



Faculty of Electrical and Electronic Engineering Technology



**DEVELOPMENT OF A SMART TRAFFIC LIGHT SYSTEM USING A
SOLAR-POWERED STANDALONE PV SYSTEM**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AZLYN ARISSYA BINTI ARIFF

Bachelor of Electrical Engineering Technology with Honours

2022

**DEVELOPMENT OF A SMART TRAFFIC LIGHT SYSTEM USING A SOLAR-
POWERED STANDALONE PV SYSTEM**

AZLYN ARISSYA BINTI ARIFF

**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology with Honours**



Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development of a Smart Traffic Light System Using a Solar-Powered Standalone PV System

Sesi Pengajian : 2022/2023

Saya AZLYN ARISSYA BINTI ARIFF mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):


SULIT*

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

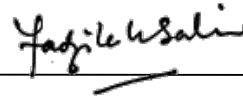
(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:



(TANDATANGAN PENULIS)



(COP DAN TANDATANGAN PENYELIA)

Alamat Tetap:
Lot 598, Jalan Pohon Mesta, Kampung
Machang Limbat, 16150 Kota Bharu,
Kelantan.

DATIN DR. FADZILAH BINTI SALIM
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Elektrik
Fakulti Teknologi Kejuruteraan Elektrik dan Elektronik
Universiti Teknikal Malaysia Melaka

Tarikh: 27/1/2023

Tarikh: 14/2/2023

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project report entitled “Development of a Smart Traffic Light System Using a Solar-Powered Standalone PV System” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

:



Student Name

:

AZLYN ARISSYA BINTI ARIFF

Date

:

27/1/2023

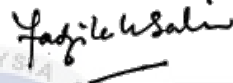


اونيورسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature

: 

Supervisor Name

: DATIN DR. FADZILAH BINTI SALIM

Date

: 14 / 2 / 2023

Signature

:  اونيورسيتي تيكنيكل ماليزيا ملاك

Co-Supervisor

: UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Name

AMALIA AIDA BINTI ABD HALIM

Date

: 20 / 2 / 2023

DEDICATION

To my beloved mother, Azuraizam Binti Omar, my late father, Ariff Bin Salleh, and my dearest sister, Alya Azrissya Binti Ariff, who have meant and continue to mean so much to me.



ABSTRACT

Nowadays, electricity generation from standalone solar energy is increasing and gaining a lot of demand, especially in developing smart technology such as intelligent traffic light systems. A standalone solar PV system can generate, store and supply power to the traffic light without depending on the grid supply. Moreover, the conventional traffic light system is inefficient. The conventional system uses a fixed timing system for each lane and depends on the grid supply to operate, which can sometimes malfunction due to power failure and cause road accidents. A smart traffic light system using a solar-powered standalone PV system has been developed to overcome this problem. This project aims to analyze the existing traffic light system by studying related articles, journals and previous works, to design and develop a smart traffic light system integrated with standalone PV solar power, and to evaluate the suitability of solar panels, charge controller, batteries and sensors in a smart traffic light system. The smart traffic light system uses infrared (IR) sensors to detect traffic density. The Arduino Nano is used as the microcontroller to control the timer of the traffic light system and change the signal appropriately based on the vehicle density. LED traffic light modules have been used to represent the traffic light signal. Thus, with the integration of a standalone PV solar system, the PV solar can provide enough electricity to power the smart traffic light system and overcome many mishaps on the road due to traffic light malfunction.

ABSTRAK

Pada masa kini, penjanaan elektrik daripada tenaga suria sendiri semakin meningkat dan mendapat banyak permintaan, terutamanya dalam pembangunan teknologi pintar seperti sistem lampu isyarat pintar. Sistem PV solar sendiri boleh menjana, menyimpan dan membekalkan kuasa kepada lampu isyarat tanpa bergantung pada bekalan grid. Selain itu, sistem lampu isyarat konvensional adalah tidak cekap. Sistem konvensional menggunakan sistem pemasaan tetap dan bergantung pada bekalan grid untuk beroperasi, yang kadangkala boleh rosak akibat kegagalan kuasa dan menyebabkan kemalangan jalan raya. Sistem lampu isyarat pintar menggunakan sistem PV sendiri berkuasa solar telah dibangunkan untuk mengatasi masalah ini. Projek ini bertujuan untuk menganalisis sistem lampu isyarat sedia ada dengan mengkaji artikel, jurnal dan karya berkaitan, untuk membentuk dan membangunkan sistem lampu isyarat pintar yang disepadukan dengan kuasa solar PV sendiri, dan menilai kesesuaian panel solar, pengawal cas, bateri dan penderia. dalam sistem lampu isyarat pintar. Penderia inframerah (IR) digunakan dalam sistem lampu isyarat pintar untuk mengesan kesibukan lalu lintas. Arduino Nano digunakan sebagai pengawal mikro untuk mengawal pemasa sistem lampu isyarat dan menukar isyarat dengan sewajarnya berdasarkan kepadatan kenderaan. Modul lampu isyarat LED telah digunakan untuk mewakili isyarat lampu trafik. Oleh itu, dengan penyepaduan sistem suria PV sendiri, solar PV boleh membekalkan tenaga elektrik yang mencukupi untuk menghidupkan sistem lampu isyarat pintar dan mengatasi banyak kemalangan di jalan raya akibat kerosakan lampu isyarat.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Datin Dr Fadzilah Binti Salim and co-supervisor, Amalia Aida Binti Abd Halim, for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) and the scholarship party for the financial support which enabled me to accomplish the project. Not forgetting my lecturer Dr Azhan Bin Ab Rahman, for his willingness to share his thoughts and ideas regarding the project.

My highest appreciation goes to my parents and family members for their love and prayer during my study period. An honourable mention also goes to Muhammad Atiqurahman Bin Mohd Rafar for his motivation and understanding. I would also like to thank my fellow coursemates from BEEY Cohort 9, who have helped me with their valuable suggestions and guidance and have been very helpful in various stages of project completion.

Last but not least, I want to thank all the Faculty of Electrical and Electronic Engineering Technology (FTKEE) staff, faculty members, and other individuals who are not listed here for being cooperative and helpful.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATIONS	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF SYMBOLS	xi
LIST OF ABBREVIATIONS	xii
LIST OF APPENDICES	xiii
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Project Objective	3
1.4 Scope of Project	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Overview of Existing Project System	4
2.2.1 Adaptive Traffic Lights through Traffic Density Calculation on Road Pattern	4
2.2.2 Density Based Traffic Signal System Using Arduino UNO	5
2.2.3 Smart Traffic Light Control System	5
2.2.4 Smart Density Based Traffic Light System	6
2.2.5 Design of Intelligent Traffic Light Controller Using Embedded System	7
2.3 Comparison of Literature Review	7
2.4 Conventional Traffic Light system	9
2.5 Statistics of Road Accidents at Traffic Lights	9
2.6 Solar Radiation in Malaysia	10
2.7 Background of PV Solar Power System	12
2.7.1 Types of Photovoltaic (PV) Solar System	12

2.7.2	Solar Cell Structure and Working Principle	15
2.7.3	Major Element of Standalone Solar Power System	16
2.7.3.1	Solar Panel	16
2.7.3.2	Charge Controller	19
2.7.3.3	Battery Bank	19
2.7.3.4	DC to DC Converter	21
2.8	Microcontroller	22
2.8.1	Arduino Nano	22
2.8.2	Raspberry Pi	23
2.8.2.1	Raspberry Pi Model-A Board	24
2.8.2.2	Raspberry Pi Model-B Board	25
2.8.3	Comparison of Arduino Nano and Raspberry Pi	26
2.9	Summary	28
CHAPTER 3 METHODOLOGY		29
3.1	Introduction	29
3.2	Methodology	29
3.3	Block Diagram of Overall System	31
3.4	Block Diagram of Standalone PV Solar System	32
3.5	Flowchart of Smart Traffic Light System	33
3.6	Overall System Sizing Design	34
3.6.1	Size of Solar Panel	34
3.6.2	Size of Battery Bank	36
3.6.3	Size of Battery Charge Controller	37
3.6.4	Summary of Standalone PV Solar System Sizing	39
3.7	Hardware Development	40
3.7.1	Polycrystalline Silicon PV Solar Panel	40
3.7.2	18650 Rechargeable Lithium-Ion Battery	41
3.7.3	TP4056 Charge Controller Module	42
3.7.4	DC-DC Boost Converter Module	43
3.7.5	Arduino Nano	44
3.7.6	Infrared Sensor	45
3.7.7	LED Traffic Light Module	46
3.8	Software Development	47
3.8.1	Proteus 8 Professional	47
3.8.2	Arduino IDE	48
3.9	Tools	49
3.9.1	Multimeter	49
3.9.2	AC-DC Switching Power Supply Adapter	50
3.10	Cost and Bill of Materials	51
3.11	Summary	52
CHAPTER 4 RESULTS AND DISCUSSIONS		53
4.1	Introduction	53
4.2	Prototype Development	53
4.3	Project Testing Result	57
4.3.1	PV Solar System Data on Day 1	58
4.3.2	PV Solar System Data on Day 2	59
4.3.3	PV Solar System Data on Day 3	60

4.3.4	PV Solar System Data on Day 4	61
4.3.5	PV Solar System Data on Day 5	62
4.3.6	PV Solar System Data on Day 6	63
4.3.7	PV Solar System Data on Day 7	64
4.4	Standalone PV Solar System Average Data Analysis	65
4.5	Smart Traffic Light System Performance Analysis	69
4.6	Summary	71
CHAPTER 5 CONCLUSION AND FUTURE IMPROVEMENTS		72
5.1	Introduction	72
5.2	Project Objectives	72
5.2.1	To analyze the existing traffic light system by studying related articles, journals and works.	73
5.2.2	To design and develop a smart traffic light system integrated with standalone PV solar power.	73
5.2.3	To evaluate the suitability of solar panels, charge controllers, batteries and sensors in a smart traffic light system.	74
5.3	Project Limitation	74
5.4	Recommendations	75
5.5	Project Potential	76
REFERENCES		77
APPENDICES		81



LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Comparison between the components used in the related existing project systems	8
Table 2.2	Comparison between lead-acid, lithium-ion and nickel-metal hydride batteries	20
Table 2.3	The technical specification of Arduino Nano	23
Table 2.4	Comparison between Arduino Nano, Raspberry Pi Model-A, and Model-B	27
Table 3.1	Specification of PV solar panel	35
Table 3.2	Specification of 18650 rechargeable Li-Ion battery	37
Table 3.3	Specification of the TP4056 charge controller with protection	38
Table 3.4	Summary of standalone PV solar system sizing	40
Table 3.5	LED conditions during the charging state of TP4056	42
Table 3.6	The specification of the DC-DC boost converter module	44
Table 3.7	Cost and bill of materials for the overall project	51
Table 4.1	The result of data collection for day 1	58
Table 4.2	The result of data collection for day 2	59
Table 4.3	The result of data collection for day 3	60
Table 4.4	The result of data collection for day 4	61
Table 4.5	The result of data collection for day 5	62
Table 4.6	The result of data collection for day 6	63
Table 4.7	The result of data collection for day 7	64

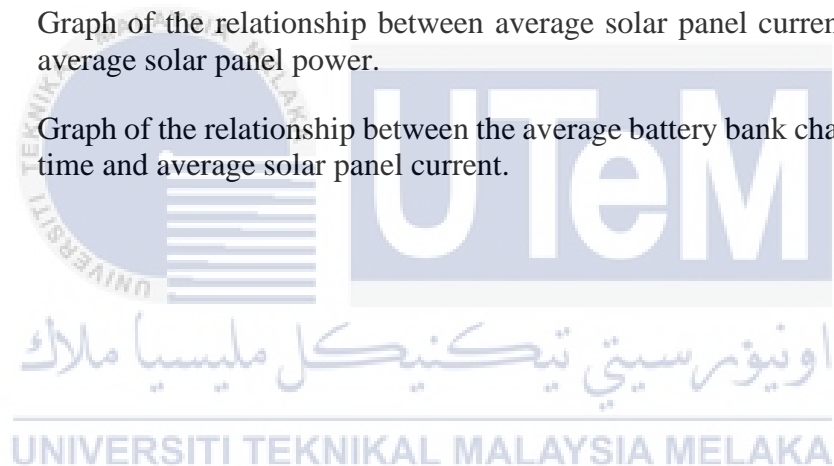
Table 4.8	The average data obtained from the standalone solar system	65
Table 4.9	Condition of IR sensors	70
Table 4.10	Duration of green traffic light signal based on the traffic density	70
Table 4.11	Comparison of conventional and smart traffic light systems	71



LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1	Annual average of solar radiation in Malaysia (MJ/m ² per day)	11
Figure 2.2	PV system types	12
Figure 2.3	The connection of the Utility Interactive PV System	13
Figure 2.4	The Connection of Bimodal PV System	13
Figure 2.5	The connection of the standalone AC PV system	14
Figure 2.6	The Connection of Hybrid PV System	15
Figure 2.7	Basic structure of solar cell	16
Figure 2.8	Types of solar panel connection	17
Figure 2.9	Standard I-V characteristics of PV cell	18
Figure 2.10	Structure of Arduino Nano	22
Figure 2.11	Raspberry Pi Model-A board	25
Figure 2.12	Raspberry Pi Model-B board	26
Figure 3.1	The flowchart of the overall project	30
Figure 3.2	Block diagram of a smart traffic light system	31
Figure 3.3	Block diagram of standalone PV solar generator	32
Figure 3.4	The flowchart of the smart traffic light system	33
Figure 3.5	Polycrystalline silicon solar panel	41
Figure 3.6	18650 rechargeable Lithium-Ion (Li-Ion) battery	41
Figure 3.7	Lithium-Ion charge controller module	43
Figure 3.8	DC-DC boost converter module	43
Figure 3.9	Arduino Nano microcontroller	45
Figure 3.10	Working operation of infrared (IR) sensor	46
Figure 3.11	Infrared (IR) sensor module	46

Figure 3.12	LED traffic light module	47
Figure 3.13	Proteus 8 Professional software	48
Figure 3.14	Arduino IDE software	49
Figure 3.15	Multimeter with probes	50
Figure 3.16	Wall power supply adapter	50
Figure 4.1	Illustration of the hardware installation plan	54
Figure 4.2	Standalone PV solar system	55
Figure 4.3	The prototype of the smart traffic light system with IR sensors	56
Figure 4.4	The completed project prototype	56
Figure 4.5	Graph of the relationship between average solar panel current and average solar panel power.	66
Figure 4.6	Graph of the relationship between the average battery bank charging time and average solar panel current.	67



LIST OF SYMBOLS

V	-	Voltage
A	-	Ampere
W	-	Watt
μm	-	Micrometre
KB	-	Kilobyte
MB	-	Megabyte
Wh	-	Watt-hour
Ah	-	Ampere-hour
MHz	-	MegaHertz
MA	-	MegaAmpere



LIST OF ABBREVIATIONS

PV	-	Photovoltaic
IR	-	Infrared
NiMH	-	Nickel-Metal Hydride
Li-ion	-	Lithium-ion
LED	-	Light-Emitting Diode
PIR	-	Passive Infrared
GSM	-	Global System for Mobile Communications
ADC	-	Analog Digital Converter
AC	-	Alternate Current
DC	-	Direct Current
RAM	-	Random Access Memory
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
ROM	-	Read-only Memory
OTP	-	One Time Programmable
USB	-	Universal Serial Bus
IC	-	Integrated Circuit
AVR	-	Automatic Voltage Regulator
GPIO	-	General-Purpose Input/Output
UART	-	Universal Asynchronous Receiver Transmitter
SD	-	Secure Digital
PC	-	Personal Computer
SOC	-	System On Chip
PWM	-	Pulse Width Modulation
HDMI	-	High-Definition Multimedia Interface
DEV	-	Developer
IDE	-	Integrated Development Environment
RCA	-	Radio Corporation of America
PCB	-	Printed Circuit Board
MPPT	-	Maximum Power Point Tracking
ICSP	-	In-Circuit Serial Programming
DOD	-	Depth of Discharge
DOA	-	Days of Autonomy
BBTM	-	Battery Bank Temperature Multiplier
PSH	-	Peak Sun Hour
PDRM	-	Polis Di-Raja Malaysia
MIROS	-	Malaysian Institute of Road Safety Research
JKR	-	Jabatan Kerja Raya

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Gantt Chart of BDP 1	81
Appendix B	Gantt Chart of BDP 2	81



CHAPTER 1

INTRODUCTION

1.1 Background

Electricity is the most crucial component of a traffic signal system's operation, as the traffic control systems can function continuously in the presence of energy. Electricity failure or interruption may impair the system's operation and affect road users' safety. Moreover, conventional traffic light systems usually use underground and overhead cables to supply electric power, which can sometimes malfunction due to power outages and cause road accidents. Nowadays, standalone PV solar traffic light systems have been deployed in developed countries. By utilising solar energy, the traffic light system can reduce or eliminate its reliance on the electrical grid, enhancing its dependability and decreasing its operating expenses. Integrating solar power into the traffic light system can also reduce energy consumption and installation costs, particularly in grid-isolated or remote areas.

Solar energy is a type of energy obtained directly from the sun and converted to electrical energy, the most environmentally friendly form of energy that does not contribute to climate change or energy crises. The two most significant advantages of solar energy are that it has no fuel costs and produces no greenhouse gases throughout the solar energy generation process [1]. Furthermore, a standalone PV solar model integrates all components necessary for electricity generation and supply, including the solar photovoltaic panel, battery, charge controller, and load [2]. A battery is added to store the excess energy generated by the solar panel, which can be utilized at night or on overcast days. A charge

controller is connected to the battery to protect it against overcharging and regulates the system's general performance.

This project focuses on developing a standalone PV solar system to power the smart traffic light system. The infrared (IR) sensors are used in the smart traffic light system to detect the traffic density and transmit the data to the Arduino Nano. This microcontroller will vary the timer of the traffic light system based on the vehicle density and change the signal appropriately. Therefore, with the integration of a standalone PV solar system, the generator can provide enough electricity to power the traffic light system and overcome many mishaps on the road due to traffic light malfunction.

1.2 Problem Statement

When an area experiences power outages, it affects the conventional traffic light system to malfunction since it uses underground and overhead cables to supply the electric power. This matter causes the smoothness of the traffic to be disrupted and causes road accidents. Moreover, the number of vehicles on the road has proportionally increased to the global population growth, resulting in road congestion, especially in urban cities. This road congestion happens due to the configuration of conventional traffic light systems that use a fixed timer program to give signals to road users. As a result, the drivers need to wait longer for the signals to turn green even though there are no vehicles at other intersections. The long traffic light timer not only stresses the drivers but also results in significant fuel waste and increases the carbon dioxide emissions from the queued vehicles. Thus, using a standalone PV solar system to power the smart traffic light system can solve the problems mentioned above.

1.3 Project Objective

The main objective of this project is to propose a systematic and effective methodology to power a smart traffic light system by using electricity produced by the PV solar panel integrated with a backup battery. Specifically, the objectives are as follows:

- i. To analyze the existing traffic light system by studying related articles, journals and previous works.
- ii. To design and develop a smart traffic light system integrated with standalone PV solar power.
- iii. To evaluate the suitability of the solar panel, charge controller, battery and sensor in a smart traffic light system.

1.4 Scope of Project

The scope of the project is defined as follows:

- a) This project is targeted to be used at road intersections.
- b) The infrared (IR) sensor is used to detect the traffic density and control the program of the traffic light system.
- c) The type of solar panel used in this project is polycrystalline solar panels.
- d) The battery used to store the excess energy generated by the solar panel is the rechargeable Lithium-ion (Li-ion) battery.
- e) The system in this project uses Arduino Nano as the main microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarises the theories and system design for a standalone PV solar generator and smart traffic light system. Moreover, this chapter also explains the overview of the conventional traffic light system and the statistic of accidents occurring at traffic light intersections. The existing projects from related articles, journals and works also have been discussed and compared so that the outcome of this project will be better.

2.2 Overview of Existing Project System

This section will review some previous project designs and implementations that have been conducted in connection with this project system. Several outstanding researchers have spent years finding the best way to optimize smart traffic signal systems and standalone PV solar systems.

2.2.1 Adaptive Traffic Lights through Traffic Density Calculation on Road Pattern

This project was developed to control the traffic light signal timing based on the traffic density calculation on the road pattern. The traffic density was calculated by processing the image on various road patterns. Then, a server collected data and managed traffic signal operations at a crossroads. The camera, mini pc (Raspberry Pi) and Wi-Fi router adapter were used. The battery Lithium Polymer (LiPo) 12.6V was utilized as a power supply, and its voltage was regulated to 5V before being linked to the Raspberry Pi through a UBEC voltage regulator. A Wi-Fi adapter was used to connect the Raspberry Pi to the

server through Wi-Fi, allowing the server to operate each traffic light via the Raspberry Pi. Then, the Raspberry Pi will send the server the current traffic density for monitoring purposes. However, the image processing method was unsuitable for this system because several noises interpreted as objects remain in the image frame even though several filtrations had been done [3].

2.2.2 Density Based Traffic Signal System Using Arduino UNO

The density-based traffic light system was designed to control traffic based on density at the road intersection with the four-ways lane. The infrared (IR) sensor was used in this project to measure the traffic density by counting the number of vehicles passing through the IR sensors. Then, the IR sensor detected the vehicle density and transmits the data to the microcontroller to process and control the delay time of the traffic signal. This project used Arduino UNO ATmega 328P as its microcontroller.

Furthermore, the system integrated three light-emitting diode (LEDs) colours: red, yellow, and green, which were applied following traffic conditions. The road with the most vehicles was given a green signal, while the remaining routes received a red signal. Additionally, they developed the technology in this project with a 1000 millisecond delay. The microprocessor monitored traffic based on the sensors' output and adjusted the signals; hence, traffic was regulated by the delay [4].

2.2.3 Smart Traffic Light Control System

The smart traffic light control system was designed and implemented as an automated traffic light system with traffic-based timing to increase the traffic flow efficiency on urban roads. This system worked by adjusting the duration of present traffic lights to durations that varied according to the density of vehicles on the roads. Besides, this smart