# CHAPTER 1

# INTODUCTION : SCOPE OF WORK AND ITS IMPORTANCE

The **Smart Street Lighting System** represents a paradigm shift in urban and rural infrastructure, offering a sustainable and energy-efficient alternative to traditional street lighting. With advancements in microcontrollers, sensor technology, and IoT integration, this system addresses critical challenges like excessive energy consumption, high operational costs, and limited adaptability of conventional lighting systems. By leveraging modern technology, smart street lights enhance urban safety, promote sustainability, and contribute to the development of smart cities.

## 1.1 SCOPE OF WORK

The scope of this project encompasses the design, development, and implementation of a smart street lighting system that can operate autonomously, adapt to environmental conditions, and provide remote monitoring capabilities. Key areas of work include:

1. **Component Integration :-**
   - Incorporating essential hardware components such as an ESP32 microcontroller, PIR sensor, LDR, LED strip, MOSFET, and power supply.
   - Ensuring seamless interaction between components for efficient operation.
2. **Energy Efficiency :-**
   - Designing the system to dynamically adjust lighting based on ambient light and motion detection, significantly reducing energy consumption.
   - Employing PWM (Pulse Width Modulation) for precise LED brightness control.
3. **IoT and Automation :-**
   - Enabling wireless communication using the ESP32's Wi-Fi capabilities for remote monitoring and control.
   - Integrating with IoT platforms to collect data and generate insights on energy usage and system performance.
4. **Prototype and Testing :-**
   - Developing a prototype to validate the functionality of the system under real-world conditions.
   - Conducting tests to optimize sensor accuracy, energy savings, and lighting effectiveness.
5. **Scalability :-**

- Creating a modular design that can be scaled for larger implementations in urban, rural, or industrial areas.

## 1.2 IMPORTANCE OF SMART STREET LIGHTING SYSTEM

The importance of this system lies in its ability to address key societal and environmental challenges:

1. **Energy Conservation :-**
   - Traditional street lighting systems consume significant energy, often operating at full brightness regardless of need.
   - Smart systems can reduce energy wastage by up to **50-80%**, aligning with global energy conservation goals.
2. **Cost Savings :-**
   - Lower energy consumption translates into reduced electricity bills and operational costs for municipalities.
   - Real-time fault detection minimizes maintenance expenses.
3. **Environmental Sustainability :-**
   - By reducing energy usage, the system lowers carbon emissions, contributing to a greener environment.
   - The potential integration of renewable energy sources, such as solar power, further enhances sustainability.
4. **Safety and Security :-**
   - Ensures well-lit streets only when necessary, enhancing pedestrian and vehicular safety.
   - Deters criminal activity by illuminating areas during motion detection.
5. **Smart City Integration :-**
   - Supports the broader vision of smart cities by enabling data-driven decisions for urban planning.
   - Can serve as a foundation for additional IoT applications, such as traffic and air quality monitoring.

The **Smart Street Lighting System** is not just a technological innovation but a necessity for modern urban and rural development. Its ability to conserve energy, reduce costs, and improve safety makes it a critical component of future infrastructure. By implementing this system, communities can take a significant step toward achieving sustainability and building resilient, smart ecosystems.

# CHAPTER 2

# METHODOLOGY

The **Smart Street Lighting System** project employs a systematic approach to design, develop, and implement an energy-efficient and adaptive lighting solution. This methodology ensures the seamless integration of hardware and software components, focusing on functionality, reliability, and scalability. Below is a step-by-step outline of the methodology followed for the project :

## 1. Requirement Analysis :-

The first step involves identifying the objectives and requirements for the smart street lighting system, including:

- Minimizing energy consumption by dynamic lighting adjustment.
- Improving safety and convenience through motion detection and ambient light sensing.
- Enabling remote control and monitoring via IoT integration.
- Ensuring scalability and cost-effectiveness for broader implementation.

## 2. System Design :-

A robust design is created to meet the functional and performance requirements. The design process includes:

- Hardware Design: Selecting suitable components, such as:
    - **ESP32 Microcontroller**: Acts as the control hub.
    - **PIR Sensor**: Detects motion for activating lights.
    - **LDR (Light Dependent Resistor)**: Measures ambient light levels to adjust brightness.
    - **MOSFET (IRF540N)**: Controls LED strip brightness.
    - **LED Strip (12V)**: Provides efficient lighting.
    - **12V Power Adapter**: Supplies power to the components.
    - **Resistor (220 ohms)**: For current regulation.
    - Breadboard and wires for circuit assembly.
- **Circuit Design**: A detailed circuit diagram is created to interconnect all components effectively.
- **Software Design**: The Arduino IDE is chosen to program the ESP32 for controlling sensor inputs and outputs.

## 3. Prototype Development :-

The prototype is assembled to test the feasibility and functionality of the system :

- Components are mounted on a breadboard for ease of testing and adjustments.
- The circuit is connected according to the design, and the ESP32 is programmed to integrate sensor data and control the LED strip.

## 4. Software Implementation :-

The ESP32 is programmed using the Arduino IDE to implement the following functions :

- Reading inputs from the PIR sensor and LDR.
- Adjusting the LED brightness dynamically based on ambient light and motion.
- Enabling wireless communication for IoT integration, allowing remote monitoring and control.

Libraries for Wi-Fi connectivity and sensor modules are utilized to streamline the coding process.

## 5. Testing and Calibration :-

The prototype undergoes rigorous testing to ensure reliable performance under varying conditions:

- Functional Testing: Verifies that sensors detect motion and light intensity accurately and that LEDs respond appropriately.
- Energy Efficiency Testing: Measures power consumption to validate energy-saving capabilities.
- Connectivity Testing: Tests IoT features such as remote monitoring and control via mobile or web platforms.
- Calibration: Adjusts sensor thresholds and lighting parameters for optimal performance.

## 6. Data Collection and Analysis :-

Data is collected during testing to evaluate system performance :

- Logs of sensor readings, energy usage, and response times are analyzed.
- Insights are used to optimize the system further.

### 7. Final Implementation :-

The refined system is deployed for real-world conditions. The modular design allows scaling the system for larger areas or integrating additional features like solar power and predictive maintenance.

## 2.1 CIRCUIT DIAGRAM

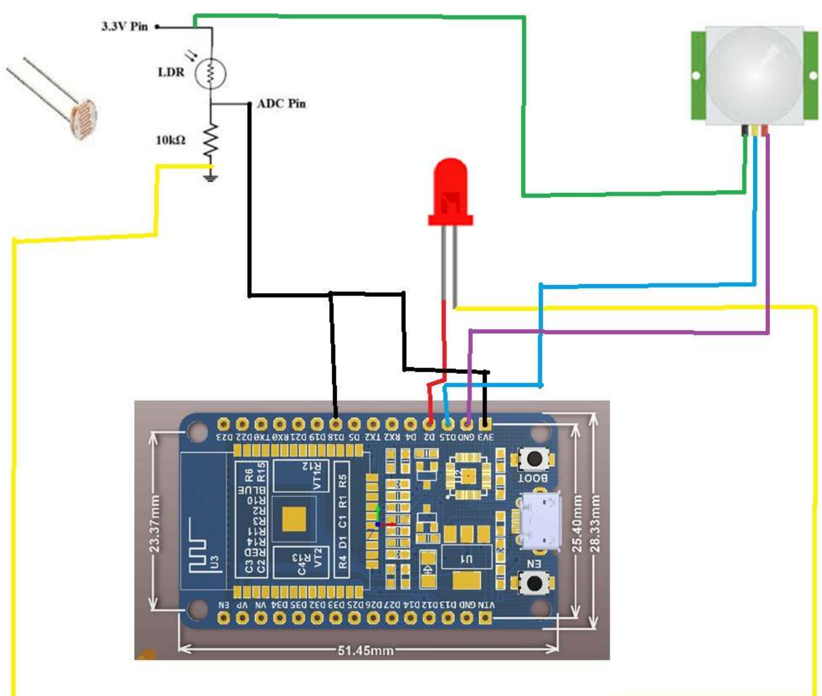



**Figure 2.1.1** Circuit Diagram

The **Smart Street Lighting System** circuit comprises key components such as the ESP32 microcontroller, LDR (Light Dependent Resistor), PIR Sensor, LED (12V), MOSFET, resistors, and a 12V power supply. The system operates to control the street light based on ambient light levels and motion detection.

1. **ESP32 (Microcontroller) :-**

The ESP32 serves as the brain of the system. It takes inputs from the LDR and PIR sensor and sends output control signals to drive the LED through the MOSFET. It decides whether to turn the LED ON or OFF based on specific conditions.

2. **LDR (Light Dependent Resistor) :-**

   - The LDR measures the ambient light intensity.
   - During the daytime, the LDR has a low resistance, generating a signal that indicates sufficient light, so the LED remains OFF.
   - At night, the LDR's resistance increases, and it sends a low signal to the ESP32, indicating low light conditions.

3. **PIR Sensor (Passive Infrared Sensor) :-**

- The PIR sensor detects motion within its range.
- It sends a HIGH signal to the ESP32 when motion is detected, indicating the presence of pedestrians or vehicles.
- If no motion is detected, the PIR output remains LOW.

4. **MOSFET (IRF540N):-**

   - The MOSFET acts as a switch for the LED.
   - It receives control signals from the ESP32. When triggered, it allows current to flow through the LED strip, illuminating it.

5. **LED Strip (12V) :-**

- The LED strip acts as the street light.
- It turns ON only if both conditions are met: nighttime (low light) and motion detected.

6. **Resistor (220 ohm):-**

   - The resistor is used to limit the current and protect the components.

7. **12V Power Adapter :-**
   - The 12V power adapter provides power to the LED strip.
   - The ESP32 operates at 3.3V, so a regulated connection to the ESP32 is necessary.

8. **Breadboard And Wires :-**
   - The breadboard is used to connect all the components together temporarily during prototyping. Wires serve as the interconnections.

## 2.2 FLOW CHART

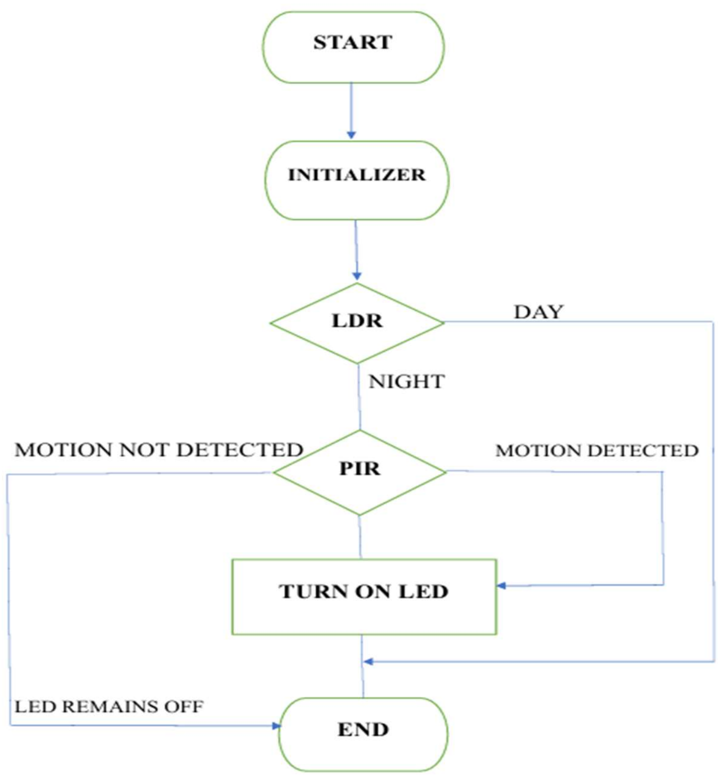



**Figure 2.2.1** Flow Chart

1. **Start :-**
   - The process begins with the initialization of the system.

2. **Initializer :-**

- The system components, such as sensors (LDR and PIR) and LED control, are initialized. This step ensures that the hardware and software configurations are ready for operation.

3. **LDR (Light Dependent Resistor) Decision :-**

- **Purpose:** The LDR detects the ambient light level to differentiate between day and night.
- **Logic:**
    - If it is **DAY** (sufficient light), the system ends the process, and the LED remains off.
    - If it is **NIGHT** (low light), the flow proceeds to the next decision step.

4. **PIR (Passive Infrared Sensor) Decision :-**

- **Purpose: The PIR sensor checks for motion in the area.**
- **Logic:**
    - If **MOTION IS DETECTED**: The LED turns on to illuminate the area.
    - If **MOTION IS NOT DETECTED:** The LED remains off, conserving energy.

5. **Turn ON LED :-**

- If motion is detected during nighttime, the LED turns on to provide illumination.

6. **END :-**

- The process ends, and the system continues to monitor the conditions (light and motion) in a loop.
    - If **LED REMAINS OFF** due to no motion or sufficient light, the process still concludes until conditions are checked again.

**Summary :-**

This flow chart demonstrates a basic yet efficient control logic for a smart street lighting system:

1. The LDR detects the light level to determine day or night.

2. During the night, the PIR sensor detects motion to decide whether the LED should be turned on.
3. If motion is detected, the LED turns on; otherwise, it remains off, ensuring energy savings.

This system optimizes power usage by illuminating only when required and contributes to energy efficiency and sustainability in urban infrastructure.

## 2.3 BLOCK DIAGRAM

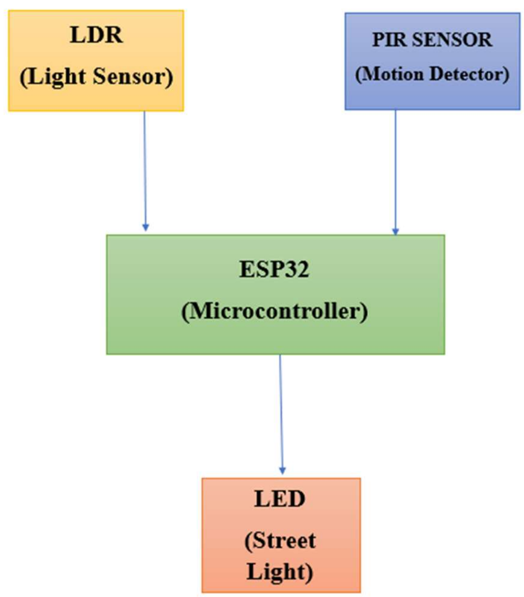



**Figure 2.3.1** Block Diagram

The given block diagram represents a **Smart Street Lighting System** designed for energy-efficient operation using an **ESP32 microcontroller**, an **LDR (Light Sensor)**, a **PIR Sensor (Motion Detector)**, and an **LED** for street lighting.

1. **LDR Sensor (Light Sensor) :-**

   - **Function :-**

     - The LDR (Light Dependent Resistor) senses ambient light intensity.
     - During the **daytime**, the LDR detects sufficient light and sends a signal to the ESP32, indicating that the light is ON.

- During the **nighttime**, the LDR detects low light conditions and notifies the ESP32 that lighting is required.

- **Connection :-**

    - The LDR is connected to the ESP32's input pin.
    - The output of the LDR is used to decide if the system should prepare for lighting operation.

2. **PIR Sensor (Motion Detector) :-**

- **Function :-**

    - The PIR (Passive Infrared) sensor detects motion within its sensing range, such as pedestrians, vehicles, or other moving objects.
    - When motion is detected, the PIR sends a **HIGH signal** to the ESP32.
    - If no motion is detected, the PIR remains in its **LOW state**, signaling no activity.

- **Connection :-**

    - The PIR sensor is also connected to an input pin on the ESP32.
    - It works in tandem with the LDR to determine if the LED (street light) should be turned ON or OFF.

3. **ESP32 (Microcontroller) :-**

- **Function :-**

    - The ESP32 acts as the central controller for the system.
    - It receives signals from both the LDR and PIR sensor and makes decisions based on the following conditions:
    - **Daytime**: LDR indicates sufficient light → LED remains OFF.
    - **Nighttime with Motion Detected**: PIR sends a HIGH signal → ESP32 turns the LED ON.
    - **Nighttime with No Motion**: PIR sends a LOW signal → ESP32 ensures the LED remains OFF to save power.

- **Operation :-**
    - The ESP32 processes the signals and controls the LED via its output pins.

4. **LED (Street Light) :-**

- **Function :-**
    - The LED serves as the street light, which is controlled by the ESP32 based on inputs from the LDR and PIR sensor.
    - The LED turns ON only under the following condition: **Nighttime** AND **Motion Detected**.
    - If either condition is false (e.g., daytime or no motion), the LED remains OFF to save energy.

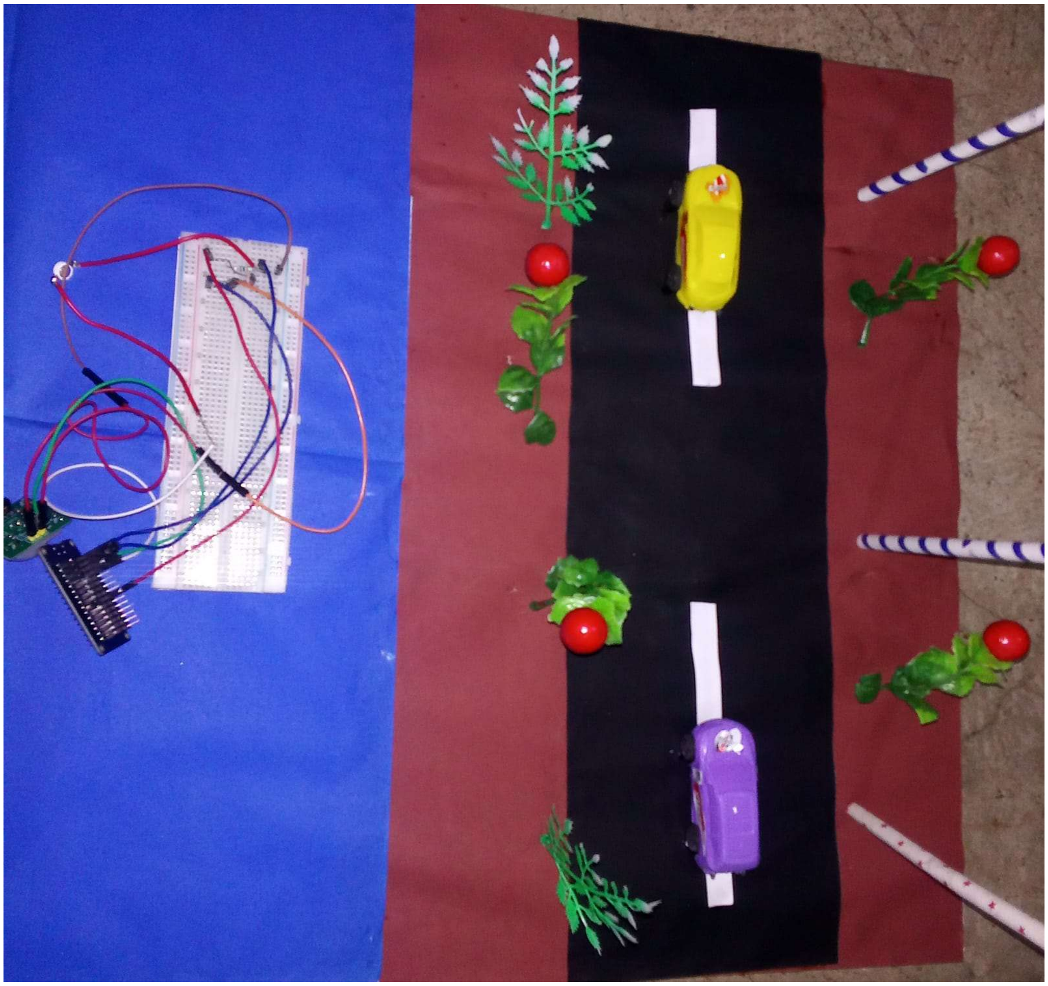
- **Connection :-**
    - The LED is connected to an output pin of the ESP32.
    - The microcontroller sends signals to activate or deactivate the LED.

## 2.4 COMPONENT LIST

| S.No. | Components | Quantity |
|---|---|---|
| 1. | ESP32 | 1 |
| 2. | LED Strip (12V, 1 meter) | 1 |
| 3. | PIR Sensor | 1 |
| 4. | LDR | 1 |
| 5. | Resistor (220 ohm) | 1 |
| 6. | 12V Power Adapter | 1 |
| 7. | Breadboard and Wires | 1 set |

**Table 2.4.2 :** List of Components

## 2.5 RESULT



The image shows a **prototype setup** for a **Smart Street Lighting System** that integrates components for motion sensing and control of street lights. Below is a detailed explanation of the result:

1. **Hardware Components:-**
    - Breadboard: Used as a platform for connecting and testing electronic components.
    - Wiring: Jumper wires are connecting different modules and sensors to the microcontroller.
    - Microcontroller (likely ESP32 or similar): The central processing unit that controls the system based on sensor inputs.
    - Sensors:
        - An LDR (Light Sensor) detects light levels (daytime or nighttime).
        - A PIR Sensor (Motion Detector) identifies the presence of moving objects (e.g., cars or people).

- LEDs or Street Lights: Lights are triggered ON or OFF based on the sensor inputs.

2. **Model of the Street:-**
    - A **miniature road model** is built with a black road strip and white markings to resemble an actual street.
    - There are **two toy vehicles** (a yellow car and a purple car) placed on the road, symbolizing vehicles that might trigger the motion sensor.
    - **Green plants and poles**: Represent street decor or light poles where the street lighting system is installed.
3. **Working of the System:-**
    - **Night Detection (LDR)**: The LDR monitors the light intensity. If the light level is low (e.g., nighttime), it signals the system that lights can be turned ON.
    - **Motion Detection (PIR Sensor)**: When a car (toy car in this case) passes by the sensor's range, the PIR sensor detects motion and sends a signal to the microcontroller.
    - This triggers the **street light (LED)** to turn ON.
    - **No Motion**: If no motion is detected, the LED remains OFF to save energy.
    - **Lights Activation**: The street lights (represented through the circuit and LEDs) will only turn ON at night when motion (vehicle or pedestrian) is detected.
4. **Outcome :-**
    - The system successfully combines **light sensing (LDR)** and **motion detection (PIR Sensor)** to automate the street lights.
    - The **street lights turn ON** when motion is detected at night, ensuring energy efficiency.
    - If there is no motion or it is daytime, the street lights remain OFF.

This prototype effectively demonstrates a **Smart Street Lighting System** where lights activate **only when necessary**, reducing energy consumption and promoting sustainable energy use. It is ideal for real-world applications like smart cities and highways.

# CHAPTER 3

# TOOLS AND TECHNOLOGIES

## 3.1 TOOLS AND TECHNOLOGIES USED :-

The development of the **Smart Street Lighting System** involves the use of specific tools and technologies to achieve an energy-efficient, automated, and IoT-enabled lighting solution. These tools and technologies span across hardware, software, and communication protocols, enabling seamless integration and functionality.

### 1. Hardware Components :-

- **ESP32 Microcontroller :-**
  - **Description:** A powerful, low-cost microcontroller with built-in Wi-Fi and Bluetooth connectivity.
  - **Usage:** Acts as the brain of the system, processing sensor data and controlling the LED strip.
- **LED Strip (12V, 1 meter) :-**
  - **Description**: Energy-efficient lighting with customizable brightness levels.
  - **Usage**: Provides illumination for the street lighting system.
- **PIR Sensor :-**
  - **Description**: A motion detection sensor that detects the presence of objects in its vicinity.
  - **Usage**: Activates lights only when motion is detected, ensuring energy savings.
- **LDR (Light Dependent Resistor) :-**
  - **Description:** A sensor that detects ambient light levels.
  - **Usage:** Adjusts the LED brightness based on surrounding light conditions.
- **MOSFET (IRF540N) :-**
  - **Description**: A power transistor used for controlling high-current devices.
  - **Usage**: Regulates the power supplied to the LED strip, enabling dynamic brightness control.
- **12V Power Adapter :-**
  - **Description**: Provides the necessary power to the system.
  - **Usage**: Powers the LED strip and other components.
- **Resistor (220 Ohm) :-**

    - **Description**: Limits current to prevent damage to components.
    - **Usage**: Ensures safe and efficient operation of the circuit.
- **Breadboard and Wires :-**
    - **Description**: Used for assembling and testing the prototype.
    - **Usage**: Facilitates easy connections and modifications during development.

## 2. Software Tools :-

- **Arduino IDE :-**
    - **Description**: An open-source software used for programming microcontrollers.
    - **Usage**: Used to write, compile, and upload code to the ESP32 microcontroller.
- **ESP32 Libraries :-**
    - **Description**: Predefined code modules for interfacing sensors, Wi-Fi, and PWM control.
    - **Usage**: Simplifies the programming of ESP32 for controlling sensors and IoT functionalities.
- **IoT Platforms :-**
    - **Description**: Cloud-based services for monitoring and controlling devices remotely.
    - **Usage**: Enables real-time data visualization, remote control, and system analysis.

## 3. Communication Protocols :-

- **Wi-Fi :-**
    - **Description**: Wireless technology for connecting devices to the internet or local network.
    - **Usage**: Enables IoT features, such as remote control and monitoring of the system.
- **PWM (Pulse Width Modulation) :-**
    - **Description**: A technique used to control the brightness of the LED strip.
    - **Usage**: Provides fine-grained control over lighting intensity.

## 4. Testing and Debugging Tools :-

- **Multimeter :-**
    - **Description**: Measures voltage, current, and resistance in circuits.
    - **Usage**: Ensures proper connections and functionality during prototyping.
- **Serial Monitor (in Arduino IDE) :-**

- **Description**: A debugging tool that displays real-time data from the microcontroller.
- **Usage**: Monitors sensor outputs and identifies issues in the code or circuit.

- **Simulation Tools :-**
  - **Examples**: Proteus, Tinkercad.
  - **Usage**: Simulates the circuit before physical implementation to ensure reliability.

## 5. Technologies :-

- **IoT (Internet of Things) :-**
  - **Description**: Connects devices to collect and exchange data over the internet.
  - **Usage**: Enables remote monitoring and control of the street lighting system.
- **Energy-Efficient Technologies :-**
  - **Description**: Combines sensors, LEDs, and PWM control to minimize energy consumption.
  - **Usage**: Aligns the system with sustainability and cost-saving goals.
- **Smart City Integration :-**
  - **Description**: A framework for implementing smart infrastructure.
  - **Usage**: Positions the system as part of broader smart city solutions.

## 3.2 CONCLUSION

The tools and technologies used in the Smart Street Lighting System project play a crucial role in achieving a sustainable and automated solution. By integrating advanced hardware like ESP32 and sensors with software tools such as Arduino IDE and IoT platforms, the project demonstrates innovation and practicality in addressing modern lighting challenges.

# CHAPTER 4

# CONCLUSION

The adoption of smart street lighting systems represents a transformative shift in urban infrastructure, combining advanced technologies such as IoT (Internet of Things), sensor networks, and automation to address contemporary urban challenges. These systems are designed to optimize energy usage, reduce maintenance costs, enhance safety, and support broader smart city initiatives, making them an integral part of modern urban planning.

## 4.1 Energy Efficiency And Environmental Impact :-

One of the primary advantages of smart street lighting is its energy efficiency. Traditional street lighting systems operate at a fixed schedule or illumination level, leading to significant energy wastage. In contrast, smart systems use motion sensors, ambient light sensors, and real-time data analysis to adjust brightness levels dynamically. Lights dim when there is no activity and brighten when pedestrians or vehicles are detected, ensuring optimal energy utilization. This approach not only reduces electricity consumption but also contributes to lowering greenhouse gas emissions, aligning with global sustainability goals.

## 4.2 Cost Savings and Maintenance Efficiency :-

Smart lighting systems significantly reduce operational costs. The integration of real-time monitoring and predictive maintenance features allows authorities to identify and address issues such as malfunctioning lights or power outages remotely. This minimizes the need for manual inspections, reduces downtime, and ensures uninterrupted service. Additionally, energy savings from the optimized use of lights lead to substantial financial benefits over time, making smart lighting a cost-effective solution.

## 4.3 Enhanced Safety and Security :-

Well-lit streets are crucial for public safety. Smart street lighting systems provide adaptive illumination, ensuring that areas with pedestrian or vehicular activity are adequately lit. This not only reduces the risk of accidents but also deters criminal activities, fostering a sense of security among residents. Emergency response systems can also be integrated, where lights can be programmed to flash or brighten in specific patterns during emergencies, aiding in quick identification and response.

## 4.4 Integration with Smart City Ecosystems :-

Smart street lighting systems act as a foundational element for broader smart city ecosystems. These systems can host additional technologies, such as environmental sensors, surveillance cameras, and communication networks, enhancing urban data collection and analysis. By integrating with traffic management, public safety, and environmental monitoring systems, smart lighting contributes to creating more efficient, sustainable, and livable cities.

## 4.5 Scalability and Future-readiness :-

Another notable aspect of smart street lighting systems is their scalability and ability to accommodate future advancements. These systems can be upgraded with new sensors or software, enabling cities to adapt to evolving technological and societal needs. This future-proof design ensures that investments in smart lighting systems remain relevant and valuable over time.

In conclusion, smart street lighting systems represent a significant leap toward sustainable urban development. They address critical challenges such as energy consumption, maintenance inefficiencies, and public safety while providing a platform for integrating advanced technologies. By reducing environmental impact, lowering costs, and enhancing quality of life, smart street lighting systems are a cornerstone of modern smart cities. Their implementation not only benefits municipal authorities and residents but also sets the stage for a more connected, intelligent, and sustainable urban future. The widespread adoption of such systems is essential for building resilient cities that meet the demands of the 21st century.

# CHAPTER 5

# FUTURE SCOPE

The future scope for smart street light systems is vast due to the increasing focus on smart cities, energy efficiency, and sustainable urban development. Here are some areas where smart street light systems have significant potential:

## 1. Energy Efficiency And Enhancements :-

- **Dynamic Brightness Control:** Use the LDR and PIR sensor to adjust the brightness of the LED strip based on ambient light levels and human/vehicle movement.
- **Scheduled Dimming:** Program the ESP32 to reduce brightness during low-traffic hours, saving energy.
- **Solar Power Integration:** Replace the 12V adapter with solar panels and a rechargeable battery system to make the system sustainable.

## 2. Advanced Automation And Control :-

- **Wireless Control:** Utilize ESP32's Wi-Fi capabilities to control the system remotely via a smartphone app or web interface.
- **Remote Monitoring:** Implement real-time fault detection for the LED strips or power supply, with alerts sent to maintenance teams.
- **Adaptive Lighting:** Introduce location-specific lighting adjustments, such as increasing brightness near pedestrian crossings or bus stops.

## 3. IoT And Smart City Integration :-

- **Data Sharing:** Use ESP32 to integrate with a larger IoT network for smart cities, sharing traffic or environmental data.
- **Environmental Monitoring:** Attach additional sensors (e.g., air quality, temperature, or noise sensors) for environmental data collection.
- **Traffic Analysis:** Use PIR sensors to gather data on traffic patterns, helping city planners optimize traffic flow.

## 4. Scalability And Customization :-

- **Expandable System:** Create modular units that can be easily scaled up to cover larger areas or integrated with additional features.

- **Customization for Specific Needs:** Configure lighting patterns or colours of the LED strip for specific applications like parks, events, or festivals.
- **Rural Applications:** Deploy cost-effective versions for rural or low-income areas to improve safety and accessibility.

## 5. AI And Machine Learning :-

- **Traffic Flow Prediction:** Use AI algorithms to analyse PIR sensor data and predict peak traffic times, adjusting light levels accordingly.
- **Maintenance Prediction:** Employ machine learning to forecast failures in the LED strip or power supply, enabling proactive maintenance.
- **Behavioural Adaptation:** Adapt lighting schedules based on observed pedestrian and vehicular movement trends.

## 6. Economic And Environmental Impact :-

- **Cost Reduction:** Optimize the use of components like MOSFETs and resistors to reduce system costs further, making it more accessible.
- **Energy Savings:** Substantial reduction in electricity consumption through smart brightness control and sustainable energy sources.
- **Light Pollution Reduction:** Use focused lighting and adjustable brightness to minimize light pollution.

## 7. Future Technology Integration :-

- **Bluetooth and LoRa Support:** Utilize ESP32's dual-mode communication (Wi-Fi + Bluetooth) or LoRa modules for long-range connectivity in remote areas.
- **5G Ready Infrastructure:** Prepare the system to support 5G small cells for improved connectivity in urban areas.
- **Augmented Reality Maintenance:** Develop AR tools for technicians to diagnose and repair the system quickly using visual cues.

## 8. Aesthetic And Functional Enhancements :-

- **Colourful Lighting:** Use RGB LED strips to provide aesthetically pleasing lighting for public spaces or events.
- **Interactive Features:** Program lights to react dynamically during events, festivals, or emergencies for better engagement.