readings locally before they are delivered to a central portal, where the data is stored in a database for further analysis and visualization. However, this system requires nodes to be installed in the vehicle and works only if the vehicle has these CarTel nodes installed in them.

Al-Khateeb and Johari (2008) proposed a RFID based traffic control system which evades problems that usually comes up with standard traffic control systems. The RFID based traffic control model that they have used consists of four parts; the first parts is the AeroScout RFID tags, the second part includes Cisco access point, the third part is the Cisco location server and finally it makes use of the Wide Area Network (WAN). The first part simulates the moving vehicles; then the second part is responsible for detecting the RFID tags. The third part acts as RFID software and fourth part simulates the global environment. The location server is the one that acts as the microcontroller of the traffic signal. This collects the location and tagging time the data from reader and then this information is sent to the management system (which uses an algorithm that is intelligent enough to control traffic) via internet. However, this technology has its own drawbacks. RFID enabled systems causes privacy concerns since movement of vehicles cannot be tracked without the usage of tags. In order for the system to function efficiently, all the vehicles are also required to use an RFID tag.

Collotta et al. (2014) have presented a technique that is based on the information gathered through a wireless sensor network which then dynamically processes green signal timing in a traffic light for an isolated intersection. Their main purpose is to optimize the waiting time in a traffic queue and to reduce the occurrence of the Red Light Running (RLR) phenomenon. Collotta et al. (2015) have also presented a new idea to dynamically control the traffic lights cycles and phases in intersections which are isolated. The method that they have proposed consists of Wireless Sensor Network (WSN) for real-time traffic monitoring and fuzzy logic controllers for each traffic light phase. The WSN collects traffic data. A phase sorting module is responsible for phase order calculations and to calculate the green signal length of every duration of the phase a fuzzy logic controller is used. However, this method does not mention about how they will manage the congestion of the forward lanes.

Abbas et al. (2015) have developed a traffic light controller with high accuracy that increases the given green time usage. The proposed model consists of three main entities; first entity is the Road‟s Status Data Collecting entity (RSDC), the second entity is the Traffic Light Controlling entity (TLC), and the third is Traffic Light Display entity (TLD). RSDC would collect vehicular data, its status and position on the lane to determine the queue length. Those data will then be passed to the TLC to make decisions regarding the next traffic light phase plan. Then it will be forwarded to TLD for implementation. When a new phase change is required then the TLC will be activated to generate a new phase plan based on a new set of data. However, this method does not take the length of the queues other phases into account and it only uses the traffic of the current phase.

Gradinescu et al. (2007) presented an adaptive traffic light system that makes the use of wireless communication between vehicles and fixed controller nodes deployed in intersections. Intersections are fixed with controller nodes that are equipped with short range wireless communications. Vehicles regularly transmit its vehicular information like speed, position, direction etc. to nearby cars that they know about. To make important decisions the Traffic light controller listens to this information. However, they have not given detailed information regarding how the algorithm will be used to optimize the traffic. They have also failed to specify how the system would function to vehicles that are not involved in the system.

Srivastava and Sudarshan (2013) have proposed an algorithm which performs adaptive traffic light control using a wireless sensor network setup. Their method reduces the average waiting time of vehicles on a junction. Also the algorithm that they have presented is adaptive to control the traffic flow at any intersection point of roads. However, the authors have only considered analyzing vehicles that are arriving at the traffic junction and failed to identify if there are any congestion in adjacent lanes when optimizing the traffic.

Chao and Chen (2014) have presented a model which uses RFID to gather traffic flow detection. The RFID then transmits this information that are related to traffic flow directly to a control system through an RS232 interface. These sensors are responsible for analyzing and making decisions based on the information gathered. It then uses an additional algorithm that is intended to achieve the objective of traffic flow control. They have also used ZigBee wireless network communication technology to send traffic flow information which is then transmitted to a remote monitoring control system. However, the authors haven"t considered the forward lanes congestion when they have proposed the model.

Salama et al. [2010] have presented a system that is designed to manage and control traffic lights based long range photoelectric sensors. The sensors are distributed in distances before and after the traffic lights. Their algorithm is based on calculating the total relative weight of every road and through RFID the system receives the information about any emergency case. Informing about the emergency cases is done by the installation of RFID tag in vehicles like police cars, ambulance, fire trucks, etc and it is detected by RFID reader located at the sideways of the road. However they have not given enough information about the used algorithm and how they plan to monitor multiple intersections.

Bhat et al. (2015) have proposed an intelligent dynamic traffic control system. They have used sensors to gather vehicular information which is installed at regular intervals along the sidewalks of the roads. Their algorithm involves calculating the green signal time and calculating the average waiting time. However, the authors have not mentioned about the type of sensors used and have not mentioned about how they want to calculate the vehicle density at the junction.

2.4 Summary

In this chapter, wire and wireless based traffic monitoring systems have been discussed. In section 2.3, intelligent traffic light systems have also been reviewed by studying their proposed ideas and highlighting its weaknesses. These methods were either applied on an isolated intersection or/and in multiple intersections. By reviewing these methods it is important to analyze all the lanes in order to efficiently minimize traffic congestion at crossroads.

However, most of the methods only consider that traffic which arrives at the junction and fails to take into account the opposite lanes congestion when adjusting the signal timing. Due to this, the most efficient solution is difficult to achieve since only the incoming lane is considered. When the forward lane gets congested it is difficult to clear the incoming lane since vehicles will pass the junction at a lower rate. It is important to consider forward lanes congestion is an intersection to efficiently provide a free flowing lane which minimizes traffic congestion.

CHAPTER 3: OBSERVATION AND ANALYSIS

3.1 Introduction

In this chapter, an observation is carried out to justify the issue mentioned in the literature review summery. Based on the observation results, the data have been used to analyze and verify the claim that considering all the lanes is a vital factor to efficiently optimize a traffic light system.

Various qualitative methods of data collection are available for research studies. In this research observation is the method used to collect the data. In this section a brief introduction will be made about observation and a justification will be given on why it is important for this research.

Despite the advances in intelligent transportation system, most traffic lights still uses fixed signal allocation mechanism. Due to this reason signal timing remains the same during normal and rush hours unless the timing is changed. To further prove this claim it"s important to conduct an observation. Aspects of this observation will be discussed here and further analysis will be made based on the data collected.

In the following section the advantages of conducting an observation will be discussed briefly before moving on to discuss the data gathered.

3.2 Why use observation

Conducting an observation has many advantages in the field of research since it provides reliable information because information gathered by observers is more likely to be accurate and consistent; making it more useful to the overall evaluation. Observation also allows the observer to select the important aspects and leave out the unnecessary information when collecting the data to address the evaluation questions.

Another reason why observation is important is because it is easy to analyze the collected data. A consistent observation will provide decent information for scientific analysis, whether that analysis is quantitative or qualitative. Observation also allows information to be collected systematically rather than leaving the observer with disconnected data that are not necessarily related to what they want to know.

When observation is conducted it is easier to justify the findings because it gives accurate information and more reliable conclusions that can be drawn from it. It"s easier to justify when the information is reliable and accurate when the observational system is designed and implemented well. Observation also helps to gain credibility with people who control the funds and make policies. When credible evaluation is presented based on the data collected; the observers are treated as a knowledgeable voice in the field. When the observation is conducted well with confidence, it is possible to feel that the evaluation results are providing the truth. Highly effective results will let the observer to pass it to colleagues in the field without worrying that the methods they use or assumptions they make might not work well. These are important factors why observations are conducted and why it"s important for a research.

3.3 Data Collection

An observation was conducted in one of the traffic junctions in Malaysia. It"s a four-way junction located in Bandar Sunway, where vehicles can either move forward/right or turn left during green light signal. The junction is also managed using actuated traffic control and signal moves from one lane to another only when a particular lane has finished its signal cycle. The observation was conducted for one seven days and during 3 different times in each day. Consideration of timing to collect the data was taken according to information given in Types of Traffic Jam That Will Be Encountered in Malaysia. (2016).

3.3.1 Normal Hours

Normal hours are from 9 am in the morning till 10 am. During this time the observation was conducted to check the flow of the traffic.

Table 3.1: Traffic during Normal Hours

Days	Green	Yellow	Vehicle Arrival	Vehicle Departure	Flow rate
Sunday	20	3	20	23	1.2
Monday	23	3	19	19	1.0
Tuesday	21	3	23	24	1.0
Wednesday	20	3	21	20	1.0
Thursday	23	3	18	23	1.3
Friday	24	3	16	21	1.3
Saturday	22	3	22	22	1.0

As shown in Table 3.1, during normal traffic hours, the flow rate is high since the departure rate of vehicles is higher. Although the green signal timing is low during these hours the amount of vehicles which come and leaves are less, therefore is does not lead to a congestion during this time. Flow rate is described at the number of vehicles which arrive and leave the junction at green light signal per cycle. In other words, the throughput rate per cycle.

3.3.2 Rush Hours

Rush hours are from 4 pm in the evening till 5 pm. During this time the observation was conducted to check the flow of the traffic.

Table 3.2: Traffic during Rush Hours

Days	Green	Yellow	Vehicle Arrival	Vehicle Departure	Flow rate
Sunday	43	3	38	37	1.0
Monday	40	3	36	35	1.0
Tuesday	45	3	46	40	0.9
Wednesday	45	3	40	38	1.0
Thursday	42	3	45	41	0.9
Friday	46	3	43	42	1.0
Saturday	47	3	48	45	0.9

As shown in Table 3.2, during rush hours, the flow rate is high since the departure rate of vehicles is higher. This is mainly because the green signal timing is increased during this time. The amount of vehicles which comes and leaves are higher during rush hours, since the signal timing is increased it does not lead to congestion during this time.

3.3.3 Forward Lanes Congestion

Rush hours after 5 pm lead to many vehicles arriving at the intersection at the same time. When this happens vehicles tend to move slower than usual and causes forward lanes to get congested. Sometimes forward lanes may also get congested if there is an accident, leading to traffic congestion. The observation was also conducted during forward lanes congestion to check the flow of the traffic.

Table 3.3: Traffic during Forward Lane Congestion

Days	Green	Yellow	Vehicle Arrival	Vehicle Departure	Flow rate
Sunday	40	3	35	20	0.6
Monday	38	3	38	28	0.7
Tuesday	42	3	40	26	0.7
Wednesday	43	3	42	30	0.7
Thursday	45	3	41	30	0.7
Friday	46	3	48	26	0.5
Saturday	42	3	45	28	0.6

As shown in Table 3.3, during forward lane congestion, the flow rate is less since the departure rate of vehicles is less than the amount of vehicles which arrive at the junction. Although the signal timing is increased during this time, the amount of vehicles which can leave the junction is fewer since the traveling speed is lower because of the forward lanes congestion. This leads to fewer vehicles to pass through the lane causing congestion at the junction.

3.4 Analysis

According to the data collected, it‟s very clear that once the forward lanes get congested it affects the flow of vehicles in a particular lane. Although different methods have been presented in the past, failing to consider traffic congestion in the forward lanes will not provide the most efficient method to solve congestion problems. Based on this data gathered, this study will enhance the existing model to provide a better solution for the traffic light systems by considering all the lanes congestion level before allocating more signal time.

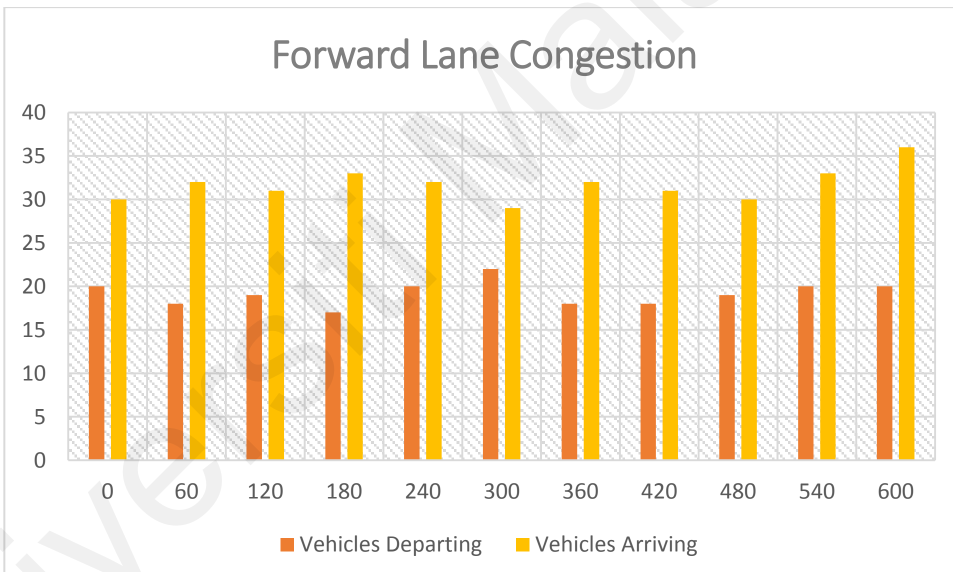


Figure 3.1: Lane congestion data

As illustrated in figure 3.1, during rush hours when the forward lane is congested the amount of vehicles that can clear the lane from the incoming lane are fewer than normal time. The collected data took a portion of that duration in which analysis was made based on the data within 10 minutes of congestion. Assuming the forward lanes are congested, a vehicle from Lane A which is moving from North to South might find one of the lanes in which it is moving to gets congested. Since the green light timing is mainly based on the vehicles arriving at the junction, it fails to consider the forward lanes. Vehicle is which moving from north to south will decrease its speed since that lane is congested, meaning it takes fewer vehicles to depart during that green cycle. Hence, vehicles might have to stay for 2-3 green cycle to clear out once it reaches a traffic junction.

The results represent that once the forward lane gets congested vehicles have to stay a long time to pass the traffic light when the signal turns green and fewer vehicles gets the chance to move out making it more difficult. If signal timing can be adjusted based on the traffic volume in the forward lane, it will give chance for more vehicles to pass the junction. In the current observation fewer vehicles get to pass at each cycle making the lane more congested.

3.5 Summary

In this chapter, an explanation was given why the observation had to be carried out and why it‟s important for this research. According to the data collected, it is clear that traffic flow rate is low during forward lane congestion hours. During normal traffic hours the flow rate is at a balanced rate where vehicles arrive and leave during one cycle without any congestion in the traffic. However, during rush hours the congestion increases and vehicles require more time to pass through the junction. Based on the observation and analysis, a new algorithm will be created which takes both of the incoming and forward lanes congestion level into consideration when allocating additional green signal timing to smoothen the flow of the traffic.

CHAPTER 4: METHODOLOGY

4.1 Introduction

Traffic light systems require intelligent methods to fix the existing problems caused by fixed signal control mechanisms. Intelligent transportation systems use automatic methods to improve road transportation by increasing the safety of the vehicles, optimizing the flow of the traffic and minimizing the energy consumption of the vehicles.

Most of the existing traffic control methods use either fixed-time, actuated or adaptive traffic control approaches. In a dynamically changes road transportation system there are many variables which needs to be accounted for before any kind of enhancement can be done. Fixed traffic control systems are mostly used around the world to control the traffic lights, but these systems fail to take into consideration factors like throughput and traffic flow before adjusting the signal timing. Therefore it is important to create a dynamic traffic light system which minimizes average waiting time and increases the throughput at the intersection.

In this chapter a dynamic traffic light control method will be proposed by making use of vehicular data gathered by sensors implemented on the road. Standard traffic light systems and some of the proposed methods do not take into account the traffic congestion of all the lanes before deciding to change the signal timing. The algorithm presented in this research is Traffic Light Signal Manipulation Algorithm (TLSMA). This algorithm contains two parts; Real-Time Vehicle Detection which will be based on the traffic data generated by the sensors and Green Signal Light Manipulation.

4.2 Assumptions

In this section, the assumptions for this study will be discussed briefly. First, this research assumes that the road intersection will be a single four way intersection which includes 2 legs on each lane. Although vehicles can move forward, left and right from each lane, it will be assumed that vehicles moving to the left do not require the traffic signal. Hence for this research assumption is made that the vehicles only move forward or turn right and only these directions will require the green light signal to move.

Second, this research assumes that vehicles which are arriving at the intersection are arriving according to certain random distribution and these vehicles will depart after waiting for some time. Also it will be assumed that vehicles will travel at a constant speed and that all of the vehicles are of the same type.

Third, this research assumes that the traffic light sequence moves from one lane to another once the sequence is completed in that particular lane. For example, Lane B signal sequence will only begin once the Lane A is completed as shown in Figure 4.2. It will also be assumed that each lane is controlled with a traffic light that offers three signals, Red; which prohibits any vehicle from proceeding, Yellow; which warns the vehicle to stop and Green; which allows the vehicles to proceed forward with the direction denoted. Assumptions is also made that sensors which are placed on the road are at a distance that it can communicate with each other.

4.3 Problem Formulation

The existing problem of traffic light systems is how to respond dynamically to an environment which changes traffic to improve the flow of vehicles, by keeping the fairness for each lane. Here, the efficiency as the intersection throughput, meaning the number of vehicles that can pass through the intersection. To model this problem, the roads or the lanes will be equipped with sensors and the intersection will consist of four directions (North, East, South, and West), and each of these directions will have two lanes, one will be used to go forward and the other lane will be used to turn right. Every lane will be controlled with a traffic light that offers three signals, red for stop, yellow for slow down and green for go. On eight lanes of the intersection, a total of sixteen sensors are placed to detect the flow of traffic. Each arrival lane has two sensor nodes; one is installed near the traffic light stop line and the other at a given distance from the intersection stop line sensor as shown in the Figure 4.1.

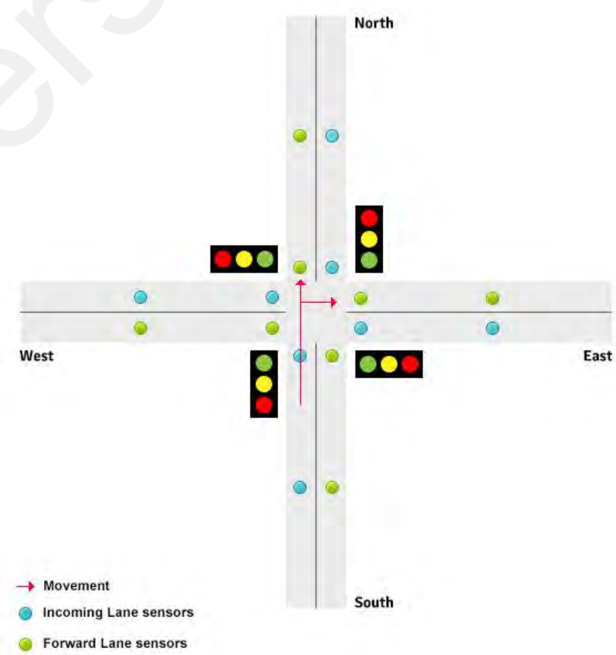


Figure 4.1: Single Intersection Model

The simulation area is created based on the traffic junction at Bandar Sunway, Malaysian. Subject to traffic safety rules, the simulation will create the flow of vehicles based on this junction. Hence a maximum of four different possible cases of green lights will exist as depicted in Figure. 4.2. Every movement is represented by the cardinal directions of its origin and destination (e.g. WE: from West to East). A phase is therefore defined by a set of allowed movements. To formulate the problem, the next section will provide the notations which will be used in this study. It will also be assumed that all vehicles run at a constant speed and that all of the vehicles are of the same type.

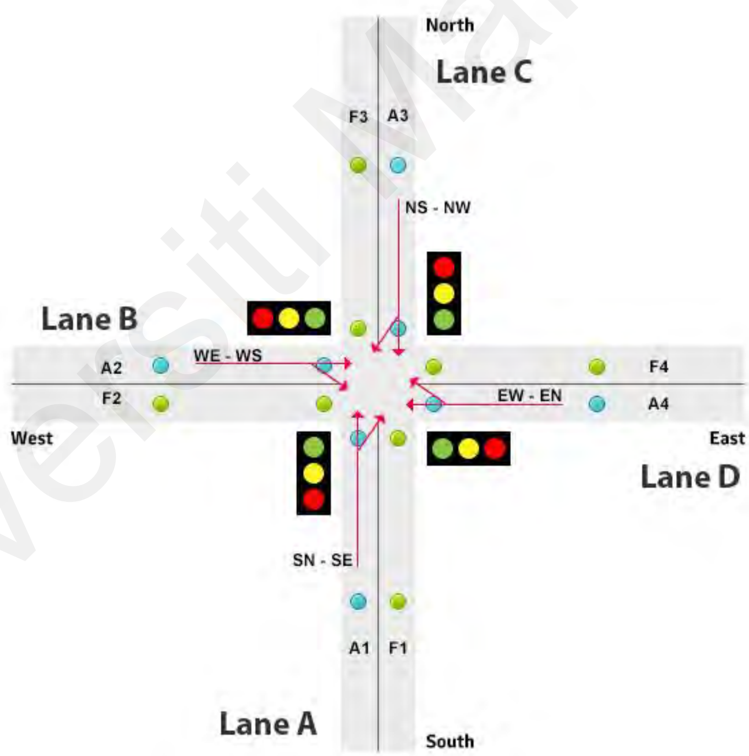


Figure 4.2: Possible Directions for Vehicle Movement

4.4 Notations

D = {North, East, South, and West}, which represents the four directions of the intersection.

M = {Forward, Right}, which represents the two movements permitted for vehicles.

A = {1, 2, 3, 4}, which represents the four lanes of the intersection where vehicles arrive and stop at red light.

F = {1, 2, 3, 4}, which represents the four lanes of the intersection where vehicles move to when the green light signal is on.

t,The time vehicles spent at the lane at each cycle.

Vd(g), is the amount of vehicles departing during green light.

Va(r), is the amount of vehicles arriving during red light.

Vr(g), is the amount of vehicles remaining during previous green light.

TP: Throughput.

TPfLane: Total Throughout at forward lanes.

4.5 Mobility Model

The mobility model of the system is divided in to two parts. The first part of the system involves by calculating the throughput of each lane where vehicles arrive at the junction. The model then moves to figure out the forward lanes congestion before calculating the average waiting time during the red light sequence. The system will then move to the second part of the algorithm that is to allocate signal timing based on the congestion level at each lane.

4.5.1 Effect of Mobility Model

The system calculates the vehicles based on the simulation which is run through SUMO. The model is run through a map which is generated through openstreetmap which has all the lanes as given in figure 4.2. The effect of the mobility model is that the mobile nodes are only fixed to the given lanes and the speeds of these nodes are limited to the allocated value. However, in a real scenario nodes are not fixed to a given lane and the speed also varies from time to time. This could have major consequences in the mobility model since the vehicular information is only fixed to the given scenario.

4.6 Traffic Light Signal Manipulation Algorithm

In this section, Traffic Light Signal Manipulation Algorithm will be developed based on the model defined in section 4.5. This algorithm contains two steps: Real-time Vehicle Detection and Green Signal Light Manipulation. Real-time vehicle detection is about detecting the vehicles in real-time and calculating the traffic information based on the data collected by the sensors. Green Signal Light Manipulation involves using traffic information to determine the amount of signal time needs to be increased or decreased based on the throughput level in a particular lane.

4.6.1 Real-time Vehicle Detection

The first step of this algorithm is to detect and collect the arrival of vehicles and the rate at which these vehicles depart in each lane, using the sensor nodes that are installed in every lane of the intersection. Sensor nodes are responsible for detecting the number of vehicles in each lane and it records every vehicle"s ID. Arrival Sensor is responsible for identifying the vehicles at the intersection which arrive at green or red signal; Departure sensor is responsible for detecting vehicles which arrive and leaves during a green signal timing.

Forward Lane arrival sensors are responsible for detecting vehicles which arrive once the vehicles leave the main lane in which they wait at red signal. Forward lane departure sensors collect data to determine which vehicles depart the forward lanes. Using these detected data, the vehicles at incoming lane and forward lane can be determined in real-time as illustrated in Figure 4.3.

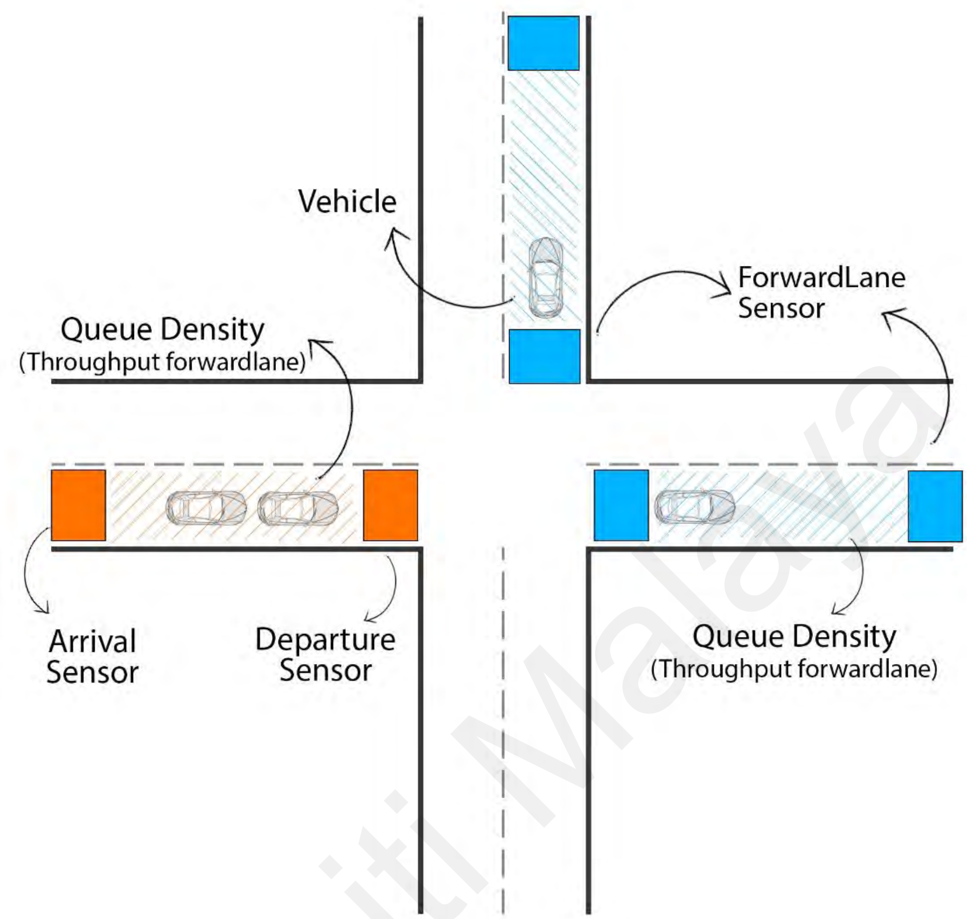


Figure 4.3: Real-time traffic detection

Two sets of sensors are installed on each lane, the incoming lane sensors detect the density of vehicles which arrive at each particular lane. The forward lanes sensors will determine if the lanes in which the vehicles are moving to are congested or not; in order to determine addition green light signal time for that lane.

4.6.1.1 Incoming Lane Traffic Detection

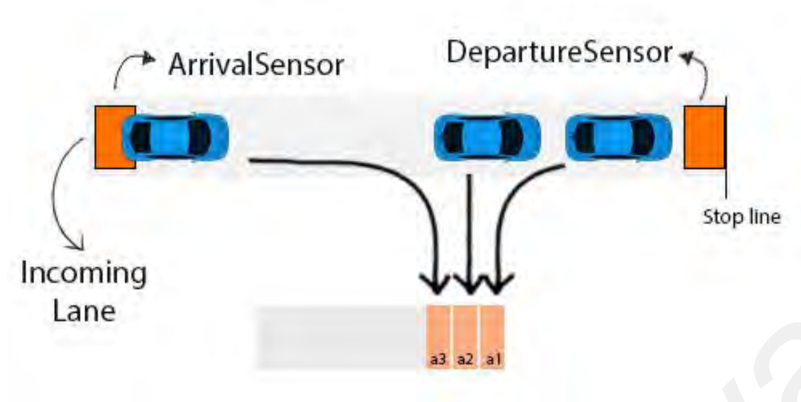


Figure 4.4: Incoming Lane Traffic Detection

The first step is to collect data from the sensor nodes to calculate the amount of vehicles in the lane. The incoming lane collects vehicle information from arrival and departure sensors. Arrival sensor will be responsible for detecting vehicles that arrive at the traffic light. Every time a vehicles passes over the arrival sensor, information will be collected and stored as a1, a2, a3….and , a(n+1) and so on as illustrated in Figure 4.4. Sensors are given the name based on the lane in which they are located. A sensor which is nearer to the stop line is the departure sensor which is called Wis, Wis on the other hand is the arrival sensor which detects the arrival rate of vehicles. The system will collect this data once the vehicles are passed over it, same applies to the rest of the lanes as well.

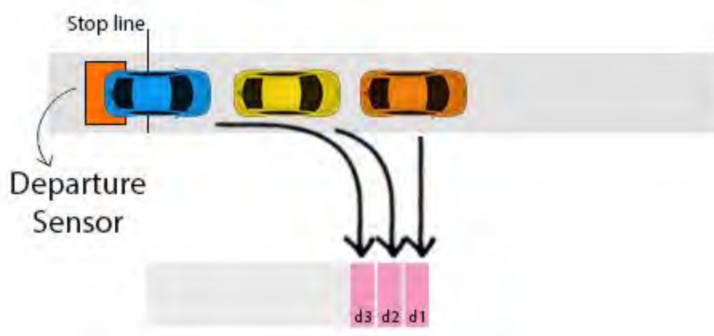


Figure 4.5: Departure Sensors from incoming lane

Departure Sensor will be responsible for vehicles which depart the lane during green light as shown in Figure 4.5. Once the vehicles depart the sensors will sense and collect this data as d1, d2, d3….and, d(n+1) so on.

The arrival rate and the departure rate of these vehicles can be detected, once these data is collected at each lane then the flow of these vehicles will calculated in real-time. In every lane once the green light is indicated, both the arrival and departure rates are calculated in real-time. In every lane once the red light is on, the departure rate becomes zero and the rate at which vehicles that arrival reflects how many vehicles are waiting in the lane during the previous green light.

Using the sensor data, the total throughput of each lane will be calculated using the given formula:

$$TP = V_{d(g)}/V_{a(r)} + V_{r(g)}$$

Where TP = Throughput, $V_{d(g)}$ = Number of vehicles departing during green signal, $V_{a(r)}$ = Vehicles which arrive during red signal timing and $V_{r(g)}$ = Vehicles which remain during previous green signal.

4.6.1.2 Forward Lane Traffic Detection

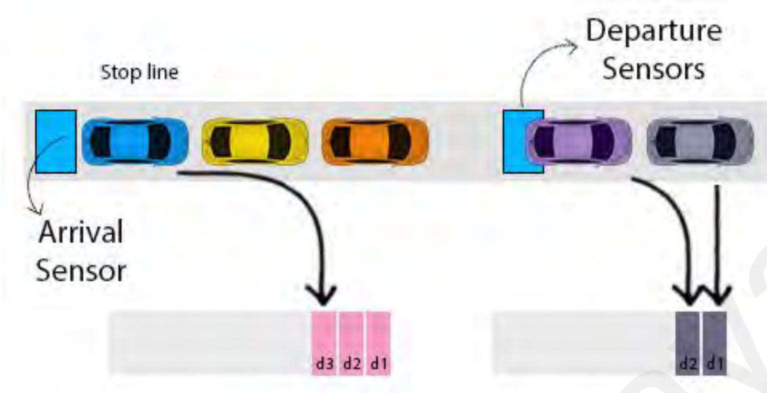


Figure 4.6: Forward lane sensors

As illustrated in Figure 4.6, the forward lane sensors will be responsible for detecting congestion in the corresponding lanes once the vehicles pass a traffic light. Forward lanes will also have 2 sensors placed within a distance whereby they can communicate each other. The arrival sensors are named as E_{fa} and the departing sensor is named $E_{fd.}$ These sensors will collect the data every time the vehicle passes over it. These sensors will calculate the throughput of the vehicles using the formula:

$$TP_{fLane} = V_d / V_a$$

Where TP_{fLane} = Total Throughput at forward lane, V_d = vehicles departing the forward lane and V_a = Total number of vehicles arriving at the forward lane. If the throughput of the forward lane is low then it is assumed that there is congestion in the forward lanes. If the throughput is high it is assumed that there is no congestion.

The arrival and departure rate of the vehicles will be determined in real-time by the sensors and the throughput of these lanes will be calculated. During green signal timing, the rate will be calculated by determining the vehicles which arrive and leave the traffic light.

During the red signal the rate will be determined the amount of vehicles which are waiting in the lane as the departure rate will be zero.

4.6.1.3 Average Waiting Time

The average waiting time of the vehicles will be calculated by determining the amount of time these vehicles have to wait at particular lane divided by the number of vehicles at the lane. Average waiting time will be calculated using the formula

$$AvW = WtV/NvL$$

Where AvW is the average waiting time, WtV is the amount of time vehicles have to wait at the lane and NvL is the number of vehicles at the lane.

4.6.1.4 Traffic Density Estimation

By identifying the average waiting time of the vehicles at each lane, traffic density will be calculated. To calculate the density, first the traffic volume of each lane needs to be checked at *t* time of the signal control by obtaining the data from the throughput. The throughput of the incoming lane at green signal at *t* time and the forward lanes throughput during the green signal at *t* will be calculated. To determine the density the throughput during the red signal at *t* time from all the lanes needs to be calculated as well. When the density is higher it will have a higher priority in the decision making. The following formula will be used to calculate the traffic density estimation.

$$TdEst(t) = \frac{AvW}{TP(t,g,l)}$$

4.6.2 Green Signal Light Manipulation

The second part of the algorithm is to determine the allocation of green signal timing based on the average waiting time and the throughput at the intersection. This decision is made by identifying the congestion level at a particular lane. If the throughput of that particular lane is low it can assume that lane is congested so that additional green signal timing will be allocated for that lane. However, the signal timing for each lane will be carried out to increase in such a way so that starvation level does not increase once the green light signal timing is increased at a congested lane.

The starvation level described in this research is to determine the minimum green signal allocation for the lanes so that all the lanes have fair signal timing. When the density is lower at the lane the starvation level is at a minimum meaning the lowest green signal timing will be allocated for that particular lane. However, when the density is higher the signal will be increased.

The waiting time at each junction can change dynamically and this depends on the real time traffic situation at the specific intersection with respect to the traffic situations that currently exist in other intersections. For example the total waiting time at a junction is 90 seconds, the period for Green and Yellow states may probably be 30 seconds at each lane.

The timing for a Yellow state can be fixed at 3 seconds which is long enough for a driver to stop the vehicle before the signal turns red. The Green state at A represents as AG and for yellow state at A represents as AY, which is similarly applied to B, C and D as BG, BY, CG, CY, DG and DY. Thus, the waiting time for A can be measured as: A(wait) = BG + BY + CG + CY + DG + DY + AY. A(wait) = BG + CG + DG + 4(3)s. A(wait) = BG + CG + DG + 12s.

The waiting time for A will not be equal to the waiting time of B, C or D since the Green state timing at each lane may change according to the traffic congestion. If no vehicles are detected in a particular lane then the traffic light sequence automatically proceeds to the next lane. For example, if no vehicles are detected at A1, then the state will move to B1 and so forth. On the other hand if the congestion on a particular lane is high, then the system will check for the conditions of other lanes and determine a suitable timing to relieve the congestion from the congested lane which maximizes the efficiency. This will allow a reasonable balance for the overall waiting time for all the lanes.

If the vehicle density is normal then the default green light timing will apply to that particular lane. However, if the forward lane sensors indicate congestion in those lanes, additional green signal time will be allocated. To calculate the waiting time, the system will collect the amount of time a vehicle spends at the junction once it arrives at a lane during red signal timing. In order to determine the waiting time, the yellow and green signal timing from all the other lanes needs to be collected. The sequence for the green lights signal length in each intersection will be determined. Signal(length) is defined as the length of green light signal allocation at an intersection a at time t, which can take all the lanes traffic conditions into consideration. Calculation will be made based on the value of the length in each lane, based on the traffic conditions. Using the following equation, Signal(length) is defined to represent the total amount of time that the vehicles need to wait until it can to pass through the intersection.

$$Signal(length) = Is(t, a) + S(cycle)$$

By considering that vehicles have to wait at red lights as few times as possible when passing through the intersections. Is(t, a) is defined as the amount of time which is sufficient for the vehicles that are permitted from intersection a to pass through during green signal. S(cycle) is defined by the amount of time the vehicle needs to wait until the it gets its next phase of green light. In order to provide fairness among all the lanes, a maximum green light signal time is also defined as Time(max) so that Signal(length) should be less than Time(max). The system will also set a Time(min) so that the signal light stays at a default level even when the traffic is less in a particular lane. The minimum amount of green time represents the least amount of time that a green signal indication will be displayed for the movement of vehicles and it is used to allow drivers to react to the start of the green interval. The duration of the timing may also be based on considerations of queue length. The minimum green time is set in such a way so that it does not result in wasted time at an intersection.

The algorithm will start by checking lane A"s signal as illustrated in figure 4.2, if its Green, it will change all the other lanes signal to Red, and the signal cycle will move on clockwise direction changing the signal from Green, Yellow and Red in each cycle. If the congestion is not detected from the incoming lanes or forward lanes, then the signal timing will use the default timing scheme set by the simulation based on the Traffic Signal Timing Manual given by US department of transportation (Koonce, 2008).

However, if the congestion is detected by the incoming lanes will check if the forward lanes for congestion, if congestion is not detected then it will allocate additional signal timing to smoothen the flow of traffic. But if the congestion is detected at both incoming lane and the forward lane then it will allocate extra green signal timing to these lanes to relieve the congestion. By doing so it will also check if the green signal timing to not exceed the maximum timing time set according to the Traffic Signal Timing Manual (Koonce, 2008). The proposed algorithm is applied to lanes B, C and D as well in order to minimize the congestion at the lane which has long queuing times. This model is also responsible in providing an efficiently flowing traffic lane to the most congested route.

Table 4.1: Green Light Allocation Determination at Intersection

```
Green Light Signal Manipulation
Input: Vehicles arriving at l lane
Output: Determining the time allocation at l lane
BEGIN
    1. Determine the incoming vehicles a1,a2…a(n+1)
    2. Calculate the TP of incoming l lanes
    3. Calculate the TPfLane of forward l lanes
    4. If TP and TPfLane is high
            Check starvation level
            Assign Signal Timing
       Else
            Calculate AvW for l lane
    5. IF AvW is higher
            Calculate the TdEst(t)
                If the TdEst(t) is high
                    Check starvation level
                    Assign Signal Timing
                Else
                    Check starvation level
                    Assign Signal Timing
                End
       Else
            Assign Signal Timing
       End
END
```

Table 4.2: Signal Time Allocation at Intersection

```
Green Signal Timing
Input: Traffic Density at l lane
Output: Green signal time
BEGIN
    1. Keep default timing at l lane
    2. IF density is high
            Calculate Signal(length)
            Allocate additional Green time for l lane
            Allocate min green signal for lanes with fewer AvW
       Else
            Allocate default Green time
END
```

Figure 4.7 shows the state diagram of the system. The system checks for the incoming vehicles in the junction. It then calculates the throughput after the signal cycle completes its first phase. At the same time the system will also calculate the throughput of the forward lanes to check the flow rate. After calculating the throughput of both incoming and the forward lane, the system will calculate the average waiting time in each lane.

If the waiting time is higher, the congestion level is calculated to estimate the congestion level. However, if no congestion is detected then the system will check for starvation level and set the default timing. If other lanes are congested the system will allocate the minimum green light timing set in the starvation level.

If congestion is detected the system will check the starvation level of all other lanes and set the minimum green signal timing for the lanes with no congestion. After that the system will allocate more timing for the lanes with higher density.

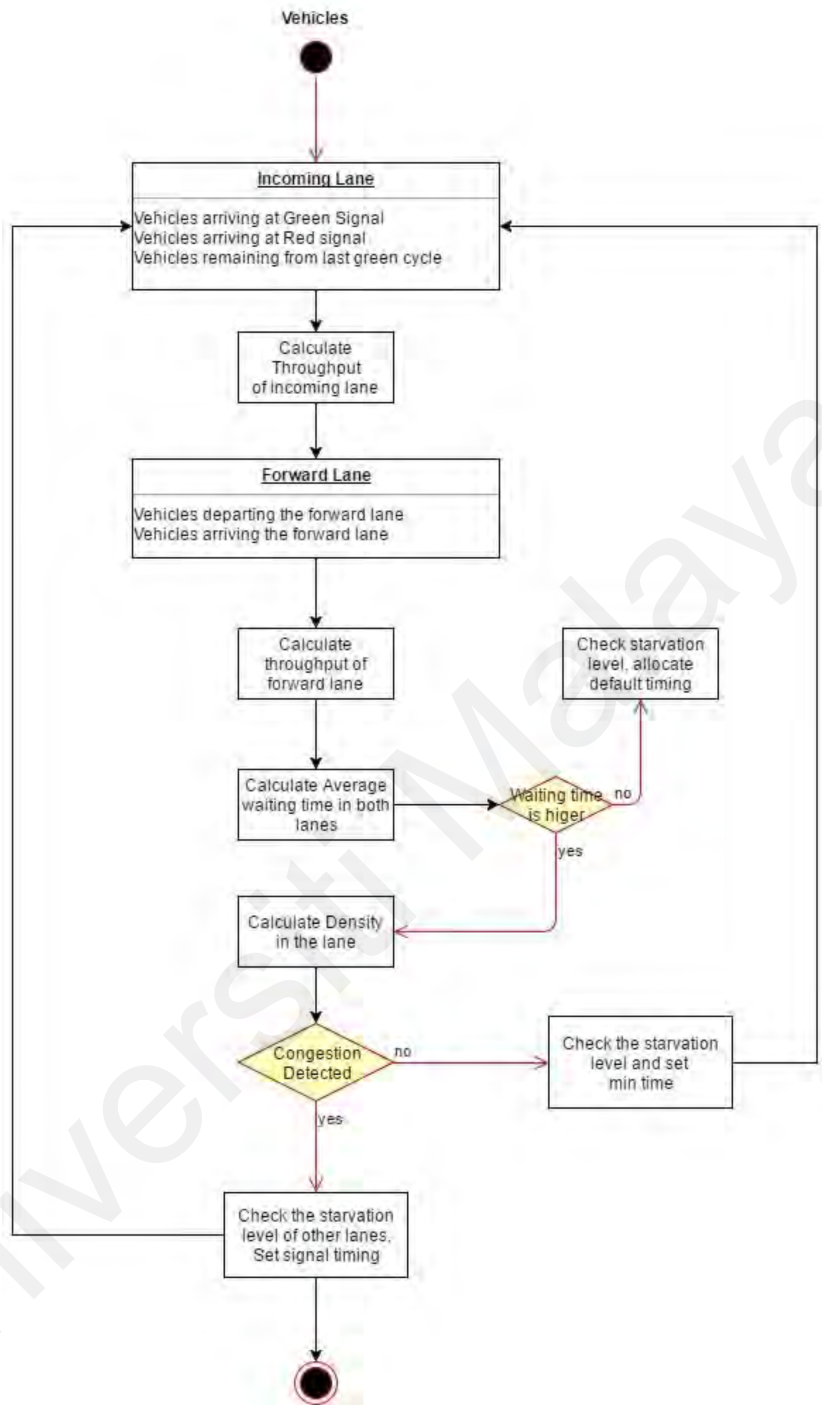


Figure 4.7: State Diagram of the System

4.7 Summary

In this Chapter Traffic Light Signal Manipulation Algorithm was presented. The algorithm is capable of changing the traffic light signal based on real-time traffic flow data generated by the on-road sensor technology. The proposed method consists of two parts; first part is gathering the necessary vehicular information and the second part if responsible for changing the signal timing.

The main purpose of this algorithm is to minimize the traffic congestion and waiting time for the vehicles. The proposed scheme is not only responsible for checking the vehicles which arrive at the traffic light, it also checks the forward lanes congestion in order to provide the most efficient signal timing to ease the congestion. In the next chapter the results of this proposed system will be evaluated and discussed.

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter will discuss about the proposed methods performance which have been carried out using SUMO simulator to determine the efficiency of the proposed dynamic traffic light system created using the Traffic Light Signal Manipulation Algorithm. This method is compared to a fixed-time traffic control (SCOOT) mechanism and an actuated traffic light control method (TAPIOCA); which is also based on the same random arrival and departure rate of vehicles at each lane (Faye, Chaudet, & Demeure, 2012).

This research is set on the location by collecting the map from OpenStreetMap, which is a mapping application that maintains and contributes the data about roads, trails, railway stations, and much more, all over the world. OpenStreetMap was specifically created for road map which eventually became one of the best free geographic database. The main reason this was used in this research is because it is an open-source software and it can be easily integrated with SUMO simulator.

5.2 Evaluation

Evaluation of the Traffic Light Signal Manipulation Algorithm (TLSMA) that is proposed in this research is evaluated using SUMO simulator, with the use of an open source traffic simulation package including net import and demand modeling component. Sumo simulator provides a free tool for the traffic simulation community into which their own algorithms can be implemented.

SUMO can help prepare and perform traffic simulation and it is an application which represents the road networks and the traffic demands while allowing the user to model the traffic scenario in a way they desire. The application can also simulate the traffic demand in its own format; both have to be imported or generated using different sources.

The simulation presented here is performed on a four-way intersection which is designed similar to the intersection at Bandar Sunway City, Malaysia, for which the vehicles traffic data is collected and distributed at a rush hours (5 p.m. to 6 p.m.). The figures of the corresponding policy (cycles, phases and timings) are collected during this time. The lanes are created such that each lane moves in the direction such as North, East, South and West.

The speed of the vehicles which travels in this simulation is designed to travel at 60km/hr at a random fashion. According to the Types of Road and Speed Limits - Malaysia. (n.d.), the state roads, or secondary roads in Malaysia which consists of one lane, mostly have a speed limit between 60 to 90 km/h. Due to this reason the proposed model have set the speed of the vehicles based on this range.

The performance evaluation includes throughput and average waiting time as a response to the objectives. The throughput rate of the intersection were calculated using the total number of vehicles that leaves the intersection during green signal time, and were collected as the number of vehicles which arrive and leave per second. Throughput rate is identified as the rate of vehicles that are passing the traffic light at each lane and the corresponding lanes in which the vehicles are moving to. Average waiting time was calculated by determining the amount of time these vehicles have to wait at particular lane divided by the number of vehicles at the lane.

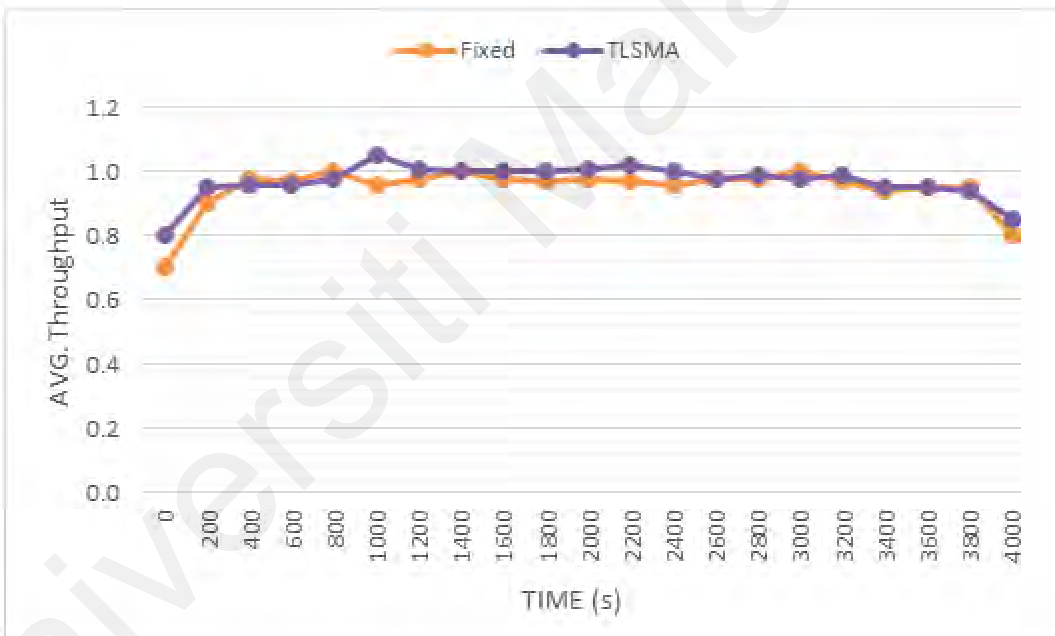


Figure 5.1: Average Throughput during normal hours

As illustrated in Figure 5.1, the average throughput of vehicles during normal hours show that the threshold is above 0.8, meaning the flow of vehicles are saturated and there are no congestion detected during this time. TLSMA is compared to the fixed traffic light system model such as Scoot (Robertson, & Bretherton, 1991). During normal traffic hours the flow of vehicles in TLSMA are almost the same the fixed timing strategy.

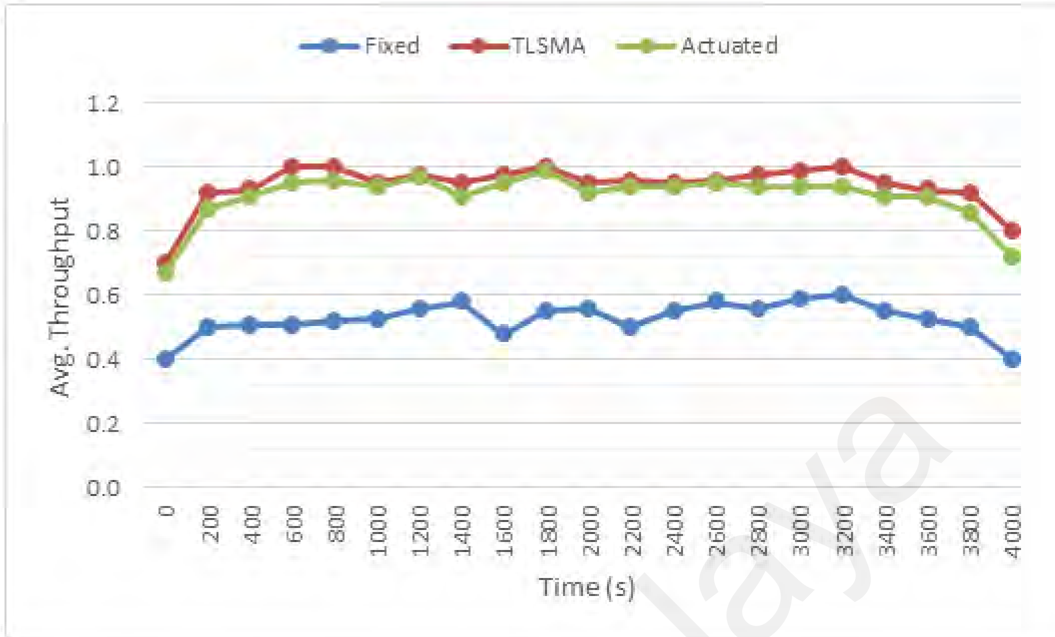


Figure 5.2: Average Throughput during rush hours

Figure 5.2 shows the average throughput rate of vehicles in rush hours. As illustrated there is not much of a difference between the proposed method and the actuated scheme. During rush hours when the vehicles are congested the fixed light system provides an average of 0.5 throughput rate which causes more vehicles to wait in the queue for a longer period of time. However, the actuated and the proposed method (TLSMA) average a throughput rate of 1.0, which allows more vehicles to pass through.

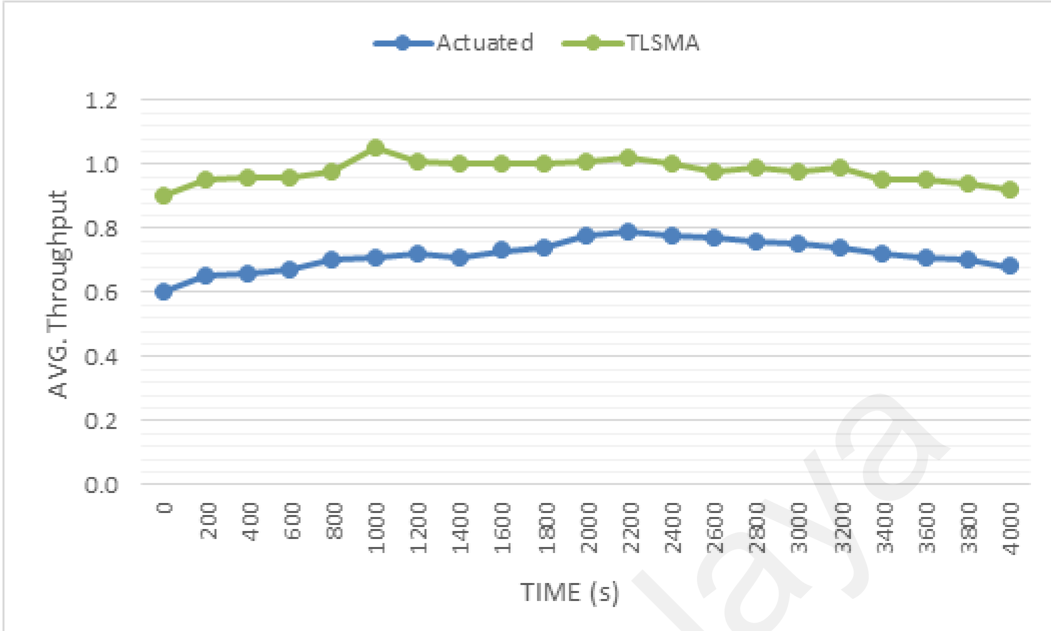


Figure 5.3: Throughput of forward lane congestion during rush hours

Figure 5.3 shows the throughput rate during forward lane congestion. The simulation for conducted for 4000s to estimate the throughput rate in these lanes. Unlike during the rush hour period where throughput rate was almost at 1.0, the actuated scheme drops its throughput rate to an average of 0.7 during forward lane congestion.

This is because fewer vehicles get to pass through the lane once the forward lane is being simulated with more vehicles. However, since this scheme calculates and increases the green signal timing, it can maintain the average rate of 1.0 throughput rate during forward lane congestion.

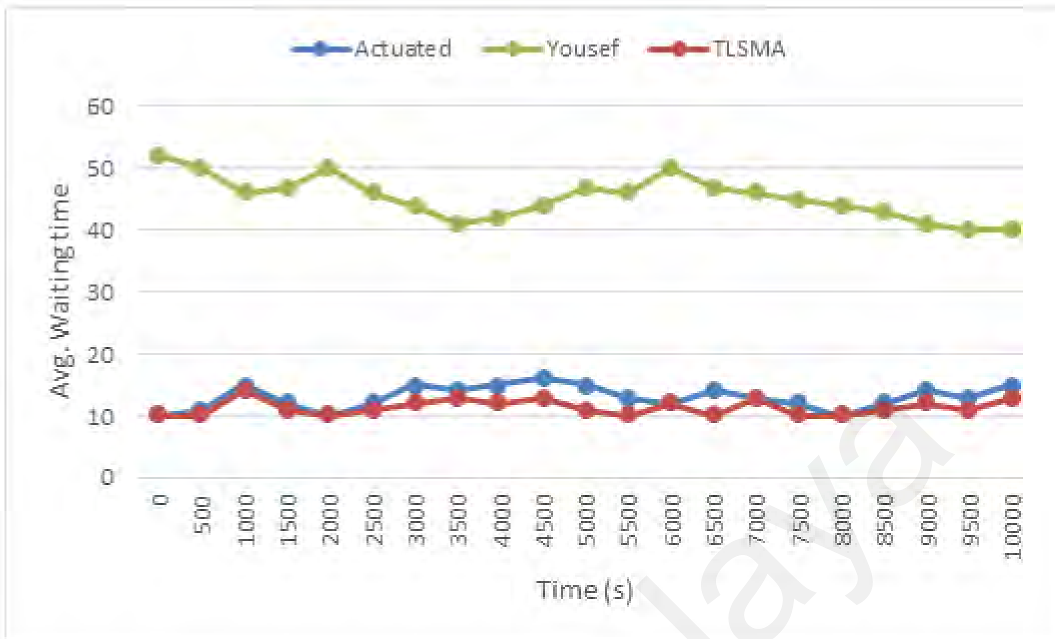


Figure 5.4: Average Waiting Time during rush hours

In figure 5.4, the average waiting time per vehicle increases during rush hours with the actuated method compared to the TLSMA. This method is also compared with the waiting time method proposed by Yousef et al (2010), their method averages are higher waiting time compared to the method proposed. Once the incoming and forward lanes congestion starts to increase the waiting time for the vehicles increases since only a few seconds is available for these vehicles to pass through the junction, hence more waiting time. The proposed method identifies the waiting time based on the congestion level at forward lane. Though there are more vehicles in the traffic environment, the average waiting time in this scheme also begins to grow, but still remains lower than TAPICO (actuated). When the average waiting time is less than 20 seconds, this leads to an almost saturated intersection. This scheme also gains the average waiting time similar to TAPICO. Finally, from the results of the simulation, it is clear that TLSMA proposed in this research can achieve higher throughput rate and lower average waiting when compared with a fixed-time traffic control method and an actuated traffic control method.

5.3 Summary

In this chapter, Traffic Light Signal Manipulation Algorithm (TLSMA) was presented. The main purpose of this model is to minimize the average waiting time for the vehicles and increase the throughput of these vehicles at the intersection. The simulation results shows that the proposed method can achieve a higher average throughput rate and a lower average waiting time for vehicles in when it is compared with a fixed-time control method and an actuated control approach.

CHAPTER 6: CONCLUSION

6.1 Introduction

In this research, first the characteristics of on-road sensor based Intelligent Transportation System was investigated. Next the sensors used in the system were discussed and why it can be important for this research. The traffic light systems were also investigated in terms of how it works and the signal control methods. The research also identified the need of traffic light systems in an Intelligent Transportation System to solve traffic congestion issues at crossroads. To further prove why the enhancement needs to be carried out with existing methods, an investigation was conducted. Based on the investigations, the issue of how to enhance the traffic light control approaches for an isolated intersection was addressed.

Regarding to the traffic light control in an isolated intersection, a dynamic traffic light control method was proposed. This method uses on road sensors to detect vehicles and transmit real-time traffic data to increase the throughput and decrease the amount of waiting time at the junction with the help of Traffic Light Signal Manipulation Algorithm (TLSMA).

First, four green lights cases was defined, under the constraints of a given intersection model and subject to traffic safety rules, and then the control decisions were made to establish the sequence and length of the traffic lights based on the cases. This method contains two steps: Real-time Vehicle Detection and Green Light Signal Allocation. Real-time vehicle detection includes detecting and calculating traffic information, e.g., traffic volumes, waiting time, and characteristics of traffic flow.

Based on the data that is calculated, all of the cases will determine their green light signal allocation, and the case with the highest will be allocated more green light signal timing. The length of the light will be determined by the volume of traffic passing at lane, and once the vehicles pass through, sufficient time will be allocated. The evaluation have been done extensively using SUMO simulator. Simulation was conducted to investigate the performance of system that is proposed in this research. The results given in this chapter clearly show that the objectives have been well fulfilled. This approach also shows that it enhances the previous methods in terms of throughput, and average waiting time of vehicles.

6.2 Future Works

This research is focused on the enhancing the traffic light system with the use of magnetic sensors based ITS. In future work, the proposed method could be investigated and improved in various related research directions.

One of the main issues that require further research is the need to modify the speed of the vehicles which is constant at the moment. In the proposed system, the speed of all vehicles is the same. However, this is not how the vehicles move around in the real world and it does not represent real world traffic conditions. If the system was created with varying speed, it would make the model of this system more dynamic and more complex, and the design of this approach gets more complicated as well. It is also important to test the simulation on a real world environment is to further improve this study.

Controlling traffic lights in multiple intersections is another area of research direction for this model. In this study, it is only focused on achieving a dynamic traffic light system on a single intersection. Single intersection might be a solution for places with fewer traffic junctions. Focus needs to be on the methods which have multiple intersections with forward lane congestion detection to enhance this research study further to improve traffic control performance in large urban areas.

Finally, it is important to take into consideration factors like pedestrians and emergency vehicles into consideration when the traffic lights are controlled. In this study, only the normal vehicles are taken into consideration. However, most of urban areas in the world include pedestrian traffic, which cannot be ruled out in the real world. Therefore, controlling traffic lights by keeping both the vehicles (normal and emergency) and pedestrians in mind should be an area that needs further research.

REFERENCE

Abbas, M., Karsiti, M., Napiah, M., Samir, B., & Al-Jemeli, M. (2015). High accuracy traffic light controller for increasing the given green time utilization. Computers & Electrical Engineering, 41, 40-51.

http://dx.doi.org/10.1016/j.compeleceng.2014.12.011

Al-Khateeb, K. & Johari, J. (2008). Intelligent dynamic traffic light sequence using RFID. 2008 International Conference On Computer And Communication Engineering. http://dx.doi.org/10.1109/iccce.2008.4580829

Amini, A. (2013). An Integrated Framework and Smart Algorithm for Vehicle Localization in Intelligent Transportation Systems. Retrieved October 5, 2014, from http://vtechworks.lib.vt.edu/bitstream/handle/10919/47463/Amini_A_T_2014.pdf?sequence=1

Bhat, A., Roy, K., Anchalia, P., & Jeevith, H. (2015). Design and Implementation of a Dynamic Intelligent Traffic Control System. 2015 17Th Uksim-AMSS International Conference On Modelling And Simulation (Uksim). http://dx.doi.org/10.1109/uksim.2015.12

Bugdol, M., Segiet, Z., & Krecichwost, M. (2014). Vehicle Detection System using Magnetic Sensors, 9(1), 51-60. Retrieved from http://transportproblems.polsl.pl/pl/Archiwum/2014/zeszyt1/2014t9z1_06.pdf

Chao, K., & Chen, P. (2014). An Intelligent Traffic Flow Control System Based on Radio Frequency Identification and Wireless Sensor Networks. International Journal of Distributed Sensor Networks, 10(5), 694545. doi:10.1155/2014/694545

Chen, R., Jin, W., & Regan, A. (2010). Broadcasting safety information in vehicular networks: issues and approaches. IEEE Network, 24(1), 20-25. http://dx.doi.org/10.1109/mnet.2010.5395779

Chen, W., Chen, L., Chen, Z., & Tu, S. (2006). WITS: A Wireless Sensor Network for Intelligent Transportation System. First International Multi-Symposiums On Computer And Computational Sciences (IMSCCS'06). http://dx.doi.org/10.1109/imsccs.2006.286

Chou, C., & Teng, J. (2002). A fuzzy logic controller for traffic junction signals. Information Sciences, 143(1-4), 73-97. http://dx.doi.org/10.1016/s0020-0255(02)00199-8

Collotta, M., Lo Bello, L., & Pau, G. (2015). A novel approach for dynamic traffic lights management based on Wireless Sensor Networks and multiple fuzzy logic controllers. ScienceDirect. Retrieved 1 February 2017, from http://www.sciencedirect.com/science/article/pii/S0957417415001104

Daubaras, A., & Zilys, M. (2012). Vehicle Detection based on Magneto-Resistive Magnetic Field Sensor. Retrieved 19 March 2017, from http://www.ee.ktu.lt/journal/2012/02/06__ISSN_1392-1215_Vehicle%20Detection%20based%20on%20Magneto%20Resistive%20Magnetic%20Field%20Sensor.pdf

Dual Channel Loop Detector. (n.d.). Retrieved March 22, 2017, from http://www.omnypark.com/products/product_details/parking-counting-system/dual-channel-loop-vehicle-detector

Ezell, S. (2010) Intelligent Transportation Systems. Information Technology and Innovation Foundation. From httt://www.itif.org/files/2010-1-27-ITS_Leadership.pdf

Farradyne, P. (2001). Intelligent Transportation Systems Applications for Airports. Retrieved October 5, 2014, from http://www.oregon.gov/ODOT/HWY/ITS/PDFs/ITSDocuments/PDXITSPlans/App4_Airport_White_Paper.pdf?ga=t

Faye, S., Chaudet, C., & Demeure, I. (2012). A distributed algorithm for multiple intersections adaptive traffic lights control using a wireless sensor networks. Proceedings Of The First Workshop On Urban Networking - Urbane '12. http://dx.doi.org/10.1145/2413236.2413240

Ferreira, M., Fernandes, R., Conceição, H., Viriyasitavat, W., & Tonguz, O. (2010). Self-organized traffic control. Proceedings Of The Seventh ACM International Workshop On Vehicular Internetworking - VANET '10. http://dx.doi.org/10.1145/1860058.1860077

Gradinescu, V., Gorgorin, C., Diaconescu, R., Cristea, V., & Iftode, L. (2007). Adaptive Traffic Lights Using Car-to-Car Communication. 2007 IEEE 65Th Vehicular Technology Conference-VTC2007-Spring. http://dx.doi.org/10.1109/vetecs.2007.17

Hegyi, A., De Schutter, B., Hoogendoorn, S., Babuska, R., van Zuylen, H., & Schuurman, H. A fuzzy decision support system for traffic control centers. ITSC 2001. 2001 IEEE Intelligent Transportation Systems. Proceedings (Cat. No.01TH8585). http://dx.doi.org/10.1109/itsc.2001.948683

Hull, B., Bychkovsky, V., Zhang, Y., Chen, K., Goraczko, M., & Miu, A. et al. (2006). CarTel. Proceedings Of The 4Th International Conference On Embedded Networked Sensor Systems - Sensys '06. http://dx.doi.org/10.1145/1182807.1182821

Klein, L. A., Mills, M. K., & Gibson, D. R. (2006). Traffic Detector Handbook (Rep. No. FHWA-HRT-06-108). Federal Highway Administration.

Koonce , P., Rodegerdts, L., Lee, K., Quayle, S., Beaird, S., Braud, C., Urbanik, T. (2008). Traffic Signal Timing Manual (Rep. No. FHWA-HOP-08-024). U.S. Department of Transportation, Federal Highway Administration.

Kosonen, I. (2003). Multi-agent fuzzy signal control based on real-time simulation. Transportation Research Part C: Emerging Technologies, 11(5), 389-403. http://dx.doi.org/10.1016/s0968-090x(03)00032-9

Leduc, G. (2008). Road Traffic Data: Collection Methods and Applications (Rep.). Joint Research Centre, European Commission

Lim, J. (2015). 6 Ways You Could Cause A Traffic Jam Without Even Trying. Retrieved March 19, 2017, from http://says.com/my/fun/traffic-jams

Mathew, T. V. (2014). Intelligent Transportation System (Rep.). IIT Bombay.

Mimbela, L. Y., & Klein, L. A. (2007). A Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems (Rep.). Federal Highway Administration‟s (FHWA) Intelligent Transportation Systems Program Office

Rhodes, A., Bullock, D., & Sturdevant, J. (2006). Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections. http://dx.doi.org/10.5703/1288284313401

Robertson, D., & Bretherton, R. (1991). Optimizing networks of traffic signals in real time- the SCOOT method. IEEE Transactions On Vehicular Technology, 40(1), 11-15. http://dx.doi.org/10.1109/25.69966Royani, T., Haddadnia, J., & Alipoor, M. (2010). Traffic signal control for isolated intersections based on fuzzy neural network and genetic algorithm. ISCGAV'10 Proceedings of the 10th WSEAS international conference on Signal processing, computational geometry and artificial vision, 87-91. Retrieved August 1, 2014.

Salama, A., Saleh, B., & Eassa, M. (2010). Intelligent cross road traffic management system (ICRTMS). 2010 2Nd International Conference On Computer Technology And Development. http://dx.doi.org/10.1109/icctd.2010.5646059

Sims, A., & Dobinson, K. (1980). The Sydney coordinated adaptive traffic (SCAT) system philosophy and benefits. IEEE Transactions On Vehicular Technology, 29(2), 130-137. http://dx.doi.org/10.1109/t-vt.1980.23833

Srivastava, J. R., & Sudarshan, T. S. (2013). Intelligent traffic management with wireless sensor networks. 2013 ACS International Conference on Computer Systems and Applications (AICCSA). doi:10.1109/aiccsa.2013.6616429

Tong, D. A. (2014). The dreadful traffic jams - Business News. Retrieved March 19, 2017, from http://www.thestar.com.my/business/business-news/2014/03/08/the-dreadful-traffic-jams/

Traffic Signals 101. (2000). Retrieved April 10, 2014, from http://library.ite.org/pub/e2654cc1-2354-d714-511b-4cad3fe7c68a

Traffic Signals Information. (n.d.). Retrieved March 19, 2017, from https://www.tmr.qld.gov.au/Travel-and-transport/Road-and-traffic-info/Traffic-Signals-Information

Tubaishat, M., Shang, Y., & Shi, H. (2007). Adaptive Traffic Light Control with Wireless Sensor Networks. 2007 4Th IEEE Consumer Communications And Networking Conference. http://dx.doi.org/10.1109/ccnc.2007.44

Types of Road and Speed Limits - Malaysia. (n.d.). Retrieved December 21, 2014, from https://www.angloinfo.com/how-to/malaysia/transport/driving/on-the-road

Types of Traffic Jam That Will Be Encountered in Malaysia. (2016). Retrieved February 02, 2016, from http://www.carblogmy.com/type-of-traffic-jam-in-malaysia/

Yokota, T. (2004). ITS For Developing Countries. Retrieved from http://siteresources.worldbank.org/EXTROADSHIGHWAYS/Resources/ITSNote1.pdf

Yousef, Khalil M., Jamal N. Al Karaki, and Ali M. Shatnawi. Intelligent Traffic Light Flow Control System Using Wireless Sensors Networks. Journal of Information Science & Engineering 26.3 (2010): 753 . Web.

Zhang, W., Wu, B., & Liu, W. (2007). Anti-Congestion Fuzzy Algorithm for Traffic Control of a Class of Traffic Networks. 2007 IEEE International Conference On Granular Computing (GRC 2007). http://dx.doi.org/10.1109/grc.2007.138

Zhou, B., Cao, J., Zeng, X., & Wu, H. (2010). Adaptive Traffic Light Control in Wireless Sensor Network-Based Intelligent Transportation System. 2010 IEEE 72Nd Vehicular Technology Conference - Fall. http://dx.doi.org/10.1109/vetecf.2010.5594435