

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belagavi-590018, Karnataka, India



A PROJECT REPORT ON

“SMARTGLO”

**A Dissertation Submitted in partial fulfilment of the requirement for the degree
of**

BACHELOR OF ENGINEERING

In

COMPUTER SCIENCE ENGINEERING

Submitted By

Poojashree R (1RG22CS059)

Risha BG (1RG22CS065)

Ruchitha N (1RG22CS067)

Spandana (1RG22CS078)

Under the guidance of

Dr.Latha P H

Assistant Professor

Dept. of CSE, RGIT



Department of Computer Science & Engineering

RAJIV GANDHI INSTITUTE OF TECHNOLOGY

Cholanagar, R.T. Nagar Post, Bangalore-560032

2025-2026

RAJIV GANDHI INSTITUTE OF TECHNOLOGY
(Affiliated To Visvesvaraya Technological University) Cholanagar,
R.T.Nagar Post, Bangalore-560032

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING



CERTIFICATE

This is to certify that the Project Report entitled "**SMARTGLO**" is a bonafide work carried out by **Ms.Poojashree R (1RG22CS059)**, **Ms.Risha BG (1RG22CS065)**, **Ms.Ruchitha N (1RG22CS067)** and **Ms.Spandana (1RG22CS078)** in partial fulfillment for the award of **Bachelor of Engineering in Computer Science Engineering** under **Visvesvaraya Technological University, Belagavi**, during the year **2025-2026**. It is certified that all corrections/suggestions given for Internal Assessment have been incorporated in the report. This project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.

Signature of Guide

Dr.Latha P H

Asst. Professor

Dept. of CSE,

RGIT, Bengaluru

Signature of HOD

Dr. Arudra A

Head Of Department

Dept. of CSE,

RGIT, Bengaluru

Signature of Principal

Dr. DG Anand

Principal

RGIT, Bengaluru

EXTERNAL VIVA

NAME OF THE EXAMINERS:

SIGNATURE WITH DATE:

1.

2.



VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belagavi-590018

**RAJIV GANDHI INSTITUTE OF TECHNOLOGY
DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING**



DECLARATION

We hereby declare that the Project Report entitled "**SMARTGLO**" submitted to the **Visvesvaraya Technological University, Belagavi** during the academic year **2025-2026**, is record of an original project done by us under the guidance of **Dr.Latha PH, Assistant Professor, Department of Computer Science and Engineering, Rajiv Gandhi Institute of Technology, Bengaluru** and this project is submitted in the partial fulfillment of requirements for the award of the degree of **Bachelor of Engineering in Computer Science & Engineering**. The results embodied in this Project report have not been submitted to any other University or Institute for award of any degree.

POOJASHREE R (1RG22CS059)
RISHA BG (1RG22CS065)
RUCHITHA N (1RG22CS067)
SPANDANA (1RG22CS078)

ACKNOWLEDGEMENT

We take this opportunity to express our sincere gratitude and respect to the **Rajiv Gandhi Institute of Technology, Bengaluru** for providing us with an opportunity to carry out this Project report work.

We express our gratitude to **Dr. DG Anand** Principal, RGIT, Bengaluru for providing the resources and support without which the completion of this project would have been a difficult task.

We extend our sincere thanks to **Dr. Arudra A**, Associate Professor and Head, Department of Computer Science and Engineering, RGIT, Bengaluru, for being a pillar of support and encouraging us in the face of all adversities.

We would like to acknowledge the through guidance and support extended towards us by **Dr. Latha PH.**, Assistant Professor, Dept of CSE, RGIT, Bengaluru. Their incessant encouragement and valuable technical support have been of immense help. Their guidance gave us the environment to enhance our knowledge and skills and to reach the pinnacle with sheer determination, dedication and hard work.

We also want to extend our thanks to the entire faculty and support staff of the Department of Computer Science and Engineering, RGIT, Bengaluru, who have encouraged us throughout the course of the Bachelor's Degree.

We would like to thank our families for always being there with full support and for providing us with a safe haven to conduct and complete our project. We are ever grateful to them for helping us in these stressful times.

Lastly, we want to acknowledge all the helpful insights given to us by all our friends during the course of this Project report.

POOJASHREE R	(1RG22CS059)
RISHA BG	(1RG22CS065)
RUCHITHA N	(1RG22CS067)
SPANDANA	(1RG22CS079)

ABSTRACT

The SMARTGLO project envisions the transformation of conventional street lighting systems into intelligent, multi-functional urban safety networks that combine automation, energy efficiency, and real-time emergency response. In rapidly expanding metropolitan regions such as Bengaluru, traditional timer-based streetlights often fail to provide adequate safety, timely emergency alerts, or efficient energy utilization. SMARTGLO addresses these limitations by integrating IoT-enabled sensors, adaptive lighting control, and embedded emergency response mechanisms into each lighting unit.

Each SMARTGLO streetlight is equipped with an emergency push button that immediately triggers local alarms and transmits alerts to a centralized monitoring system. The incorporation of audio sensors enables automatic detection of abnormal sounds such as crashes or gunshots, activating emergency protocols without human intervention. In addition, the system features traffic-responsive brightness control, replacing static timers with adaptive illumination that adjusts to real-time conditions, thereby minimizing energy wastage. To enhance on-site preparedness, every unit also includes first-aid kits and fire extinguishers, ensuring immediate support in critical situations.

Powered by renewable solar energy with backup storage, the SMARTGLO system ensures uninterrupted operation even during power outages. By merging automation, safety, and sustainability, the project aligns with the goals of smart city initiatives, offering a scalable solution for modern urban environments. Ultimately, SMARTGLO contributes to a safer, greener, and more connected city infrastructure that enhances public welfare, reduces energy consumption, and strengthens the responsiveness of urban emergency systems.

CONTENTS

Acknowledgement	i
Abstract	ii
Contents	iii
List of Figures	vi

CHAPTER	TITLE	PAGE NO
1	INTRODUCTION	1
1.1	Overview	1
1.2	Motivation	1
1.3	Problem Identification	2
1.4	Scope	4
1.5	Objectives	5
1.6	Existing System	6
1.7	Proposed System	7
1.8	Report Organization	9
1.9	Introduction Summary	10
2	LITERATURE SURVEY	11
2.1	Automatic Street Light Intensity Control	11
2.2	IoT-Based Automatic Street Lighting System	12
2.3	Automatic Street Lights	13
2.4	Smart-lighting for indoor comfort & human-centric lighting	14
2.5	Security, privacy, and firmware update challenges for consumer smart lighting	15
2.6	App ecosystems, voice-assistant integration, and user experience	16
2.7	Literature survey summary	17

3	SYSTEM ANALYSIS	18
3.1	Introduction to System Analysis	18
3.2	Feasibility Study	18
3.2.1	Technical Feasibility	18
3.2.2	Economic Feasibility	18
3.2.3	Operational Feasibility	18
3.3	Functional Requirements	19
3.4	Non-Functional Requirements	19
3.5	System Analysis Summary	20
4	REQUIREMENT ANALYSIS	21
4.1	Hardware Requirements	21
4.2	Software Requirements	21
4.3	Requirement Analysis Summary	27
5	SYSTEM DESIGN	28
5.1	Logical Design	28
5.2	Design Goal	29
5.3	System Architecture	30
5.4	Gantt Chart	32
5.5	System Design Summary	33
6	SYSTEM IMPLEMENTATION	34
6.1	Module Description	34
6.1.1	Data Acquisition	35
6.1.2	Data Processing Phase	35
6.1.3	Action/ Output Phase	36
6.1.4	Data flow	37
6.2	Program Code	39
6.3	System Implementation Summary	44
7	TESTING	45
7.1	Validation and System Testing	45
7.1.1	Regression Testing	46
7.1.2	Recovery Testing	46

7.1.3	Security Testing	46
7.1.4	Stress Testing	46
7.1.5	Performance Testing	46
7.1.6	Usability Testing	46
7.1.7	Integration Testing	46
7.1.8	Unit Testing	47
7.1.9	Acceptance Testing	47
7.2	Testing Summary	47
8	SAMPLE OUTPUT	49
8.1	Sample Output Summary	55

CONCLUSION

REFERENCES

LIST OF FIGURES

SL.NO	FIGURES	PAGE NO
Fig 5.1	Logical Design	28
Fig 5.2	Design Goal	29
Fig 5.3	System Architecture	30
Fig 5.4	Gantt Chart	33
Fig 6.1	Data Flow	39
Fig 8.1	Prototype Model of Automatic Streetlight System with buzzer-based Emergency Alert	49
Fig 8.2	Serial Monitor Output Indicating Successful Wi-Fi Connection	49
Fig 8.3	Working Model Showing Emergency Alert Activation	50
Fig 8.4	Emergency Triggered Message Displayed on Serial Monitor	50
Fig 8.5	Emergency Alert Webpage Displaying Live Google Map with Location Coordinates	51
Fig 8.6	GPS Module Fetching Location (Red Light Indication)	51
Fig 8.7	Prototype Display Indicating Emergency Mode and Location Transmission	52
Fig 8.8	Emergency Alert Webpage Displaying Retrieved GPS Coordinates	52
Fig 8.9	SMARTGLO Homepage	53
Fig 8.10	User Registration Page	53
Fig 8.11	User Login Page	54
Fig 8.12	Alertify Portal- Dashboard Home	54
Fig 8.13	Live Map View	55
Fig 8.14	Emergency Alert Page	55

CHAPTER 1

INTRODUCTION

1.1 Overview

The increasing challenges of urbanization in rapidly developing cities like Bengaluru have emphasized the need for smarter, safer, and more energy-efficient infrastructure. Traditional street lighting systems, which function solely to illuminate roads, are no longer sufficient to meet the growing demands of modern cities. To address these limitations, SMARTGLO has been developed an intelligent streetlight system designed to enhance public safety, optimize energy consumption, and contribute to sustainable urban living.

SMARTGLO integrates Internet of Things (IoT), Artificial Intelligence (AI), and renewable energy technologies to transform conventional streetlights into multi-functional smart units. Each unit operates autonomously using solar power, ensuring continuous functionality even during power outages. The system utilizes sensors to detect ambient light, motion, and environmental conditions, automatically adjusting brightness based on traffic flow and pedestrian movement to conserve energy.

Beyond illumination, SMARTGLO incorporates emergency alert mechanisms such as panic buttons and audio sensors capable of detecting abnormal events like crashes, gunshots, or loud disturbances. In such situations, the system triggers instant alarms and sends notifications to a centralized monitoring platform, enabling faster response times. Each smart light is also equipped with on-site safety resources, including first-aid kits and fire extinguishers, ensuring immediate assistance during emergencies.

By combining adaptive lighting, automated incident detection, and integrated emergency response, SMARTGLO aligns with the objectives of smart city initiatives. It serves as a scalable and eco-friendly solution that enhances public safety while reducing energy usage and operational costs. The project envisions the creation of a connected urban environment where infrastructure not only serves its functional purpose but also contributes to the overall safety, sustainability, and quality of life for citizens.

1.2 Motivation

In today's fast-growing urban environments, cities like Bengaluru face critical challenges such as rapid population growth, increased traffic congestion, high energy consumption, and rising safety concerns. While advancements in technology have improved certain aspects of urban infrastructure, traditional systems like street lighting have remained largely static and inefficient.

SMARTGLO

These limitations highlight the pressing need for an intelligent, adaptive, and multi-functional lighting infrastructure that not only provides illumination but also contributes to urban safety and sustainability. The motivation behind the SMARTGLO project stems from this necessity to modernize traditional systems into a more dynamic, self-sustaining, and responsive network capable of addressing multiple urban challenges simultaneously.

Furthermore, Bengaluru, known for its dense population and high vehicular traffic, experiences frequent congestion and safety hazards during both day and night. Power outages or system failures often result in prolonged darkness, creating unsafe conditions for pedestrians and motorists. Delays in emergency response during such situations can increase the likelihood of accidents and crimes. The lack of real-time monitoring and absence of safety features like panic buttons or on-site emergency tools further worsen the situation. These gaps motivated the design of SMARTGLO—a system capable of responding intelligently to its surroundings while supporting public safety and energy efficiency.

Another major motivation for this project is the global shift toward smart and sustainable cities. Governments and urban planners worldwide are focusing on integrating renewable energy, data-driven decision-making, and automation into city infrastructure. By harnessing solar power and incorporating IoT and AI technologies, SMARTGLO not only promotes environmental sustainability but also reduces dependency on conventional power grids. Its adaptive lighting mechanism helps lower carbon emissions and operational costs, aligning with India's Smart City Mission and the UN Sustainable Development Goals (SDGs) for sustainable urban development.

Additionally, the motivation extends from the desire to create a community-centric safety ecosystem. The integration of panic buttons, audio sensors, and real-time communication with emergency authorities enables immediate action during critical incidents. This feature ensures that every streetlight becomes an active guardian for citizens rather than a passive utility fixture. The inclusion of on-site emergency aids like first-aid kits and fire extinguishers further enhances public readiness, bridging the gap between incident occurrence and emergency response.

On a broader scale, the project aims to set a benchmark for future smart infrastructure by combining energy conservation, public safety, and intelligent automation in a single platform. The development of SMARTGLO is not just about creating a smarter lighting system—it's about reimagining how cities can leverage technology to protect lives, conserve resources, and foster sustainable growth.

1.3 Problem Identification

- Inefficiency of Traditional Street Lighting Systems:** Existing streetlights in cities like Bengaluru

SMARTGLO

light conditions or traffic flow. This leads to unnecessary energy consumption during low-traffic hours and insufficient illumination during emergencies or high-traffic periods. The systems lack adaptive control, resulting in energy wastage and reduced operational efficiency.

- **Absence of Intelligent Monitoring and Automation:** Current streetlight systems function as independent and non-communicative units, with no centralized monitoring or data analytics. They cannot detect or respond to environmental changes, movement, or incidents such as road accidents or crimes. There is no integration with smart city networks, which limits data collection and decision-making capabilities for urban management.
- **Lack of Emergency Response Mechanisms:** In emergencies such as accidents, crimes, or natural disasters, streetlights do not provide any alert or support functions. The absence of panic buttons, alarm systems, or automatic alerts delays emergency responses and increases the risk to public safety. There are no basic on-site resources like first-aid kits or fire extinguishers available near streetlights for immediate assistance.
- **Dependency on Non-Renewable Power Sources:** Most conventional streetlight systems rely heavily on electricity from non-renewable sources, increasing both carbon emissions and operational cost. Power outages cause prolonged darkness, creating unsafe conditions for pedestrians and motorists. The absence of renewable energy integration makes the system unsustainable in the long term.
- **Inadequate Public Safety and Security:** Poor lighting in critical zones contributes to higher accident rates and increased vulnerability to crimes during night hours. Without smart surveillance or motion detection, authorities cannot monitor high-risk areas in real time. Limited communication between infrastructure and emergency responders further reduces situational awareness and rapid response.
- **Environmental and Economic Concerns:** Continuous operation of high-intensity lights increases energy bills and carbon footprint. Inefficient lighting infrastructure fails to support sustainability goals, contradicting the Smart City Mission's objectives of eco-friendly urban development. Municipal budgets are burdened by maintenance and power costs that could be reduced through intelligent automation.
- **Lack of Integration with Smart City Frameworks:** Traditional systems do not collect valuable data such as traffic density, air quality, or pedestrian movement, which are vital for smart city planning. Without IoT connectivity and data-driven analytics, cities cannot make proactive decisions for energy optimization or safety management. This isolation prevents cities from evolving into fully connected, intelligent ecosystems.
- **Need for an Advanced Smart Lighting Solution:** There is a critical need for a self-sustaining, AI-enabled street lighting system that can autonomously adjust lighting, detect emergencies, and

SMARTGLO

time analytics, and emergency response capabilities to create a safer, more efficient urban environment.

The SMARTGLO project aims to bridge these gaps by redefining streetlights as intelligent safety and communication nodes within the smart city ecosystem.

1.4 Scope

The scope of the SMARTGLO project is centered on developing and implementing an AI-powered, IoT-based smart street lighting system that enhances energy efficiency, public safety, and sustainability in urban environments. The project aims to transform conventional streetlights into intelligent, responsive, and multi-functional units capable of adapting to real-time environmental conditions and supporting emergency management systems.

The project's scope can be defined under the following key aspects:

- **Smart Energy Management:** Integration of solar panels and battery storage to ensure renewable, uninterrupted power supply even during outages. Adaptive lighting control that adjusts brightness automatically based on ambient light intensity, traffic density, and pedestrian movement. Reduction in energy wastage through motion-based activation and real-time monitoring of power usage.
- **Public Safety and Emergency Response:** Installation of panic buttons and audio sensors to detect unusual events such as crashes, gunshots, or loud disturbances. Automatic activation of alarms and real-time notification to authorities through an IoT-based communication system. Integration of on-site safety tools, including first-aid kits and fire extinguishers, for immediate emergency response before professional help arrives.
- **Environmental Monitoring and Data Collection:** Deployment of environmental sensors to monitor air quality, temperature, noise levels, and pollution, helping city planners make data-driven decisions. Cloud-based data storage and analysis for urban pattern recognition and predictive maintenance of lighting infrastructure. Support for integrating AI analytics to forecast high-risk or high-traffic areas.
- **IoT and Cloud Connectivity:** Use of LoRa, ZigBee, NB-IoT, or Wi-Fi communication protocols for seamless data exchange between streetlights and central control systems. Centralized cloud platform for remote monitoring, data visualization, and system updates through a web or mobile dashboard. Ability to scale the network easily across different regions, ensuring wider smart city integration.

SMARTGLO

algorithms for adaptive illumination and congestion prediction. Automatic failure detection and maintenance alerts to minimize downtime and operational disruptions.

- **Sustainability and Cost Efficiency:** Promotion of eco-friendly urban infrastructure through reduced dependence on the main power grid and optimized energy utilization. Long-term cost savings for municipal corporations through lower electricity bills and reduced maintenance requirements. Contribution to green city initiatives and support for government Smart City Missions.
- **Scalability and Future Expansion:** Designed to be modular and expandable, allowing integration of new technologies such as CCTV cameras, smart traffic control, and environmental sensors. Applicable not only for urban roads but also for college campuses, industrial zones, and residential areas. Future upgrades may include AI-based predictive lighting, integration with public Wi-Fi, and smart traffic analytics.
- **Social and Technological Impact:** Enhances citizen safety, environmental awareness, and energy consciousness. Bridges the gap between technology and daily life, making infrastructure more responsive and community-oriented. Encourages data-driven governance and fosters a more connected and sustainable urban ecosystem.

1.5 Objective

The SMARTGLO project aims to design and implement an intelligent, energy-efficient, and safety-focused street lighting system that aligns with the goals of smart city development. Its primary objective is to transform traditional streetlights into multi-functional smart units that not only provide illumination but also enhance public safety, energy conservation, and environmental sustainability.

The specific objectives of the project are as follows:

- **To Develop a Smart Street Lighting System:** Create an intelligent lighting system that operates autonomously using IoT and AI technologies. Enable adaptive brightness control based on ambient light, traffic flow, and pedestrian movement.
- **To Enhance Public Safety and Emergency Response:** Integrate panic buttons, audio sensors, and motion detectors to identify abnormal events such as accidents or crimes. Ensure instant alert transmission to local authorities and nearby citizens during emergencies. Provide on-site emergency support with tools like first-aid kits and fire extinguishers for immediate response.
- **To Promote Energy Efficiency through Renewable Power:** Utilize solar panels and battery backup systems to ensure self-sustaining, uninterrupted power supply. Optimize energy usage by enabling automatic control and minimizing wastage during low-traffic periods. Reduce the

SMARTGLO

- **To Integrate IoT-Based Communication and Monitoring:** Establish a real-time data network using LoRa, ZigBee, NB-IoT, or Wi-Fi technologies. Enable centralized monitoring and control through cloud-based dashboards accessible by municipal authorities. Facilitate remote updates, system diagnostics, and data analysis for efficient urban management.
- **To Improve Urban Sustainability and Smart City Connectivity:** Support data-driven decision-making by collecting information on traffic density, air quality, and environmental parameters. Contribute to Smart City Mission goals by creating infrastructure that supports automation and sustainability. Design a modular system that can be scaled and integrated with other smart urban technologies such as surveillance, traffic management, and environmental monitoring.
- **To Improve Urban Sustainability and Smart City Connectivity:** Support data-driven decision-making by collecting information on traffic density, air quality, and environmental parameters. Contribute to Smart City Mission goals by creating infrastructure that supports automation and sustainability. Design a modular system that can be scaled and integrated with other smart urban technologies such as surveillance, traffic management, and environmental monitoring.
- **To Ensure Cost-Effective and Reliable Operation:** Reduce electricity and maintenance costs through automated operations and renewable energy integration. Enhance long-term reliability by including fault detection, predictive maintenance, and remote-control features.

To Foster a Safer and Smarter Urban Environment: Establish a responsive and intelligent lighting network that ensures citizen safety, convenience, and comfort. Demonstrate how smart technologies can transform urban infrastructure into a proactive safety and communication network.

1.6 Existing System

In most modern cities, including Bengaluru, street lighting systems continue to rely on traditional fixed-timer mechanisms that switch the lights on and off at pre-set times, regardless of actual conditions such as traffic movement, pedestrian activity, or ambient light levels. These systems operate in a one-dimensional manner, providing only basic illumination without any intelligence or adaptability. As a result, a significant amount of electricity is wasted when lights remain switched on during low-traffic hours or unnecessary conditions, leading to high operational costs and increased energy consumption.

The absence of automation and intelligent control is one of the major shortcomings of the existing streetlight systems. They lack integrated sensors capable of detecting motion, traffic flow, or environmental parameters. This means that the system cannot adjust lighting intensity based on real-

SMARTGLO

Maintenance activities are typically performed manually, often only after failures are reported, resulting in delayed response times and inefficient system management.

Another major limitation of the existing setup is the lack of emergency response and safety features. Traditional streetlights serve only as passive lighting devices and play no role in public safety or security. In the event of accidents, crimes, or emergencies, these systems are unable to detect abnormal situations or send alerts to nearby authorities. They lack basic safety features such as panic buttons, emergency buzzers, or audio sensors that could assist in rapid incident reporting. Consequently, the absence of automated communication mechanisms often results in delayed responses during critical situations, putting citizens at greater risk.

Moreover, the existing infrastructure is entirely dependent on non-renewable electricity sources. Power supply failures or outages leave large stretches of roads in complete darkness, compromising visibility and public safety. Since these systems do not incorporate renewable energy solutions such as solar power or battery backups, they are not sustainable in the long term and contribute to higher carbon emissions and environmental degradation. This dependence also imposes a significant financial burden on municipal authorities in terms of energy costs and maintenance.

Additionally, the current system offers no integration with modern smart city frameworks. The streetlights function in isolation, without communication links to other urban systems such as traffic management, environmental monitoring, or surveillance networks. This limits the city's ability to collect valuable data for improving infrastructure planning or enhancing citizen safety. The lack of interconnectivity also prevents these systems from being upgraded or scaled in line with evolving smart city initiatives.

Overall, the existing streetlight system is outdated, energy-inefficient, and non-interactive, providing only basic illumination without addressing modern urban challenges. It fails to support sustainability, automation, or emergency response, leaving cities vulnerable to both energy waste and public safety risks. These limitations clearly indicate the urgent need for an intelligent, self-sustaining, and responsive lighting solution—one that integrates IoT, AI, and renewable energy technologies.

1.7 Proposed System

The proposed system, SMARTGLO, is an advanced AI-powered and IoT-enabled smart street lighting system designed to overcome the drawbacks of traditional lighting. It transforms conventional streetlights into intelligent, multi-functional smart units that provide efficient illumination, real-time emergency response, and environmental monitoring.

SMARTGLO

- **Renewable Energy Integration:** Each streetlight operates using solar panels with an efficient battery backup system to ensure continuous functionality even during power outages. The use of renewable energy significantly reduces dependency on the main power grid and supports sustainable urban development. This setup helps lower energy costs and carbon emissions, promoting an eco-friendly infrastructure.
- **Adaptive Lighting Control:** SMARTGLO automatically adjusts light intensity based on real-time environmental and traffic conditions. Light Dependent Resistors (LDRs) detect ambient light levels, while PIR and ultrasonic sensors identify vehicle or pedestrian movement. The system increases brightness during peak hours and reduces it during low-traffic periods, ensuring maximum energy efficiency without compromising visibility.
- **Emergency Alert Mechanism:** Each smart streetlight is equipped with an emergency panic button that can be used by the public to report accidents or crimes instantly. On activation, the light flashes a warning signal and sends an alert with location details to a centralized monitoring station. Audio sensors detect unusual sounds such as crashes, gunshots, or loud disturbances, automatically triggering alerts and alarms for faster response.
- **Safety and Emergency Resources:** Every smart pole includes essential safety tools such as a first-aid kit and a fire extinguisher, allowing immediate help during emergencies. This ensures that each streetlight acts as a mini emergency response point, improving citizen safety during critical situations.
- **IoT and Communication Network:** The system uses IoT-based wireless communication technologies such as LoRa, ZigBee, or NB-IoT for real-time data transmission. All streetlights are interconnected and communicate with a central control unit for live status updates and remote operations. The system enables authorities to monitor, manage, and control the lighting network from a centralized dashboard through web or mobile applications.
- **AI-Based Data Analytics and Control:** Artificial Intelligence algorithms analyze traffic density and environmental data to predict and optimize lighting patterns dynamically. The system performs predictive maintenance by detecting faults and sending alerts before failures occur. Data collected from sensors can be used for traffic planning, pollution monitoring, and smart city analytics.
- **Centralized Cloud Monitoring:** SMARTGLO is connected to a cloud-based platform that allows remote access to all operational data, energy statistics, and system alerts. The platform enables real-time monitoring, fault tracking, and performance analysis for each smart pole.
- **Modular and Scalable Design:** The system follows a modular architecture, allowing easy expansion and integration with other smart city technologies. Future enhancements can include CCTV integration, environmental sensors, public Wi-Fi, or smart traffic lights. The same setup

- **Expected Impact of the Proposed System:** Ensures public safety through rapid emergency detection and response. Achieves significant energy savings via intelligent automation and renewable energy usage. Reduces operational costs through predictive maintenance and centralized control. Contributes to the creation of smarter, safer, and more sustainable cities aligned with India's Smart City Mission.

1.8 Report Organization

Chapter 1: This chapter gives the overall description about the project. It gives the overview of the proposed project work. It tries to answer why this project is needed in current scenario and what are various motivation factors that motivated to implement this project. This chapter also points out the limitations in the existing systems and tells how these limitations can be overcome by using this project.

Chapter 2: This chapter gives details about various base papers that are related to the proposed project work. It shows how various activities related to the project were carried out at different point of time. It gives a short introduction to each base paper, talks about their shortcomings and tells how this project can overcome those shortcomings.

Chapter 3: This chapter introduces the system analysis process. It gives brief idea whether this project should be done or not based on various feasibility study. It gives the summary of various feasibility studies that were carried out and shows the advantages of doing this project. At the same time, it also gives the overview of various functional and non-functional requirements of the system.

Chapter 4: This chapter talks about various hardware and software tools that are necessary in order to implement this project. It provides details of software and languages that will be used and also lists the minimum requirements needed to run the project.

Chapter 5: This chapter shows the detailed design of the architecture, components, modules, interfaces, and data for the proposed system to satisfy specified requirements. It shows various standard UML diagrams that are needed to design the system

Chapter 6: This chapter shows the implementation of the structure created during architectural design and the results of system analysis to construct system elements that meet the stakeholder requirements and system requirements developed in the early life cycle phases.

Chapter 7: This chapter shows the various test results produced by the system various kinds of test are performed for each part of the system and as well as the whole system. It shows various

SMARTGLO

predefined test cases and result of running these test cases on the system. It provides the comparison of expected output and the actual output produced by system based on which bugs are identified and eliminated.

Chapter 8: This chapter shows various screenshots of the system. It also shows how data processing happens at various stages of the system and the final output is also displayed. And it also shows the outer interface design of the system.

1.7 Introduction Summary

This Introduction chapter gives the overview about the project and gives the short description of the proposed project work. It tries to answer why this project is needed in current scenario and what are various scopes and advantages of this project.

CHAPTER 2

LITERATURE SURVEY

2.1 Automatic Street Light Intensity Control:

NAME	YEAR	AUTHOR	ADVANTAGES	DISADVANTAGES
Automatic Street Light Intensity Control	2020	V. Prakash et al.	- Uses ultrasonic sensors and LDR for real-time brightness control. - Efficient for highways, university roads, and parking areas.	- Limited sensor range for large-scale deployment. - System reliability depends on cloud connectivity. - CF bulbs less efficient compared to LED solutions.

This design uses Arduino, LDR, Ultrasonic sensors, and NodeMCU (IoT module) to automatically adjust streetlight brightness.

- The LDR detects day or night.
- The Ultrasonic sensor detects the presence of vehicles or objects and adjusts the light intensity — dim when idle and bright when movement is detected.
- Data such as voltage and current are uploaded to the cloud for monitoring.
- An Android app allows users to manually control or monitor lights remotely.

This hybrid system provides energy conservation, automation, and IoT-based data management for smart lighting.

The project effectively eliminates manual operation and ensures automatic, reliable control of street lighting. It is energy-efficient, low-cost, and adaptable for university roads, parking areas, and city streets. The system's smart dimming and motion-detection mechanism improve safety while reducing power waste. It also demonstrates how IoT and sensor integration can transform traditional lighting systems into

2.2 IoT-Based Automatic Street Lighting System :

NAME	YEAR	AUTHOR	ADVANTAGES	DISADVANTAGES
IoT-Based Automatic Street Lighting System	2023	Kalyani Anna et al.	<ul style="list-style-type: none">- Integrates IoT with Arduino, IR, and LDR sensors.- Real-time control and monitoring through IoT cloud.- Automatically adjusts lighting based on motion and ambient light.- Promotes smart city development and sustainability.	<ul style="list-style-type: none">- Initial installation and maintenance costs are high.- Requires stable network for IoT connectivity.- Needs environmental testing for large deployment.

This system integrates IoT, Arduino, LDR, and IR sensors for smart lighting control.

- The LDR detects ambient light to turn lights on only during darkness.
- The IR sensor detects movement to illuminate only occupied or active areas.
- The Arduino serves as the central controller using real-time sensor inputs.
- IoT connectivity allows remote monitoring, data storage on the cloud, and performance analysis.

This ensures real-time, adaptive lighting that responds to environmental conditions, improving energy efficiency and supporting smart city scalability.

The project proves that an IoT-based lighting system can be practical, sustainable, and cost-effective. It overcomes traditional power waste and offers scalability for smart cities. Though the initial setup cost is higher, it provides significant long-term savings and environmental benefits. The system can be applied in parking lots, campuses, and urban infrastructures, making it an essential part of future smart and sustainable cities.

2.3 Automatic Street Lights:

NAME	YEAR	AUTHOR	ADVANTAGES	DISADVANTAGES
Automatic Street Lights	2013	Sakshee Srivastava	<ul style="list-style-type: none"> - Eliminates manpower by automating street lighting. - Reduces energy consumption using IR sensors and LDR. - LEDs replace HID lamps for efficiency and long life. - Can save ~40% of electrical energy on highways. - Cost-effective and eco-friendly. 	<ul style="list-style-type: none"> - Initial setup cost is high. - Requires regular maintenance. - Limited scalability for large smart city integration.

The project automates street lighting using an LDR (Light Dependent Resistor) and IR sensors interfaced with a microcontroller. The system switches lights ON when ambient light is low and detects vehicle movement to control which specific streetlights glow — the one ahead, behind, and alongside the vehicle. Power regulation is handled by ICs 7805 and 7812. LEDs replace traditional HID lamps for better efficiency.

This system offers a cost-effective, eco-friendly, and reliable solution for saving energy and eliminating manual control. It can save up to 40% of energy compared to conventional systems. Though initial costs and maintenance are limitations, they are outweighed by the system's long-term efficiency, low maintenance, and LED advantages (long life, low heat, non-toxic). It can also be extended for lighting in industrial areas, campuses, and parking spaces.

2.4 Smart-lighting for indoor comfort & human-centric lighting :

NAME	YEAR	AUTHORA	ADVANTAGES	DISADVANTAGES
Human-centric lighting & adaptive indoor systems	2018 – 2023	Multiple (studies on circadian lighting and tunable white LED systems)	Improves occupant comfort and productivity; Tunable color temperature supports circadian rhythm; integration with sensors and schedules.	Requires careful UI/automation design; user acceptance and privacy for occupancy sensing; cost for high-quality tunable luminaires.

Smart lighting systems like SmartGlo go beyond decorative use by supporting Human-Centric Lighting (HCL) — an approach that aligns indoor lighting with natural circadian rhythms and human biological needs. By automatically adjusting brightness and color temperature (cool white for focus, warm white for relaxation), SmartGlo enhances mood, focus, and comfort while reducing eye strain and improving sleep quality. These systems adapt dynamically to the time of day, season, and user activity, helping create healthier, more productive indoor environments that simulate the natural daylight cycle.

In workplaces, schools, and healthcare settings, SmartGlo can be programmed to provide bright, cool lighting during morning hours to boost alertness and concentration, then transition to softer, warmer tones in the evening for relaxation and recovery. This adaptability not only supports physical and mental well-being but also increases energy efficiency through intelligent scheduling and sensor-based automation. As research in HCL continues to grow, SmartGlo demonstrates how lighting can evolve from a purely functional element into a proactive tool that nurtures human health, comfort, and sustainability.

2.5 Security, privacy, and firmware update challenges for consumer smart lighting:

NAME	YEAR	AUTHOR	ADVANTAGES	DISADVANTAGES
Security & privacy analyses for IoT lighting devices	2019–2024	IoT security research community	Highlights need for secure boot, encrypted comms, authenticated OTA updates.	Many consumer bulbs use weak or cloud-only auth; supply-chain / OTA vulnerabilities remain.

For SmartGlo and other connected smart lighting systems, security is a critical design priority. Since these devices connect to networks and cloud services, they must ensure secure onboarding, encrypted communication, and safe over-the-air (OTA) updates. Each device should have a unique cryptographic identity to prevent unauthorized access, while all data exchange should be encrypted using secure protocols like TLS or MQTT. OTA updates must include digital signatures and integrity checks to avoid malicious firmware installation. Developers should also follow vendor security guidelines and whitepapers to maintain a system that is both user-friendly and cyber-resilient.

In addition to safety, human-centric smart lighting like SmartGlo enhances comfort and saves energy. By integrating daylight sensing, occupancy detection, and automated scheduling, it ensures lighting operates only when needed, reducing energy use by up to 50%. Modern features such as tunable white LEDs, RGB lighting, and AI-based adaptive control allow light to be optimized for health, focus, and mood. Overall, SmartGlo represents a shift from basic automation to intelligent, wellness-oriented, and sustainable illumination for modern environments.

2.6 App ecosystems, voice-assistant integration, and user experience:

NAMEA	YEAR	AUTHORA	ADVANTAGES	DISADVANTAGES
Smart lighting app & ecosystem evaluations	2020–2024	Industry notes, UX reviews, product manuals	App+voice integration increases adoption; scheduling, scenes, and Routines are high-value features.	Fragmentation across vendor ecosystems; user confusion with multiple apps; cloud outages can remove control.

For SmartGlo to succeed as a smart lighting product, it must deliver a simple, intuitive, and reliable user experience. While advanced options like color tuning and scheduling add appeal, most users value easy setup and consistent control. A well-designed mobile app should simplify device connection, brightness adjustment, and scene creation with guided setup and clear feedback. Integrating voice assistants like Alexa, Google Assistant, or Siri enhances accessibility, while offline control through wall switches or LAN ensures usability even without internet. Clear instructions and responsive visual cues help build trust and make SmartGlo effortless for all users.

The success of SmartGlo also depends on its app ecosystem and interface design. Built on platforms like Tuya, Smart Life, Google Home, or Apple HomeKit, SmartGlo enables real-time monitoring, remote access, and personalized lighting scenes such as Reading, Relax, or Party. Voice integration further improves convenience and accessibility, especially for elderly or differently abled users. By linking with other smart devices—like thermostats or security systems—SmartGlo can execute automation routines such as a “Good Night” command that dims lights and locks doors, offering a seamless and engaging smart-home experience.

2.7 Literature survey summary:

The reviewed literature and research highlight the rapid evolution of smart lighting technologies from simple sensor-based automation to intelligent, IoT-driven, and human-centric solutions. Early systems using LDRs, IR sensors, and microcontrollers improved energy efficiency by eliminating manual control, while IoT-based systems added remote monitoring, adaptive control, and data analytics for smart city integration. Building on these foundations, SmartGlo introduces an advanced approach that integrates Human-Centric Lighting (HCL) principles to enhance comfort, mood, and productivity by automatically adjusting brightness and color temperature to mimic natural daylight cycles. It also incorporates security and reliability features such as encrypted communication, device authentication, and verified over-the-air updates to ensure safe and stable operation across networks. Furthermore, SmartGlo emphasizes user experience (UX) with an intuitive mobile app, voice assistant compatibility (Google Home, Alexa, Siri), and offline control for continuous operation. Its integration with cloud platforms enables remote access, automation, and energy management, supporting sustainability goals. In essence, SmartGlo combines automation, intelligence, security, and human-focused design, positioning itself as a next-generation smart lighting system that enhances quality of life, reduces energy consumption, and supports the vision of connected, sustainable smart cities.

CHAPTER 3

SYSTEM ANALYSIS

3.1 Introduction to System Analysis

- **System:** A system is an orderly group of interdependent components linked together according to a plan to achieve a specific objective. Its main characteristics are organization, interaction, interdependence, integration, and a central objective.
- **Analysis:** Analysis is a detailed study of the various operations performed by a system and their relationships within and outside of the system. One aspect of analysis is defining the boundaries of the system and determining whether a candidate system should consider other related systems. During analysis data are collected on the available files decision points and transactions handled by the present system.
- **System Analysis:** System analysis and design are the application of the system approach to problem solving generally using computers. To reconstruct a system the analyst must consider its elements output and inputs, processors, controls, feedback and environment.

3.2 Feasibility Study

Feasibility is the determination of whether a project is worth doing. The process followed in making this determination is called feasibility Study. This type of study if a project can and should be taken. In the conduct of the feasibility study, the analyst will usually consider seven distinct, but inter-related types of feasibility.

3.2.1 Technical Feasibility

This is considered with specifying equipment and software that will successfully satisfy the user requirement the technical needs of the system may vary considerably but might include

- The facility to produce outputs in each time.
- Response time under certain conditions.
- Ability to process a certain column of transaction at a particular speed.

3.2.2 Economic Feasibility

Economic analysis is the most frequently used technique for evaluating the effectiveness of a proposed system. More commonly known as cost / benefit analysis. The procedure is to determine the benefits and savings are expected form a proposed system and a compare them with costs.

3.2.3 Operational Feasibility

SMARTGLO

- What changes will be brought with the system?
- What organizational structures are distributed?
- What new skills will be required?
- Do the existing system staff members have these skills?
- If not, can they be trained in the course of time?

3.3 Functional Requirements

Functional Requirement Specification is the documentation of operations and activities that require competent enabling to perform the system. Functional requirements include:

- Dataset Requirement: The system must handle structured data and unstructured data.
- Data Collection: Collect, filter, and store real-time data from various sensors.
- Define Management Strategies: Develop rules and strategies for management based on real-time data. These rules include threshold values that trigger actions, such as alerts or optimizations
- System Analysis: Analyze collected data against defined strategies to make real-time decisions, like adjusting traffic signals or activating street light management actions.
- Data Storage and Retrieval: Store and retrieve system configurations and models (e.g., management strategies) from databases for future use and comparison.

3.4 Non-Functional Requirements

There are many non-functional requirements which are traded off between each another e.g. increased performance often comes at an increased total cost of ownership. Non-functional algorithmic trading system requirements include:

- **Scalability:** The system should be easily expandable to support a large number of smart streetlights distributed across different urban zones. It must handle an increased volume of sensor data, communication nodes, and user interactions without degrading performance. Future integration with other smart-city subsystems—such as traffic monitoring, surveillance cameras, or air-quality sensors—should be possible without major redesign.
- **Performance:** SMARTGLO should respond to environmental and emergency events within minimal latency. Lighting adjustments and emergency alerts must occur in near real time (less than two seconds after detection). Data transmission between streetlight nodes and the central cloud platform should maintain low-delay communication to ensure timely monitoring.

SMARTGLO

- **Reliability and Availability:** The system must ensure continuous operation even during power outages or network interruptions by using solar panels with battery backup and fault-tolerant communication protocols. Each node should operate autonomously if disconnected from the cloud, synchronizing automatically once connectivity is restored
- **Security:** All communication between IoT nodes, gateways, and cloud servers must be encrypted to prevent unauthorized access and data breaches. Authentication mechanisms and role-based access control must be implemented to protect sensitive location and emergency information. Regular software updates and security patches should be enforced.
- **Maintainability and Modifiability:** The architecture should be modular, allowing updates to hardware modules (e.g., sensors, controllers) or software components without disrupting system functionality.
- **Fault Tolerance:** In case of individual node failures, the remaining streetlights must continue operating independently. The system should automatically reroute communication through alternate nodes or notify administrators of failures while preserving normal operation of unaffected units.
- **Energy Efficiency:** Since SMARTGLO emphasizes sustainability, its control algorithms must minimize energy use by dynamically adjusting illumination and ensuring solar-battery optimization. Power consumption reports should be automatically generated for continuous assessment.
- **Usability:** The web and mobile dashboards should have intuitive graphical interfaces for municipal authorities to monitor, control, and analyze system performance. Emergency alerts, energy analytics, and maintenance reports should be easy to access and interpret without technical expertise.
- **Environmental Sustainability:** Components must be durable, weather-resistant, and compliant with eco-friendly standards. The system should support renewable-energy integration and minimize electronic waste by enabling component reusability and recyclability.

3.5 System Analysis Summary

This chapter introduces the system analysis process. It gives brief idea whether this project should be done or not based on various feasibility study. It gives the summary of various feasibility studies that were carried out and shows the advantages of doing this project. At the same time, it also gives the overview of various functional and non-functional requirements of the system.

CHAPTER 4

REQUIREMENT ANALYSIS

To be used efficiently, all computer software needs certain hardware components or other software resources to be present on a computer these prerequisites are known as system requirements. System requirements are the configuration that a system must have in order for a hardware or software application to run smoothly and efficiently. Failure to meet these requirements can result in installation problems or performance problems. The former may prevent a device or application from getting installed, whereas the latter may cause a product to malfunction or perform below expectation or even to hang or crash.

The system requirements are of two types:

- Hardware Requirements
- Software Requirements

4.1 Hardware Requirements

- White LED Bulbs
- Resistor (blue color around 220 ohm)
- copper wires
- IR sensor
- switch
- battery (9v)
- buzzer
- push button (4 legs)
- USB Cable Type B
- PCB Board
- SDA and SCL Display
- NEO-6M GPS Module with EPROM
- Red LED (Basically alert signal gets light on)
- Lithium Ion Battery- 3.7 V 3000mAh
- NodeMCU ESP8266

4.2 Software Requirements

- Arduino IDE
- Platform IO
- VS code

SMARTGLO

1. White LED Bulbs:

white LED bulbs consist of several key components that work together to produce efficient lighting. The LED chip emits blue light, which is converted to white using a phosphor coating. A driver circuit regulates power supply, ensuring stable performance and protecting against voltage fluctuations. Heat sinks dissipate excess heat to prolong the bulb's lifespan, while the diffuser lens spreads light evenly and reduces glare. Together, these elements create a durable, energy-saving lighting solution ideal for smart and sustainable systems.



2. Resistor:

A resistor is a fundamental electronic component used to limit or control the flow of electric current in a circuit. It consists of a resistive material—often carbon, metal film, or wire-wound—encased in a protective shell with color-coded bands indicating resistance value. Resistors help regulate voltage, protect components from excess current, and divide signals in circuits. They are essential in LED circuits to prevent overcurrent and ensure stable operation. Their simple yet crucial role makes them a backbone of both analog and digital electronics.



3. Copper Wires:

Copper wires are essential conductors used in electrical and electronic systems due to their excellent conductivity and flexibility. They consist of pure copper strands, either solid or stranded, often coated with insulation like PVC or rubber to prevent short circuits. Copper wires are used to transmit electrical signals and power efficiently across circuits. In smart systems, they connect sensors, microcontrollers, and power sources, ensuring stable and low-resistance pathways. Their durability and corrosion resistance make them ideal for both indoor and outdoor applications.

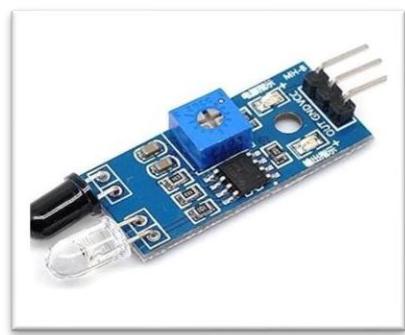


4. IR Sensor:

An IR (Infrared) sensor is an electronic device that detects infrared

SMARTGLO

(receiver). When an object reflects the emitted IR light, the sensor detects the change and triggers a response. IR sensors are widely used for motion detection, obstacle sensing, and proximity measurement in smart systems. Their low power consumption and fast response make them ideal for automation and real-time monitoring applications.



5. Switch:

A switch is an electrical component used to control the flow of current in a circuit by opening or closing the connection. It typically consists of conductive contacts housed in a casing, which can be toggled manually or electronically. When the switch is closed, current flows through the circuit; when open, the flow is interrupted. Switches are essential in systems for turning devices on or off, selecting modes, or triggering actions. In smart setups, they can be integrated with sensors or microcontrollers for automated control



6. Battery:

A 9V battery is a compact power source commonly used in portable electronics, sensors, and microcontroller-based projects. It consists of six 1.5V cells connected in series, enclosed in a rectangular casing with snap terminals. Known for its stable voltage output, it's ideal for powering small circuits like IR sensors, LED modules, and Arduino boards. In smart systems, 9V batteries offer reliable energy for short-term operations or backup power. Their ease of use and availability make them a popular choice for DIY and embedded applications.



7. Buzzer:

A buzzer is an audio signaling device that produces sound when electrical current is applied. It typically consists of a piezoelectric element or electromagnetic coil that vibrates to generate tones or beeps. Buzzers are used in electronic circuits for alerts, notifications, and status indicators.



SMARTGLO

8. Push Button (4 legs):

A 4-leg push button is a tactile switch commonly used in electronic circuits to provide user input or control. It has four terminals arranged in a square, with two pairs internally connected. When pressed, the button completes the circuit between the connected legs, allowing current to flow. This design ensures stable contact and easy mounting on breadboards or PCBs. In smart systems, it's used to trigger actions like turning devices on/off or initiating sensor readings.



9. USB Cable Type B:

The USB Type-B cable is a crucial hardware component used for establishing reliable wired communication between microcontrollers (such as Arduino or ESP32 boards) and external devices like computers or power sources. Characterized by its square-shaped connector, the Type-B interface is commonly found in printers, embedded systems, and development boards. In the context of the SMARTGLO project, the USB Type-B cable facilitates data transfer and power delivery during system setup, programming, and debugging phases. It ensures stable connectivity for uploading firmware, monitoring sensor outputs, and interacting with cloud platforms like Blynk. The cable's robust design supports repeated connections and disconnections, making it ideal for prototyping and testing environments. Its plug-and-play nature simplifies integration into the system architecture, contributing to efficient development and deployment of smart city modules.



10. PCB Board:

The Printed Circuit Board (PCB) serves as the foundational platform for assembling and interconnecting electronic components in the SMARTGLO system. It provides a compact, organized layout for mounting sensors, microcontrollers, and communication modules, ensuring stable electrical connections and efficient signal routing. The PCB's layered design allows for precise control of current flow, minimizing interference and enhancing system reliability.



SMARTGLO

in urban environments, while its modularity allows for easy upgrades and maintenance. By centralizing the hardware architecture, the PCB plays a critical role in streamlining the implementation of smart city functionalities like water monitoring, waste tracking, and automated lighting control.

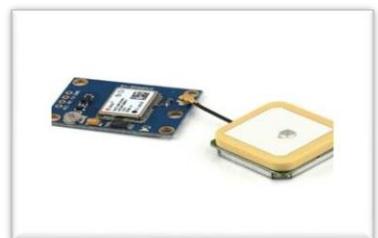
11. SDA and SCL Display:

The SDA (Serial Data) and SCL (Serial Clock) lines are fundamental components of the I²C communication protocol, enabling seamless data exchange between microcontrollers and peripheral devices such as OLED displays, sensors, and memory modules. In the SMARTGLO project, these lines are used to interface with a digital display unit that provides real-time visualization of system metrics like water levels, waste bin status, parking availability, and energy consumption. The SDA line transmits data while the SCL line synchronizes the communication, ensuring accurate and timely updates on the display. This setup allows for efficient monitoring of urban operations, enhancing user interaction and system transparency. The I²C protocol's simplicity and low pin usage make it ideal for compact, scalable smart city solutions, contributing to the overall modularity and responsiveness of the SMARTGLO infrastructure.



12. NEO-6M GPS Module with EEPROM:

The NEO-6M GPS Module with EEPROM is a vital component in the SmartGlo system, enabling precise geolocation capabilities essential for emergency response and real-time monitoring. This module receives satellite signals to determine accurate latitude and longitude coordinates, which are crucial for pinpointing the location of streetlight units during incidents such as accidents, panic alerts, or suspicious activity. The integrated EEPROM allows the module to retain configuration settings even after power cycles, ensuring consistent performance and faster satellite acquisition. In SmartGlo, the GPS data is transmitted to cloud platforms via GSM or Wi-Fi.



13. Red LED (Basically alert signal gets light on):

The Red LED serves as a visual alert mechanism in the SmartGlo system, designed to signal emergency events and draw immediate attention to critical situations. Activated by triggers such as panic button presses, abnormal motion detection, or audio anomalies like crashes or gunshots, the Red LED provides a clear, high-visibility indication that an incident has occurred. Its bright illumination ensures that pedestrians, drivers, and nearby responders can quickly identify the affected streetlight unit, enhancing situational awareness and safety. Integrated with the microcontroller, the LED responds in real-time to sensor inputs and remains active until the alert is acknowledged or resolved. This simple yet effective component plays a vital role in SmartGlo's emergency response framework, reinforcing its goal of creating safer and more responsive urban environments.



14. Lithium Ion Battery- 3.7 V 3000mAh:

Here's a paragraph you can include in Chapter 4 under hardware components for the **Lithium-Ion Battery (3.7V, 3000mAh)** in your SmartGlo project: Lithium-Ion Battery – 3.7V, 3000mAh The Lithium-Ion Battery rated at 3.7V and 3000mAh is a key power source in the SmartGlo system, providing reliable and efficient energy storage for uninterrupted operation. Paired with solar panels, this rechargeable battery ensures that the smart streetlight units remain functional even during power outages or low sunlight conditions. Its high energy density and compact form factor make it ideal for embedded applications, supporting components such as sensors, microcontrollers, and emergency alert systems. The 3000mAh capacity allows for extended runtime, enabling continuous monitoring and responsiveness throughout the night. Integrated with power management circuitry, the battery supports safe charging and discharging cycles, contributing to the overall sustainability and resilience of the SmartGlo infrastructure.



15. NodeMCU ESP8266

The NodeMCUESP8266 is a compact, Wi-Fi-enabled microcontroller that serves as the central processing unit in the SmartGlo system. It is responsible for collecting data from sensors, executing control logic, and transmitting alerts to cloud platforms. With built-in support for IoT applications, the ESP8266 enables seamless integration with wireless networks, allowing real-time communication between streetlight units and remote monitoring dashboards. Its GPIO pins facilitate connections to components like PIR sensors, panic buttons, LEDs, and GPS modules, while its low power consumption ensures energy efficiency—especially when paired with solar-powered setups. The NodeMCU's programmable environment and compatibility with platforms like Arduino IDE make it ideal for rapid development and deployment in smart city infrastructure. In SmartGlo, it plays a pivotal role in enabling intelligent automation, emergency responsiveness, and data-driven decision-making.



4.3 Requirement Analysis Summary

This chapter talks about various hardware and software tools that are necessary in order to implement this project. It provides details of software and languages that will be used and also lists the minimum requirements needed to run the project.

CHAPTER 5

SYSTEM DESIGN

System design is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements. Systems design could be seen as the application of systems theory to product development. Object-oriented analysis and design methods are becoming the most widely used methods for computer systems design. The UML has become the standard language in object-oriented analysis and design.

5.1 Logical Design:

The logical design of the SMARTGLO system outlines how the different modules function and interact to support the smart city infrastructure. The system includes the following modules:

- **Automated Incident Detection:** Integrated audio sensors will detect high-frequency sounds such as accidents, crimes, or gunshots, automatically activating alarms and alerting emergency services.
- **Emergency Alert Response:** Streetlights equipped with emergency buttons will allow individuals to trigger an instant alarm buzz. Alerts will be sent in real time to a central monitoring dashboard and local authorities with precise location data.
- **On-Site Emergency Resources:** Each unit will be equipped with a first-aid kit and fire extinguisher, enabling immediate response to emergencies before professional help arrives.
- **Energy Efficiency in Campus Roads:** Motion sensors (IR) will control lighting in low-traffic campus areas, automatically switching lights on only when movement is detected.



Fig 5.1: Logical Design

SMARTGLO

Each of these modules communicates with the central Control Unit, which processes data from the sensors and sends appropriate commands to activate or alert the user. The design is structured for real-time data processing, event-triggered actions, and user notifications.

5.2 Design Goal:

The SMARTGLO project aims to create a robust and efficient smart city management system by automating key urban services and integrating advanced technologies. The design goals are outlined below:

1. Enhance Public Safety:

- Integrate emergency alert systems such as panic buttons and audio-based detection (crashes, gunshots) to enable instant emergency response.
- Deploy flashing beacon lights and sirens for real-time alerts to pedestrians, vehicles, and authorities.



Fig 5.2: Design Goal

2. Energy Efficiency:

- Implement adaptive street-light brightness control based on traffic density and ambient light.
- Replace fixed-timer operations with intelligent automation to minimize energy wastage.
- Use solar panels and battery backups to ensure uninterrupted eco-friendly power supply.

3. Real Time Monitoring & Response:

- IoT-enabled communication for continuous monitoring of incidents and system health.
- Automated detection of abnormal sounds or vibrations to trigger alerts instantly.
- Cloud-based dashboards for authorities to track and manage events remotely.

4. Emergency Response:

SMARTGLO

- Equip every streetlight with first-aid kits and fire extinguishers for quick citizen response before rescue teams arrive.
- Ensure accessibility and maintenance of these safety resources for maximum readiness.

5. Scalability & Integration:

- Modular system design that can be expanded city-wide and integrated with other smart-city networks (CCTV, traffic systems, etc.).
- Open IoT architecture enabling future upgrades like AI-based predictive alerts.

5.3 System Architecture:

The System Architecture of the SMARTGLO project is designed to provide an intelligent, automated, and responsive streetlight network that enhances urban safety and energy efficiency. The architecture integrates multiple functional units, including sensors, controllers, communication modules, and cloud-based monitoring systems. Each smart streetlight functions as an independent node within the network, equipped with sensors for motion detection, sound recognition, and ambient light measurement. These sensors continuously collect real-time environmental data to identify activities such as vehicle movement, accidents, or unusual sounds.

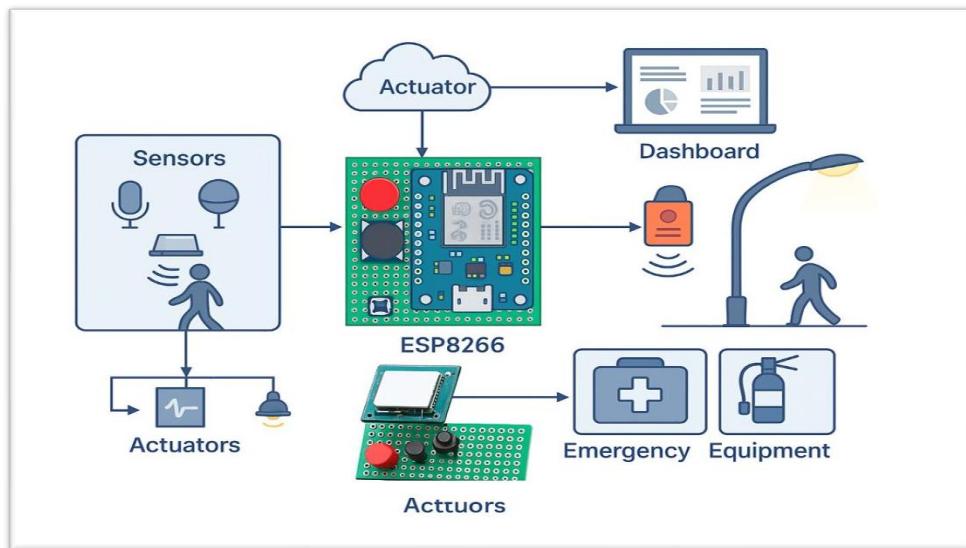


Fig 5.3: System Architecture

• User Interface:

The User Interface (UI) of the SMARTGLO system provides an interactive and user-friendly dashboard that enables real-time monitoring and control of streetlight operations. It displays essential parameters such as light status, motion detection, emergency alerts, and power levels. The UI is connected to the ESP8266 module through cloud connectivity. It allows authorized users to view alerts, control

SMARTGLO

lighting manually, and track system performance efficiently. The simple and clear layout ensures quick response and effective management of streetlight functions, contributing to improved urban safety and energy efficiency.

- **Sensor Modules:**

The sensor modules in the SMARTGLO system play a crucial role in collecting real-time environmental data for intelligent streetlight operation. The system includes an IR sensor for motion detection, which activates the light when movement is detected, and an LDR sensor to monitor ambient light intensity for automatic brightness control. Additionally, audio sensors are used to detect abnormal sounds such as crashes or alarms, triggering emergency responses. These sensors work in coordination with the ESP8266 microcontroller, which processes the input data and communicates with the cloud for remote monitoring. The integration of multiple sensors ensures accurate data collection, automated operation, and enhanced public safety.

- **Control Unit:**

The control unit is the central component of the SMARTGLO system, responsible for processing sensor inputs and executing corresponding actions. It is built around the ESP8266 microcontroller, which collects data from various sensors such as the IR, LDR, and audio sensors, and processes it to control streetlight operation and emergency responses. The control unit manages real-time communication with the cloud through Wi-Fi, enabling remote monitoring and control via the Blynk IoT platform. It also triggers outputs such as turning the lights ON when motion is detected, activating buzzers during emergencies, and sending alerts to the central dashboard. This unit ensures seamless automation, efficient data handling, and reliable system performance.

- **Communication Protocols:**

The SMARTGLO system employs efficient communication protocols to ensure seamless data transmission between the sensors, control unit, and cloud platform. The ESP8266 microcontroller utilizes Wi-Fi connectivity to establish communication with the Blynk IoT cloud, enabling real-time monitoring and remote control of streetlight operations. Data such as sensor readings, emergency alerts, and system status are transmitted securely through the internet using MQTT and HTTP protocols, ensuring reliability and low latency. These communication protocols facilitate continuous synchronization between hardware components and the cloud interface, allowing authorities to receive instant notifications and manage the system efficiently from any location.

- **Actuators & Output Device:**

The actuators and output devices in the SMARTGLO system are responsible for executing

SMARTGLO

streetlight, turning it ON only when motion is detected through the IR sensor. Additionally, emergency alerts trigger audio-visual indicators like flashing beacon lights and buzzers to notify nearby individuals and authorities. These actuators ensure that the system responds promptly to real-time conditions, enhancing safety, energy efficiency, and overall system reliability.

- **Data Storage & Analytics:**

The SMARTGLO system incorporates data storage and analytics to ensure effective monitoring and performance evaluation. Sensor data such as motion detection events, light intensity levels, and emergency alerts are transmitted via the ESP8266 to the Blynk IoT cloud platform, where they are securely stored. This stored data is used to generate analytical insights, including patterns of streetlight usage, frequency of emergency incidents, and overall energy consumption. Through cloud-based visualization and historical analysis, system administrators can monitor performance trends, optimize energy utilization, and enhance maintenance scheduling. The integration of storage and analytics ensures data-driven decision-making for improved efficiency and long-term sustainability.

- **Security:**

The SMARTGLO system incorporates multiple security measures to ensure safe and reliable operation of its IoT-based infrastructure. All data transmitted between the ESP8266 microcontroller and the Blynk cloud platform is protected using encrypted communication protocols, preventing unauthorized access or data tampering. User authentication is implemented on the monitoring dashboard to restrict control access to authorized personnel only. Additionally, system logs are maintained to track activity and detect any abnormal operations. These security features safeguard sensitive information, maintain system integrity, and ensure trustworthy communication across the network, contributing to a secure and dependable smart streetlight system.

- **Scalability and Future Proofing:**

The SMARTGLO system is designed with scalability and future-proofing in mind to accommodate technological advancements and urban expansion. Its modular architecture allows additional streetlight units and sensors to be integrated seamlessly without altering the core system design. The use of the ESP8266 microcontroller and cloud-based IoT connectivity ensures compatibility with upcoming communication standards and smart city frameworks.

5.4 Gantt Chart:

A Gantt chart is a project management tool that visually represents the timeline, tasks, and

SMARTGLO

milestones of a project. It helps in planning, scheduling, and tracking the progress of activities, ensuring efficient time management and resource allocation. By organizing tasks into a sequential or parallel timeline, a Gantt chart provides a clear overview of the project workflow, making it easier to identify dependencies, prioritize activities, and meet deadlines.

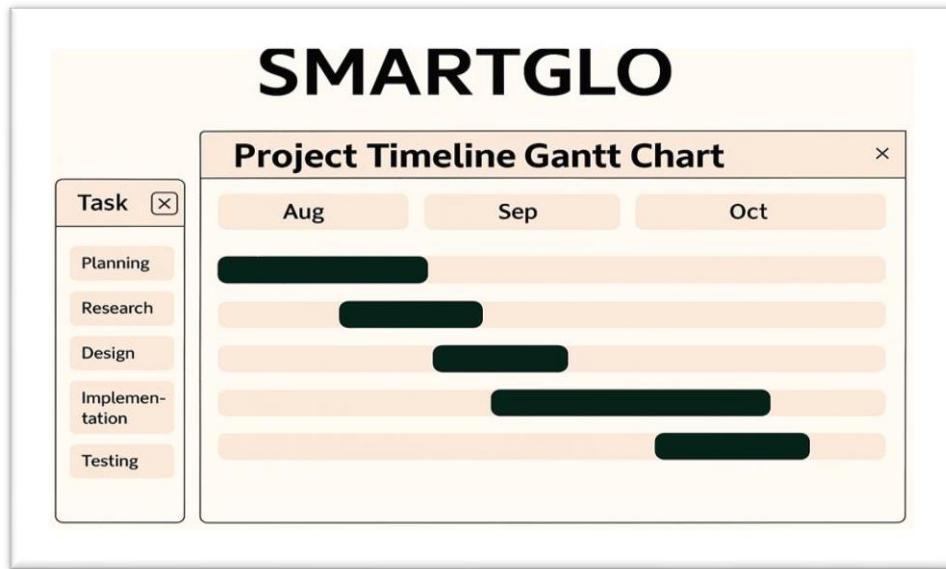


Fig 5.4: Gantt chart

5.5 System Design Summary:

This chapter shows the detailed design of the architecture, components, modules, interfaces, and data for the proposed system to satisfy specified requirements. It shows various standard UML diagrams that are needed to design the system. It provides a visualization of how the data will flow among various components of the system.

CHAPTER 6

SYSTEM IMPLEMENTATION

The implementation of the SmartGlo system focuses on integrating hardware, software, and communication modules to create an intelligent, energy-efficient, and user-friendly smart lighting solution. The system is designed to provide automated control of lighting based on user preferences, environmental conditions, and remote access via mobile and cloud platforms. The hardware implementation consists of a microcontroller (such as ESP32 or Arduino), RGB + tunable white LED bulbs, motion and ambient light sensors, and Wi-Fi/Bluetooth communication modules. The microcontroller acts as the central processing unit, receiving sensor data and executing control commands for the light intensity and color adjustment. The power supply circuit ensures stable voltage for all components, while safety measures are incorporated to protect against overcurrent or short circuits.

The software implementation includes both the embedded program and the user interface application. The embedded code is developed using Arduino IDE or equivalent, programmed to handle sensor input, manage communication protocols (MQTT or HTTP), and control the LED driver according to user settings. The mobile or web-based SmartGlo app enables users to control brightness, color temperature, and lighting modes manually or through automation schedules. Integration with voice assistants like Alexa or Google Assistant provides added convenience.

6.1 Module Description:

The SmartGlo system is divided into several functional modules that work together to provide intelligent, user-friendly, and energy-efficient lighting control.

1. Power Supply Module:

This module provides stable and regulated power to all components of the system, including the microcontroller, sensors, and LED lights. It converts AC mains supply to a low-voltage DC output suitable for electronic circuits

2. Microcontroller Module:

The microcontroller (such as ESP32 or Arduino) acts as the core control unit of the system. It receives input signals from sensors, processes the data, and controls the output to the LED driver based on predefined conditions or user commands.

SMARTGLO

3. Lighting Module:

This module includes the RGB + Tunable White LED bulb, which supports multiple color and brightness settings. It is driven by a PWM (Pulse Width Modulation) control signal from the microcontroller to vary intensity and color temperature as per user preferences or automation.

4. Communication Module:

Responsible for enabling wireless communication between the SmartGlo device and the user's smartphone or cloud. It can use Wi-Fi, Bluetooth, or IoT protocols (like MQTT or HTTP) to exchange data. This allows remote access, real-time control, and monitoring of lighting status through the app or voice assistant.

6.1.1 Data Acquisition:

The Data Acquisition module plays a crucial role in the SmartGlo system, serving as the interface between the physical environment and the digital control system. Its main function is to sense, collect, and transmit environmental and operational data from various input devices to the central processing unit or cloud server for further analysis and intelligent decision-making.

This module utilizes a combination of analog and digital sensors to monitor parameters such as ambient light intensity, temperature, humidity, motion, and user interaction. For instance, an LDR (Light Dependent Resistor) is used to measure light levels, enabling the system to automatically adjust the lamp's brightness. A PIR (Passive Infrared) sensor detects human movement to activate or dim the light when motion is sensed or absent, ensuring energy efficiency. Additional sensors like DHT11 or DHT22 can be included to measure temperature and humidity for enhanced comfort control.

6.1.2 Data Processing Phase:

1. Data Reception:

The microcontroller (such as ESP32 or Arduino) receives continuous streams of data from various sensors integrated in the Data Acquisition module. This includes input from the LDR sensor (light intensity), PIR sensor (motion), and temperature/humidity sensors.

2. Signal Conditioning:

Before processing, raw sensor signals may contain electrical noise, fluctuations, or environmental interference.

SMARTGLO

Signal conditioning techniques such as filtering, amplification, and smoothing are applied to clean the data. This ensures the reliability and stability of sensor readings before further computation.

3. Analog-to-Digital Conversion (ADC):

Since the microcontroller processes digital data, any analog signals (e.g., from LDR or temperature sensors) must be converted to digital form. The built-in ADC module converts voltage levels into numeric digital values. This allows the controller to analyze and compare sensor inputs precisely for automation purposes.

4. Data Validation:

The system checks incoming sensor data for accuracy and consistency. Faulty or missing values are detected through predefined error-checking routines. Invalid data (due to noise or faulty sensors) is either corrected using previous valid data or ignored to prevent incorrect control actions.

6.1.3 Action/Output Phase:

1. Execution of Control Commands:

- After the data has been analyzed and decisions are made in the processing phase, specific control signals are generated.
- These signals are sent from the microcontroller's output pins to actuators or driver circuits that directly control the SmartGlo lighting system.

2. Activation of Output Devices:

- The key output device in the SmartGlo system is the LED light module, which can change brightness, color, or color temperature.
- The microcontroller uses PWM (Pulse Width Modulation) signals to control LED intensity smoothly.

3. Relay or Driver Control:

- For high-power operations or electrical isolation, the system may employ transistor driver circuits or relay modules.
- These components act as intermediaries between the microcontroller and the LED power circuit, ensuring safe and reliable switching operations.

SMARTGLO

- The microcontroller communicates through Wi-Fi or Bluetooth protocols, executing commands such as “turn off lights,” “set brightness to 60%,” or “change to warm white.”

4. User Feedback Indication:

- The system provides visual or digital feedback to confirm that an action has been executed successfully.
- For example, the app interface updates status indicators (ON/OFF, brightness level, color tone), or an LED indicator on the device blinks briefly after command execution.
- This ensures transparency and user confidence in the system’s responsiveness.

5. Energy Optimization:

- The Action Phase also ensures power efficiency by controlling brightness only as needed.
- When no motion is detected for a defined period, lights automatically dim or switch off, reducing unnecessary energy consumption.
- Smart algorithms balance illumination and power saving intelligently.

6. Safety and Fault Handling:

- Safety mechanisms are incorporated to prevent over-current, overheating, or incorrect switching.
- In case of sensor malfunction or command failure, the system enters a safe fallback mode (e.g., default brightness level or system shutdown) to protect components.

6.1.4 Data Flow:

Level 0 (Context Diagram)

External Entities:

- User / Public → Presses emergency button or triggers event.
- Environment → Provides real-world data (light, sound, motion).
- Authorities / Control Center → Receives alerts and notifications.

Level 1 (Detailed Data Flow)

1. Data Acquisition Module

SMARTGLO

- Inputs:
 - Light intensity (LDR sensor)
 - Motion (PIR sensor)
 - Emergency button input
- Outputs:
 - Raw sensor data → Data Processing Unit

2. Data Processing Module

- Inputs: Raw sensor data from acquisition unit
- Processes:
 - Signal filtering, ADC conversion, and validation
 - Event detection (e.g., loud sound, motion, low light)
 - Decision-making using threshold and logic conditions
- Outputs:
 - Control signals → Action/Output Unit
 - Alert data → Cloud / Monitoring Server

3. Action / Output Module

- Inputs: Processed control signals
- Actions:
 - Adjust LED brightness / color temperature
 - Activate alarms for emergency alerts
 - Send notifications to authorities
- Outputs:
 - Physical light control, buzzer activation, data to cloud

SMARTGLO

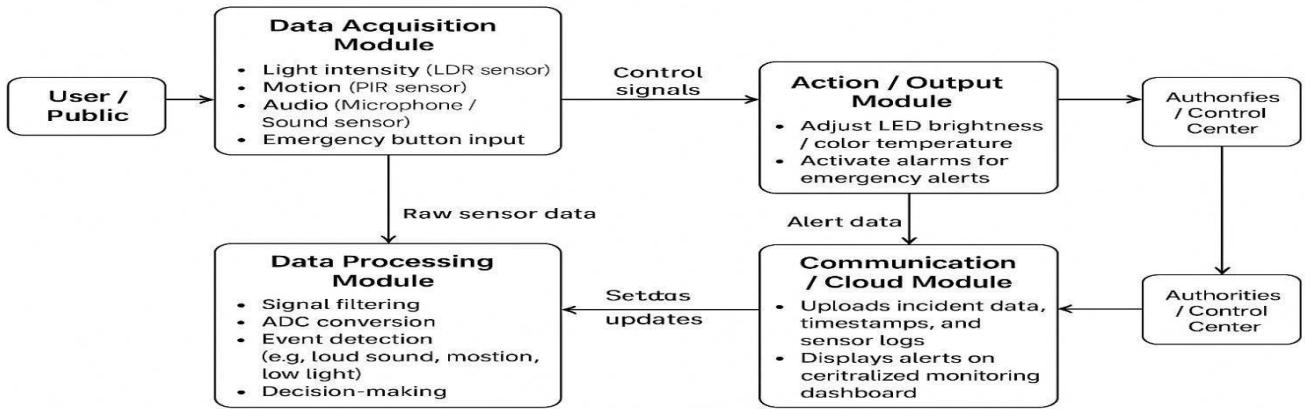


Fig 6.1: Data Flow

6.2 Program code:

CODE:

```

#include <SoftwareSerial.h>
#include <TinyGPS++.h> #include
<ESP8266WiFi.h> #include
<ESP8266WebServer.h> #include
<Adafruit_GFX.h> #include
<Adafruit_SSD1306.h>

// ----- PIN CONFIG -----
#define RXPin D7
#define TXPin D8
#define BUTTON_PIN D3
#define BUZZER_PIN D5
#define LED_PIN D6

// ----- GPS SETUP -----
static const uint32_t GPSBaud = 9600;
TinyGPSPlus gps;
SoftwareSerial gpsSerial(RXPin, TXPin);
// ----- OLED SETUP -----
#define SCREEN_WIDTH 128
    
```

SMARTGLO

```
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, -1);

// ----- WiFi + Server -----
const char* ssid = "Airtel_Tarai";
const char* password = "9008326585@Skt";
ESP8266WebServer server(80);

bool emergencyActive = false;
unsigned long buttonPressTime = 0;
double lat = 0.0, lng = 0.0;

// ----- SETUP -----
void setup() {
    Serial.begin(9600);
    gpsSerial.begin(GPSBaud);

    pinMode(BUTTON_PIN, INPUT_PULLUP);
    pinMode(BUZZER_PIN, OUTPUT);
    pinMode(LED_PIN, OUTPUT);
    digitalWrite(BUZZER_PIN, LOW);
    digitalWrite(LED_PIN, LOW);

    // OLED init
    if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
        Serial.println("OLED init failed");
        while (true);
    }
    display.clearDisplay();
    display.setTextSize(1);
    display.setTextColor(SSD1306_WHITE);

    // WiFi connect
    WiFi.begin(ssid, password);
    Serial.print("Connecting to WiFi");
    while (WiFi.status() != WL_CONNECTED) {
```

SMARTGLO

```
Serial.println("\nConnected! IP: " + WiFi.localIP().toString());\n\n// Setup server\nserver.on("/", handleRoot);\nserver.begin();\n\ndisplayNormal();\n}\n\n// ----- MAIN LOOP ----- \nvoid loop() {\n    server.handleClient();\n\n    // GPS Update\n    while (gpsSerial.available()) {\n        gps.encode(gpsSerial.read());\n        if (gps.location.isValid()) {\n            lat = gps.location.lat();\n            lng = gps.location.lng();\n        }\n    }\n\n    // Check Button State\n    if (digitalRead(BUTTON_PIN) == LOW) {\n        if (buttonPressTime == 0) buttonPressTime = millis();\n        if (millis() - buttonPressTime > 3000 && !emergencyActive) {\n            activateEmergency();\n        }\n    } else {\n        buttonPressTime = 0;\n    }\n\n    // Display in normal mode\n    if (!emergencyActive) {\n        displayNormal();\n    }\n}
```

SMARTGLO

```
}

// ----- FUNCTIONS -----
void activateEmergency() {
    emergencyActive = true;
    Serial.println("EMERGENCY TRIGGERED!");
    displayEmergency();

// Blink LED and Buzzer
for (int i = 0; i < 10; i++) {
    digitalWrite(BUZZER_PIN, HIGH);
    digitalWrite(LED_PIN, HIGH);
    delay(200);
    digitalWrite(BUZZER_PIN, LOW);
    digitalWrite(LED_PIN, LOW);
    delay(200);
}
}

void displayNormal() {
    display.clearDisplay();
    display.setCursor(0, 0);
    display.setTextSize(2);
    display.println("SMARTGLO");

    display.setTextSize(1);
    display.setCursor(0, 20);
    display.println("Time:");

if (gps.time.isValid()) {
    char buffer[10];
    sprintf(buffer, "%02d:%02d:%02d", gps.time.hour(), gps.time.minute(), gps.time.second());
    display.setCursor(40, 20);
    display.println(buffer);
} else {
```

SMARTGLO

```
display.display();
}

void displayEmergency() {
    display.clearDisplay();
    display.setTextSize(2);
    display.setCursor(0, 0);
    display.println("EMERGENCY!");

    display.setTextSize(1);
    display.setCursor(0, 25);
    display.println("Sending Location...");
    display.display();
}

// ----- SERVER PAGE -----
void handleRoot() {
    String page = "<html><head><meta http-equiv='refresh' content='5'>";
    page += "<style>body{ font-family:Arial;text-align:center; }";
    page += "h1{ color:red; } p{ font-size:18px; }</style></head><body>";

    if (emergencyActive) {
        page += "<h1>⚠️ EMERGENCY ALERT ⚠️</h1>";
        page += "<p><b>Latitude:</b> " + String(lat, 6) + "</p>";
        page += "<p><b>Longitude:</b> " + String(lng, 6) + "</p>";
    } else {
        page += "<h2>System Normal</h2>";
        page += "<p>Awaiting Emergency Trigger...</p>";
    }

    page += "</body></html>";
    server.send(200, "text/html", page);
}
```

6.3 System Implementation Summary:

The implementation of the SmartGlo system focuses on developing an intelligent and safety-oriented streetlight solution that integrates IoT-based sensing, adaptive control, and emergency response features. The system consists of several modules, including data acquisition, data processing, and action/output, which work together to ensure efficient operation and intelligent decision-making. The hardware implementation involves various sensors such as an LDR for detecting ambient light, a PIR sensor for motion detection, and a sound sensor for identifying abnormal noises or accidents. An emergency button is also included for manual alert activation. These sensors are interfaced with a microcontroller, such as an ESP32 or Arduino, which acts as the central control unit responsible for receiving, analyzing, and processing sensor data. The output section consists of LED lights controlled through PWM signals for automatic brightness and color adjustment, along with a buzzer and relay circuits to manage emergency alerts.

Overall, the implementation of SmartGlo demonstrates a practical and efficient approach to smart street lighting that not only enhances energy efficiency but also improves public safety through real-time monitoring and automated emergency response. The modular design ensures scalability and easy integration with future smart city infrastructure.

CHAPTER 7

TESTING

Testing is an essential phase in the SmartGlo project, aimed at ensuring that the system functions accurately, reliably, and efficiently under various operating conditions. It verifies that each module — from hardware components such as sensors and microcontrollers to software components like the mobile application and cloud interface — performs as expected. The main goal of testing is to identify and eliminate errors, validate design requirements, and confirm that the final product meets user needs and technical specifications.

In the SmartGlo project, testing involves both hardware testing (checking connectivity, sensor readings, LED responses, and power consumption) and software testing (verifying data transmission, user interface functionality, and automation logic). Various methods such as unit testing, integration testing, and system testing are applied to evaluate the performance, reliability, and compatibility of all components. Through comprehensive testing, SmartGlo ensures a smooth, user-friendly, and energy-efficient smart lighting experience.

7.1 Validation and System Testing:

Validation and system testing are critical stages in the SmartGlo project to ensure that the overall system meets its design goals, performance standards, and user requirements. The primary objective of this phase is to confirm that the developed SmartGlo system — including hardware, software, and communication modules — functions as intended in real-world scenarios. Validation testing focuses on verifying that the final product satisfies the functional and non-functional requirements defined during the design phase. It ensures that the system delivers the desired smart lighting features, such as brightness control, color adjustment, automation through sensors, and mobile app integration.

System testing, on the other hand, involves testing the complete integrated system. All modules — data acquisition, processing, control, and output — are tested together to ensure seamless operation. This includes checking data flow between sensors and microcontrollers, ensuring accurate command execution from the mobile app, and validating real-time response to environmental changes. Through systematic validation and system testing, SmartGlo achieves high reliability, consistent performance, and user satisfaction. Any identified defects or inconsistencies are documented and corrected to ensure the final system is fully functional, stable, and ready for deployment.

SMARTGLO

7.1.1 Regression Testing:

For regression testing, the current version of the SmartGlo system is tested using automated or semi-automated test cases employed in previous versions. This ensures that all existing functionalities — such as brightness adjustment, color tuning, scheduling, and sensor-based automation — continue to work correctly after updates or modifications.

7.1.2 Recovery Testing:

Recovery testing for SmartGlo involves simulating unexpected interruptions like power loss, Wi-Fi disconnection, or app crashes to ensure the system can recover smoothly. After such failures, the system is expected to restore the previous lighting state, reconnect to the network, and resume normal operations without user intervention.

7.1.3 Security Testing:

Security testing ensures that the SmartGlo system is resistant to unauthorized access and data breaches. Tests include attempts to intercept communication between the mobile app, cloud server, and lighting devices to verify secure data transmission using encryption. The goal is to strengthen privacy protection, prevent unauthorized device control, and safeguard user data stored within the system.

7.1.4 Stress Testing:

Stress testing subjects the SmartGlo system to extreme operational conditions, such as simultaneous commands from multiple users or continuous sensor triggers. It evaluates the system's ability to handle heavy network traffic, numerous connected bulbs, and prolonged usage without failure. This helps verify the scalability, stability, and performance of SmartGlo under peak loads.

7.1.5 Performance Testing:

Performance testing measures SmartGlo's response time, power efficiency, and system resource utilization under normal and high-demand conditions. This involves testing how quickly commands are executed, how efficiently data is processed, and how much power the lighting modules consume.

7.1.6 Usability Testing:

Usability testing focuses on how intuitive and user-friendly the SmartGlo system is for end users. It involves real users interacting with the mobile application and the lighting control interface to assess ease of use, accessibility, and satisfaction.

7.1.7 Integration Testing:

SMARTGLO

Integration testing ensures that all SmartGlo components — including the sensors, microcontroller, cloud platform, and mobile app — work together as a unified system.

- **Top-Down Testing:** Begins with high-level modules like the main control logic or mobile interface, using stubs for hardware modules.
- **Bottom-Up Testing:** Starts with testing individual sensors and communication units, then integrates them into higher-level functions. A combined approach verifies smooth data exchange and consistent system performance across all integrated components.

7.1.8 Unit Testing:

Unit testing isolates and verifies individual components of the SmartGlo system, such as sensor modules, LED control functions, and Wi-Fi communication routines. Each unit is tested independently using simulated inputs to ensure correct output behavior. Black-box testing techniques are used to confirm that each module performs according to its design and functional specifications.

7.1.9 Acceptance Testing:

Acceptance testing is conducted to validate the complete SmartGlo system in real-world scenarios before deployment. It involves simulating typical usage — such as automated lighting based on ambient sensors, manual app control, and recovery after disconnections — to ensure the system meets all design objectives and user expectations. Successful acceptance testing confirms that SmartGlo is ready for installation and public use.

7.2 Testing Summary:

This chapter presents various tests performed on the SmartGlo system to verify its functionality, stability, and efficiency. Each module and the complete integrated system were tested using predefined test cases, and the actual outcomes were compared with the expected results. Any discrepancies or bugs identified during testing were corrected to enhance system reliability. The final SmartGlo system successfully passed all major test cases, ensuring dependable performance, user satisfaction, and readiness for real-world application.

During unit testing, each module such as the Data Acquisition, Data Processing, and Action/Output phases was tested independently to verify that individual functionalities operated without errors. Integration testing followed, where the interaction between these modules was examined to ensure smooth data flow and compatibility across interfaces. Regression testing ensured that newly added features did not disrupt existing functionality, while recovery testing confirmed that the system could restore operation after interruptions such as power loss or connectivity issues.

SMARTGLO

Finally, user acceptance testing (UAT) was carried out with sample users to evaluate usability, interface design, and responsiveness. The feedback collected was used to make minor adjustments for better performance and user satisfaction. Overall, the testing phase verified that SmartGlo meets functional, performance, and reliability requirements, ensuring a stable and user-friendly smart lighting solution ready for deployment.

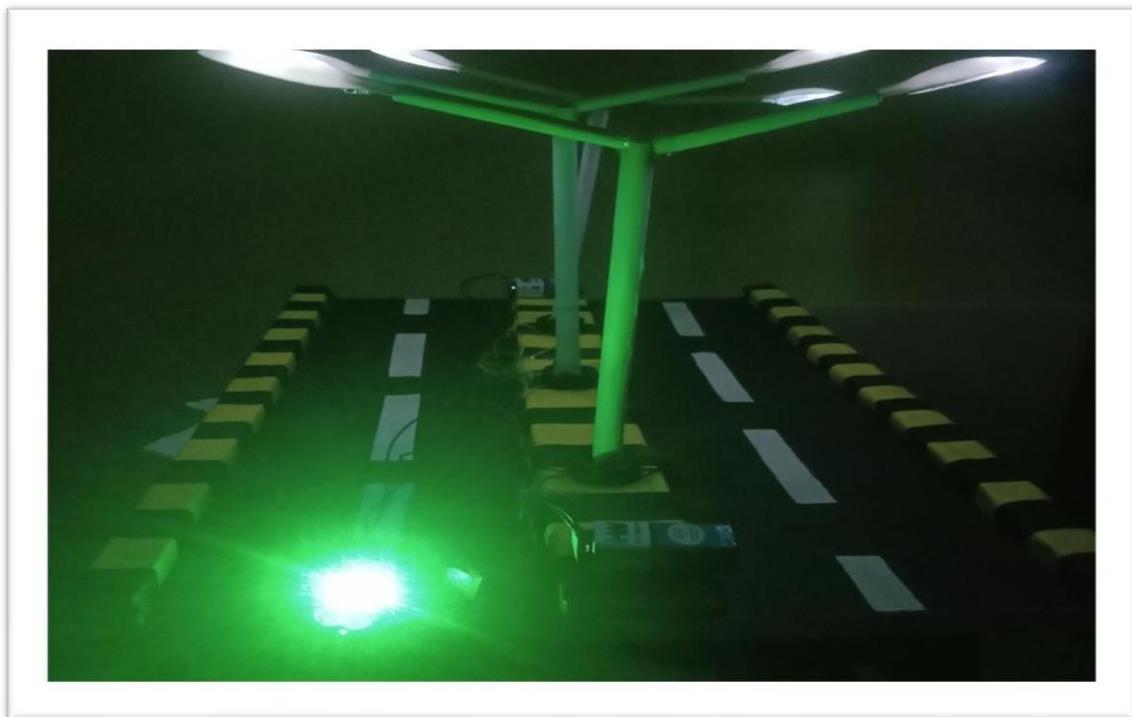
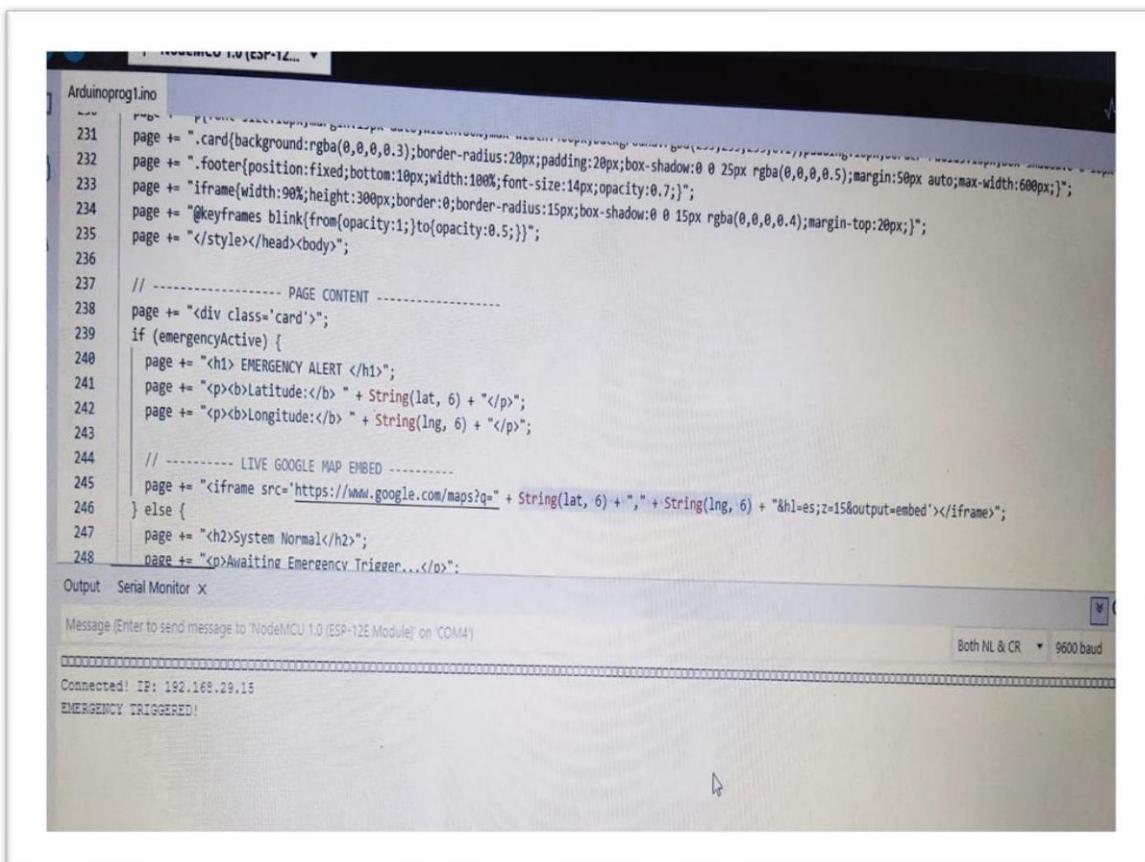
CHAPTER 8**SAMPLE OUTPUT**

Fig 8.1: Prototype Model of Automatic Streetlight System with buzzer-based Emergency Alert

```
Arduinoprog1.ino
231 page += ".card{background:rgba(0,0,0,0.3);border-radius:20px;padding:20px;box-shadow:0 0 25px rgba(0,0,0,0.5);margin:50px auto;max-width:600px;}";
232 page += ".footer{position:fixed;bottom:10px;width:100%;font-size:14px;opacity:0.7;}";
233 page += "imgkeyframes blink{from{opacity:1;}to{opacity:0.5;}}";
234 page += "</style></head><body>";
235
236 // ----- PAGE CONTENT -----
237 page += "<div class='card'>";
238 if (emergencyActive) {
239     page += "<h1>EMERGENCY ALERT </h1>";
240     page += "<p><b>Latitude:</b> " + String(lat, 6) + "</p>";
241     page += "<p><b>Longitude:</b> " + String(lng, 6) + "</p>";
242 }
243 // ----- LIVE GOOGLE MAP EMBED -----
244 page += "<iframe src='https://www.google.com/maps?q=" + String(lat, 6) + "," + String(lng, 6) + "&hl=es;z=15&output=embed'></iframe>";
245 } else {
246     page += "<h2>System Normal</h2>";
247     page += "<p>Awaiting Emergency Trigger...</p>";
248
Output Serial Monitor X
Message (Enter to send message to 'NodeMCU 1.0 (ESP-12E Module)' on 'COM4')
Connected! IP: 192.168.29.15
Both NL & CR 960
```

Fig 8.2: Serial Monitor Output Indicating Successful Wi-Fi Connection

**Fig 8.3: Working Model Showing Emergency Alert Activation****Fig 8.4: Emergency Triggered Message Displayed on Serial Monitor**

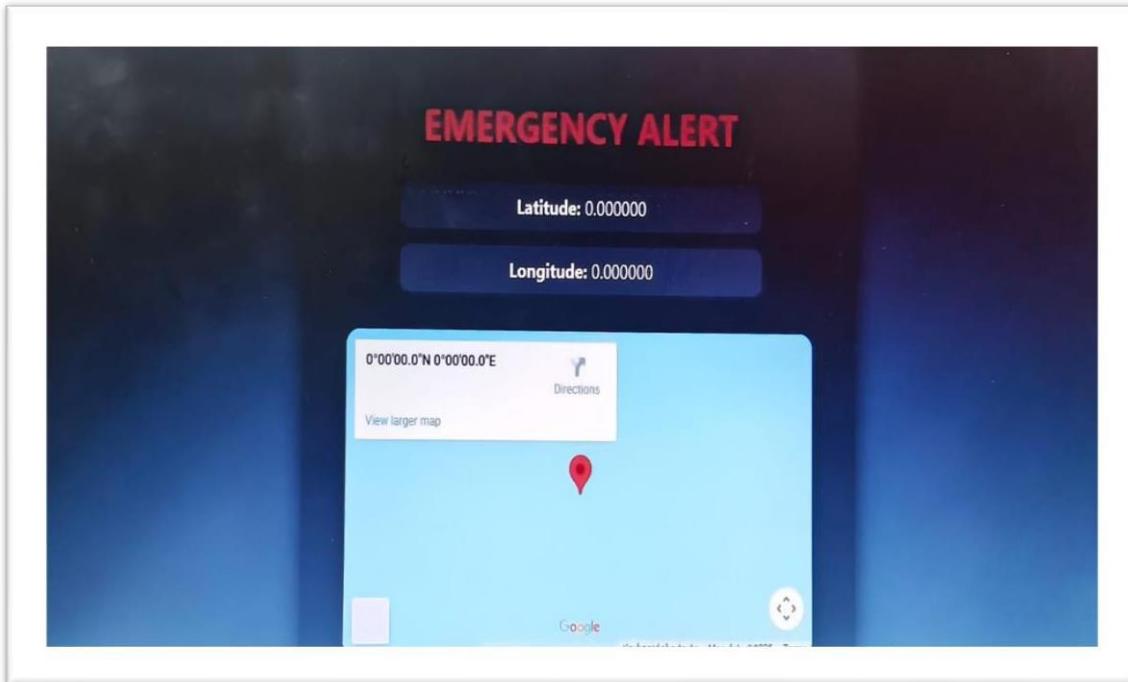


Fig 8.5: Emergency Alert Webpage Displaying Live Google Map with Location Coordinates

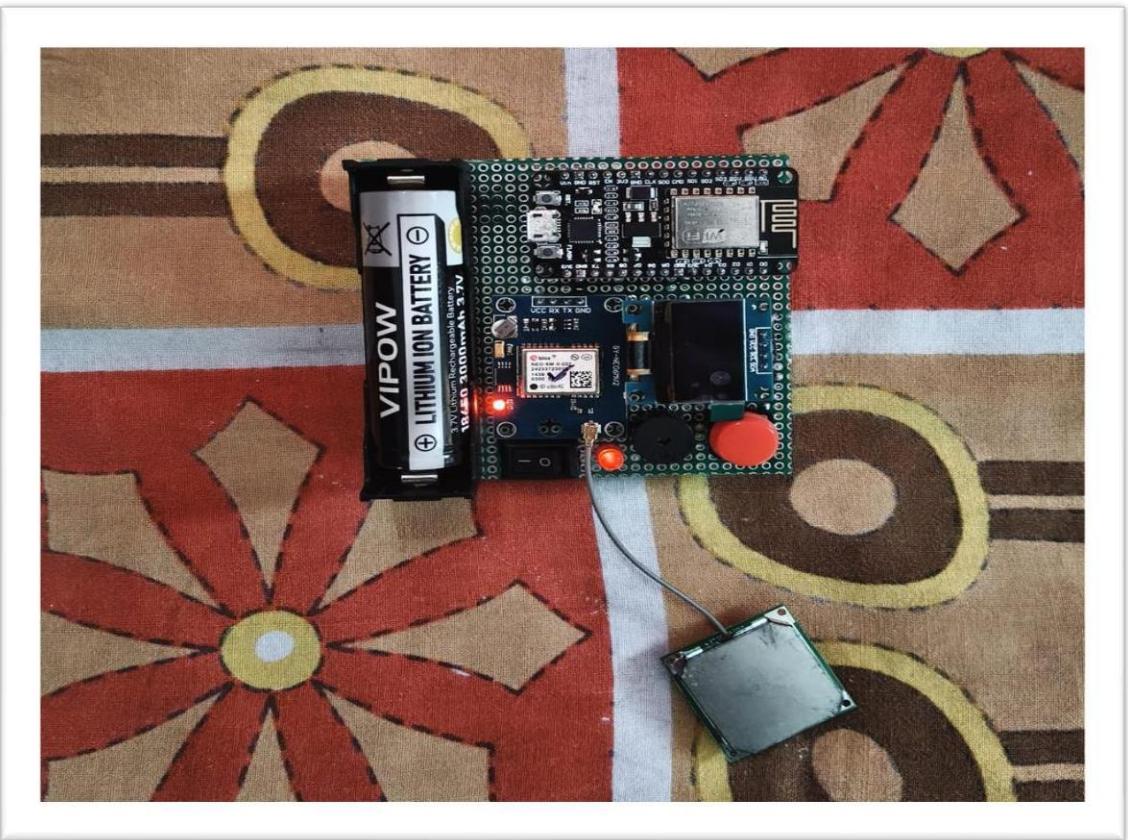


Fig 8.6: GPS Module Fetching Location (Red Light Indication)



Fig 8.7: Prototype Display Indicating Emergency Mode and Location Transmission

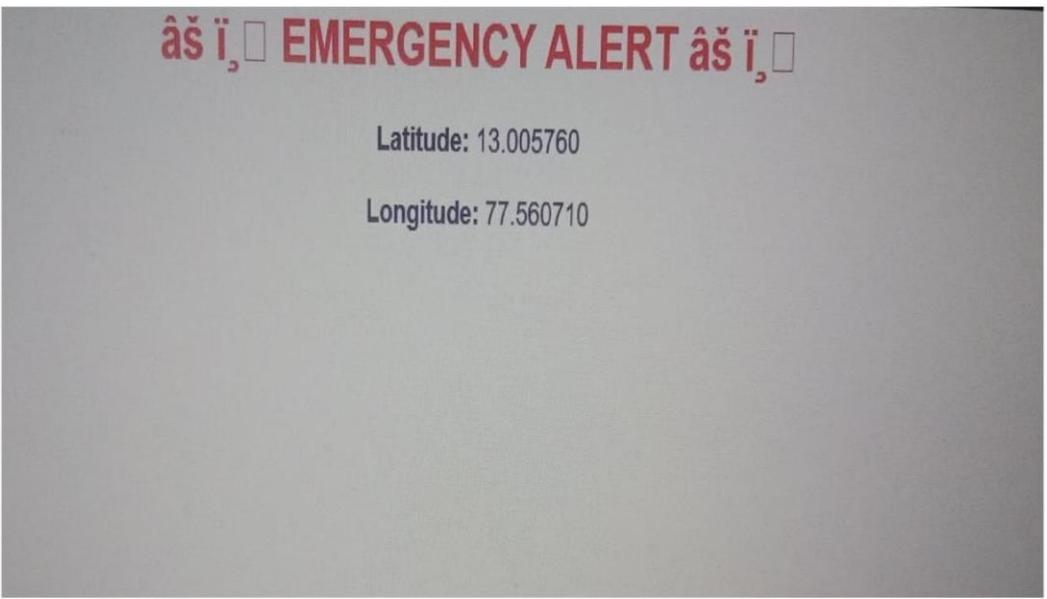


Fig 8.8: Emergency Alert Webpage Displaying Retrieved GPS Coordinates

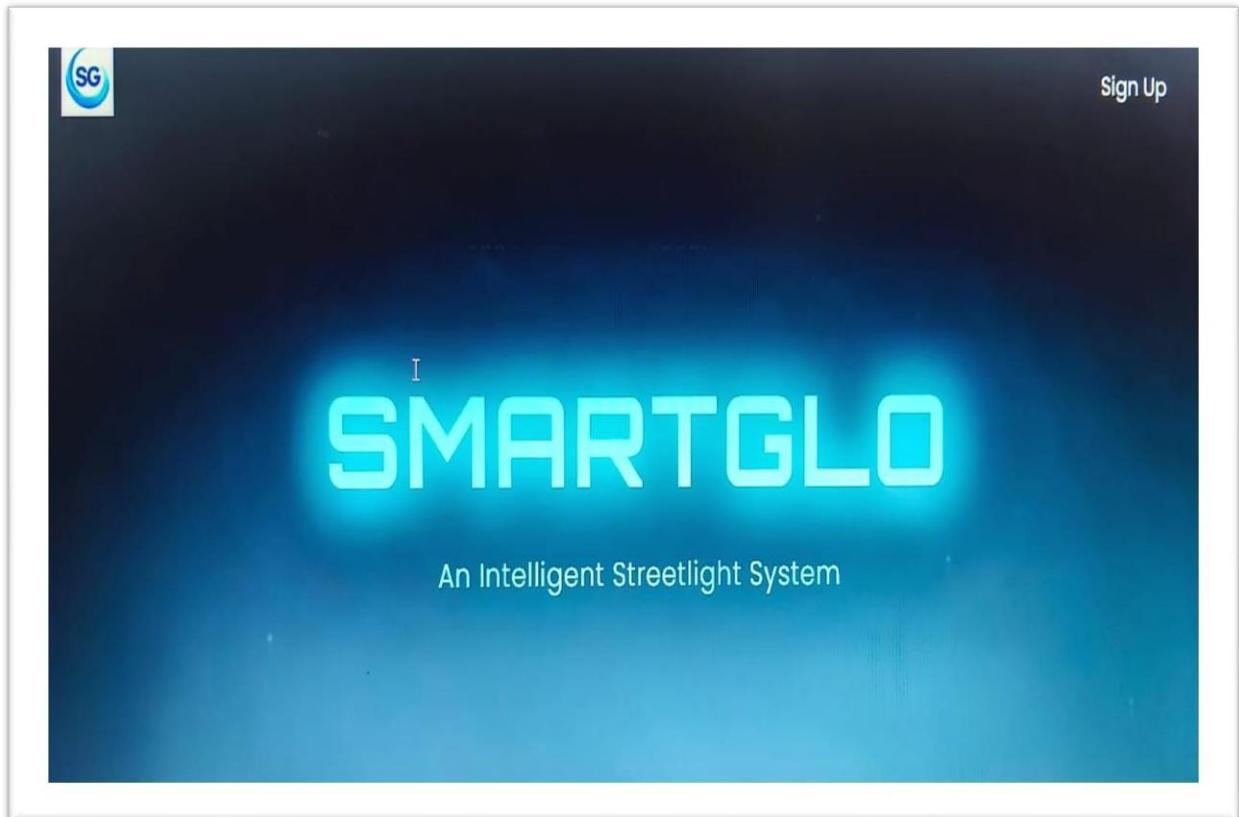
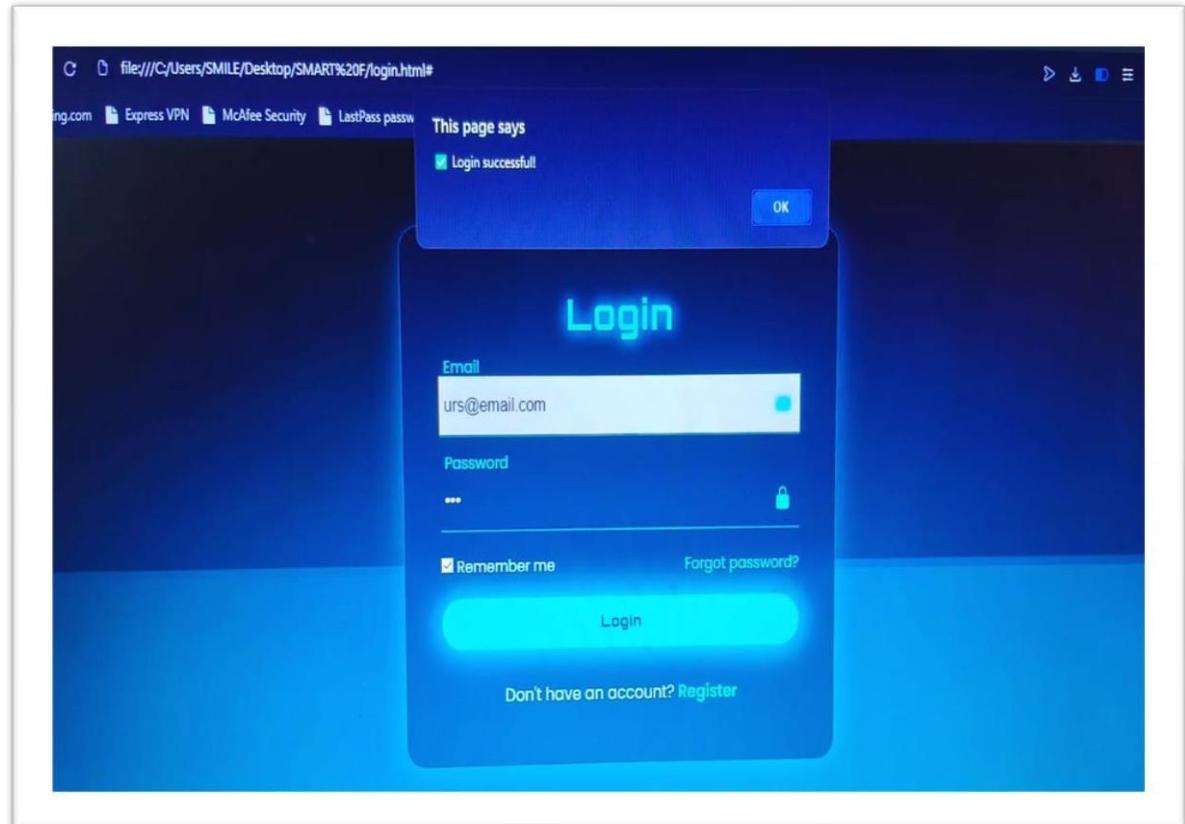
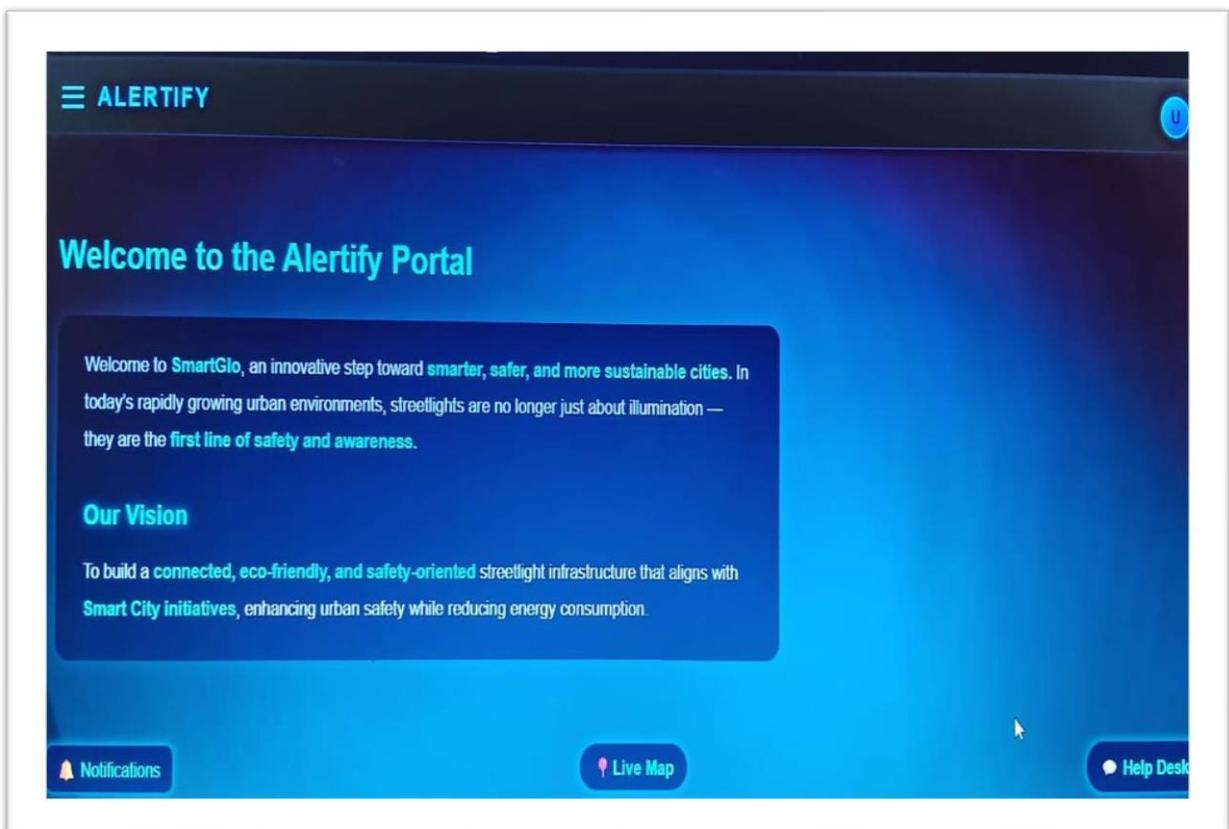
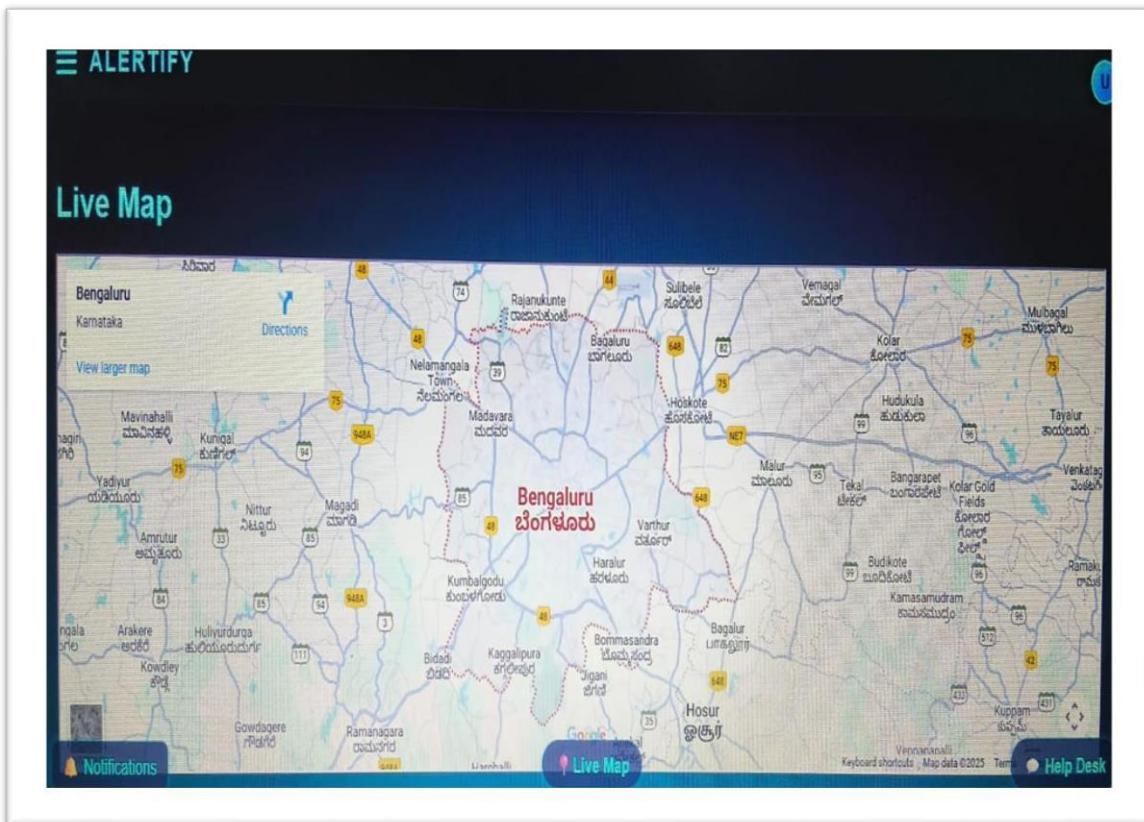
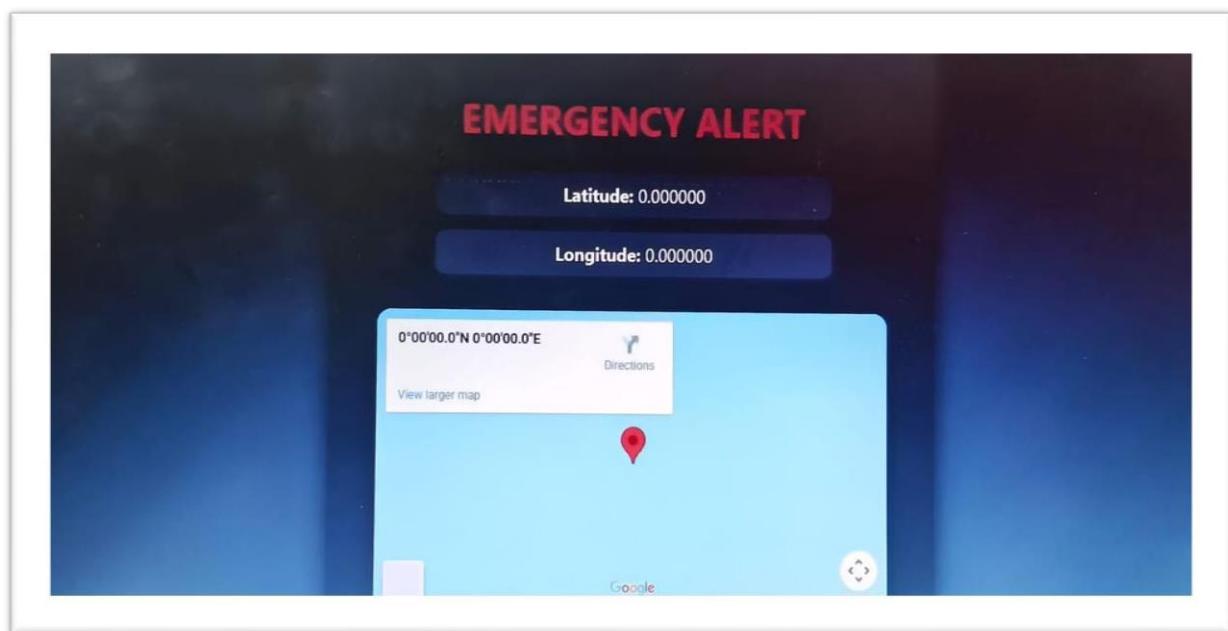


Fig 8.9: SMARTGLO Homepage

The image shows the user registration page. It has a dark blue background with a central light blue rectangular form. The form is titled 'Registration' in blue text. It contains three input fields: 'Username' with a person icon, 'Email' with a checkmark icon, and 'Password' with a lock icon. Below these is a 'Submit' button. At the bottom of the form, there is a link 'Already have an account? Login'. In the bottom right corner of the page, there is a 'Show desktop' button.

Fig 8.10 User Registration Page

**Fig 8.11: User Login Page****Fig 8.12: Alertify Portal- Dashboard Home**

**Fig 8.13: Live Map View****Fig 8.14: Emergency Alert Page**

8.1 Sample Output Summary

This chapter shows various screenshots of the system. It also shows how data processing happens at various stages of the system and the final output is also displayed. And it also shows the outer interface

CONCLUSION

The SmartGlo project successfully demonstrates the integration of IoT technology with smart lighting systems to create an energy-efficient, user-friendly, and intelligent illumination solution. Through the combination of sensors, wireless communication, and mobile app control, SmartGlo enhances comfort, convenience, and energy conservation in both residential and commercial environments.

The system's ability to automatically adjust brightness, colour, and scheduling based on user preferences and ambient conditions reflects the growing importance of automation and sustainability in modern living. Furthermore, SmartGlo contributes to the broader vision of smart cities by promoting efficient energy usage and improved user experience. In conclusion, SmartGlo not only highlights the potential of IoT in smart home innovation but also sets a foundation for future advancements, such as AI-based adaptive lighting, voice control integration, and advanced data analytics for energy optimization.

FUTURE ENHANCEMENTS:

- **Integration of Renewable Energy Sources:** SmartGlo can be powered through renewable energy, such as solar panels, to operate automated smart lighting systems efficiently. This ensures sustainable energy use, reduces dependency on the power grid, and supports eco-friendly initiatives.
- **Smart Analytics for Lighting Optimization:** By employing AI-driven analytics, SmartGlo can predict lighting requirements, analyze usage patterns, and automatically adjust brightness or color settings to enhance energy efficiency and user comfort.
- **User-Centric Mobile Application:** A dedicated SmartGlo mobile app can allow users to control lighting, schedule operations, monitor energy consumption, and receive maintenance alerts, offering a seamless and personalized experience.
- **Scalability for Future Expansion:** The SmartGlo system is designed with scalability in mind, enabling future integration with broader smart city infrastructures such as traffic systems, environmental monitoring, or public lighting networks.
- **Smart Waste and Energy Management:** SmartGlo can integrate with automated waste segregation or power monitoring systems, ensuring optimal resource management and contributing to a cleaner, greener environment.
- **Intelligent Traffic and Street Lighting:** Incorporating AI-based algorithms, SmartGlo can adapt streetlight brightness based on real-time traffic flow, pedestrian movement, and weather conditions, improving safety and reducing energy waste.
- **Community Engagement Features:** SmartGlo can include interactive features and awareness

programs to educate users on energy-saving practices, sustainable usage, and the benefits of smart lighting solutions.

- **Emergency Response Integration:** SmartGlo streetlights can be linked with emergency services to flash or change colour during accidents or natural disasters, ensuring quick identification of danger zones and improving response times.
- **Automated Incident Detection:** Integrated audio sensors will detect high-frequency sounds such as accidents, crimes, or gunshots, automatically activating alarms and alerting emergency services.

REFERENCE

- [1] Anna, K., Maharaj, G. S., Yashwanth, G., & Raju, S. S. H. (2024). *IoT Based Automatic Street Lighting System*. Nalla Narasimha Reddy Education Society's Group of Institutions, Hyderabad, India. SSRN. <https://ssrn.com/abstract=5068407>
- [2] Prakash, V., Pavithra, D., Nisha, R., & Nishanthini, P. (2020). *Automatic street light intensity control*. *International Journal of Advance Research, Ideas and Innovations in Technology*, 6(2), 258–261. ISSN: 2454-132X. Retrieved from <https://www.ijariit.com>
- [3] Srivastava, S. (2013). *Automatic Street Lights. Advance in Electronic and Electric Engineering*, 3(5), 539–542. Research India Publications. <http://www.ripublication.com/aeee.htm>
- [4] S. Bhagavathy & J. Melone, “Smart Streetlights for Smart Cities,” *IEEE Smart Grid Bulletin*, May 2022.
- [5] L. Paredes Muse, “Smart Streetlights as a Tool for Grid and City Resilience,” *IEEE Smart Grid Bulletin*, Feb 2022.
- [6] Assis Tanji, Mohamed Essaaidi, and Ghezlane Halhoul Merabet, “Towards an Integrated Smart City Platform: Enhancing Urban Services through IoT and Cloud,” *IEEE Smart Cities Conference (ISC2)*, 2020.
- [7] A. Bansal and S. Singh, “IoT Based Solar Street Lighting System with Smart Monitoring and Fault Detection,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 9, no. 8, pp. 780–785, 2020.
- [8] N. Gupta, R. Sharma, and P. Sharma, “Artificial Intelligence Driven Smart Street Light System for Sustainable Cities,” *International Journal of Computer Applications*, vol. 183, no. 42, pp. 22–28, 2022.
- [9] Government of India, *Smart Cities Mission: Guidelines and Framework*, Ministry of Housing and Urban Affairs, New Delhi, 2023.
- [10] United Nations, *Sustainable Development Goals Report*, United Nations Department of Economic and Social Affairs (UN DESA), 2022.
- [11] S. Alshatnawi, “Smart Street Lighting System Architecture Based on Internet of Things and Cloud Computing,” *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 10, no. 3, pp. 45–51, 2022.
- [12] Pooja Devi, Wajge Shubham Ravindra, and Sai Prakash S.K.L.V, “An IoT Enabled Smart Street Lighting and Emergency Response System for Smart Cities,” *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 9, no. 4, pp. 1204–1212, 2021.

- [13] Tran Phuong Nam and Nguyen Van Doai, “Application of Intelligent Lighting Control for Street Lighting Systems,” *International Journal of Electrical and Computer Engineering*, vol. 9, no. 6, pp. 4930–4937, 2019.
- [14] Luis Felipe Herrera-Quintero, Julián Vega-Alfonso, Diego Bermúdez, Luis Andrés Marentes, and Klaus Banse, “ITS for Smart Parking and Street Lighting Systems Using IoT and Cloud Approaches,” *IEEE Access*, vol. 7, pp. 145126–145139, 2019.
- [15] Elham Okhovat and Michael Bauer, “Autonomic Smart City Management Model for Energy-Efficient Streetlight Control,” *Procedia Computer Science*, vol. 190, pp. 527–534, 2021.