Chapter 1

1.1 Introduction

As technology is on a rapid growth curve it has affected how manufacturing, production, health, social and business is conducted. With a note to this, it means work has been reduced and time has been reduced allowing for a higher production rate. Vehicle manufacturing has been on a rise for the purpose of transportation allowing for more road networks to be in place to service the movement. Similarly, more lighting systems have been developed and are put on these roads to enlighten them allowing for vehicles to reach their destinations safely in the night, movement of people on these streets also has been improved. As they are operating at night they are always lit and some during the day are left on, increasing the cost of electricity and the overall consumption of electrical power over time.

1.2 Background of Study

As witnessed in Zimbabwe for the past decades there has been a sharp increase in road networks in and around major towns and remote areas, this has thrusted for adequate lightning systems to be put in place to enhance visibility at night. With this situation at hand it has facilitated the need to generate more power over time and has resulted in raised power consumption across the nation triggering an increase in electricity levy to curb the heightened demand for power as power is imported to the country via the main national grid for the consumers.

In light of this, it has been noted that with the ever evolving technology there is need to consider a smart way to save and improve on efficiency to reduce the importation bill on electrical power in the nation. In order for the nation to start reducing on the cost of electrical power importation there is a need to incorporate smart systems to establish a mechanism that would automate the process of turning on street light when needed and switching them off when not.

1.3 Research Problem

After a much in depth study to the case of electricity consumption in the country and have picked up on key facet areas that need to be addressed to try reduce the high consumption and increase efficiency which include:

- With the high consumptions of electrical energy translates to high amount of generated energy resulting in high level of noxious emissions.
- The bills the municipalities have to cater for street lighting is high due to the fact that they are an unmetered load and run throughout the day meaning the various town councils have to foot the bill.

1.3.1 Aim of Research Study

The aim of this study is to develop a more efficient lighting system that's smart and seeks to reduce the bill to the countries municipalities. In light of this the research also seeks to encourage the use of long lasting lighting system and reduce the maintenance cost of these lamps across the nation.

1.3.2 Objectives of Research

- To establish a mechanism that would automatically turn on lights when objects approach and turn them off after they pass in the dark.
- Use light dependent sensor to cut off power to the lighting system when there is adequate natural lighting from the surrounding.
- Use proximity sensors to detect objects as they approach the street lights and switch on the light being approached.

1.4 Methods and Instruments

A method is simply defined as a specific approach followed routinely to accomplish a task and an instrument can be thought of as a tool, device or mechanism utilized to aid in the implementation of the method.

1.4.1 Instruments

To allow for the construction or development of a functional working prototype at scale and to prove the concept at hand there is need to acquire the required software development tools and components to achieve the fully automated prototype.

1.4.1.1 Software Tools

Arduino IDE –it is an integrated development environment that was created to allow hobbyists, students or professionals make it possible to load their sketch files onto the Arduino micro controllers or replicas. It makes it possible to monitor serial communication between the computer and microcontroller.

1.4.1.2 Components

- Arduino Uno Third Revision (R3)
- Light Dependent Resistor
- Infrared Proximity Sensor
- 830 Breadboard
- Jumper wires
- 10 k Ohm Resistor
- 220 Ohm Resistor

1.4.2 Methods

Having all the required tools both components and software, a predefined course of actions to be followed has to be in place in order to achieve the goal set. With the use of the open source software like Arduino makes it easy to learn its core concepts as there is a large community to infer from to gain the experience needed. Circuiting is also relatively simple to accomplish as there are many resources to aid in their construction. A basic representation of the methodology employed for this prototype is described in the diagram that follows:

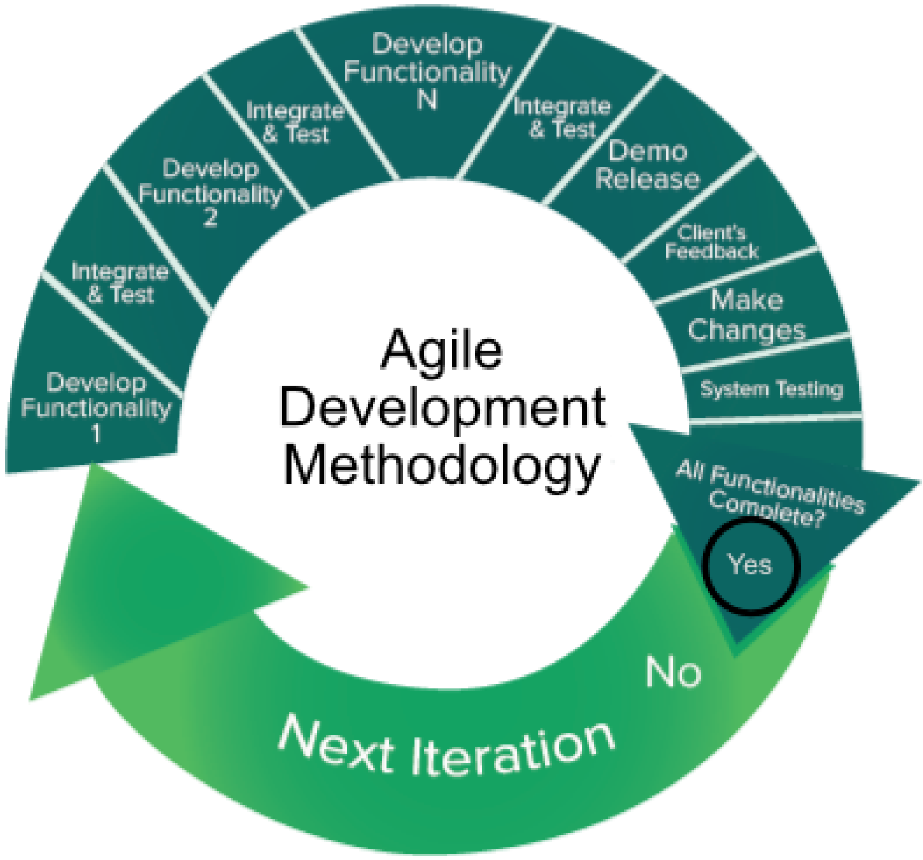

Fig 1.1 Agile Development Methodology

The above methodology was implemented for the development of the prototype, with this methodology in use it had a host of benefits which includes incremental functionality development, integration and testing. With this being a greater benefit it means that there is continual evolution of the system which fine tunes its full scope to its intended use by the consumer.

1.5 Expected Results/Contribution and future scope of the project

For every project undertaken there is always need to set expectations which measure the overall progress of the projects'. Since each project has certain results that are expected to be the outcome of its completion these are in terms of its deliverables, costs, goals or deadlines .To pave way for further enhancement of the project due to the ever changing technology there is always need to consider the future scope of the project, this allows for others to continually engage in research and development to better the project.

1.5.1 Expected Results

- To be able to control street lightning by automation
- To enable saving on electrical bills overtime due to curbing the unmetered bill on various town councils through the use of the automated system.

1.5.2 Future Scope

- Encourage use of an ecofriendly source of electric power to power the street lighting system through the use of solar panels.
- Able to implement GPS location based fault detection and monitoring to allow direct replacement of lamps or maintenance of the lighting system.

1.6 Research Limitations and Delimitations

Limitations could simply translate to the potential flaws that can be revealed in a particular study and are far from reach of the researchers' control. These potential weaknesses can be met in every aspect of the study and should not be ignored, mitigation solutions should be devised so as to avoid if possible. Delimitations can be viewed as factors that may pose a threat to the project but the researcher has control over, as so, these delimitations assist in controlling the scope of the study undertaken.

1.6.1 Limitations

- In areas with wild life there is no way system may differentiate between humans, vehicles or wild life to provide light for or not and this may cause wastage of electric power as they may stand in front of the IR sensors.
- Components needed to develop the system may be hard to acquire due to out of reach price points.

1.6.2 Delimitations

- User training might be considerably difficult due to user resistance to change.
- Town councils may take time to gain confidence in the system due to their legacy system and way of working.

1.7 Significance of the Research

Since Zimbabwe is a developing country it needs to implement cost reduction solutions to cater for other developing key areas to reach a sustainable threshold for the benefit the greater parts of the nation. With the system in place would boost the technological sphere which is in line with the vision of developing smart and sustainable systems.

1.8 Proposed Budget

To ensure the success or failure of any project endeavor there is need to carefully cater for the financing of the project material and making sure they are all readily available as when needed to allow for a smooth commencement of the project. The below tabulation provides the developer with an overview of the cost to complete the project.

Table 1.1 Hardware Components

Component	UnitPrice ($USD)	Quantity	Price($USD)
Arduino R3	15	1	15
Light Dependent Resistor	1	1	1
Infrared Proximity Sensor	5	5	25
Bread board	12	1	12
Jumper wires	0.20	25	5
10 k Ohm Resistor	0.20	1	0.20
		Total	58.20

1.9 Time Scheduling

For the successful project completion, time management is a major facet to allow for thorough completion of the solution. To highlight the expected time schedule to develop the system the below Table 1.2 shows a carefully scheduled time plan for the tasks undertaken during course of the projects life cycle.

Table 1.1

Task/Activity	Begin of Task	End of Task	Duration (Weeks)
Project Proposal	18/03/2019	25/03/2019	3
Planning	26/03/2019	16/04/2019	3
Analysis	17/04/2019	17/05/2019	4
Design	20/05/2019	15/07/2019	8
Coding	30/07/2019	10/10/2019	10
Testing	11/10/2019	25/10/2019	2
Maintenance	30/05/2019	Ongoing	Ongoing

1.10 Conclusion

With the implementation of the concept in this proposal the country will now be able to easily manage their lighting to improve efficient use of power and reduce the cost of power generated and imported.

Chapter 2 Literature review

2.1 Introduction

As the world continuously avails information to what new technology is impacting world economies all over there is need to evaluate how other similar economies introduce and develop systems to aide in doing business or improve livelihoods. As we live in the information age the need to stay updated is key, an eruption of automation across all borders has impacted on how governments and governing bodies consider on saving resources which could be channeled to other key areas. With the automation of street lighting in towns and cities reduces on council bills as there is saving on electricity, under this section it sought to stack previous working smart street lighting systems that paved way for this technology to be where it is to date and also consider systems in use that could be applicable in the Zimbabwean environment.

2.2 Background Street Lighting Systems

Street lighting came as a way to ensure passenger, pedestrian and vehicle safety during the night and was influenced in the early eighteenth hundreds in a city called Baltimore in the United States of America which used gas as a source of illumination of their street lamps. The discovery of electricity influenced the need to develop street lighting systems that used this source of energy for the various towns and cities across the world. With the early adopters of the electric street lighting system being dominantly within Europe had a pivotal part to play in influencing the design of the lamps to illuminate their streets.

With the development of the different lamps there was a breakthrough of the high pressure sodium lamp which allowed for the lamp to cut off power when the voltage drawn made it hot enough to avoid it burning out and to date it is still being used for lighting in other third world countries. In the early twentieth century there was need to monitor and control these lights remotely thus the development of remotely controlled and monitored street lighting systems.

This investigation takes an in depth approach to the various systems implemented, scrutiny of their modern usage are also reviewed to achieve a more efficient and non-costly approach to contemporary street lighting systems.

2.3 Evaluation of previous implementations

Street lighting systems have been under intense research and development across the world as means to effectively develop a reliable system that seeks to save power and provide lighting when needed. Various Universities and Research Labs have conducted this research and many systems have been developed to date which demonstrated these key features but realized high cost implementation in certain economies of the world.

With many research teams being involved in the development of smart lighting systems many have reached to an agreed state of automation. This state has allowed many research teams to fully develop embedded systems that allow for this to happen. One of these particular teams came up with an automated light control system that depended on the luminous light incident on its photo sensitive detector (sensor). This Indian based team argued that there was need to develop a system that could allow for power to be saved and desist from manual control as it was not on trend in the modern era.

This street lighting system made use of a micro controller, relays and photo sensitive detector (Light dependent Resistor). The working principle of this system was that as light from the environment was being detected by the photo sensor; it would send the data to the micro controller which converted this data into various discrete levels ranging from 0 to 1023.

To further gain an understanding if it was midnight the discrete value would be 0 and output voltage to the LED would be maximum and hence the lights would be brightest. More over as this discrete value would be 512, towards dawn the voltage would be recalculated and supplied to the LEDs hence brightness would be varied and as it goes up to the maximum discrete value 1023 there would be no voltage supplied to the LEDs hence the lights would be off completely. Below is a figure that shows the working principle of the automated light control system.

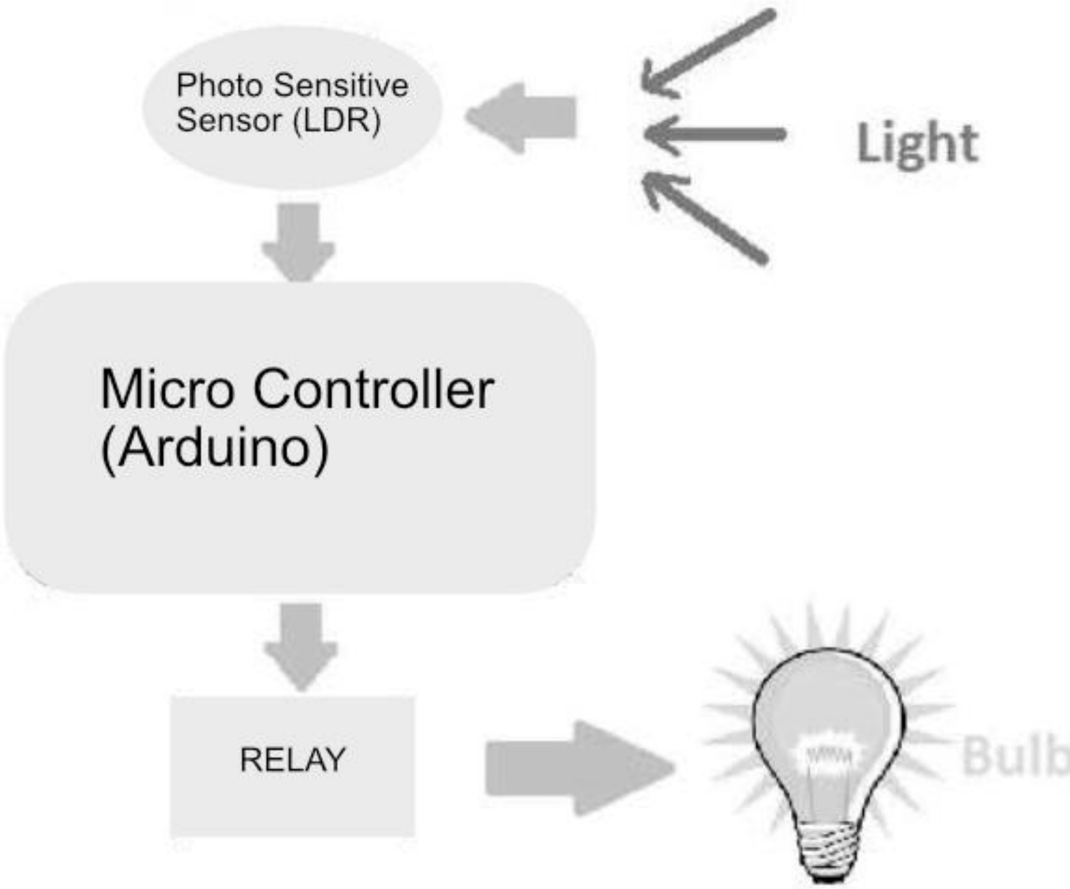

Figure 2.1 Automated street light system Principle

This system seeked to curb wastage of power and remove the manual control of the lighting system within cities. In so doing it showed to be reliable to run in cities as it was cost effective and easy to install, easy to maintain and gave the lamps a longer life span due to this feature. These features showcased by this system had its shortcomings on the issue of providing lighting when not needed and to an extent caused an effect on power usage in the long run. Further studies were conducted to develop an even more power efficient lighting system.

In the early months of the year 2013, a Japanese team of facilitators and students in the computing and engineering departments of Gunma University came up with a Zigbee based autonomous distributed controlled light system. This system used Zigbeemodule, which is a short distance communication module that facilitated sensory communication among the different lamps in the area. It also included a sensory network which consisted of motion sensor, brightness sensor and the micro controller. The system would consist of three major units which are the Lamp unit, sensor unit and access points. In the lamp unit there was housed a power adjustable LED array, brightness sensor, motion sensor, Zigbee module and micro controller. This unit detected motion and switched on the lamp in a defined area and would communicate this to the other units, if motion was not detected it would reduce power or switch off the lamp.

Sensor unit consisted of another motion sensor, Zigbee and controller and it was placed in different locations like electric poles, gates, house doors or fences to assist in relaying the message to other units under the condition that motion is detected. Access point consisted of a controller and communication module and its sole purpose was toreduce the distance in communication between the lamp units and sensor units. An illustration of these units is depicted in the below figure

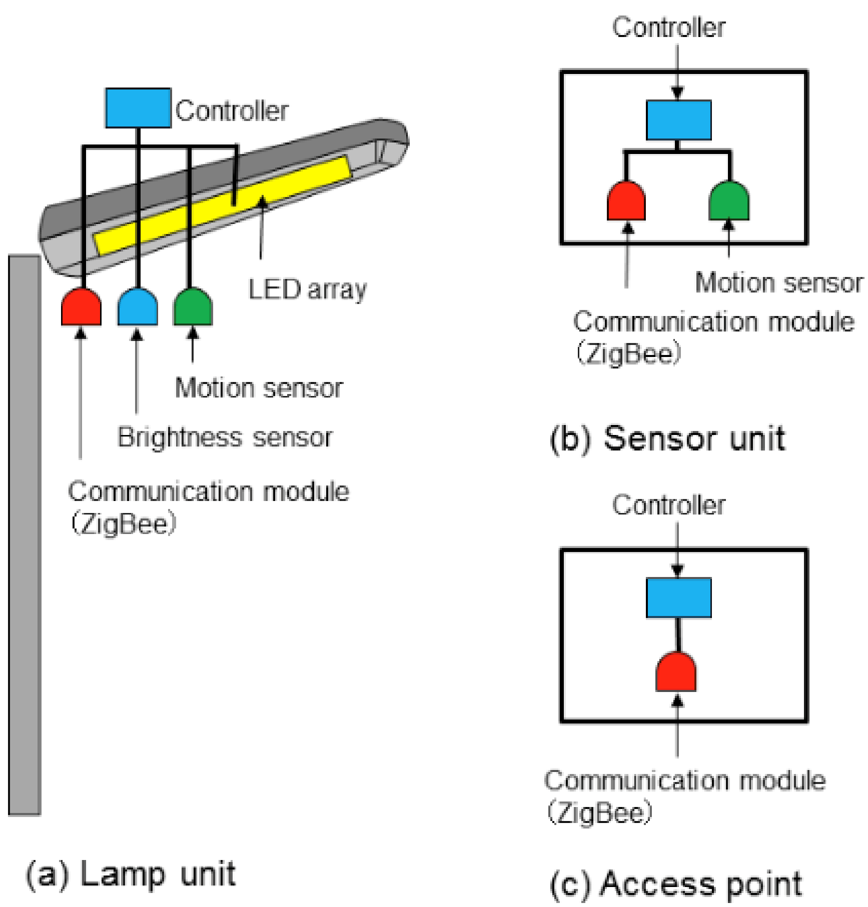

Figure 2.2 Lamp Unit, Sensor Unit and Access point

With all the units in place there would be a distributed installed sensor network that assists in turning the street lights on before the pedestrian or vehicle approach the lamps and turn off or reduce power when there is no object detected. Figure 2.2 below shows this network in play

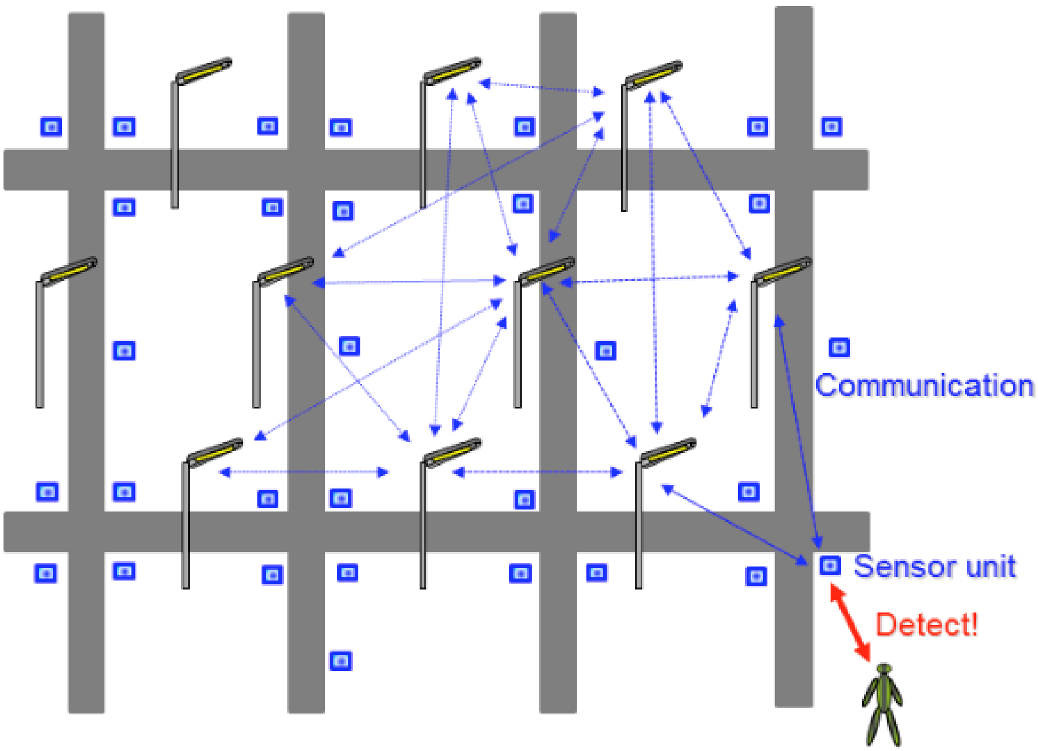

Figure 2.3 Autonomous distributed controlled light system

2.4 Proposed Implementation

After a close evaluation of the past implemented systems, there is a clear cut trend in how these systems seek to use sensors to detect and switch on or off lamps when needed by pedestrians or vehicles and aim to reduce power usage by only switching on the lamps when needed, there is a need to develop a smart street light system that houses all sensors and reduce cost of implementation on developing economies.

The new system borrows from these previous systems many ideas and tries to further enhance and rectify this robustness component, which would significantly enhance the implementation costs and reduce power usage as there a few components at play to achieve the smart part of the street lighting system. This new system will include a LDR unit which deals with detecting light intensity of the environment and cuts off the system completely and regulate brightness based on the light incident on it and motion sensors to detect motion at a distance to switch on the lamp.

2.4.1 Limitations of the proposed system

With any project, a number of variables can be recognized during its development lifecycle that can have a negative effect on the project and can behave as bottle necks or project development c onstraints. The following were acknowledged as constraints with the growth of this scheme.

- Adoption of the system in the different cities may face major resistance as they are settled to their legacy way of operating.
- With Arduino being an open sourced platform it is vulnerable to intruders tempering and exploiting the system by individuals who have intimate knowledge.
- Due to lack of a communication module maintenance of the Lighting system is dependent on physical inspection of the individual lights.

2.4.2 Benefits of the proposed system

Smart street lighting is still in its infancy in Zimbabwe and in order to enable the nation to achieve the level of the developed countries to compete with the fastgrowing and changing technology leaders of the globe, major efforts are being made to embrace these developments. With the proposed system in place, it seeks to narrow the gap and its benefits are as follows.

- As the system employs LED as source of illumination, it is with no doubt that the life span of these lamps is longer hence maintenance cost is reduced.
- This system is cost effective on the issue of power consumption due to its automation nature, as its sensors enable the system to operate when needed.
- Another benefit is the ease of extension of the system to suite user needs, as can be in the event of changing from conventional LED modules to solar based LED modules hence encouraging use of green energy.
- This system can also be implemented in parking lights of hospitals, universities, home automation, agriculture field monitoring, shopping malls and airports to list a few.

2.5 Foreknowledge

To get a full appreciation of the implementation of this project, one must at least pose some background information or foreknowledge about a smart lighting system’s development and maintenance. Additional knowledge can be gained from smart city automation projects, making it possible to make good decisions about which parts can best be automated to produce the most efficient system. With this minimal understanding, the proper selection of electronic equipment and components that are relevant to the project's scalability would be helpful. The knowledge of components such as the Arduino board and the host of sensors it supports in this project is a must not only help to reduce operating costs but also help with maintenance costs.

Basic appreciation of the technology in use allows for a smooth implementation of this study as the knowledge to connect the components is possessed. Depending on the scale to which one wishes to implement this study, one may choose to use various other communicating modules to assist in this project. All the information on the various components used has been availed on the various forums or groups on the internet which have been done by other engineers and their implementation strategies, areas of difficult and how they overcame them during their project development.

2.6 Conclusion

Under this section, the reader was informed about the history and other progress produced in the growth of automated or smart lighting systems around the globe. This includes the early iterations of street lighting and how it developed to where it is to date, how these systems seek to tackle power consumption and replacement of legacy lighting system. With the proposed system being under comparison to these previous systems, has further solidified the stance of why there’s need to adopt smart lighting systems in this era of technology advancements world over.

Chapter 3 Methodology

3.1 Introduction

The other smart street lighting systems have been assessed in the previous section and compared to the other lighting technologies used is the past. However, the focus in this section is on each component's theoretical evaluation. A comprehensive description of an individual hardware component's functionality is provided. The parts of the prototype's hardware are: Arduino Revision 3 (microcontroller), breadboard, infrared sensor, jumper wires, resistor, Light Dependent Resistor and Light Emitting Diode.

3.2 Component Description

On the above subheading the writer seeks to shed more light on the components key function and use within the project as well as give the reader a much greater understanding of their specification towards the fully functional system all together.

3.2.1 Sensors

According to Ravi (2017), a sensor is a device capable of either measuring or detecting some sort of physical quantity as its input, such as light, humidity, motion detection, etc., and producing an output signal containing values that can be used in different procedures. Sensors are categorized under many categories based on their intended use, with this prototype, the lead sensory module used detects motion of objects (vehicles, people, etc).

i) **Infrared Sensor**

An infrared sensor consists of two tubes that allows it to function with the system. This pair of tubes allows this sensor to detect objects as the working theory behind involves one of the tubes works as an infrared emitting tube and the other one as receiving tube, as the infrared tube emits this light at a certain frequency, when the direction of the object is detected (reflection surface), this light is then received by the reception tube and registers motion to the system. Below is a pictorial depiction of this sensor module.

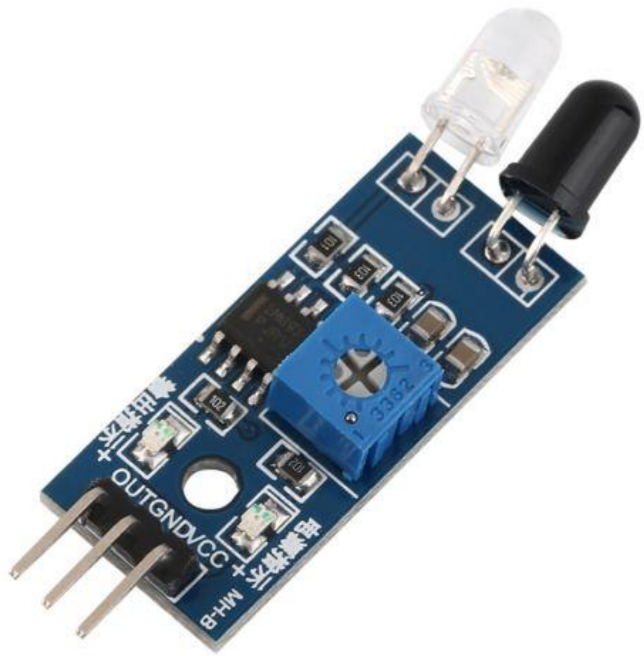

Fig 3.1 Infrared Sensor

The table below shows the Infrared sensors working specifications to ensure optimum working order.

Property	Value
Working Voltage	DC 3.3V-5V
Working Current	≥20mA
Working Temperature	－10℃—＋50℃
Detection Distance	2-40cm
Output Signal	TTL voltage
Accommodation Mode	Multi-circle resistance regulation
Effective Angle	35°

Table 3.1 Infrared sensor specifications

ii) Light Dependent Resistor (Light Sensor)

A photo resistor (LDR) is a resistor module that solely relies on light incident on its surface to employ its resistivity function. In order to conduct this function this module uses photo cells to sense the light incident and the working principle behind this is photo conductivity, which is a state in which a material is able to conduct based on the light absorbed by the conductive cells. In this project this module allows the system to detect amount of light in the environment that is incident on the module and allows current to move to the lighting lamps of system or completely cuts this current when there is adequate light in the environment. Below is a figure which shows this module.

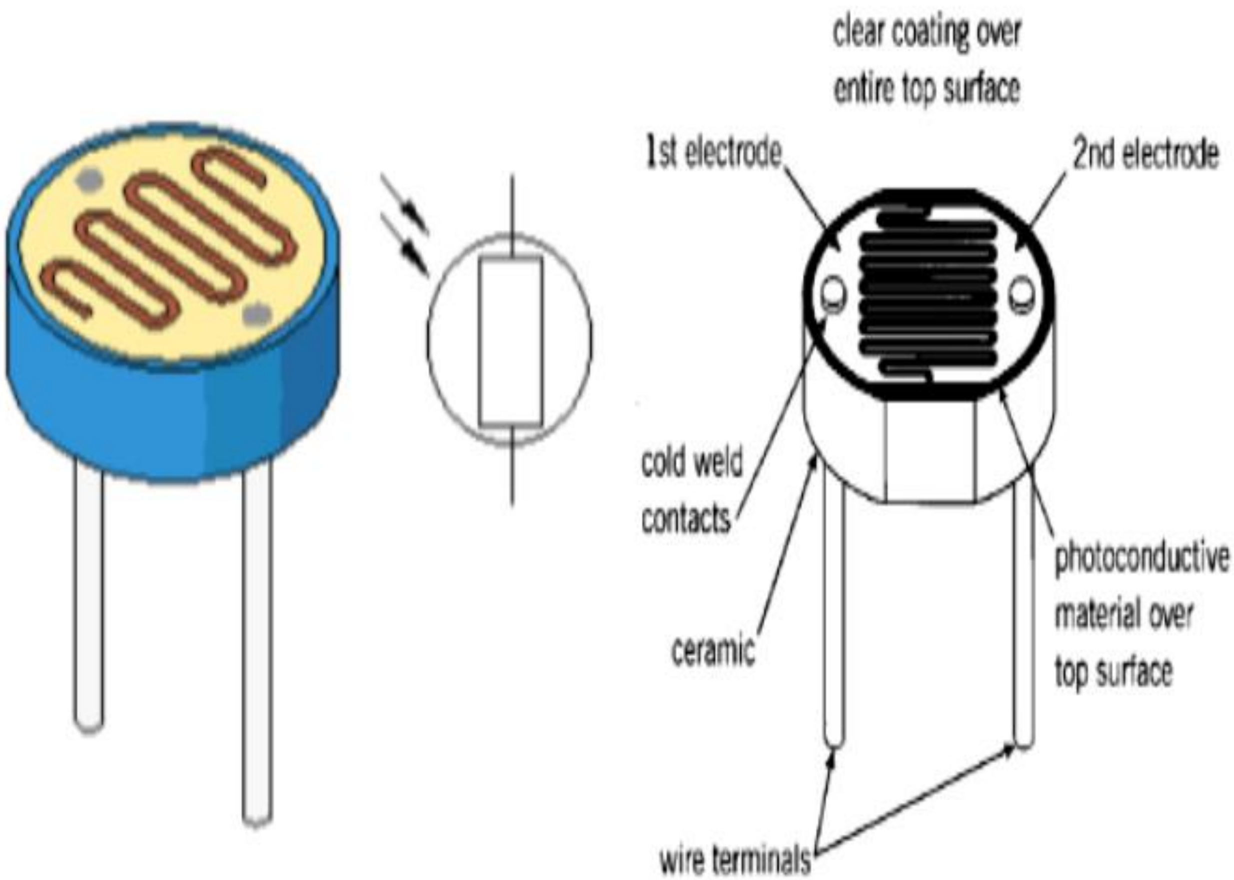

Fig 3.2 Light Dependent Resistor

3.2.2 Lighting Device

i) Light emitting diode

It is a lighting source which is based on semi conductive material that does not rely on any reflective material or gas to produce lighting. Light emitting diodes possess p-n junction diode that produces light as a voltage is passed to its leads. As electrons recombine with the holes contained in the LED, this releases energy in the form of photons which gives the light.

Because of this function, the structure of a light emitting diode makes it possible to generate more light per watt, it is also helpful in energy-saving appliances or energy-saving lighting systems, as a strong LED enables its light to be more concentrated compared to the traditional light sources like high intensity discharge lamps, that depend on an internal reflector to collect and provide useful lighting.

LEDs desist from changing their color tint as a low current passes as opposed to the High intensity discharge lamps which turn to a different color. This feature of this specific diode makes it possible to use it in dimming lighting systems allowing for power saving overally. Figure below shows the schematic view of the LED and its pictorial representation.

Fig LED 3.3

3.2.3 Arduino Revision 3

The Arduino R3 is what is termed a micro controller with its core role within the system to accept input from the sensor, which is an analog signal, coverts it to digital signals which are then used to perform computations to produce an output in the form of electrical signals to the various component to conduct its task. The Arduino R3 relies on the ATMega 328 chipset which has fourteen pins for digital readings both input and output, six input pins for analog readings, 16Mega Herts processor, a USB connection port, a power input port and reset button. The microcontrollers working thresholds are summarized in the below table.

Property	Value
Operating Voltage	5V
Input Recommended Voltage	5V –9V (Max 12V)
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328)
length	68.6 mm
width	53.4 mm
weight	25g

Table 3.2 Arduino R3 specifications.

Figure 3.4 Arduino R3 ATMega328 board

The board is able to combine with the other components mentioned to produce a perfect standalone autonomous lighting system that operates as a single unit.

3.24 Resistor

This component limits the amount of current being passed within the circuit and plays a huge pivotal role in regulating the current passed on to LDR to ensure the right amount of current is being supplied to the component.

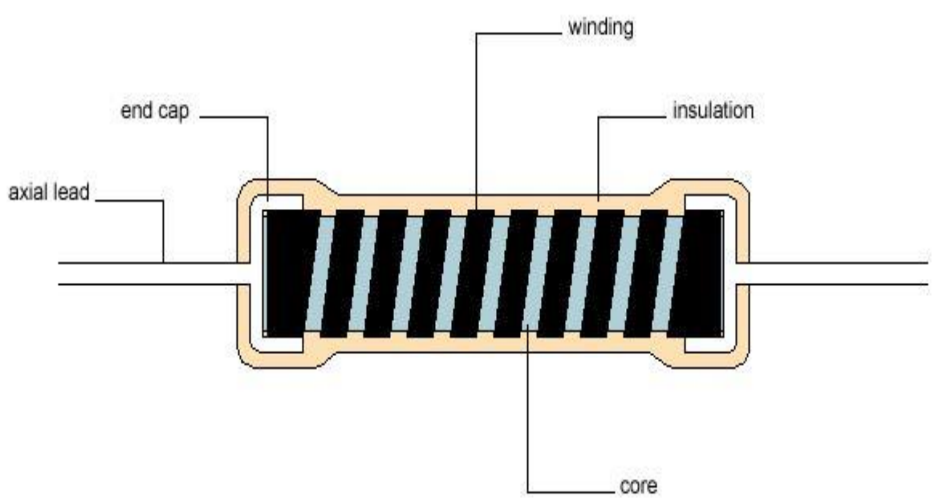

Fig 3.5 Resistor

3.2.5 Jumper Wires

These type of wires are used by students or hobbyists to prototype their circuitry on breadboards before they finally move their sure connection on to a PCB which requires creation of tracks that connect components as if they were on a bread board. Jumper wires come in various forms such as solid tips, crocodile clips and insulated terminals, solid tipped jumper wires allow for them to be connected to the female heads connectors or breadboard pin holes.

Fig 3.6 Jumper Wires

3.2.6 Breadboard

This is a prototyping board which is made of plastic material and has interconnected metal strips which allows for users to quickly create common polarity on the board. Since the breadboard is made of plastic it means no soldering is done hence circuits can be quickly built or changes made can be made without much effort. In this project the breadboard allows us to quickly test and make improvements to the circuitry without a hustle.

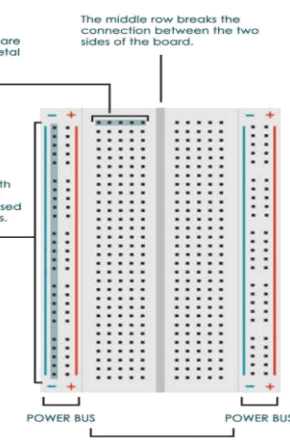

Fig 3.7 Breadboard

3.3 Software Requirements of the Project

These requirements are seen as non-physical components used to prototype this project to life which include an Integrated Development Environment (IDE), the high level programming language used to code to the microcontroller to allow the physical components work as one unit.

3.3.1 IDEs

An integrated development environment provides a developer with an interface that allows them to write pieces of code in a certain high level programming language which also may include a compiler which converts this readable code into low level which is understood by the micro controller and linting feature to allow the developer to notice any syntax errors as they write their code. In this project the IDE that would be used to write the piece of code to be uploaded to the micro controller is Arduino IDE which is open sourced and free to use.

3.3.2 Programming Language

It is a language that is considered to be a high level readable language which is used for setting rules, create functions, which are vital to the system to allow it to fully function when converted to an equivalent machine readable form. The programing language used in the project is C++ for embedded systems.

3.4 Conclusion

In light of the above in depth analysis, the components used are fully discussed and made clearly understandable to the reader to give them a visualization of how these components come handy in the development of this system and ensure the systems success.

Chapter 4: System Design

4.1 Introduction

For every building plan for any structure erected the architect draws up the plan which entails and defines all parts in detail for the concerned structure to provide more clarity on the vision of the client. As to prior information attained from the previous chapters, this chapter in particular setups the full detailed system design which includes the systems flow chart, system architectural design and other key facets that grant the designer the overall view of all the users' requirements. In this chapter, the reader will attain the full knowledge of the different parts that form up the design phase of the system proposed.

4.2 Data flow

With the design of a system, its main focal point is to reveal the movement of data or information that takes place among communicating points within a system which could be servers in different geographical locations or it can be between two people in an organization. Under this heading the developer seeks to show the movement of data among the communicating components which are the various sensors and micro controller, this is made possible by the use of a flow chart. A flowchart can be thought of as a graphical representation of a system workflow, its process or can be linked to an algorithm to solve a certain problem. The illustration (Fig 4.1) below depicts the flow within the proposed system, beginning from the sensors that collects the current environmental light state which initiates various collective events with different states.

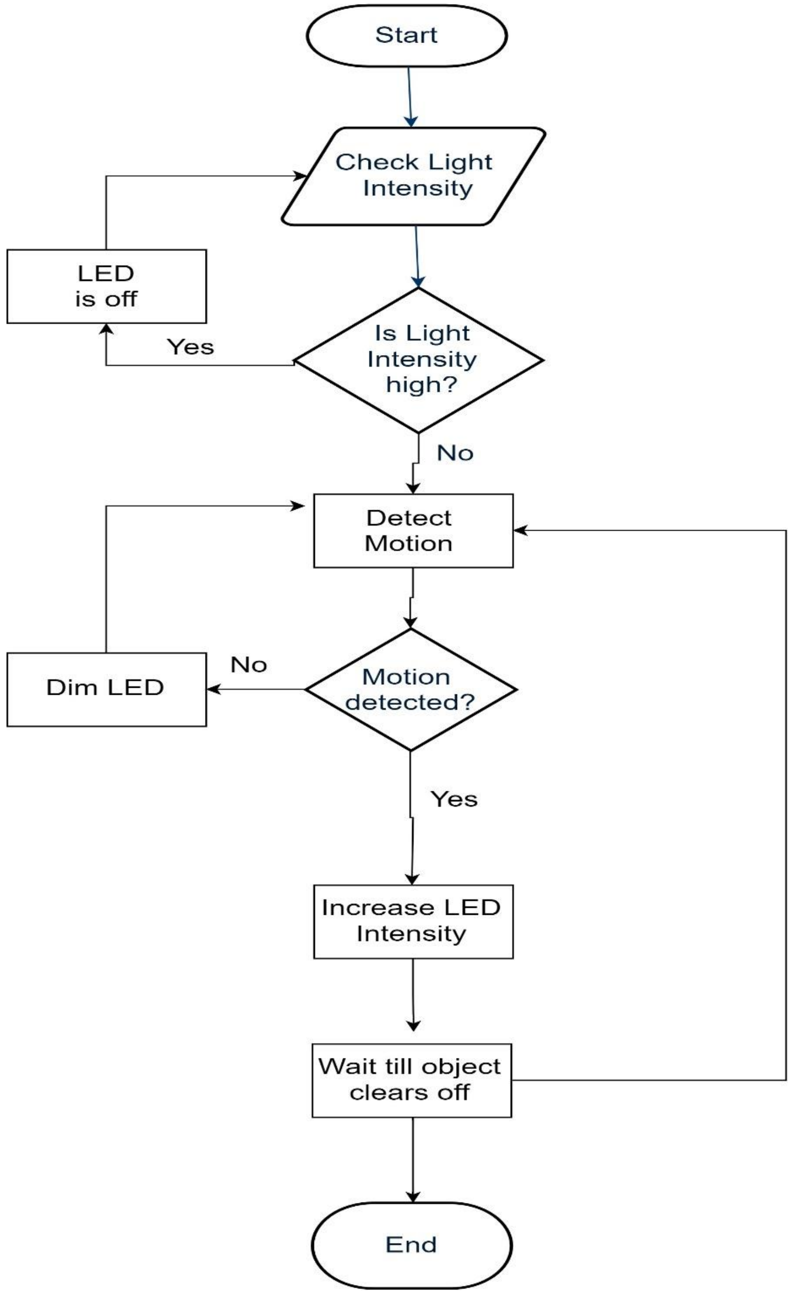

Figure 4.1 System Flow Chart

4.3 Architectural design

The architectural design of the system is considered as a blueprint defining every involved component of the project be it hardware or software. According to (Qian et al, 2011), architectural or constructive design is borrowed from representations of the program expected description and analysis of the framework. The designs focal point is mainly centered on dividing the system into its components and their interrelationship with each other in order to match up the systems requirements either functional or non-functional. This relationship is shown in the below diagram.

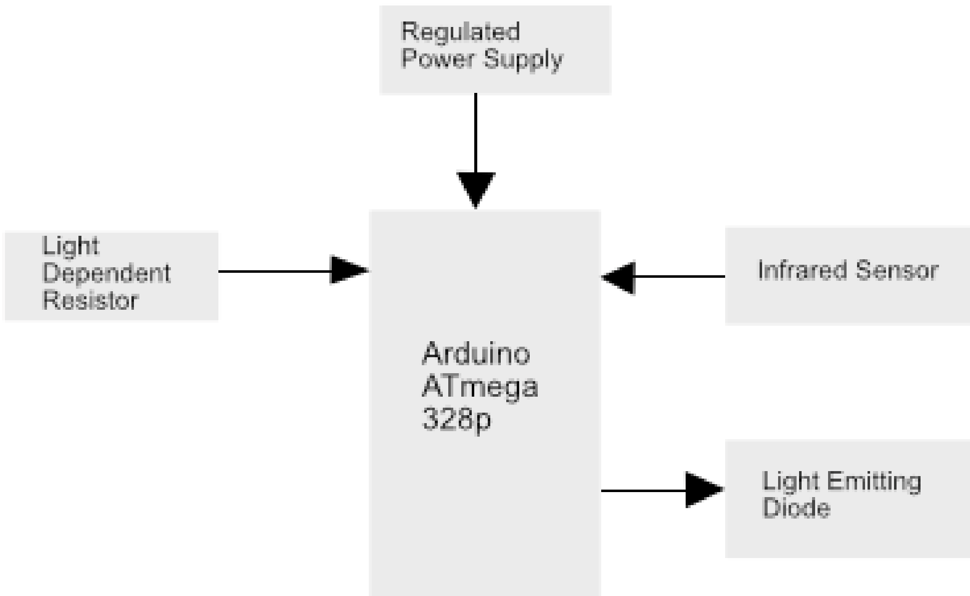

Figure 4.2 System Block Diagram.

4.4 Circuit and Schematic design

Circuit construction is a cautious method used to determine the logical paths required to join electrical parts in order to create a functional and most complete circuit, avoiding any short circuits to guarantee that no component harm is feasible as current is passed through. The above method is essential in helping to create a schematic that can be used to create a Printed Circuit Board (PCB) to create a more integrated system. In this project the designer will use a breadboard to develop the system, this circuit design is shown in Figure 4.3 showing how each element is logically interconnected with each other.

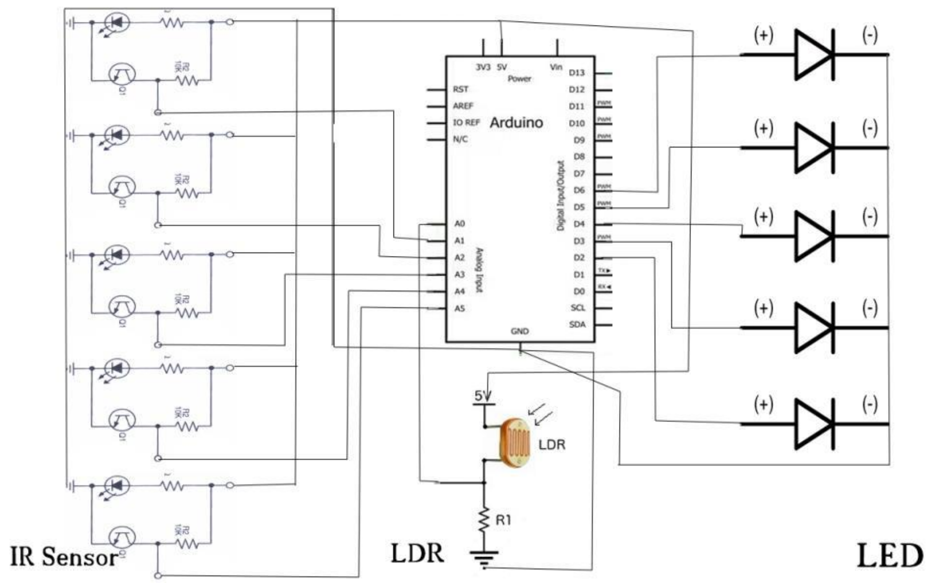

Figure 4.3 Circuit Diagram

4.5 Physical Design

(Peter, 2006) Identifies physical design as phases in which the distance between domain and present system is manageably connected. It focuses on how information is entered, checked, processed and presented as output in the scheme. Under this heading the author takes an in-depth look on the physical outlay of the smart street lighting system upon its completion and how the smart part of the system is achieved. The below representation depicts the proposed system as it works when deployed on the streets. The Infrared sensors detect motion of traffic or objects and communicate to the microcontroller which then sends electric signals to the LEDs to increase brightness as the object passes by the sensory system. Also as the environments light is detected by the LDR it sends its signals to the micro controller that then decides, based on the intensity of the light, to either completely cut off power to the whole system or initiate electric signals to the LEDs to enter dim state.

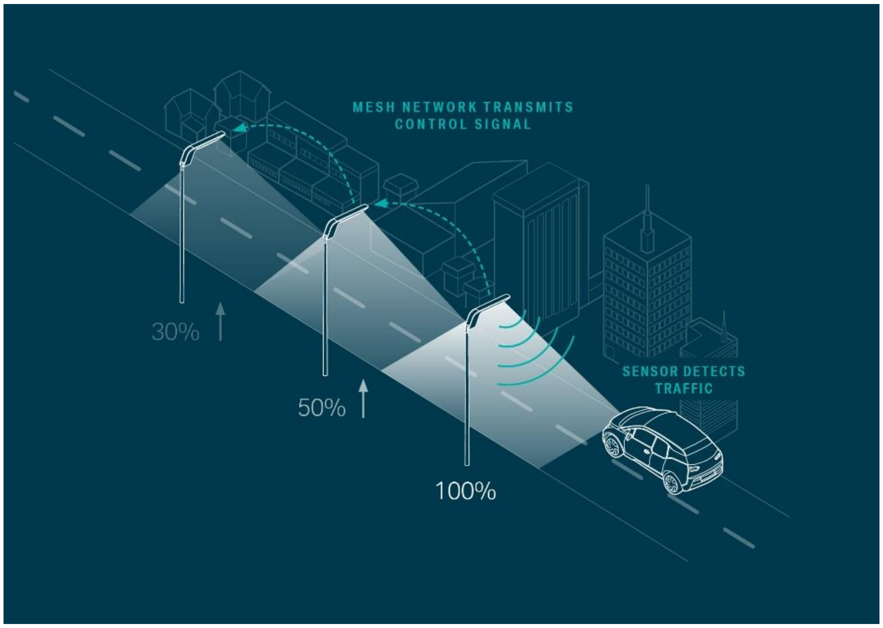

Figure 4.4 Physical System

4.6 PSeudocode

According to (Rousie, 2012) defines pseudo code as a language that can be read naturally and is used to define the execution expected in a program. As it is provided to programmers, it is used as a template to create the required scheme after the pseudocode has been formulated.

a) Pseudo code for ATmega 328p microcontroller

Initialize variables declared

b) Infrared Sensor function

IR Sensor waits

IF

Object has been detected

Check LDR

Increase LED intensity

Else

LDR status

Adequate light

c) **LDR connection method**

LDR awaits command

IF

Light intensity <= 500

Allow LED status dim

Else

LED status off

d) **LEDs connection method**

Awaits command If

LDR <=500

IR detects

Increase intensity

Else

LDR >=600

Switch off

4.7 Security Design

Security development includes methods that integrates with safety scale from the initial stages into the software by incorporating certain considerations which are testing and authentication that ensures security. The product gains a more efficient security strategy by creating these safeguards at each design point and will assist in conforming to standard programming methods. This test is not only restricted to software development, but it is an ongoing method that passes through the execution phase and the maintenance phase. To achieve a deeper understanding, a crucial subsection to the project that make up the safety layout will be introduced to the reader.

4.7.1 Physical Security

This layout focuses on the safety of physical facets and methodologies used in stopping these components from unwanted manipulation. The system being created consists mainly of hardware components and software. As realized, much effort is dwelled on securing the hardware parts which are of value from unforeseen compromising threats such as environmental disasters, livestock and people attempting to burglar or temper with the equipment. To uphold the safety of the project's physical components, parts that are extremely vulnerable to harm from these factors must be housed in a safe enclosure that holds the capacity to shield them from fire, precipitation or any catastrophe and that can be secured to protect them from being physically damaged.

4.8 Conclusion

As this section concludes, it has granted the developer a seamless overall view of the project to be built by allowing the designer to conduct tests and ensure the scope of the project is in tandem with the objectives to be met. After the careful study of the proposed system, the developers work is eased out basing of that the system has been constructed to its specified recommendations. The implementation section presented in the next chapter concludes the phases involved with the development of the system.

Chapter 5: Implementation

5.1 Introduction

This chapter concludes the research conducted by the writer as it takes the reader into the final stages of the project proposed. According to the methodology used in this research, Agile framework, it combines the system testing with deployment which in turn equates to the Implementation Phase of a project. The major key facets discussed in this chapter include coding, system testing, installation, maintenance, results produced by the system and lastly recommendations made towards the future development of the system.

5.2 Coding

Standing out as the most vital aspect of software development, coding forms the backbone of all communication between human and computers, executed properly, project timelines can be respected well and hence software is produced in a timely manner. With this system, all coding will be done for the microcontroller that forms the core of the system.

5.2.1 Microcontroller source code

For the system to be able to send the relevant signals to the light modules, sensors and to allow for the components to work together it is made possible by the Arduino R3 board. This Arduino board basically becomes the brain of the system entirely. Possessing the capability of being programmable, this board utilizes its unique IDE which facilitates in the uploading, coding and debugging of code which is written in C programming language. The following code snippets constitute of the actual code used in the system to control the connected modules on the board.

Figure 5.1 First Microcontroller Code Snippet

Figure 5.2 Second Microcontroller code Snippet

Figure 5.3 Third Microcontroller code Snippet

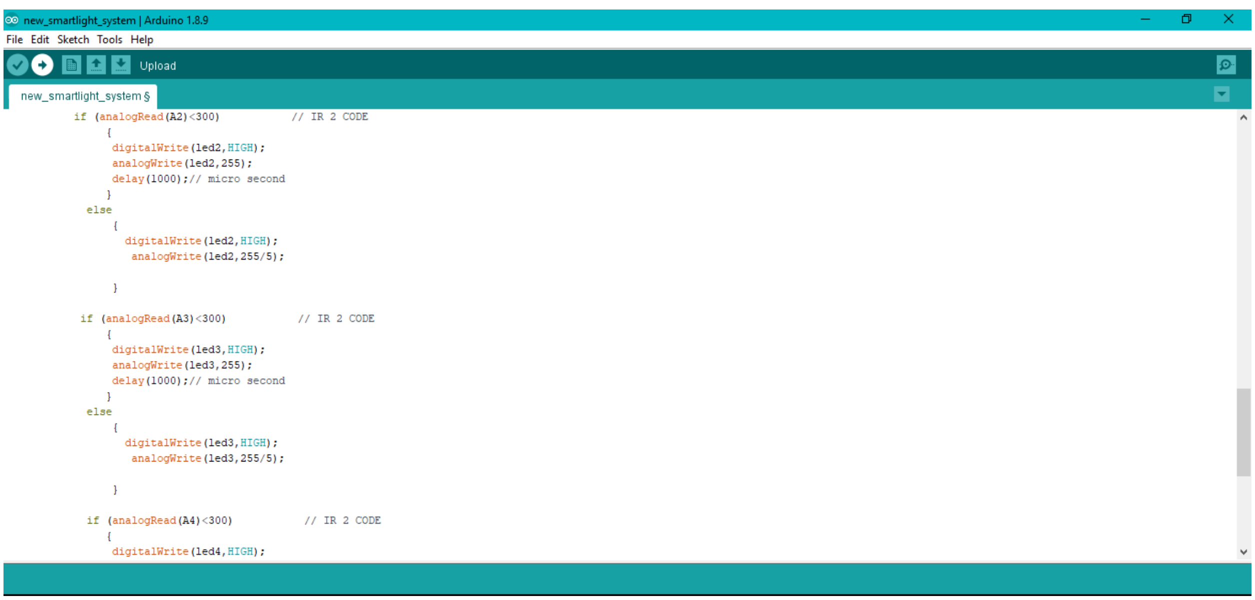

Figure 5.4 Fourth Microcontroller Code Snippet

5.3 Software testing

According to Rajkumar (2016) software testing is the process of reviewing the software against the specified user specifications and also ensuring that the software is not faulty and bug-free or anything that may inhibit its maximum performance. From the above citation we clearly derive that this encounter is vital to the methodology implemented in the design of this system. It seeks to compare the user defined requirements and the actual functionality evident to the system. A brief look at the various aspects of evaluation testing for the Arduino microcontroller must be undertaken to determine this.

5.3.1 Microcontroller testing

This test mainly deals with providing the visual representation of how the systems' brain communicates with all the components connected to it to confirm proof of concept has been fully implemented. This includes the sensor tests which will confirm the presence of an object or object nearing the LED lamps. Figure 5.xx will depict this test in use.

5.4 Results

As there are no value based results being shown through the use of this system but what confirms the desired results are shown as the system responds to the various conditions it has been subjected as it is being run. The underneath representations shows the results as the system performs its functions.

5.5 Objectives vs System

This is a clinical comparison of the systems objectives and the physical implementation, as the objectives set by the user. Users of the implementation have to see the objectives set at the beginning being met to consider the projects development as a success. These goals set are viewed upon the systems being tested upon its set objectives and their viewed by the users.

5.6 Installation

Upon completion of the various tests on the system, there's a need to install the system in the environment for full implementation and use. The processes involved work in preparing the physical (hardware) and software parts of the system for use. Another facet that's included under this heading is user training on the system, its intended use and how it is supposed to be used and the relevant changeover strategy is discussed upon implementation from the previous system.

5.6.1 Implementation Strategies

These are methods employed to move from an existing implementation to the new system taking into consideration risk factors that may hinder the usual flow of the business and its functions as a whole. Changeover strategies that can be utilized differ on the preceding situation, system, to be replaced, these methods are direct changeover, phased changeover, parallel changeover and pilot changeover. As the mentioned strategies might be employed to a specific situation they possess their advantages and disadvantages over the others.

As the developer concluded with the development of the system, there was a need to consider resources and time in implementation, the suitable changeover strategy would be phased. Rational behind is that areas being implemented this system would need time for preparation and material needed to construct the necessary structures would be timely hence in such areas lighting shouldn't be cut off immediately. This strategy allows for the new system to be tested further and allows for modifications to be made supporting the methodology used in its development.

5.6.2 User training

This is a process of familiarizing the users with the new system. It is made possible through workshops were various literature material is availed to them such as user training manuals, live demonstrations on specific lessons and video tutorials. With this system there is little to none specific training to be conducted as the system is self-monitored and requires less overseeing opposed to maintenance.

5.7 System Maintenance

Maintenance of system software is a timeline procedure that seeks to continuously eradicate errors or malfunctioning of the software by also providing room for updates, modifications and making corrections to the system. System maintenance gives the chance to allow for customer feedbacks to be considered in the next iteration of the system. Maintenance leverages on four main types of maintenance methods namely adaptive maintenance, corrective maintenance, preventive maintenance and perfective maintenance.

5.7.1 Adaptive Maintenance

This maintenance philosophy deals with how the system can respond to technology changes and how the system can be used on multiple platforms. For example there could a transition of the device from an Arduino microcontroller to a raspberry pie microcontroller that utilizes a different system architecture to which Arduino provides.

5.7.2 Corrective Maintenance

Under this maintenance philosophy, it commonly looks to deal with correcting design flaws or bugs that may fallout in the daily use of the system. Careful practices should be taken to conduct these corrections which might be in malfunctioning hardware components or their performance issues exposed during use.

5.7.3 Preventive Maintenance

With preventive maintenance it major goal is to effect modifications or changes before an error or bug surfaces as the system is being used. A relevant case to consider might be when the developer chooses to leave the use of a breadboard and considers using a PCB instead.

5.7.4 Perfective Maintenance

The philosophy behind this type of maintenance dwells more on the never ending user requirements as the system continues to be in use. The user's requirement could be a function of counting traffic as it passes by and considering employing this already places their requirement under perfective maintenance.

5.8 Recommendations for future development

Agile application development is not an exhaustive methodology but rather gives room for further development of the system being worked on to not only advance it but also provide space for others to build many variations of the system allowing for the system to be continuously being perfected. Since this project is built on this methodology the researcher has below listed recommendations to which might better the system.

1. With the use of a much larger microcontroller and replacing the Mega 328p provides the system with more leverage to allow more devices to be connected such as the communicating module like gsm module. This would introduce a maintenance call to councils in the event there’s a failure with the hardware components.
2. The developer also recommends the use of printed circuit boards over breadboards as this looks smarter in the sense of wires being less scattered around the board and also curbs loose wiring to the system.
3. Use of a renewable source of power to the system like solar as a means of reducing the carbon footprint in the environment.

5.9 Conclusion

As means of bringing this chapter to closure it would be utmost worth mentioning that in the implementation phase, careful considerations need to be made to make a project a success as it relies on carefully chosen strategies and procedures in the development and to its final implementation, this determines fully its success or failure.