# SIMULATION OF TRAFFIC SIGNAL USING FUZZY LOGIC 

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#### Abstract

ABSTRAK

Tujuan tesis ini adalah untuk membangunkan sistem kawalan trafik yang pintar untuk mengawal aliran lalu lintas yang optimum di persimpangan lalu lintas. Cadangan sistem "fuzzy" telah digunakan dalam kajian untuk mengurus persimpangan lalu lintas bandar di Malaysia dengan berkesan. Kepentingan sistem kawalan lalulintas pintar yang dicadangkan terdiri daripada pertimbangan ketidakpastian dan kekaburan maklumat mengenai nilai parameter input dan output sistem. Dengan menggunakan parameter input berdasarkan kesimpulan dari peraturan kabur, pengawal lalu lintas. Kajian ini telah melakar Simulasi dengan mengguanakan Software Matlab dalam sepanjang eksperimen. Lampu isyarat hijau dapat ditentukan dengan berkesan dengan menggunakan enjin inference Mamdani. Trafik pintar yang berkesan dapat diaplikasi dalam projek ini dengan menggunakan pengawal trafik kabur dengan empat parameter input trafik.


#### Abstract

The aim of this thesis is to simulate the fuzzy intelligent traffic for the optimal controlling of the traffic green signal flow at the traffic intersections. The proposed fuzzy control system is used to effectively manage the urban traffic junction of the intersections in Malaysia. The importance of the proposed fuzzy intelligent traffic control system consists in consideration of uncertainty and vagueness of information about the values of the input and output parameters of the system. Using the input parameters and based on the inferences from the fuzzy rules, the fuzzy traffic controller decides the priority street to become the green light on the next phase in the traffic intersection. Computer simulation is carried out using Matlab software. The result of select the green light on the intersection road is purposed using the Mamdani inference engine. The effectiveness of the fuzzy traffic controller with four input parameters is explained.


## TABLE OF CONTENT

DECLARATION
TITLE PAGE
ACKNOWLEDGEMENTS ..... ii
ABSTRAK ..... iii
ABSTRACT ..... iv
TABLE OF CONTENT ..... v
LIST OF TABLES ..... viii
LIST OF FIGURES ..... ix
LIST OF SYMBOLS ..... xi
LIST OF ABBREVIATIONS ..... xii
CHAPTER 1 INTRODUCTION ..... 1
1.1 Background History ..... 1
1.2 Problem Statement ..... 3
1.3 Objectives ..... 4
1.4 Scope of the work ..... 5
1.5 Thesis Organization ..... 5
CHAPTER 2 LITERATURE REVIEW ..... 6
2.1 Traffic Signal Situation ..... 6
2.2 Existing System Used in Fuzzy Logic ..... 6
2.2.1 Fuzzy Logic-Based Controller of Traffic Intersection ..... 6
2.2.2 Fuzzy Traffic Controller for Urban Intersection Developed in Simulink ..... 7
2.2.3 Proposed Fuzzy Traffic Light Control system by optimizing green light duration ..... 9
2.2.4 Control of complex Traffic Junction using Fuzzy Inference ..... 11
2.2.5 Comparison between the Existing Models ..... 13
2.3 The Concept of the Fuzzy Rules System ..... 13
2.4 Summary ..... 14
CHAPTER 3 METHODOLOGY ..... 15
3.1 Introduction ..... 15
3.2 Research Framework ..... 15
3.3 The Traffic Simulation Model ..... 16
3.4 The Fuzzy Traffic Process ..... 18
3.4.1 Fuzzification ..... 20
3.4.2 Knowledge base ..... 20
3.4.3 Database ..... 20
3.4.4 Inference mechanism ..... 21
3.4.5 Defuzzification ..... 21
3.4.6 Controlled process ..... 22
3.4.7 Sensing device ..... 22
3.4.8 Estimator ..... 22
3.4.9 The state machines ..... 23
3.4.10 Evaluation module ..... 23
3.4.11 Traffic light interface ..... 23
3.5 Traffic Structure and Algorithm ..... 24
3.6 Hardware and Software Requirement ..... 25
3.6.1 Hardware Requirement ..... 25
3.6.2 Software Requirement ..... 25
CHAPTER 4 RESULTS AND DISCUSSION ..... 26
4.1 Introduction ..... 26
4.2 Fuzzy Logic of Determine the demand of Green Light on the next phase ..... 26
4.2.1 Input parameters of fuzzy green time ..... 27
4.2.2 Output parameter of the fuzzy green time ..... 29
4.2.3 Fuzzy rule based of the fuzzy green time ..... 30
4.3 Fuzzy Logic of the Green Light Street ..... 36
4.3.1 Input parameter of the fuzzy green light street ..... 36
4.3.2 Output parameter of the green light street ..... 38
4.3.3 Fuzzy rule based of the green time selection ..... 40
4.4 Computer simulation results of fuzzy green time ..... 46
4.4.1 Scenario 1 ..... 46
4.4.2 Scenario 2 ..... 50
4.4.3 Scenario 3 ..... 54
CHAPTER 5 CONCLUSION ..... 58
5.1 Introduction ..... 58
5.2 Research Constraint ..... 58
5.3 Research Conclusion ..... 59
5.4 Future Work ..... 59
REFERENCES ..... 60
APPENDIX A GANTT CHART ..... 63

## LIST OF TABLES

Table 1.1 The Most Method Used in Transportation ..... 1
Table 1.2 The responds of the traffic congestion problem in Malaysia ..... 4
Table 2.1 Comparison of the Fuzzy Logic Used in Existing Model ..... 13
Table 3.1 Hardware Requirement ..... 25
Table 3.2 Software Requirement ..... 25
Table 4.1 The level of input parameters of the fuzzy green time ..... 27
Table 4.2 The level of output parameters of the fuzzy green time ..... 30
Table 4.3 The input parameters of the green light street ..... 36
Table 4.4 The level of output parameter of the fuzzy green light street ..... 39

## LIST OF FIGURES

Figure 2-1 Fuzzy Logic proposed by (Vratislav Jerabek, 2001) ..... 7
Figure 2-2 Average time with pre-time and fuzzy logic controller ..... 8
Figure 2-3 Average queue length with fuzzy logic controller ..... 9
Figure 2-4 FIS editor proposed by (Md Anwarul Azim, 2014) ..... 9
Figure 2-5 Membership function (WQred) by (Md Anwarul Azim, 2014) ..... 10
Figure 2-6 Membership function (VFgreen) by (Md Anwarul Azim, 2014) ..... 10
Figure 2-7 Membership function (Gduration) by (Md Anwarul Azim, 2014) ..... 10
Figure 2-8 Rule Viewer by (Md Anwarul Azim, 2014) ..... 11
Figure 2-9 Performance traffic flow of density average by (Md. Nazmul Huda, 2001) ..... 12
Figure 3-1 Phases of Research Methodology ..... 16
Figure 3-2 General traffic flow intersection ..... 17
Figure 3-3 Phases in the traffic intersection ..... 17
Figure 3-4 Fuzzy traffic control system ..... 19
Figure 3-5 shown the Centroid of defuzification ..... 22
Figure 3-6 Centroid defuzzification ..... 22
Figure 3-7 Fuzzy traffic intersection flow ..... 24
Figure 4-1 Input and output parameters of Fuzzy Logic "fuzzygreentime" ..... 27
Figure 4-2 The membership functions of parameter "Street1" in fuzzy green time ..... 28
Figure 4-3 The membership functions of parameter "Street2" in fuzzy green time ..... 28
Figure 4-4 The membership functions of parameter "Street3" in fuzzy green time ..... 29
Figure 4-5 The membership functions of parameter "Street4" in fuzzy green time ..... 29
Figure 4-6 The membership functions of the output parameter "green-time" ..... 30
Figure 4-7 Inputs and output parameters of Fuzzy Logic "GreenLightStreet" ..... 36
Figure 4-8 The membership funtions of parameter "Street 1" in fuzzy green light street ..... 37
Figure 4-9 The membership funtions of parameter "Street 2" in fuzzy green light street ..... 37
Figure 4-10 The membership funtions of parameter "Street 3" in fuzzy green light street ..... 38
Figure 4-11 The membership funtions of parameter "Street 4" in fuzzy green light street ..... 38
Figure 4-12 The membership functions of the output parameter "which-street" ..... 40
Figure 4-13 Result of determination the demand of green time on the next phase in first scenario ..... 46
Figure 4-14 Result of green light selection to the street in first scenario ..... 47
Figure 4-15 Green light on street 1in first scenario ..... 48
Figure 4-16 Green light on street 4 on the next phase in first scenario ..... 49
Figure 4-17 Result of determination the demand of green time on the next phase in second scenario ..... 50
Figure 4-18 Result of green light selection to the street in first scenario ..... 51
Figure 4-19 Green light on street 1 in second scenario ..... 52
Figure 4-20 Green light on street 3 on the next phase in second scenario ..... 53
Figure 4-21 Result of determination the demand of green time on the next phase in first scenario ..... 54
Figure 4-22 Result of green light selection to the street in first scenario ..... 55
Figure 4-23 Green light on street 4 in third scenario ..... 56
Figure 4-24 Green light on street 3 on the next phase in second scenario ..... 57

## LIST OF SYMBOLS

| Z $^{*}$ | difference between the mean of the variable in a sample set |
| :--- | :--- |
| $d x$ | an infinitely small width of x |
| $\int$ | Opposite to derivation <br> $\hat{\mathbf{c}}$ |
| $\mu$ | c with a bar over it |

## LIST OF ABBREVIATIONS

| SBPWM | Simple Boost Pulse Width Modulation |
| :--- | :--- |
| ZSI | Z source inverter |

## CHAPTER 1

## INTRODUCTION

### 1.1 Background History

The aims of install the traffic light is to control the traffic flow due to the increasing of the volume of vehicles on the road. According to (Skabardonis et al., 2014) presented even the technology growing fast and the changes of the social structures brought us huge benefit in growth of economic, infrastructure, education but at the same time the changes also can be lead to some disadvantages indirectly. The impact of the changes leads to the serious problem which is traffic problem. The size of the community growth rapidly nowadays is one of the issues turn to traffic problem. Furthermore, it will become a complex problem for the urban workers especially who are working in the urban city if we let the problem go unsolved (Times, 2017). Table 1.1 shows the table of the most method used in transportation in Malaysia.

Table 1.1 The Most Method Used in Transportation

| Type of | Kuala Lumpur |  |  | Other |  | Grand Total |  |
| :--- | :--- | :--- | :--- | :---: | :--- | :---: | :---: |
| Vehicle Used | Frequency | $\%$ | Frequency | $\%$ | Frequency | $\%$ |  |
| Private Car | 120 | 52.2 | 156 | 57.8 | 276 | 55.2 |  |
| Motorbike | 55 | 23.9 | 68 | 25.2 | 123 | 24.6 |  |
| Private Bus | 40 | 17.4 | 37 | 13.7 | 77 | 15.4 |  |
| Taxi | 15 | 9 | 9 | 3.3 | 24 | 4.8 |  |
| Total | 230 | 270 | 270 | 100 | 500 | 100 |  |

In the survey of Table 1.1 shown us the most method used in transportation in Malaysia. Table 1.1 prove that most of Malaysian rely on private cars as the most transportation strategic where $55.20 \%$ of the residents use their own car as main transportation. The table show that there are only $15.4 \%$ of the respondents using bus as their transportation. As the result that we can conclude from the Table 1.1 that one of the
main problems lead to traffic congestion is increasing the use of the private cars on the road.

It is necessary to having a method that can reduce the traffic problem especially at the traffic intersection. One of the best ways to minimize the situation happened is control the traffic light between the consecutive traffic intersections(Chansiri Suksri, 2011). As the density of the vehicles move in traffic road getting more nowadays in Malaysia, it is better to having an intelligent traffic control system to improve the traffic flow problem.

The common used method of installing the traffic light in Malaysia is "Preset Cycle Time (PCT) Controller where it is a control framework where it is a fixed control of traffic light followed the priority of the structure cycle time and there could manual control the setting of the traffic light based in research (Krzysztof, 2016). The PCT use the fixed control plan where the green time is fixed under the plan without considering the situation on the road.

Vehicle Activated (VA) Controllers is another customary traffic light framework recently, (Jomaa, 2014) shown that the different method used in VA is installed magnetic sensor at the end of each road intersection and the sensor is not obvious to see compared to the dark rectangular line which next to the traffic light. There are three parameters used in VA: Beginning Interim, Extension Unit and Extension Limit, the concept is focus on the changes of the cycle traffic light depends on measurement of limitation units of cars which cross over the junction road and also reached the exceeding limit of the cars in the every phase on the road. If the green phase were reached the maximum limitation units of cars crossing it will directly turn to red phase without considering the volume of each intersection road.

As the usage of the vehicles on the road getting high nowadays while the current control traffic light system does not improve the traffic congestion effective. Thus, the traffic control system is needed to overcome traffic jam and improve the efficiency of the traffic flow in order to help community to reach their destinations safely and quickly.(Karmore2, 2012)

In order to solve the congestion problem by optimize the appropriate timing of each road in the intersection based on the current situation, a model call Fuzzy Logic has been proposed in this project. According the research from (I.N.Askerzade (Askerbeyli), 2010), by implement of FL model, the result will show an appropriate direction of the green light on each road in traffic intersection to improve the efficiency of traffic flow and minimize the traffic congestion.

### 1.2 Problem Statement

The traffic congestion in urban areas became serious depends on the car moving increased on the road. According to the traffic situation presented by (K. Mahirah1, A. A. Azlina1, 2015), most of the traffic light in Malaysia used a fixed traffic control plan which resulting inappropriate behaviour in traffic where the system are based on the traffic counts and its sometime will changed manually. In order to make the traffic flow to become smoothly and safely, it is necessary to implement an efficient algorithm to reduce the traffic congestion in the road intersection.

Most of the traffic light in Malaysia installed fixed-time controller called "Preset Cycle Time"(PCT) (Jomaa, 2014)as main traffic flow controller especially in the urban area. This fixed time controller is using the fixed plan to control the red, yellow and green colour of the traffic light. The advantage of installing the fixed time control is it is very easy to control as the duration time of the green time is fixed for every traffic phase and cycle on each of the road while the disadvantage is it does not consider the density of the vehicles. Based on the paper from (Project Scholar, Dept. of Computer Science and Engg., G. H. Raisoni College of Engineering, Nagpur (MS), n.d.) the concept on the fixed-time controller is being an open-loop system where the green time is fixed followed the setting of controller and it is not extended time if there is full of cars at the junction. Nevertheless, these times is fixed for all phase and its will up to a maximum of the time limit. It can be found in the case of traffic situation the green time is set to be seconds which until the maximum time limit when a car is detected.

For the purpose to enhance the effectiveness of traffic flow in intersection, a suggested algorithm fuzzy logic is proposed in this project which is a real time controller where the system could control the direction of green light in the intersection road depends on the traffic volume and minimize the waiting time on a single intersection. The
function of "IF" "THEN" rules included in the project to determine which lane have the priority to become green light on the next phase cycle according to the situation of road. This project used the Matlab software to present the simulation of traffic green light in different situation of the vehicles in traffic intersection.

In order to study the reason about the traffic congestion in Malaysia, a google form has been placed to measure the perception of respondent in Malaysia. There are 500 respondents in Malaysia participate on fill in the survey and collected on January 2018.

Table 1.2 The responds of the traffic congestion problem in Malaysia

| The most critical | Kuala Lumpur |  | Other |  | Grand Total |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| transportation problem | Frequency | $\%$ | Frequency | $\%$ | Frequency | $\%$ |
| Inadequate green time in <br> traffic lights | 115 | 50 | 142 | 52.6 | 257 | 51.4 |
| Traffic incident | 50 | 21.7 | 61 | 22.6 | 111 | 22.2 |
| The behaviour <br> driver on the road | 40 | 17.4 | 35 | 12.9 | 75 | 15 |
| Road utility work | 25 | 10.9 | 32 | 11.9 | 57 | 11.4 |
| Grand Total | 230 | 100 | 270 | 100 | 500 | 100 |

This survey revealed that the main traffic problem is "Inadequate green time in traffic lights" in Table 1.2 which is $50.5 \%$ reported from the respondents in KL. The results may evidence our idea to improve the arrangements of phase time in traffic light for reduce the delay time in traffic road.

### 1.3 Objectives

The purpose of this project is to develop an integrated model to accomplish the following objectives:
i. To study the existing approach of traffic signal in the intersection road.
ii. To develop the fuzzy simulation of traffic signal in the traffic intersection.
iii. To validate the model of traffic green light phrase in the traffic light simulation.

### 1.4 Scope of the work

The scope of this project as follows:
i. The targeted of scope of this project is simulate the direction of traffic green light phase in the 4 arms of isolated intersection road.

### 1.5 Thesis Organization

The outcomes of the thesis will give advice to traffic policeman to adjust the suitable signal time for controlling the traffic at the studied intersection. This thesis organized by five significant components:
i. Introduction
ii. Discussing the theory background
iii. Research methodology
iv. Implementing, testing and result discussion
v. Conclusion and discussion

## CHAPTER 2

## LITERATURE REVIEW

### 2.1 Traffic Signal Situation

Traffic congestion is a significant problem that occurs with the situation of increasing of the density of vehicles where lead to increasing length of queue, trip time becomes longer and slower speeds. When the volume of the vehicles getting high in road intersection then it will force vehicle to slow down the speed and increase the capacity of the usage of the road. This is a worse situation when the road intersection full of the vehicles and stopped with for period time, this is called as traffic congestion or traffic jam. In order to optimize the traffic control system, Fuzzy Logic algorithm has been applied in this project.

### 2.2 Existing System Used in Fuzzy Logic

There are many of the system completely done by using the Fuzzy Logic where it is performed very well in critical areas (San-MinWangaBao-ShuWangbDao-WuPeib, 2005) where it presented ins intelligent information system and also intelligent control system. Therefore, there are many of the research proved that the used of the Fuzzy Logic could enhance and improve the situation of logical system.

### 2.2.1 Fuzzy Logic-Based Controller of Traffic Intersection

According to (Vratislav Jerabek, 2001) recommended a Fuzzy Rule model where it divided into two main procedures Fixed-Time System and On-Line System. The FixedTime System uses predefined time intermissions to adjust the flow of vehicles on the intersection. On-Line System utilises the croximity sensors and syndicates the predefined time to changes in the specific cycles.

The objective of the method is to reduce the waiting time of vehicles in the intersection. The research contains of five elements:

1. Sensing device reading
2. First estimator (Delay>Limit)
3. Filter "OR"
4. Fuzzy engine
5. Traffic light interface


Figure 2-1 Fuzzy Logic proposed by (Vratislav Jerabek, 2001)
The fuzzy rules that applied by (Vratislav Jerabek, 2001) is to determines whether to extend or terminate the current green phase based on fuzzy rules.

### 2.2.2 Fuzzy Traffic Controller for Urban Intersection Developed in Simulink

According to (Zoran Gacovski, 2012) presented a traffic controller for isolated intersection. This research is focus on the queue length and waiting time at the shifting traffic light phase. The main of this research is to compare the pre-defined light control and fuzzy controller where the result decide to extend or terminate current signal phase.
(Zoran Gacovski, 2012) applied the concept of first in first out (FIFO) which green phase depends on the queue length.

There are four approaches to the intersection (east, north, west and south). The process that used in this research:

Phase 1: Identify the density of traffic in isolated traffic road

Phase 2: Run fuzzy rule base

Phase 3: Define the output
Phase 4: Output compare with Predefined- time

There are two input that applied which are vehicle queue length and waiting time. The basic structure of FIS fuzzy logic controller contains the membership function for each input parameter. The output parameter is extension time of the green time.

The simulation result compared the Pre-timed and Fuzzy controlled to evaluate the vehicles situation in the intersection road. Figure 2.2 and figure 2.3 shows that fuzzy logic controller produces the lower waiting time, queue length and delay time compared to the pre-time which is vehicle actuated traffic control.


Figure 2-2 Average time with pre-time and fuzzy logic controller


Figure 2-3 Average queue length with fuzzy logic controller

### 2.2.3 Proposed Fuzzy Traffic Light Control system by optimizing green light duration

According to (Md Anwarul Azim, 2014) proposed fuzzy traffic light control to optimize the green time duration in order to handle the congestion in the traffic light intersection. This research mainly focused to measure the level of duration of the green time in the traffic cycle phase with different condition.

Fuzzy Logic Toolbox in Malab worked in this research to implement the graphic user interface (GUI) where there are two input parameter has been create which is duration of the traffic green light and duration of the traffic red light where cab be defined as "Low", "Medium" or "High" and the output parameter is the level of the duration of the green time.


Figure 2-4 FIS editor proposed by (Md Anwarul Azim, 2014)


Figure 2-5 Membership function (WQred) by (Md Anwarul Azim, 2014)
WQred: low=0 to 6.4 , Medium $=4$ to 12 , High= 9 to 16


Figure 2-6 Membership function (VFgreen) by (Md Anwarul Azim, 2014)


VFgreen: low=0 to 5 , Medium $=3$ to 9 , High= 7 to 14

Figure 2-7 Membership function (Gduration) by (Md Anwarul Azim, 2014)
Figure 2.7 shows that the membership function of Gduration which are Short=0 to 12 , Medium $=8$ to 18 , High= 16 to 25 .
(Md Anwarul Azim, 2014) also defined the fuzzy rules IF THEN rules and gets the output of Gduration. Figure 2.8 shows that the input of red signal and input of green signal which
are "Medium" and "Medium" then the output of Gduration is "Medium" where the aggregate output shows at the bottom and center of the area is considered for defuzzification as shown in red colour.


Figure 2-8 Rule Viewer by (Md Anwarul Azim, 2014)

### 2.2.4 Control of complex Traffic Junction using Fuzzy Inference

Based on the research from (Md. Nazmul Huda, 2001) proposed the traffic simulator where the result compare the density of the traffic flow in the intersection by using fuzzy logic and the other two controller which is Preset-cycle time and Vehicle Actuated.

In order to compare the density performance of the fuzzy logic, Vehicle Actuated and Preset Cycle, flow density average used as measurement to define the performance of these three methods. Figure 2.9 shows the result of the performance of the density average in each intersection.


Figure 2-9 Performance traffic flow of density average by (Md. Nazmul Huda, 2001)

From the graph proposed by (Md Anwarul Azim, 2014) observed that the fuzzy controller showed slightly better performance compare to the Preset cycle time and vehicle actuated in the situation of low, high traffic volume and the real case study as well.

### 2.2.5 Comparison between the Existing Models

Table 2.1 Comparison of the Fuzzy Logic Used in Existing Model

| System | Function | Advantages | Disadvantages |
| :--- | :--- | :--- | :--- |
| Fuzzy Logic- <br> Based Controller <br> of Traffic | Defined the level of <br> extend or terminated <br> the green time <br> Intersection.(Vrati <br> slav Jerabek, <br> depend the situation <br> of the vehicles on <br> each street. | Green time of the <br> traffic is adjustable, <br> reduce the waiting <br> time on street. | Not encourage for <br> the high volume of <br> traffic situation. |
| Traffic Controller <br> for Urban | Compare the traffic <br> situation of delay <br> Intersection | The best traffic <br> controller can be <br> time, waiting time <br> selected based on | Limitation for <br> single isolated <br> intersection |
| Simulink. (Zoran <br> Gacovski, 2012) | between the fuzzy <br> with vehicle actuated <br> traffic control. | the delay time, <br> waiting time, and <br> queue length on the <br> traffic road. |  |
| Proposed Fuzzy | Define the level of <br> duration of the green | Analyse every <br> traffic cycle of <br> traffic situation | Traffic congestion <br> hard to define on <br> this method. |
| Control system by <br> optimizing green <br> light duration. (Md | intersection |  |  |
| indic |  |  |  |

### 2.3 The Concept of the Fuzzy Rules System

Fuzzy Logic (FL) was proposed by Professor Lotfi Zadeh in 1965. The proposed FL intended to deliver the vague of the information instead of the accurate of the numerical data or information. (Zadeh, 1956) said that fuzzy logic is good in used in inaccurate situation or problem that could need to use the logical knowledge to solve the issue. This technique is totally different with crisp logic where it have only provide two options similar with the Boolean environment which contain only "true" or false or "zero" or "one" in the general.

The Fuzzy Logic has no precise of measurement where it deals with the uncertain value for a situation. In the case regarding to the speed of car, there are different stage of the linguistic variable like "low", "medium" and "high". Talking about the speed of the car, it can be different value in any stage and the value can within the stage of the value. This process named membership function.

Fuzzy logic contains of three stages: input, process and output. The first stage (input stage) there was some of the equipment collected to the produce the membership functions in the input stage. The second stage (process stage) will define the suitable rules for each of the input and construct all the results of the rules. The last stage (output stage) will combine all the result and convert to control output value.

In 70 's, the (Zadeh, 1956) believed that the control system included the fuzzy information was capable to self-control by the environment. There have the different equations to describe the model, and the mathematical models used to apply in the designing control system.

Fuzzy Logic control system can be used in solving the traditional techniques where it has been successful carry out in industrial by develop useful product such as washing machine, signal processing and robotics which are related of nature human knowledge.

### 2.4 Summary

This chapter is discussed about the basic knowledge of the fuzzy logic and also the existing system used by the fuzzy logic theory. The fuzzy logic can be explained by using the human expert knowledge to solve the uncertain problem and find the optimal solution. The fuzzy logic theory is suitable to use in the traffic controller in order to produce an appropriate green signal according to the situation of the traffic road. By using the fuzzy logic to control the duration of the green time in traffic road, it will significantly reduce the density of car moving on the intersection road.

## CHAPTER 3

## METHODOLOGY

### 3.1 Introduction

This chapter will discuss about the traffic light simulation using fuzzy logic. In the previous chapter, the problem of the traffic light has been proposed which the using the PCT and VA controller system in most of the traffic intersection cases but it seems to be not effective when it comes to heavy vehicles situation. This chapter started discussing about the research framework continued by traffic control problem and methodology of the fuzzy logic which proposed in the traffic control case. This chapter also covered the discussion of hardware and software that used in the process of development. Lastly, Gantt Chart also proposed at the last part of this chapter.

### 3.2 Research Framework

This research distributed into four phases which shown in the Figure 3.1. The first phase of the research is to identify the research problem statement, scope and goals, study and understanding the research objective and study the existing work. Second phase is proposed algorithm for traffic light control by using fuzzy logic and design the traffic light flow. Third phase is implementation and develop the code and testing the prosed algorithm. Last phase is documentation for research paper.


Figure 3-1 Phases of Research Methodology

### 3.3 The Traffic Simulation Model

As mentioned in the research framework, the project defined the traffic control problem which is traffic congestion within the junction road in phase 1 of Figure 3.1. Traffic light play very important role in control the traffic flow and density of vehicles especially in intersection in order to improve the efficiency of traffic and keep the traffic flow safe. Figure 3.2 shows the general traffic intersection in Malaysia.


Figure 3-2 General traffic flow intersection
In the above Figure 3.2 shown that the intersection has 4 arms. Each of the main roads consisted of four lanes while other is three lanes. The traffic users able to select any direction, left, right and move forward. In the model of the traffic flow control there having different kinds of the phases showing in the Figure 3.3.

(1)

(2)

(3)

Figure 3-3 Phases in the traffic intersection
i. The first picture showing the direction from south to north (straight), south to west (turning), north to south (straight), north to east (turning).
ii. The second picture showing the direction from west to east (straight), west to north (turning).
iii. The third picture showing the direction from east to west (straight), east to south (turning).

All these phases have its own sequence either $\{1,2,3\}$ or $\{1,3,2\}$ (based on the number given in the Figure 3.3). There are many ways to control the sequence of the phase. Basically, the traffic system controller managed the sequence of each phase from each input parameter from each road in the intersection and the situation in the road.

Most of the traffic light controller having the fixed time on the green, amber and res signal. The fixed time controller is more convenient use in the traffic situation which have consistent rate of vehicles moving in each road of the intersection. However, fixed time controller not capable to solve the heavy traffic situation especially in the peak hour, morning and evening time.

In the recent years, the vehicles number moving on the road getting higher than before and this situation happened getting serious when it comes in the situation of slow development of the road way. By using the common methods which is the fixed time controller, it is hard for solve the any situation and changes happened on the road.

In order to solve and improve the existing traffic controller, according to the research (Project Scholar, Dept. of Computer Science and Engg., G. H. Raisoni College of Engineering, Nagpur (MS), n.d.) the fuzzy logic algorithm could able to reduce the traffic congestion by reducing the delay of the time waiting in traffic and manage to control an appropriate phase time according to the level of the traffic congestion.

Fuzzy Logic controller is an effective tool that performed well in controlling the extension and deduction of green phase signal in the intersection road followed by the road situation.(I.N.Askerzade (Askerbeyli), 2010)

In the next section 3.4 will discuss in detail regarding the process of traffic signal control by using the Fuzzy Logic algorithm.

### 3.4 The Fuzzy Traffic Process

The overall process of the fuzzy traffic shows in the figure 3.3 where the figure contained two parts which are traffic controller system and controller components.

This project proposed four main inputs in the fuzzy traffic control system in order to calculate the situation of the traffic road.
i. Situation of vehicles behind the traffic light in street 1 (Street 1 )
ii. Situation of vehicles behind the traffic light in street 2 (Street 2)
iii. Situation of vehicles behind the traffic light in street 3 (Street 3)
iv. Situation of vehicles behind the traffic light in street 4 (Street 4)


Figure 3-4 Fuzzy traffic control system

Figure 3.4 showing the overall process of the Fuzzy Controller in the traffic intersection. In a process of validate a functional traffic light, the traffic controller system need some specific devices to produce a runnable system. There are some of the components in the traffic signal such as Sensing Devices, Evaluation Module, State Machines and Estimator. All the components of the traffic have its own responsibility to transfer the information of the situation traffic control such as the rate of speed of the vehicles, length of queue in every phase of the red and green signal in every road
intersection follow the time period and hours. Fuzzy Controller System starts the fuzzification which is the step 1 after all the input parameters from traffic components devices. In the fuzzification phase, the result of current situation on each traffic road will be presented by using the membership function. After step 1 done, step 2 inferences machines take placed and this step apply the IF...THEN rules on the current situation and produced a logical result based on the input given. At the last step defuzzification, generate a non-fuzzy value based on the result get from the step 2. This step will calculate the result in numeric form in terms of decrease the green time or extend the green time for each current situation of traffic light.

### 3.4.1 Fuzzification

Fuzzification is a process of converting the accurate information or value to produce a result in a vague form. In order to complete this process, it is needed to commit membership function, knowledge base and database. All the input should relate with the logical rules based on the knowledge base and all the membership function have each own linguistic variable which can present as input value.

### 3.4.2 Knowledge base

Knowledge base in the fuzzy logic consist the input and fuzzy rule set. The main function of the fuzzy rule is to produce and run the rule base or rule set in the Fuzzy Controller. Knowledge base also come out a result based on the input and output given and construct with the logical rules according the situation.

### 3.4.3 Database

Database works as control the most appropriate rule base from the input collected and generate the rule according the rule base in control system. In the traffic light case, database focus on set the time for each phase of the intersection road. The database also needs have the sequence of the traffic light from the state machine and its will loop smoothly followed the sequence of traffic light.

### 3.4.4 Inference mechanism

Inference mechanism is the main part in the fuzzy controller where it determined the situation on the traffic and applying the appropriate rule which is match with the traffic situation. A result will come out based on the suggestion of the best matched rules.

The inference mechanism is combining the previous step of the fuzzy logic such as membership function, logical operation and IF-THEN rules. In the example traffic control case, the membership function given the value of 0 and 1 , means the result value can within the 0 and 1 , " 0 " represent "light" and " 1 " represent "heavy". The membership function will produce a result and it will be converted in crisp output. The output can be determine into "heavy" or "light" in the traffic situation. After done the membership function, the "IF-THEN" rules will take placed where describes as:

## IF $a$ is $X$ THEN $b$ is $Y$

Based on the above statement, it clear delivered the "IF...THEN" rules into two part where the front part "a is X" called antecedent while "b is Y" called consequent.

Inference mechanism act to manage the changing of the state on each single traffic intersection. The IF ...THEN rules will decide the time of changing of the state depends on the condition like "heavy" or "light" traffic situation to decide either maintain or extend the duration of the traffic signal time.

### 3.4.5 Defuzzification

Defuzzification is a process that is totally opposite the fuzzification where all the result will be converted into accurate variable as the output cannot be the fuzzy value. There are some of the techniques used in this part such as centroid, middle of maximum or mean-max membership, max-membership principle, centre of largest area, weighted average method, centre of sums and first of maxima or last of maxima. In this project, the method centroid of the defuzzification based Mamdani inference was presented (Figure 3.4) where the value taken from the center of area or center of gravity.

The function of $z *$ is calculated as:

$$
z *=\int 1 \frac{\mu \hat{c}(z) z d x}{\mu \hat{c}(z) d z}
$$

Figure 3-5 shown the Centroid of defuzification


Figure 3-6 Centroid defuzzification

### 3.4.6 Controlled process

In this phase, there are require send the crisp form of the input and the output to the controlled process. Therefore, it is important to convert the value from defuzzification process and membership function into a crisp form.

### 3.4.7 Sensing device

Sensing device detect the current queue length of vehicle, arrival speed of car for each single intersection road in the junction.

### 3.4.8 Estimator

The main responsibility of estimator is to calculate the each vehicle in the junction from information of the sensing devices and it also estimate the length of time needed during green phase. Estimator also responsible to counts the queue length and speed of car after red signal.

### 3.4.9 The state machines

State machine controls the state in the traffic sequence flow follow by the fixed sequence of the traffic lights states judgment.

### 3.4.10 Evaluation module

Database sent data to evaluation mode to record the information of each road in term the data of hours and days. Evaluation module also responsible to keeps the data from estimator to evaluate the importance of each road.

### 3.4.11 Traffic light interface

Traffic light interface collect all the result from controller and manage to change the states of the traffic light depends on the situation on the traffic.

### 3.5 Traffic Structure and Algorithm

In this paper, the implementation of fuzzy logic simulator for the traffic flow is discussed. The objective of using fuzzy method in traffic situation is to simulate the green light cycle phase based on the traffic situation. Figure 3.7 shows the fuzzy traffic intersection flow.


Figure 3-7 Fuzzy traffic intersection flow

Figure 3.7 shows the figure of the traffic intersection flow that proposed in this research paper. In the first stage, this traffic simulation will detect the input which is the data of the number vehicles on each street. The fuzzy logic detected the input on each street, the vehicles situation will define which are "low", "medium" or "high" based on the value detected on each street. After categories the level of the traffic situation on each street, fuzzy rule based will propose automatically. The level of green signal prediction will be defined after processes fuzzy rule. After predict the demands of green
light in the intersection, fuzzy logic could decide which street have the priority to become green light based on the traffic situation on each street.

### 3.6 Hardware and Software Requirement

This section will discuss about the hardware and software that required in completing this project.

### 3.6.1 Hardware Requirement

Table 3.1 Hardware Requirement

| Hardware | Descriptions | Unit | Propose |
| :---: | :---: | :---: | :---: |
| Thumb Drive | 32GB x1 | 2 | Backup in softcopy |
| Laptop, Computer | Asus G751JT, Intel (TM) <br> Core i5-5200U, 2.20 GHz , 8.00 GB DDR3L SDRAM, 1TB HDD Serial256 GB SSD, ATA-300 | 1 | Use for documenting and designing, develop and testing the system |

### 3.6.2 Software Requirement

Software requirement is software needed in developing and documentation for this project.

Table 3.2 Software Requirement

| Software | Version/Specification | Propose |
| :--- | :--- | :--- |
| Word Processor | Microsoft Office, 2010 | Research, Documentation <br> and development |
| Interface design and <br> development | Matlab, 2010 | Propose the method of <br> Fuzzification |
| Web Browser <br> Citation | Google Chrome <br> Mandeley 1.18, 32bit | Search information <br> For the purpose to cite the <br> journal or paper |
| Presentation | Microsoft Power Point 2016 | Slides Presentation |

## CHAPTER 4

## RESULTS AND DISCUSSION

### 4.1 Introduction

In this section the results of the simulation traffic signal will be carried out where there are two different of the fuzzy logic approaches applied using the fuzzy logic Toolbox in the Matlab Software. In order to simulate the result of the traffic signal by Fuzzy Logic Mamdani, the GUI of the traffic signal created to showing the result clearly. There are two different of the Fuzzy Logic Mamdani implemented in this study which are Fuzzy Logic that determine the demand of the green light on the next phase and the Fuzzy Logic of selection the green light at the right street.

### 4.2 Fuzzy Logic of Determine the demand of Green Light on the next phase

The objective of created this fuzzy logic is to determine the demand of the green light on the next phase where the input parameters are 4 which is "Street 1 ", "Street 2 ", "Street 3", "Street 4" and 1 output parameter which is "green-time". The aim of the input parameters in this fuzzy logic is to determine the volume of the vehicle behind the street then the output parameter is the result of determine the time that the light will be green. Figure 4.1 is the of the input parameters and the output parameter that generated using Matlab Toolbox.


Figure 4-1 Input and output parameters of Fuzzy Logic "fuzzygreentime"

### 4.2.1 Input parameters of fuzzy green time

There are 3 variables "Low", "Medium" and "High" to evaluate the volume of vehicles in the input parameters of the Street1, Street 2, Street 3 and Street 4. The data showed on the table 4.1 has been generated based on the basic traffic density in the traffic intersection.

Table 4.1 The level of input parameters of the fuzzy green time

| Input parameters | Low | Medium | High |
| :--- | :--- | :--- | :--- |
| Street 1 | $0-20$ | $15-45$ | $40-60$ |
| Street 2 | $0-20$ | $15-45$ | $40-60$ |
| Street 3 | $0-20$ | $15-45$ | $40-60$ |
| Street 4 | $0-20$ | $15-45$ | $40-60$ |

The input parameters used a number to represent the density of vehicles behind the traffic light on each road where $0-20$ considered the queue behind the traffic light is "Low", $15-45$ considered the queue behind the traffic light is "Medium" and 40-60 considered as long queue "High".

### 4.2.1.1 Membership functions of the input parameters of fuzzy green time

There are four membership functions with three different level of variable "low", "medium" and "high" shows at the below figures.


Figure 4-2 The membership functions of parameter "Street1" in fuzzy green time The membership function of the linguitic variable of the parameter Street 2 represented in figure 4.3.


Figure 4-3 The membership functions of parameter "Street2" in fuzzy green time The membership function of the linguitic variable of the parameter Street 3 represented in figure 4.4.


Figure 4-4 The membership functions of parameter "Street3" in fuzzy green time The membership function of the linguitic variable of the parameter Street 4 present in figure 4.5 .


Figure 4-5 The membership functions of parameter "Street4" in fuzzy green time

### 4.2.2 Output parameter of the fuzzy green time

With four parameters, the fuzzy traffic controller has the information about the status in the intersection, and the controller should determine which street has the level of demand to change the green light on the next phase. The membership functions of the linguistic variable of the output parameter are stated clearly in table 4.2 and figure 4.6.

Table 4.2 The level of output parameters of the fuzzy green time

| Output parameter | Low | Medium | High |
| :--- | :--- | :--- | :--- |
| Green Time | $0-2$ | $3-5$ | $6-8$ |

Table 4.2 showed the level of the demand to change the green light on the next phases where the result of level depends the number of vehicles behind the traffic light on each street.

### 4.2.2.1 The membership function of the output parameters of the fuzzy green time

The output parameters of the fuzzy green time has three different level of variable "low", "medium" and "high" shows at the below figures.


Figure 4-6 The membership functions of the output parameter "green-time"

### 4.2.3 Fuzzy rule based of the fuzzy green time

The fuzzy traffic green time priority have four input parameters and one output parameter where fuzzy rules have generated based on the fuzzy inputs and linguistic variable. So the total of the fuzzy rules is the multiple of four input parameters and three linguistic variable for each input parameters. The total of the fuzzy rules is 81 ( $3 \times 3 \times 3 \times 3=81$ ).

1. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is low) then (green-time is high)
2. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is medium) then (green-time is high)
3. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is high) then (green-time is high)
4. If (street 1 is low) and (street 2 is low) and (street 3 is medium) and (street 4 is low) then (green-time is high)
5. If (street 1 is low) and (street 2 is low) and (street 3 is medium) and (street 4 is medium) then (green-time is medium)
6. If (street 1 is low) and (street 2 is low) and (street 3 is medium) and (street 4 is high) then (green-time is high)
7. If (street1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is low) then (green-time is high)
8. If (street 1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is medium) then (green-time is high)
9. If (street 1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is high) then (green-time is medium)
10. If (street1 is low) and (street2 is medium) and (street 3 is low) and (street 4 is low) then (green-time is high)
11. If (street 1 is low) and (street 2 is medium) and (street 3 is low) and (street 4 is medium) then (green-time is medium)
12. If (street 1 is low) and (street 2 is medium) and (street 3 is low) and (street 4 is high) then (green-time is high
13. If (street 1 is low) and (street 2 is medium) and (street 3 is medium) and (street 4 is low) then (green-time is medium)
14. If (street1 is low) and (street2 is medium) and (street3 is medium) and (street4 is medium) then (green-time is medium)
15. If (street 1 is low) and (street 2 is medium) and (street 3 is medium) and (street 4 is high) then (green-time is low)
16. If (street1 is low) and (street2 is medium) and (street3 is high) and (street4 is low) then (green-time is high)
17. If (street 1 is low) and (street 2 is medium) and (street 3 is high) and (street 4 is medium) then (green-time is low) (1)
18. If (street 1 is low) and (street 2 is medium) and (street 3 is high) and (street 4 is high) then (green-time is low)
19. If (street 1 is low) and (street 2 is high) and (street 3 is low) and (street 4 is low) then (green-time is high)
20. If (street 1 is low) and (street 2 is high) and (street 3 is low) and (street 4 is medium) then (green-time is high)
21. If (street 1 is low) and (street 2 is high) and (street 3 is low) and (street 4 is high) then (green-time is medium)
22. If (street 1 is low) and (street 2 is high) and (street 3 is medium) and (street 4 is low) then (green-time is high)
23. If (street 1 is low) and (street 2 is high) and (street 3 is medium) and (street 4 is medium) then (green-time is low)
24. If (street 1 is low) and (street 2 is high) and (street 3 is medium) and (street 4 is high) then (green-time is low)
25. If (street 1 is low) and (street 2 is high) and (street 3 is high) and (street 4 is low) then (green-time is low)
26. If (street1 is low) and (street2 is high) and (street3 is high) and (street4 is medium) then (green-time is low)
27. If (street 1 is low) and (street2 is high) and (street3 is high) and (street 4 is high) then (green-time is low)
28. If (street 1 is medium) and (street 2 is low) and (street 3 is low) and (street 4 is low) then (green-time is high)
29. If (street 1 is medium) and (street 2 is low) and (street 3 is low) and (street 4 is medium) then (green-time is medium)
30. If (street 1 is medium) and (street 2 is low) and (street 3 is low) and (street 4 is high) then (green-time is high)
31. If (street 1 is medium) and (street 2 is low) and (street 3 is medium) and (street 4 is low) then (green-time is medium)
32. If (street1 is medium) and (street2 is low) and (street3 is medium) and (street4 is medium) then (green-time is low)
33. If (street 1 is medium) and (street 2 is low) and (street 3 is medium) and (street 4 is high) then (green-time is low)
34. If (street 1 is medium) and (street 2 is low) and (street 3 is high) and (street 4 is low) then (green-time is medium)
35. If (street 1 is medium) and (street 2 is low) and (street 3 is high) and (street 4 is medium) then (green-time is low)
36. If (street1 is medium) and (street2 is low) and (street3 is high) and (street4 is high) then (green-time is low)
37. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is low) then (green-time is medium)
38. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is medium) then (green-time is medium)
39. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is high) then (green-time is low)
40. If (street 1 is medium) and (street 2 is medium) and (street 3 is medium) and (street 4 is low) then (green-time is medium)
41. If (street 1 is medium) and (street 2 is medium) and (street 3 is medium) and (street 4 is medium) then (green-time is low)
42. If (street 1 is medium) and (street 2 is medium) and (street 3 is medium) and (street 4 is high) then (green-time is low)
43. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street 4 is low) then (green-time is low)
44. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street 4 is medium) then (green-time is low)
45. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street4 is high) then (green-time is low)
46. If (street 1 is medium) and (street2 is high) and (street3 is low) and (street 4 is low) then (green-time is low)
47. If (street 1 is medium) and (street 2 is high) and (street 3 is low) and (street 4 is medium) then (green-time is low)
48. If (street1 is medium) and (street2 is high) and (street3 is low) and (street4 is high) then (green-time is low)
49. If (street 1 is medium) and (street 2 is high) and (street3 is medium) and (street 4 is low) then (green-time is low)
50. If (street 1 is medium) and (street 2 is high) and (street 3 is medium) and (street 4 is medium) then (green-time is low)
51. If (street 1 is medium) and (street 2 is high) and (street 3 is medium) and (street4 is high) then (green-time is low)
52. If (street1 is medium) and (street2 is high) and (street3 is high) and (street4 is low) then (green-time is low)
53. If (street 1 is medium) and (street 2 is high) and (street 3 is high) and (street 4 is medium) then (green-time is low)
54. If (street 1 is medium) and (street 2 is high) and (street 3 is high) and (street 4 is high) then (green-time is low)
55. If (street 1 is high) and (street2 is low) and (street3 is low) and (street4 is low) then (green-time is high)
56. If (street 1 is high) and (street 2 is low) and (street 3 is low) and (street 4 is medium) then (green-time is medium)
57. If (street 1 is high) and (street 2 is low) and (street 3 is low) and (street 4 is high) then (green-time is low)
58. If (street 1 is high) and (street 2 is low) and (street 3 is medium) and (street 4 is low) then (green-time is medium)
59. If (street 1 is high) and (street 2 is low) and (street 3 is medium) and (street 4 is medium) then (green-time is low)
60. If (street 1 is high) and (street 2 is low) and (street 3 is medium) and (street 4 is high) then (green-time is low)
61. If (street1 is high) and (street2 is low) and (street3 is high) and (street4 is low) then (green-time is low)
62. If (street 1 is high) and (street 2 is low) and (street 3 is high) and (street 4 is medium) then (green-time is low)
63. If (street 1 is high) and (street 2 is low) and (street 3 is high) and (street 4 is high) then (green-time is low)
64. If (street 1 is high) and (street 2 is medium) and (street 3 is low) and (street 4 is low) then (green-time is medium)
65. If (street 1 is high) and (street 2 is medium) and (street 3 is low) and (street 4 is medium) then (green-time is low)
66. If (street1 is high) and (street 2 is medium) and (street 3 is low) and (street 4 is high) then (green-time is low)
67. If (street 1 is high) and (street 2 is medium) and (street 3 is medium) and (street 4 is low) then (green-time is low)
68. If (street1 is high) and (street2 is medium) and (street3 is medium) and (street4 is medium) then (green-time is low)
69. If (street 1 is high) and (street 2 is medium) and (street 3 is medium) and (street 4 is high) then (green-time is low)
70. If (street 1 is high) and (street 2 is medium) and (street 3 is high) and (street 4 is low) then (green-time is low)
71. If (street 1 is high) and (street2 is medium) and (street3 is high) and (street4 is medium) then (green-time is low)
72. If (street 1 is high) and (street 2 is medium) and (street 3 is high) and (street 4 is high) then (green-time is low)
73. If (street1 is high) and (street 2 is high) and (street 3 is low) and (street 4 is low) then (green-time is low)
74. If (street1 is high) and (street2 is high) and (street3 is low) and (street 4 is medium) then (green-time is low)
75. If (street 1 is high) and (street 2 is high) and (street 3 is low) and (street 4 is high) then (green-time is low)
76. If (street1 is high) and (street 2 is high) and (street 3 is medium) and (street 4 is low) then (green-time is low)
77. If (street 1 is high) and (street2 is high) and (street 3 is medium) and (street 4 is medium) then (green-time is low)
78. If (street1 is high) and (street2 is high) and (street 3 is medium) and (street 4 is high) then (green-time is low)
79. If (street 1 is high) and (street 2 is high) and (street 3 is high) and (street 4 is low) then (green-time is low)
80. If (street 1 is high) and (street 2 is high) and (street 3 is high) and (street 4 is medium) then (green-time is low)
81. If (street1 is high) and (street2 is high) and (street3 is high) and (street 4 is high) then (green-time is low)

### 4.3 Fuzzy Logic of the Green Light Street

This fuzzy logic designed to switch the green light to the suitable street on the next phase where the result is based on the volume of vehicles on each street. The input parameters are 4 which is "Street 1 ", "Street 2 ", "Street 3 ", "Street 4 " and 1 output parameter which is "which-street". The aim of the input parameters in this fuzzy logic is to determine the volume of the vehicle behind the street then the output parameter is the result of which street will be on green phase. Figure 4.7 is the of the input parameters and the output parameter of "GreenLightSelection".


Figure 4-7 Inputs and output parameters of Fuzzy Logic "GreenLightStreet"

### 4.3.1 Input parameter of the fuzzy green light street

There are 3 variables "Low", "Medium" and "High" to estimate the volume of vehicles in the input parameters of the Street 1, Street 2, Street 3 and Street 4. The data showed on the table 4.1 has been generated based on the basic traffic density in the traffic intersection.

Table 4.3 The input parameters of the green light street

| Input parameters | Low | Medium | High |
| :--- | :--- | :--- | :--- |
| Street 1 | $0-22$ | $10-42$ | $38-60$ |
| Street 2 | $0-22$ | $10-42$ | $38-60$ |
| Street 3 | $0-22$ | $10-42$ | $38-60$ |
| Street 4 | $0-22$ | $10-42$ | $38-60$ |

The number represented the level of the volume of vehicles on each street. The number 0-22 "Low" considered as short queue of vehicle behind the traffic light, 10-42 "Medium" considered as medium queue of the vehicle behind the traffic light and 38-60 "High" considered as long queue behind the traffic light.

### 4.3.1.1 Membership function of the input parameters of fuzzy green light street

The three different level of membership function of the input parameters of fuzzy green light street of "low", "medium" and "high" shows at the below figures.


Figure 4-8 The membership funtions of parameter "Street 1" in fuzzy green light street

The membership function of the linguitic variable of the parameters green time street "Street 2" represented in figure 4.9.


Figure 4-9 The membership funtions of parameter "Street 2" in fuzzy green light street

The membership function of the linguitic variable of the parameters green time street represented in figure 4.10.


Figure 4-10 The membership funtions of parameter "Street 3" in fuzzy green light street

The membership function of the linguitic variable of the parameters green time selection "Street 4" represented in figure 4.11.


Figure 4-11 The membership funtions of parameter "Street 4" in fuzzy green light street

### 4.3.2 Output parameter of the green light street

The output parameter can decide and select which street will be the green light on the next phase since the fuzzy traffic controller has the information about the result of the volume of vehicles on street 1 , street 2 , street 3 , street 4 and the situation of street that has the most demand of the green light on the next phase status at the intersection. As the result the output parameter will choose the most desire of the street to be green light. The
membership functions of the linguistic variable of the parameter Green time street are stated in table 4.4 and figure 4.12.

Table 4.4 The level of output parameter of the fuzzy green light street

| Output <br> parameter | Lstreet1 | Lstreet2 | Lstreet3 | Lstreet4 | No-differ |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Which-street | $0-2$ | $3-5$ | $6-8$ | $9-11$ | $12-14$ |

There is a number that represented which street will be the green light on the next phase. If the result of "which street" showed the number is between $0-2$, it defined that the green light will goes to Lstreet 1 . If the number between 3-5 will goes to Lstreet 2 and if the number between 6-8 then green light will goes to Lstreet 3 , else if number between 9-11 then the green time will turn to Lstreet 3, else the number between 12-14 then the green light will maintain at that street until the there is a changing of the green light at other street.

### 4.3.2.1 The membership function of the output parameters of the fuzzy green light street

Figure 4.12 showed that the membership function of the output parameter of the fuzzy green light street "which-street".


Figure 4-12 The membership functions of the output parameter "which-street"

### 4.3.3 Fuzzy rule based of the green time selection

The green time selection also have four input parameters and one output parameter where fuzzy rules have generated based on the fuzzy inputs and linguistic variable. So the total of the fuzzy rules is the multiple of four input parameters and three linguistic variable for each input parameters. The total of the fuzzy rules is 81 ( $3 \times 3 \times 3 \times 3=81$ ).

1. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is low) then (witch-street is no-differ)
2. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is medium) then (witch-street is Lstreet4)
3. If (street 1 is low) and (street 2 is low) and (street 3 is low) and (street 4 is high) then (witch-street is Lstreet4)
4. If (street 1 is low) and (street 2 is low) and (street 3 is medim) and (street 4 is low) then (witch-street is Lstreet3)
5. If (street1 is low) and (street2 is low) and (street3 is medim) and (street4 is medium) then (witch-street is no-differ)
6. If (street 1 is low) and (street 2 is low) and (street 3 is medim) and (street 4 is high) then (witch-street is Lstreet4)
7. If (street 1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is low) then (witch-street is Lstreet3)
8. If (street 1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is medium) then (witch-street is Lstreet3)
9. If (street 1 is low) and (street 2 is low) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
10. If (street 1 is low) and (street 2 is medium) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet2)
11. If (street 1 is low) and (street 2 is medium) and (street 3 is low) and (street 4 is medium) then (witch-street is no-differ)
12. If (street 1 is low) and (street 2 is medium) and (street 3 is low) and (street 4 is high) then (witch-street is Lstreet4)
13. If (street 1 is low) and (street 2 is medium) and (street 3 is medim) and (street 4 is low) then (witch-street is no-differ)
14. If (street 1 is low) and (street 2 is medium) and (street 3 is medim) and (street 4 is medium) then (witch-street is no-differ)
15. If (street 1 is low) and (street 2 is medium) and (street 3 is medim) and (street 4 is high) then (witch-street is Lstreet4)
16. If (street 1 is low) and (street 2 is medium) and (street 3 is high) and (street 4 is low) then (witch-street is Lstreet3)
17. If (street 1 is low) and (street 2 is medium) and (street 3 is high) and (street 4 is medium) then (witch-street is Lstreet3)
18. If (street1 is low) and (street2 is medium) and (street3 is high) and (street4 is high) then (witch-street is no-differ)
19. If (street 1 is low) and (street 2 is high) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet2)
20. If (street 1 is low) and (street 2 is high) and (street 3 is low) and (street 4 is medium) then (witch-street is Lstreet2)
21. If (street 1 is low) and (street2 is high) and (street3 is low) and (street4 is high) then (witch-street is no-differ)
22. If (street 1 is low) and (street 2 is high) and (street 3 is medim) and (street 4 is low) then (witch-street is Lstreet2)
23. If (street 1 is low) and (street 2 is high) and (street 3 is medim) and (street 4 is medium) then (witch-street is Lstreet2)
24. If (street 1 is low) and (street2 is high) and (street3 is medim) and (street4 is high) then (witch-street is no-differ)
25. If (street 1 is low) and (street 2 is high) and (street 3 is high) and (street 4 is low) then (witch-street is no-differ)
26. If (street 1 is low) and (street 2 is high) and (street 3 is high) and (street 4 is medium) then (witch-street is no-differ)
27. If (street 1 is low) and (street 2 is high) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
28. If (street 1 is medium) and (street 2 is low) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet1)
29. If (street 1 is medium) and (street 2 is low) and (street 3 is low) and (street 4 is medium) then (witch-street is no-differ)
30. If (street 1 is medium) and (street 2 is low) and (street3 is low) and (street4 is high) then (witch-street is Lstreet4)
31. If (street 1 is medium) and (street 2 is low) and (street 3 is medium) and (street 4 is low) then (witch-street is no-differ)
32. If (street 1 is medium) and (street 2 is low) and (street 3 is medium) and (street 4 is medium) then (witch-street is no-differ)
33. If (street 1 is medium) and (street 2 is low) and (street 3 is medium) and (street 4 is high) then (witch-street is Lstreet4)
34. If (street 1 is medium) and (street 2 is low) and (street 3 is high) and (street 4 is low) then (witch-street is Lstreet3)
35. If (street 1 is medium) and (street 2 is low) and (street 3 is high) and (street 4 is medium) then (witch-street is Lstreet3)
36. If (street1 is medium) and (street2 is low) and (street3 is high) and (street4 is high) then (witch-street is no-differ)
37. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is low) then (witch-street is no-differ)
38. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is medium) then (witch-street is no-differ)
39. If (street 1 is medium) and (street 2 is medium) and (street 3 is low) and (street 4 is high) then (witch-street is Lstreet4)
40. If (street 1 is medium) and (street 2 is medium) and (street 3 is medim) and (street 4 is low) then (witch-street is no-differ)
41. If (street 1 is medium) and (street 2 is medium) and (street 3 is medim) and (street 4 is medium) then (witch-street is no-differ)
42. If (street 1 is medium) and (street 2 is medium) and (street 3 is medim) and (street 4 is high) then (witch-street is Lstreet4)
43. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street 4 is low) then (witch-street is Lstreet3)
44. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street4 is medium) then (witch-street is Lstreet3)
45. If (street 1 is medium) and (street 2 is medium) and (street 3 is high) and (street4 is high) then (witch-street is no-differ)
46. If (street 1 is medium) and (street 2 is high) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet2)
47. If (street 1 is medium) and (street 2 is high) and (street 3 is low) and (street 4 is medium) then (witch-street is Lstreet2)
48. If (street 1 is medium) and (street 2 is high) and (street 3 is low) and (street 4 is high) then (witch-street is no-differ)
49. If (street1 is medium) and (street2 is high) and (street3 is medim) and (street4 is low) then (witch-street is Lstreet2)
50. If (street 1 is medium) and (street 2 is high) and (street 3 is medim) and (street 4 is medium) then (witch-street is Lstreet2)
51. If (street 1 is medium) and (street 2 is high) and (street 3 is medim) and (street 4 is high) then (witch-street is no-differ)
52. If (street1 is medium) and (street2 is high) and (street3 is high) and (street4 is low) then (witch-street is no-differ)
53. If (street 1 is medium) and (street 2 is high) and (street3 is high) and (street 4 is medium) then (witch-street is no-differ)
54. If (street 1 is medium) and (street 2 is high) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
55. If (street 1 is high) and (street 2 is low) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet1)
56. If (street 1 is high) and (street2 is low) and (street 3 is low) and (street 4 is medium) then (witch-street is Lstreet1)
57. If (street 1 is high) and (street 2 is low) and (street 3 is low) and (street 4 is high) then (witch-street is no-differ)
58. If (street 1 is high) and (street 2 is low) and (street 3 is medim) and (street 4 is low) then (witch-street is Lstreet1)
59. If (street 1 is high) and (street2 is low) and (street 3 is medim) and (street 4 is medium) then (witch-street is Lstreet1)
60. If (street 1 is high) and (street 2 is low) and (street 3 is medim) and (street 4 is high) then (witch-street is no-differ)
61. If (street 1 is high) and (street 2 is low) and (street 3 is high) and (street 4 is low) then (witch-street is no-differ)
62. If (street1 is high) and (street2 is low) and (street3 is high) and (street4 is medium) then (witch-street is no-differ)
63. If (street 1 is high) and (street 2 is low) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
64. If (street 1 is high) and (street 2 is medium) and (street 3 is low) and (street 4 is low) then (witch-street is Lstreet1)
65. If (street 1 is high) and (street2 is medium) and (street3 is low) and (street 4 is medium) then (witch-street is Lstreet 1)
66. If (street1 is high) and (street2 is medium) and (street3 is low) and (street4 is high) then (witch-street is no-differ)
67. If (street 1 is high) and (street 2 is medium) and (street 3 is medim) and (street 4 is low) then (witch-street is Lstreet1)
68. If (street1 is high) and (street2 is medium) and (street3 is medim) and (street4 is medium) then (witch-street is Lstreet1)
69. If (street 1 is high) and (street 2 is medium) and (street 3 is medim) and (street 4 is high) then (witch-street is no-differ)
70. If (street 1 is high) and (street 2 is medium) and (street 3 is high) and (street 4 is low) then (witch-street is no-differ)
71. If (street 1 is high) and (street2 is medium) and (street3 is high) and (street4 is medium) then (witch-street is no-differ)
72. If (street 1 is high) and (street2 is medium) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
73. If (street 1 is high) and (street 2 is medium) and (street 3 is high) and (street 4 is high) then (witch-street is no-differ)
74. If (street 1 is high) and (street 2 is high) and (street 3 is low) and (street 4 is medium) then (witch-street is no-differ)
75. If (street 1 is high) and (street 2 is high) and (street 3 is low) and (street 4 is high) then (witch-street is no-differ)
76. If (street 1 is high) and (street 2 is high) and (street 3 is medim) and (street 4 is low) then (witch-street is no-differ)
77. If (street 1 is high) and (street 2 is high) and (street 3 is medim) and (street 4 is medium) then (witch-street is no-differ)
78. If (street 1 is high) and (street2 is high) and (street 3 is medim) and (street 4 is high) then (witch-street is no-differ)
79. If (street 1 is high) and (street 2 is high) and (street 3 is high) and (street 4 is low) then (witch-street is no-differ)
80. If (street 1 is high) and (street 2 is high) and (street 3 is high) and (street 4 is medium) then (witch-street is no-differ)
81. If (street1 is high) and (street2 is high) and (street3 is high) and (street4 is high) then (witch-street is no-differ)

### 4.4 Computer simulation results of fuzzy green time

In order to evidence that the results to showing the level of demand which street have the high possibility to become green light at the next phase. Several of the scenarios the with different fuzzy inputs parameters are generated randomly and its result of the output parameter stated in GUI by using Matlab Toolbox.

### 4.4.1 Scenario 1

Figure 4.13 show the result of the determination of the green phase demand in the traffic intersection based on each street condition where the green signal prediction is high in this scenario.


Figure 4-13 Result of determination the demand of green time on the next phase in first scenario

In the first scenario suppose the number of vehicles on Street 1 has short queue which is 10 . The same situation happened to the Street 2 and Street 3 where the number of vehicles is 4 and 3 respectively. We suppose the number of vehicles on the Street 4 is

37 which is categories as "Medium" queue. Fuzzy logic will run the most suitable of fuzzy rule. In this scenario, a rule was defined where it located in rule number 2 of the fuzzy rule green time "IF street 1 is low, AND street 2 is low, AND street 3 is low, AND street 4 is medium, THEN green-time is high". The output parameter showed the result of green-time equal 6.96 means the result is matched to the rule where the fuzzy logic could define the result correctly. In this scenario, street 4 which is 37 is the highest number among 4 of the streets compare to others street which are 10,4 , and 9 for the street 1 , street 2 and street 3 respectively. As the result, the possibility of the green light can be defined as accurately where the determination of the green light on next phase is "High". In this scenario, street 4 has the high probability to shifting red signal to green signal since the green light determination is high in this scenario and the street 4 has the highest number of vehicles and it can be considered as the targeted street to turn to green signal on the next phase. Figure 4.14 showed the result of the direction of green light selection on the next phase.


Figure 4-14 Result of green light selection to the street in first scenario

In order to simulate the correct direction of the green light on each street, the other fuzzy logic carried out for identify which street will become green light on the next phase.

The input parameters are the same where street 1 is 10 , street 2 is 4 and street 3 and 4 are 9 and 37, respectively. The prediction of the green light showed in figure 4.13 is high means that the priority street of the green light selection will be accurate for this scenario because the highest number of vehicles on the street will selected as the priority of street to become green light. In this scenario, street 4 is selected as the green light on next phase where the situation of vehicles on street 4 is longer than the street 1,2 , and 3 . The output parameters of 9.94 represented street 4 which will be the green light on the next phase. Figure 4.15 showed the simulation traffic light in the intersection road using Matlab GUI.


Figure 4-15 Green light on street 1in first scenario
There are 4 arms of the road in this intersection which are North (Street 1), West (Street 2), East (Street 3) and South (Street 4). In this scenario suppose the green light is street 1 which is 10 , street 2 is 4 , street 3 is 9 and street 4 is 37 , the selection of the green light will be go to the street 4 which allocatted at south of the intersection where the number of vehicles is 37 . The result of select the street are follow the result of fuzzy green time and the fuzzy selection of direction of green time based on the figure 4.13 and
figure 4.14. The figure 4.16 are the result of green light on street 4 after the changing of green light from street 1.


Figure 4-16 Green light on street 4 on the next phase in first scenario

Figure 4.16 shows the shifting of the green signal from the street 1 figure 4.15 to street 4. Fuzzy logic followed the different condition on each rule then defined the matched rule to come out with the result of which street has the most priority to be the green light on next phase.

### 4.4.2 Scenario 2

The prediction of green light affected by the condition on each street situation.
Figure 4.17 shows the result of prediction of green light in the traffic scenario 2.


Figure 4-17 Result of determination the demand of green time on the next phase in second scenario

In the second scenario suppose the number of vehicles on street 1 is 32 categories as "Medium" queue, number of vehicles on street 2 is 6 categories as "Low", number of vehicles on street 3 is 48 categories as "High" and the street 4 have low number of vehicles which is 9 . After fuzzy logic collected all the number of vehicles on every street then the fuzzy logic will define which level of the situation on each street. In this scenario, the rule that selected is "IF street 1 is medium AND street 2 is low AND street 3 is high AND street 4 is low THEN green-time is medium". In this scenario, the level of prediction the green signal on the next phase are medium which the green time is 4 . The result of the fuzzy green time will be the green light selection on the intersection for the next phase. The highest of the vehicles has the high priority to become the green light on the next phase where street 3 is the highest number of vehicles and can be considered as
the green phase has high probability will shift to street 3 . Figure 4.19 showed the result green light direction on the next phase.


Figure 4-18 Result of green light selection to the street in first scenario
The other fuzzy logic which is fuzzy green time selection applied for determine which street will become green light on the next phase. The input parameters are the same where street 1 is 32 , street 2 is 6 and street 3 and 4 are 48 and 9 , respectively. The prediction of the green light showed in figure 4.18 is medium means there have no significant different of the queue length between the street where it can be found on the street 1,32 and street 3 , 48 where the different is 16 compared to first scenario which is 27 of vehicles of different between the street 1 and 4 . As the result, the prediction of the green light on this scenario considered as medium but the fuzzy logic will select the green light which is the highest number of vehicles on the street as the priority of street to become green light. In this scenario, street 3 is selected as the green light on next phase where the situation of vehicles on street 3 is longer than the street 1,2 , and 4 . The output parameters "which-street" 7 represented street 3 which will be the green light on the next phase. Figure 4.20 show the green light on street 1 .


Figure 4-19 Green light on street 1 in second scenario
Figure 4.20 showed the simulation traffic light in the intersection road using Matlab GUI. There are 4 arms of the road in this intersection which are North (Street 1), West (Street 2), East (Street 3) and South (Street 4). In this scenario suppose the green light is street 1 which is 32 , street 2 is 6 , street 3 is 48 and street 4 is 9 , the selection of the green light will be go to the street 3 which locatted at east of the intersection which is 48 on the next phase. The result of select the street are follow the result of fuzzy green time and the fuzzy selection of green time based on the figure 4.18 and figure 4.19. The figure 4.21 are the result of green light on street 3 after the shifting green light from street 1.

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Figure 4-20 Green light on street 3 on the next phase in second scenario

### 4.4.3 Scenario 3

Figure 4.22 stated that the result of the green light prediction which is low on this scenario.


Figure 4-21 Result of determination the demand of green time on the next phase in first scenario

In the third scenario suppose the number of vehicles on Street 1 has 45 vehicles where categories as "High" of the number of vehicles. Street 2 has 3 vehicles which is "Low" and street 3 is 33 considered as "Medium" and street 4 is 44 considered "High" of the number of vehicles. In this scenario, a rule was defined where it located in rule number 60 where the fuzzy rule green time presented "IF street 1 is high, AND street 2 is low, AND street 3 is medium, AND street 4 is high, THEN green-time is low". The output parameter showed the result of green-time equal 1.04 which is "Low" of the green time prediction where the result is matched to the rule that the fuzzy logic could define the result correctly. In this scenario, street 1 which is 45 is the highest number among 4 of the streets compare to others street which are 3,33 , and 44 for the street 2 , street 3 and street 4. In this scenario, street 1 has the high probability to shifting red signal to green
signal since the number of the vehicles are the highest among 4 of street in in this scenario. The prediction of the green light is low because the traffic congestion found on the street 1 and 4 where the queue behind the traffic light is long. As the result the green time would not be shifting to other street for the current situation but the street 1 has the highest number of vehicles and it can be considered as the targeted street to turn to green signal on the next phase. Figure 4.22 showed the result of the direction of green light selection on the next phase.


Figure 4-22 Result of green light selection to the street in first scenario

Figure 4.22 show that the input parameters are the same where street 1 is 45 , street 2 is 3 and street 3 and 4 are 33 and 44, respectively and the output is 13 which is categories as "no-differ" in this scenario. The prediction of the green light showed in figure 4.21 is low means that the priority street of the green light selection will be terminate for this scenario because the highest number of vehicles 45 on street 1 is almost similar with street 4 which is 44 and the difference within these two streets is 1 . Although the green phase prediction is low but the highest number of the vehicles on the other street will be
considered to move on the next phase. Figure 4.23 show the traffic green light phase in this scenario.


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Figure 4-23 Green light on street 4 in third scenario
Figure 4.23 show the green light direction on the street 4 where the green light current will not shift to other street until the highest number of the vehicles coming on the other street then the street with highest number will be consider shift to green light. In this scenario, fuzzy logic selected the street 1 ( 45 vehicles) as the target street even the number of vehicles is 1 more than the current number of vehicles on the green street ( 44 vehicles). Figure 4.24 shows the result of green light direction after shifting the green light from street 4 to street 1.


Figure 4-24 Green light on street 3 on the next phase in second scenari

## CHAPTER 5

## CONCLUSION

### 5.1 Introduction

In this thesis has introduced the Fuzzy Logic of the simulation of green signal in the isolated intersection road. The main purpose of develop the simulation traffic light is to propose a better solution to overcome the congestion and reduce the waiting time of traffic light in the isolated intersection road. The result of using the fuzzy logic have showed that the green signal on the intersection is shifted to an appropriate street based on the number of vehicles on each street by using the fuzzy rule to analyse the suitable traffic flow for every phase cycle in the traffic intersection road.

### 5.2 Research Constraint

i. Resources

In this research, the data is generated randomly for the fuzzy input parameters. It is sufficient to have the real data from current situation by using the traffic detections like sensors for each street at the same time.
ii. Limited time

Limited time to have the further research regarding the whole process in designing the simulation traffic green phase flow. In order to select the better method to simulate the traffic signal, time spent for analyse phase to select the suitable methods in traffic intersection.

### 5.3 Research Conclusion

In this thesis the fuzzy intelligent traffic control model is performed optimally that fuzzy handled different traffic situation by determine and control the priority of the green light in intersection. The result of the computer simulation show that the combination of the fuzzy green light prediction level and fuzzy green light street selection performed better by produces the accurate result of the green light direction with the different condition of the input parameters where improve the accuracy of the fuzzy controller. The performance of the traffic fuzzy controller is better than the conventional fixed time controller weather in the low volume of traffic situation or high density of traffic situation. Fuzzy traffic controller contributed in minimize the delay vehicles which maintain in a minimum of safe traffic volume in the traffic intersection. The result of the traffic green light phase is controlled by Mamdani inference.

### 5.4 Future Work

In future, pedestrian control logic consider as further research combining with this fuzzy traffic controller. Network connection can be added by detecting the current traffic situation on each street and sending the information each street which become the fuzzy input parameters. As the results by received the real time data of traffic information, the fuzzy model will perform better with solving the traffic congestion in real scenario of traffic situation.

## REFERENCES

Chansiri Suksri, P. M. A. P. T. and D. W. L. Y. (2011). Exploring stop-line traffic flows at signalised intersections in the Adelaide CBD. Australasian Transport Research Forum 2011 Proceedings, Adelaide, Australia.

Guneri1, A. F., \& Muhammet Gul1 and Mehmet Lok1. (2015). A FUZZY APPROACH FOR HOTEL LOCATION SELECTION IN MUGLA, TURKEY. IJBTS International Journal of Business Tourism and Applied Sciences, 3(1).
I.ChamodrakasN.AlexopoulouD.Martakos. (2009). Customer evaluation for order acceptance using a novel class of fuzzy methods based on TOPSIS, 36(4), 7409-7415.
I.N.Askerzade (Askerbeyli), M. M. (2010). Control the Extension Time of Traffic Light in Single Junction by Using Fuzzy Logic. International Journal of Electrical \& Computer Sciences IJECS-IJENS, 10(02), 55.

Jomaa, D. (2014). The Optimal Trigger Speed of Vehicle Activated Signs. Dalarna Licentiate Theses, 2, 72.
K. Mahirah1, A. A. Azlina1, I. N. \& R. Y. (2015). Valuing Road User's Willingness to Pay to Reduce Traffic Congestion in Klang Valley, Malaysia. Asian Social Science, 110(25), 5.

Karmore2, D. R. P. S. (2012). Intelligent Traffic Signal Control System Using Embedded System. Innovative Systems Design and Engineering, 3(5).

Krzysztof, M. (2016). The importance of automatic traffic lights time algorithms to reduce the negative impact of transport on the urban environment. 2nd International Conference "Green Cities - Green Logistics for Greener Cities," 329-342.
L.Martínez. (2006). International Journal of Approximate Reasoning. International Journal of Approximate Reasoning, 44(2), 148-164.
Md. Nazmul Huda. (2001). Control of complex Traffic Junction using Fuzzy Inference. School of Computing Queen's University, 10-19.

Md Anwarul Azim, M. N. H. (2014). Fuzzy Traffic Control System. School of Coputing Queen's University, 5-8.

Mencar, C. (2011). Interpretability assessment of fuzzy knowledge bases: A cointension based approach. International Journal of Approximate Reasoning, 52(4), 501-518.

Project Scholar, Dept. of Computer Science and Engg., G. H. Raisoni College of Engineering, Nagpur (MS), I. (n.d.). Traffic Signal Timings Optimization Using Fuzzy Logic Controller, 7(4).

San-MinWangaBao-ShuWangbDao-WuPeib. (2005). A fuzzy logic for an ordinal sum tnorm. Fuzzy Sets and Systems, 149(2), 297-307.

Skabardonis, A., Shladover, S., Zhang, W.-B., Zhang, L., Li, J.-Q., \& Zhou, K. (2014). Advanced Traffic Signal Control Algorithms. CALIFORNIA PATH PROGRAM INSTITUTE OF TRANSPORTATION STUDIES UNIVERSITY OF CALIFORNIA, BERKELEY.

Times, N. S. Poor timing of traffic lights causing congestion (2017).

Vratislav Jerabek, G. L. (2001). FUZZY BASED CONTROLLER OF TRAFFIC INTERSECTION. Universite de Sherbrooke, Faculte Des Sciences Appliquees DGpartement de Genie Electrique et de Genie Informatique Sherbrooke (Quebec) CANADA, 57.

Zadeh, L. (1956). Lotfi Zadeh, Father of Mathematical 'Fuzzy Logic,' Dies at 96. $N$ Academic Paper.

Zoran Gacovski, Stojce Deskovski, K. V. (2012). Fuzzy Traffic Controller for Urban
Intersection Developed in Simulink. FON University, Faculty for ICT, Bul. Vojvodina, $2(2-4), 122-125$.

## APPENDIX A

## GANTT CHART




