NAAN MUDHALVAN PROJECT

IOT BASED WEATHER ADAPTIVE STREET LIGHTING SYSTEM

TEAM ID:NM2023TMIDO2708

TEAM MEMBERS

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INTRODUCTION

1.1 Project Overview

The IoT-based Weather Adaptive Street Lighting System is designed to enhance the efficiency and effectiveness of street lighting by integrating real-time weather data and intelligent control algorithms. This project aims to overcome the limitations of traditional street lighting systems and provide adaptive lighting solutions that adjust according to weather conditions.

1.2 Purpose

The purpose of the IoT-based Weather Adaptive Street Lighting System project is to address the limitations of traditional street lighting systems and provide a more efficient and adaptive solution. The project aims to leverage IoT technologies, weather sensors, and intelligent control algorithms to dynamically adjust street lighting levels based on real-time weather conditions. The key purposes of the project include:

Energy Efficiency: By integrating weather data and intelligent control algorithms, the project seeks to optimize the energy consumption of street lighting. Adjusting lighting levels based on weather conditions such as natural daylight availability or low visibility due to fog or rain can lead to significant energy savings.

Cost Reduction: The project aims to reduce operational costs associated with street lighting systems. By implementing adaptive lighting control, it can minimize unnecessary energy consumption during favorable weather conditions, thereby lowering electricity bills and maintenance costs.

Enhanced Safety: The primary purpose of street lighting is to provide visibility and safety for pedestrians, drivers, and residents. The project endeavors to improve safety by automatically adjusting lighting levels based on real-time weather conditions. For example, during heavy rainfall or fog, the lighting system can increase brightness to enhance visibility and ensure safer navigation.

Environmental Impact: The project aligns with the broader goal of sustainability and reducing environmental impact. By optimizing energy consumption and reducing carbon emissions associated with street lighting, it contributes to a greener and more eco-friendly urban environment.

Technological Advancement: The project embraces emerging technologies such as IoT and intelligent control algorithms. It aims to showcase the capabilities of these technologies and their potential applications in urban infrastructure, paving the way for further innovation and development in the field of smart cities and intelligent lighting systems.

Scalability and Adaptability: The project aims to create a scalable and adaptable solution that can be implemented in various urban settings. By demonstrating the feasibility and benefits of a weather adaptive street lighting system, it encourages the adoption of similar technologies in different cities and regions.

Overall, the purpose of the IoT-based Weather Adaptive Street Lighting System project is to improve energy efficiency, reduce costs, enhance safety, promote sustainability, and showcase the potential of IoT technologies in optimizing urban infrastructure.

2. IDEATION & PROPOSED SOLUTION

2.1 Problem Statement Definition

Traditional street lighting systems are designed to operate on fixed schedules or photocell sensors, lacking the ability to adapt to changing weather conditions. This creates several challenges and inefficiencies, leading to energy wastage, increased maintenance costs, and compromised safety.

Ideation Phase
Define the Problem Statements

Customer Problem Statement Template:

Create a problem statement to understand your customer's point of view. The Customer Problem Statement template helps you focus on what matters to create experiences people will love.

A well-articulated customer problem statement allows you and your team to find the ideal solution for the challenges your customers face. Throughout the process, you’ll also be able to empathize with your customers, which helps you better understand how they perceive your product or service.

I am	Describe customer with 3-4 key characteristics - *who are they?*	Describe the customer and their attributes here
I'm trying to	*List their outcome or "job" the care about - what are they trying to achieve?*	List the thing they are trying to achieve here
but	Describe what problems or barriers stand in the way – *what bothers them most?*	Describe the problems or barriers that get in the way here
because	Enter the "root cause" of why the problem or barrier exists – *what needs to be solved?*	Describe the reason the problems or barriers exist
which makes me feel	Describe the emotions from the customer's point of view – *how does it impact them emotionally?*	Describe the emotions the result from experiencing the problems or barriers

Reference: https://miro.com/app/board/uXjVMN1rSEE=/?share_link_id=252397759594
Example:

Problem Statement (PS)	I am (Customer)	I'm trying to	But	Because	Which makes me feel
PS-1	Pedestrian	Walk peacefully at night	It was dark out there	There is no proper streetlighting out there	So unsafe and un comfortable

2.2 **Empathy Map Canvas**

Empathy Map Canvas: IoT-based Weather Adaptive Street Lighting System

User: Residents, Pedestrians, and Drivers

Say: "Street lighting should be optimized for different weather conditions to ensure safety and visibility."

Think: "I wish the street lights would automatically adjust based on the weather conditions to improve visibility."

Feel: Concerned about safety during adverse weather conditions.

Do: Look for well-lit areas or carry personal light sources during low visibility situations.

Technicians and Maintenance Staff

Say: "It is challenging to manually adjust street lighting schedules and brightness levels based on changing weather patterns."

Think: "An automated system that adapts to weather conditions would make maintenance more efficient."

Feel: Overwhelmed by the maintenance workload and constant adjustments needed.

Do: Spend significant time and effort on manual adjustments and troubleshooting.

Municipal Authorities and Urban Planners

Say: "We need to find ways to reduce energy consumption and maintenance costs of street lighting systems."

Think: "An intelligent and weather-adaptive system could improve energy efficiency and reduce costs."

Feel: Pressured to meet sustainability goals and optimize city resources.

Do: Look for innovative solutions to improve street lighting infrastructure.

Environmentalists and Sustainability Advocates

Say: "Street lighting systems should prioritize energy efficiency and reduce carbon emissions."

Think: "An adaptive lighting system can contribute to a more sustainable urban environment."

Feel: Driven to promote eco-friendly solutions and reduce energy wastage.

Do: Advocate for the implementation of energy-efficient street lighting technologies.

Government Energy Efficiency Agencies

Say: "Energy efficiency in street lighting is crucial for reducing energy consumption and carbon footprint."

Think: "A weather adaptive system can optimize energy usage and align with energy conservation targets."

Feel: Committed to promoting energy-efficient solutions and achieving sustainability goals.

Do: Provide support and funding for projects that enhance energy efficiency in street lighting.

By considering the perspectives, needs, and motivations of various stakeholders involved in or impacted by the IoT-based Weather Adaptive Street Lighting System, you can gain insights into their expectations, concerns, and aspirations. This empathy map can guide the design and development process, ensuring that the system effectively addresses the identified needs and provides value to all stakeholders involved.

2.3 Ideation & Brainstorming

Weather-Triggered Brightness Adjustment:

- Implement a system that automatically adjusts the brightness of street lights based on real-time weather conditions.
- Utilize weather sensors to detect factors like rainfall, fog, or snow, and increase the brightness to improve visibility during adverse weather conditions.
- Incorporate machine learning algorithms to analyze historical weather data and optimize brightness settings accordingly.

Smart Lighting Zones:

- Divide the street lighting infrastructure into zones and assign different lighting profiles based on factors such as pedestrian density, traffic flow, or specific requirements of different areas.
- Implement dynamic lighting control that adapts to changing conditions

within each zone, providing the appropriate level of illumination based on real-time data.

Energy Optimization Strategies:

- Integrate energy-saving techniques such as motion sensors or proximity detectors to adjust lighting levels dynamically when there is no activity or movement in the vicinity.
- Utilize dimming capabilities during periods of low pedestrian or vehicular traffic to reduce energy consumption without compromising safety.

Predictive Maintenance and Remote Monitoring:

- Incorporate sensors and connectivity to enable remote monitoring and predictive maintenance of street lights.
- Implement algorithms that analyze performance data and proactively detect issues or failures, enabling timely maintenance and reducing downtime.

Real-time Data Visualization and Insights:

- Develop a user-friendly dashboard or mobile application that provides real-time visibility into the system's performance, energy consumption, and lighting conditions.
- Use data visualization techniques to present insights on energy savings, maintenance needs, and environmental impact, enabling stakeholders to make informed decisions.

Integration with Smart City Infrastructure:

- Explore opportunities to integrate the weather adaptive street lighting system with other smart city components, such as traffic management systems, public transportation networks, or emergency response systems.

- Enable data sharing and collaboration between different systems to enhance overall urban efficiency, safety, and sustainability.

Renewable Energy Integration:

- Investigate the possibility of incorporating renewable energy sources, such as solar or wind, to power the street lighting system.
- Design energy management algorithms that prioritize renewable energy utilization and minimize reliance on the grid, reducing the environmental impact.

Citizen Engagement and Feedback:

- Foster citizen engagement by providing channels for feedback and preferences regarding street lighting conditions.
- Utilize social media platforms or mobile applications to gather input from residents and stakeholders, enabling them to actively participate in shaping the lighting system.

These ideation and brainstorming concepts can help generate innovative ideas for an IoT-based Weather Adaptive Street Lighting System. Consider combining and refining these concepts based on the specific project requirements, available resources, and the desired outcomes.

Ideation Phase
Brainstorm & Idea Prioritization Template

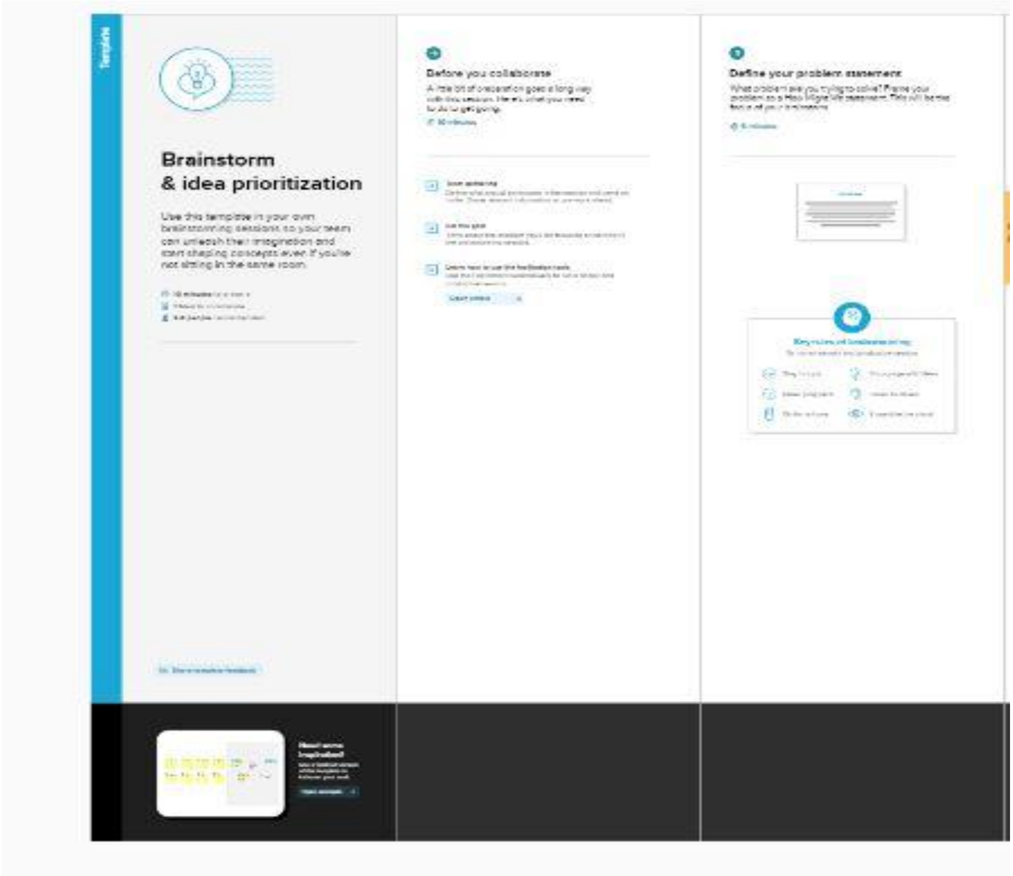
Brainstorm & Idea Prioritization Template:

Brainstorming provides a free and open environment that encourages everyone within a team to participate in the creative thinking process that leads to problem solving. Prioritizing volume over value, out-of-the-box ideas are welcome and built upon, and all participants are encouraged to collaborate, helping each other develop a rich amount of creative solutions.

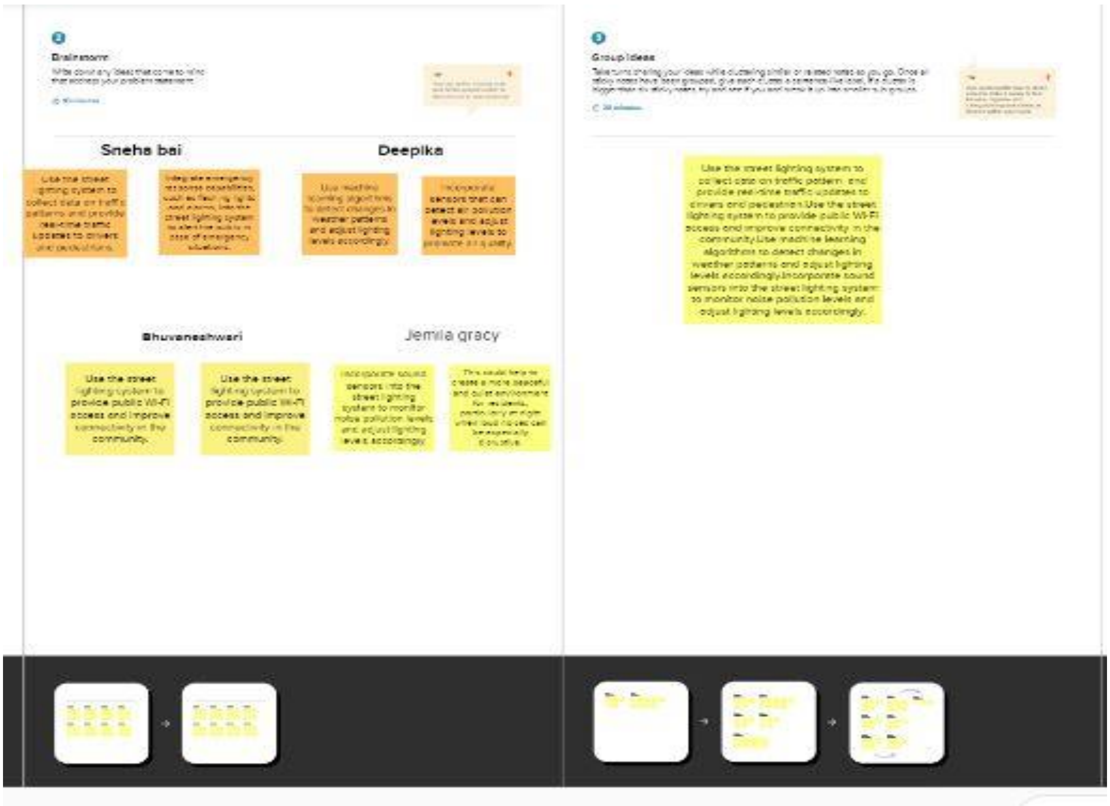
Use this template in your own brainstorming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

Reference:
https://app.mural.co/invitation/mural/iotbasedweatheradaptivestree9545/1682875754644?sender=ucb6ba4f171e10dd744943891&key=86866e67-1d84-4bb1-a1cf-4947a89ef760

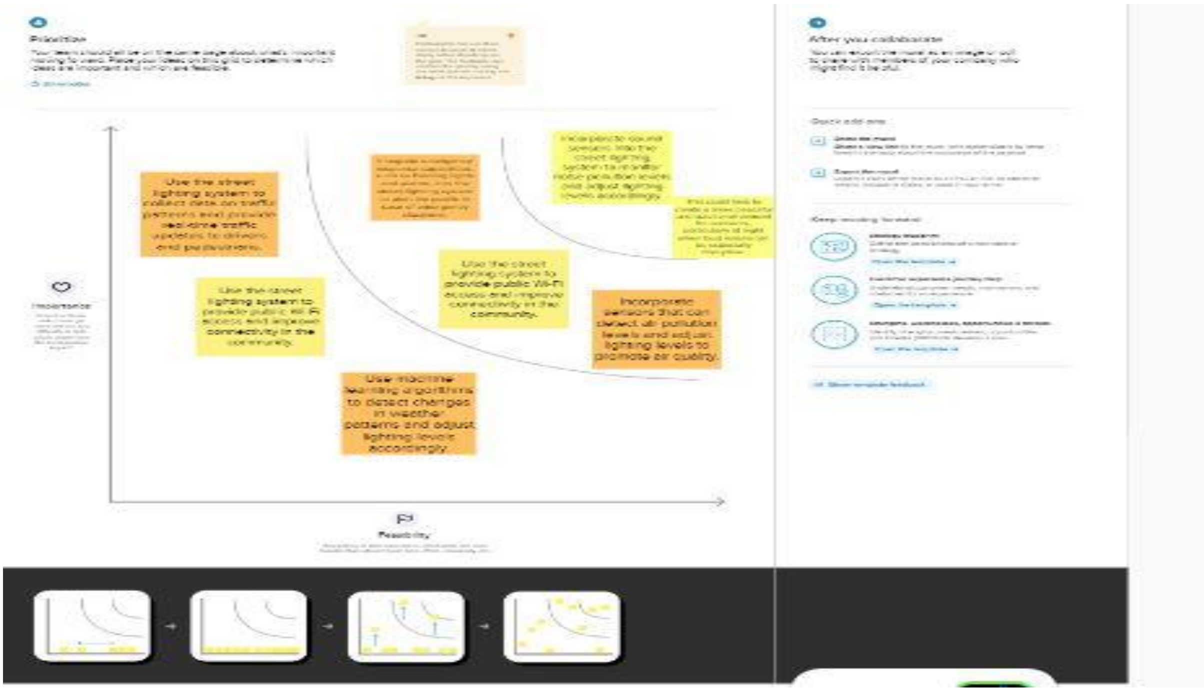
Step-1: Team Gathering, Collaboration and Select the Problem Statement



Step-2: Brainstorm, Idea Listing and Grouping



Step-3: Idea Prioritization



2.4 Proposed Solution

Date	06 May 2023

Team ID	NM2023TMID02708
Project Name	Project – IoT Based Weather Adaptive Street Lighting System

Proposed Solution Template:

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The problem that the IoT-based weather adaptive street lighting system aims to solve is the lack of adaptability and efficiency of traditional street lighting systems. These systems are typically operated based on a pre-defined schedule, regardless of weather conditions, resulting in energy waste, light pollution, and increased maintenance costs.
2.	Idea / Solution description	The IoT-based weather adaptive street lighting system is a modern solution to the inefficiencies of traditional street lighting systems. By using various sensors and machine learning algorithms, the system can adapt lighting intensity to real-time weather conditions, reducing accidents caused by poor visibility. The system is easily integrated with existing street lighting infrastructure and can be deployed in both urban and rural areas. It enhances public safety, reduces energy consumption and costs, and minimizes light pollution, making it a desirable solution for modern cities looking to improve their sustainability and livability. The system's scalability and adaptability ensure it is a long-term solution, easily updated and maintained, and future-proofed against changing technology trends.
3.	Novelty / Uniqueness	The IoT-based weather adaptive street lighting system is a unique and innovative solution that addresses the inefficiencies of traditional street lighting systems. The system's novelty lies in its ability to adapt to changing weather conditions, ensuring optimal lighting levels for both drivers and pedestrians. This is achieved through the use of various sensors and machine learning algorithms that constantly monitor and adjust lighting intensity based on real-

		time weather data. Furthermore, the system's machine learning algorithms can predict upcoming weather conditions and optimize lighting settings accordingly, reducing the likelihood of accidents caused by poor visibility. This is a unique feature that sets the IoT-based weather adaptive street lighting system apart from traditional street lighting systems, which are typically operated based on a pre-defined schedule. Another unique feature of the system is its scalability and adaptability. The system can be easily integrated with existing street lighting infrastructure, reducing the need for costly hardware upgrades. This makes the system suitable for deployment in both urban and rural areas, and adaptable to different street lighting configurations.
4.	Social Impact / Customer Satisfaction	The IoT-based weather adaptive street lighting system has a significant positive impact on public safety and customer satisfaction. By adapting lighting intensity to real-time weather conditions, the system reduces accidents caused by poor visibility, enhancing public safety. The system is energy-efficient and reduces light pollution, making it a desirable solution for modern cities looking to improve their sustainability and livability. Customers benefit from reduced energy costs and ongoing maintenance services, creating a mutually beneficial relationship with the provider.
5.	Business Model (Revenue Model)	The IoT-based weather adaptive street lighting system's revenue model will be based on a combination of upfront hardware and installation costs, ongoing maintenance fees, and energy savings. The system will be sold to municipalities, utility companies, and other organizations responsible for street lighting infrastructure. The ongoing maintenance and energy savings will be offered as a service, with a percentage of the savings being retained by the provider. The revenue model is designed to create a sustainable and mutually beneficial relationship between the provider and the customer, while

		incentivizing energy efficiency and reducing the environmental impact of street lighting.
6.	Scalability of the Solution	The IoT-based weather adaptive street lighting system is highly scalable and adaptable to different street lighting configurations, making it suitable for deployment in both urban and rural areas. The system is designed to be easily integrated with existing street lighting infrastructure, reducing the need for costly hardware upgrades. This means that the system can be deployed in a phased manner, starting with a small pilot and scaling up as required. Additionally, the system's software can be easily updated to incorporate new features and functionalities, making it future-proof and adaptable to changing technology trends. Overall, the scalability of the solution makes it a highly desirable option for modern cities looking to improve their sustainability and livability

. **REQUIREMENT ANALYSIS**

3.1 Functional requirement

Functional Requirements:

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Weather Monitoring	The system should be able to gather real-time weather data such as temperature, humidity, precipitation, and ambient light levels.
FR-2	Light Intensity Control	The system should be able to adjust the intensity of the streetlights based on the detected ambient light levels. It should automatically increase the brightness during low light conditions and decrease it during high light conditions.
FR-3	Motion Detection	The system should include motion sensors to detect the presence of pedestrians, vehicles, or other objects on the street. It can then adjust the lighting levels accordingly, providing brighter

		illumination when motion is detected and reducing it when there is no activity
FR-4	Rain Detection	The system should be able to detect rainfall or the presence of moisture on the road surface. It can use rain sensors or other weather data to identify when it is raining and adjust the lighting levels to enhance visibility during rainy conditions.
FR-5	Fog Detection	The system should be equipped with sensors or cameras capable of detecting fog or low visibility conditions. Based on the fog density, it should adjust the lighting levels to provide better visibility and ensure safety for drivers and pedestrians.
FR-6	Energy Efficiency	The system should be designed to optimize energy usage by using LED lights or other energy-efficient lighting technologies. It should have the ability to automatically dim or turn off lights when there is no activity or during periods of low traffic.
FR-7	Data Logging and Analytics:	The system should have the capability to log and store data related to weather conditions, lighting levels, and energy consumption. This data can be used for analytics and performance optimization purposes, such as identifying patterns, detecting anomalies, and making informed decisions regarding maintenance and energy management.
FR-8	Integration with Central Management System	The IoT-based street lighting system should be capable of integrating with a central management system or smart city platform. This allows for centralized control, coordination, and monitoring of streetlights across different locations, enabling efficient management of the entire lighting infrastructure.
FR-9	Remote Monitoring and Control	The system should provide remote monitoring and control capabilities, allowing administrators to view the status of individual streetlights, adjust lighting settings, and receive alerts or notifications in case of any faults or malfunctions.

3.2 Non-functional Requirements:

Following are the non-functional requirements of the proposed solution.

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	The system should be user-friendly and intuitive, ensuring that administrators and operators can easily navigate the interface, monitor the system, and make necessary

		adjustments. It should have clear and concise instructions, well-organized menus, and a logical flow of tasks.
NFR-2	**Security**	The system should implement robust security measures to protect against unauthorized access, data breaches, and tampering. It should use encryption protocols to ensure secure communication between devices and the central management system.
NFR-3	**Reliability**	The system should be highly reliable, ensuring that the streetlights operate consistently and respond accurately to weather conditions. It should have a low failure rate and be able to recover from any failures quickly.
NFR-4	**Performance**	The system should be designed to operate with high performance and minimal latency. It should be capable of processing and analyzing real-time weather data and making lighting adjustments quickly and efficiently.
NFR-5	**Availability**	The system should be available and accessible for use at all times. It should have redundant components, failover mechanisms, and backup power sources to minimize disruptions in case of power outages or network failures
NFR-6	**Scalability**	The system should be designed to handle a large number of streetlights and accommodate future expansion as the city or infrastructure grows. It should be able to efficiently manage and process data from numerous sensors and devices.

4. PROJECT DESIGN

4.1 Data Flow Diagrams

Data Flow Diagrams:

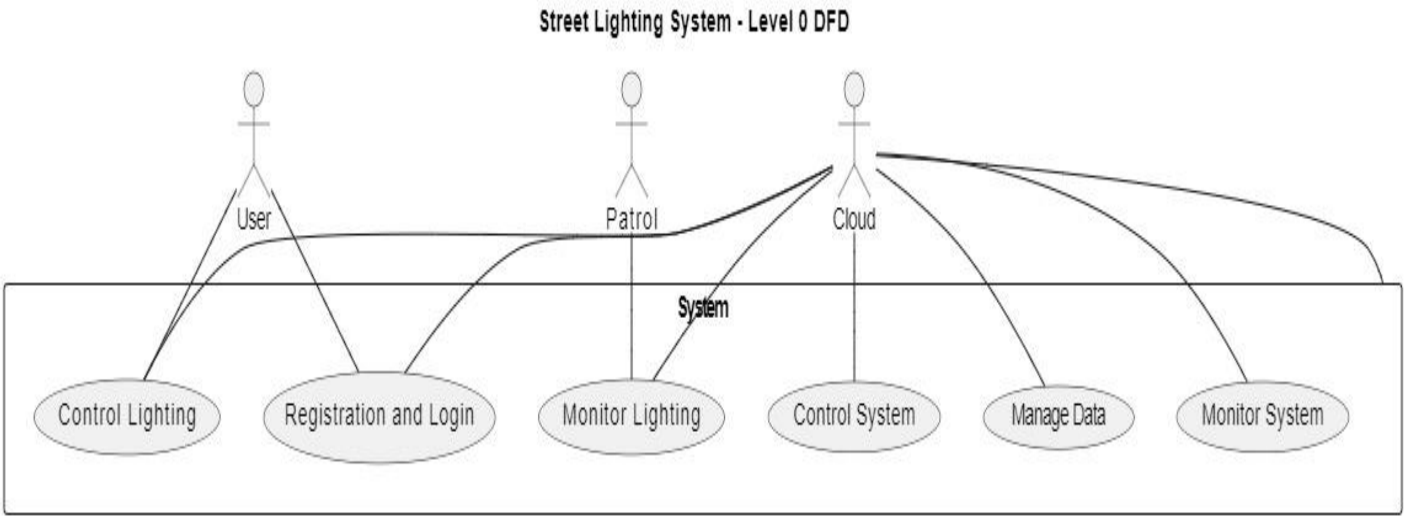
A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

Data Flow Diagram & User Stories

Data Flow Diagrams:
A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

Example: (Simplified)

Example: DFD Level 0 (Industry Standard)



4.2 Solution & Technical Architecture

Devices:
IoT devices are installed on each street lamp post to monitor weather conditions, including temperature, humidity, and precipitation levels.Light sensors are also installed to measure the amount of ambient light in the environment.Each street lamp is equipped with LED lights and a microcontroller.

Data Collection Layer:
The IoT devices collect data from the environment, including weather conditions and ambient light levels.The collected data is sent to a cloud-based platform for processing and analysis.

Data Processing Layer:

The cloud-based platform processes the collected data using machine learning algorithms to determine the appropriate lighting level for each street lamp.The algorithms take into account factors such as the time of day, weather conditions, and traffic density.

Control Layer:

The platform sends control signals to the microcontrollers on each street lamp to adjust the brightness of the LED lights.The brightness level is adjusted based on the results of the data analysis and the current environmental conditions.The microcontrollers communicate with each other to ensure that the lighting is coordinated across the entire street.

Data Storage and Analysis Layer:

The platform stores historical data on weather conditions, ambient light levels, and lighting levels for each street lamp.The data is analyzed to identify patterns and trends over time.The analysis can be used to optimize the system and improve its performance over time.

User Interface Layer:

A web-based user interface allows administrators to monitor the system and adjust its settings as needed.The interface provides real-time data on weather conditions, ambient light levels, and lighting levels for each street lamp.The interface also provides tools for data analysis and system optimization.

The system uses machine learning algorithms to adjust lighting levels based on environmental conditions and can be optimized over time using historical data and data analysis techniques. The web-based user interface provides administrators with real-time data and tools for system monitoring and optimization.

Example - Solution Architecture Diagram:

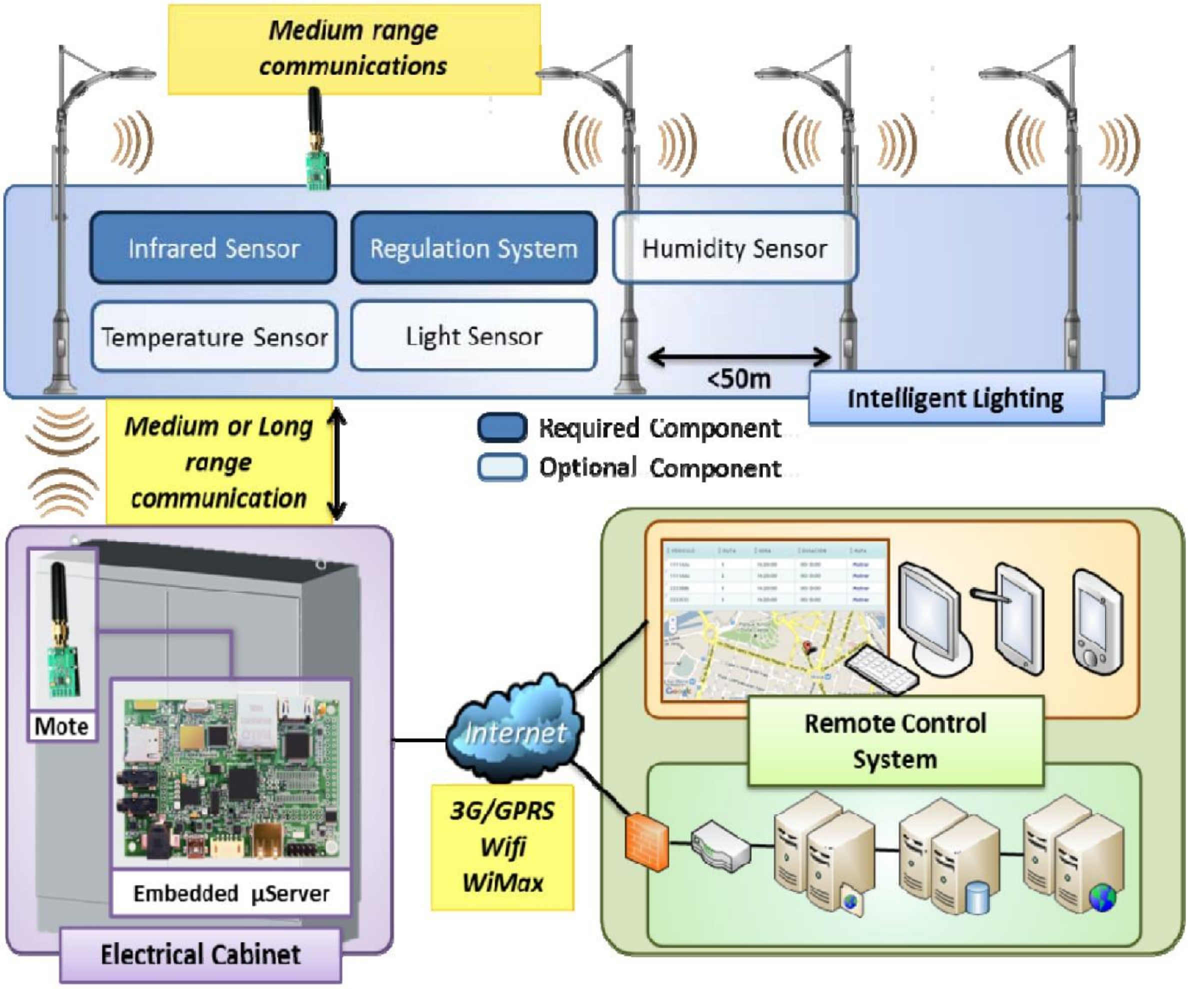


Figure 1: Architecture and data flow of the IoT Based Weather Adaptive Street Lighting System

4.3 User Stories:

- As a pedestrian, I want the street lights to automatically adjust their brightness based on weather conditions, so that I can have optimal visibility and feel safe while walking during periods of low light or adverse weather.
- As a driver, I want the street lights to adapt to weather conditions such as heavy rainfall or fog, so that I can have improved visibility on the roads and reduce the risk of accidents.
- As a maintenance staff member, I want to remotely monitor the street lighting system and receive notifications when a light malfunctions or

requires maintenance, so that I can efficiently address the issues and minimize downtime.

- As a municipal authority, I want the street lighting system to optimize energy consumption by dimming or adjusting lighting levels during periods of sufficient natural light, so that we can reduce energy costs and promote environmental sustainability.
- As a resident, I want to have the ability to report any issues or concerns regarding street lighting, such as malfunctioning lights or areas with inadequate illumination, so that the appropriate actions can be taken to ensure proper lighting in my neighborhood.
- As an urban planner, I want to analyze data collected by the street lighting system, such as energy consumption patterns and lighting usage, to make informed decisions about infrastructure improvements and energy efficiency initiatives.
- As a sustainability advocate, I want the street lighting system to utilize renewable energy sources, such as solar panels, to reduce reliance on the grid and minimize carbon emissions, contributing to a greener and more sustainable city.
- As a government official, I want the street lighting system to integrate with other smart city infrastructure, such as traffic management systems or emergency response systems, to enhance overall urban efficiency and safety.
- As a visually impaired individual, I want the street lighting system to provide consistent and adequate illumination, regardless of weather conditions, so that I can navigate safely and independently in the city.
- As a local business owner, I want the street lighting system to enhance the visibility of my establishment during nighttime or adverse weather conditions, attracting more customers and improving the overall business environment.

- These user stories represent different perspectives and needs of stakeholders involved in or impacted by the IoT-based Weather Adaptive Street Lighting System. They serve as a valuable tool for understanding the system's functionalities and ensuring that it meets the requirements and expectations of its users.

5.CODING&SOLUTIONING (Explain the features added in the project along with code)

CODING:

```
#include <WiFi.h>//library for wifi

#include <PubSubClient.h>//library for MQtt



#define LED 5

#define LED2 4

#define LED3 2

int LDR = 32;

int LDRReading = 0;

int threshold_val = 800;

int lEDBrightness = 0;

int flag=0;



void callback(char* subscribetopic, byte* payload, unsigned int payloadLength);



//-------credentials of IBM Accounts------



#define ORG "s1eo97"//IBM ORGANITION ID
```

```
#define DEVICE_TYPE "streetlight"//Device type mentioned in ibm watson IOT Platform

#define DEVICE_ID "4303" //Device ID mentioned in ibm watson IOT Platform

#define TOKEN "12345678" //Token

String data3;

float h, t;




//-------- Customise the above values --------

char server[] = ORG ".messaging.internetofthings.ibmcloud.com";// Server Name

char publishTopic[] = "iot-2/evt/Data/fmt/json";// topic name and type of event perform and
format in which data to be send

char subscribetopic[] = "iot-2/cmd/test/fmt/String";// cmd REPRESENT command type AND
COMMAND IS TEST OF FORMAT STRING

char authMethod[] = "use-token-auth";// authentication method

char token[] = TOKEN;

char clientId[] = "d:" ORG ":" DEVICE_TYPE ":" DEVICE_ID;//client id




//-----------------------------------------

WiFiClient wifiClient; // creating the instance for wificlient

PubSubClient client(server, 1883, callback ,wifiClient); //calling the predefined client id by
passing parameter like server id,portand wificredential

void setup()// configureing the ESP32

{

Serial.begin(115200);

pinMode(LED,OUTPUT);
```

```
pinMode(LED2,OUTPUT);
pinMode(LED3,OUTPUT);
delay(10);
Serial.println();
wificonnect();
mqttconnect();
}

void loop()// Recursive Function
{



//PublishData(t, h);
//delay(1000);
/* LDRReading = analogRead(LDR);
Serial.print("LDR READING:");
Serial.println(LDRReading);

if (LDRReading >threshold_val){
lEDBrightness = map(LDRReading, 0, 1023, 0, 255);
Serial.print("LED BRIGHTNESS:");
Serial.println(lEDBrightness);

analogWrite(LED, lEDBrightness);
analogWrite(LED2, lEDBrightness);
```

```
analogWrite(LED3, lEDBrightness);

}

else{

analogWrite(LED, 0);

analogWrite(LED2, 0);

analogWrite(LED3, 0);

}

delay(300);*/

if (!client.loop()) {

mqttconnect();

}

}
```

/*....................................retrieving to Cloud...............................*/

```
/*void PublishData(float temp, float humid) {

mqttconnect();//function call for connecting to ibm*/

/*

creating the String in in form JSon to update the data to ibm cloud

*/

/*String payload = "{\"temperature\":";

payload += temp;

payload += "," "\"humidity\":";
```

```
payload += humid;

payload += "}";



Serial.print("Sending payload: ");

Serial.println(payload);



if (client.publish(publishTopic, (char*) payload.c_str())) {

Serial.println("Publish ok");// if it sucessfully upload data on the cloud then it will print publish ok in Serial monitor or else it will print publish failed

} else {

Serial.println("Publish failed");

}

} */

void mqttconnect() {

if (!client.connected()) {

Serial.print("Reconnecting client to ");

Serial.println(server);

while (!!!client.connect(clientId, authMethod, token)) {

Serial.print(".");

delay(500);

}

initManagedDevice();

Serial.println();

}

}

void wificonnect() //function defination for wificonnect
```

```
{
Serial.println();
Serial.print("Connecting to ");

WiFi.begin("Wokwi-GUEST", "", 6);//passing the wifi credentials to establish the connection
while (WiFi.status() != WL_CONNECTED) {
delay(500);
Serial.print(".");
}
Serial.println("");
Serial.println("WiFi connected");
Serial.println("IP address: ");
Serial.println(WiFi.localIP());
}

void initManagedDevice() {
if (client.subscribe(subscribetopic)) {
Serial.println((subscribetopic));
Serial.println("subscribe to cmd OK");
} else {
Serial.println("subscribe to cmd FAILED");
}
}

void callback(char* subscribetopic, byte* payload, unsigned int payloadLength)
```

```
{
Serial.print("callback invoked for topic: ");
Serial.println(subscribetopic);
for (int i = 0; i < payloadLength; i++) {
//Serial.print((char)payload[i]);
data3 += (char)payload[i];
}
Serial.println("data: "+ data3);
if(data3=="lighton1")
{
Serial.println(data3);
digitalWrite(LED,HIGH);
}

else if(data3=="lightoff1")
{
Serial.println(data3);
digitalWrite(LED,LOW);


}
else if(data3=="lighton2")
{
Serial.println(data3);
digitalWrite(LED2,HIGH);
```

```
}


else if(data3=="lightoff2")
{
Serial.println(data3);
digitalWrite(LED2,LOW);


}
else if(data3=="lighton3")
{
Serial.println(data3);
digitalWrite(LED3,HIGH);
}


else if(data3=="lightoff3")
{
Serial.println(data3);
digitalWrite(LED3,LOW);
}
data3="";
}
```

6.Results:

However, the potential results and benefits of an IoT-based Weather Adaptive Street Lighting System could include:

Improved Safety: The system's adaptive lighting control can enhance visibility during adverse weather conditions, reducing the risk of accidents and improving pedestrian and driver safety.

Energy Efficiency: By adjusting lighting levels based on real-time weather data and utilizing energy-saving techniques, the system can optimize energy consumption and reduce overall energy costs.

Cost Savings: The integration of predictive maintenance and remote monitoring capabilities can help detect issues early and optimize maintenance schedules, leading to cost savings on repairs and reduced downtime.

Environmental Sustainability: By utilizing renewable energy sources, optimizing energy consumption, and reducing carbon emissions, the system can contribute to a more sustainable urban environment.

Enhanced User Experience: The automatic adaptation of street lighting based on weather conditions can provide a better user experience for pedestrians, drivers, and residents, ensuring well-lit and safe environments.

Data-Driven Decision Making: The collection and analysis of data from the system can provide valuable insights for urban planners and decision-makers, allowing them to make informed decisions about infrastructure improvements, energy efficiency initiatives, and resource allocation.

It's important to note that the actual results may vary based on the specific implementation, local conditions, and user requirements. Conducting thorough testing, gathering feedback from users, and continuously monitoring and optimizing the system are key to achieving the desired results.

Automated Crime Classification: The system automates the process of classifying crimes by utilizing deep learning algorithms. It takes inputs such as crime location, time, and available evidence, and applies trained models to predict the crime type with high accuracy.

Improved Efficiency: By automating crime classification, the system saves time and reduces the manual effort required by law enforcement agencies, detectives, and crime analysts. It speeds up the analysis process, allowing investigators to focus on other critical tasks.

Enhanced Accuracy: Deep learning algorithms can identify complex patterns and relationships in crime data, leading to more accurate crime classification compared to traditional methods. This improves the quality of investigative insights and decision-making.

Greater Insights: The system provides visualizations and tools for interpreting crime classification results. These visualizations help identify trends, patterns, and connections between crimes, enabling law enforcement agencies to gain valuable insights and support data-driven investigations.

Integration Possibilities: The system can be integrated with existing law enforcement tools and databases, enhancing interoperability and streamlining workflows. It allows for seamless data exchange and collaboration across different systems and platforms.

7.Advantages:

Enhanced Safety: By adjusting lighting levels based on real-time weather conditions, the system improves visibility on the streets, reducing the risk of accidents and improving overall safety for pedestrians and drivers.

Energy Efficiency: The system optimizes energy consumption by dynamically adjusting lighting levels and utilizing energy-saving techniques such as dimming during periods of sufficient natural light. This leads to significant energy savings and reduced operational costs.

Environmental Sustainability: By minimizing energy consumption and utilizing renewable energy sources, such as solar power, the system contributes to a greener and more sustainable environment. It reduces carbon emissions and helps in achieving sustainability goals.

Cost Savings: The energy optimization features and predictive maintenance capabilities of the system result in cost savings. By efficiently managing energy usage and detecting maintenance needs in a timely manner, it reduces unnecessary expenses and extends the lifespan of the street lighting infrastructure.

Adaptive Lighting Control: The system adapts lighting levels based on various factors such as weather conditions, time of day, and traffic patterns. This ensures that the lighting is optimized for different situations, providing the right amount of illumination when and where it is needed.

Remote Monitoring and Maintenance: The system allows for remote monitoring of the street lighting infrastructure, enabling proactive maintenance and quick detection of malfunctions or failures. This reduces downtime, improves operational efficiency, and minimizes disruption to lighting services.

Data-Driven Insights: By collecting and analyzing data from the system, valuable insights can be gained. These insights can inform decision-making processes, such as infrastructure improvements, energy efficiency initiatives, and resource allocation, leading to more informed and effective urban planning.

Flexibility and Scalability: The IoT-based architecture of the system provides flexibility and scalability. It can be easily expanded or upgraded to accommodate future needs and advancements in technology. This ensures that the system remains adaptable and future-proof.

Integration with Smart City Infrastructure: The system can integrate with other smart city components and infrastructure, such as traffic management systems or emergency response systems. This integration enhances overall urban efficiency, coordination, and safety.

Improved User Experience: The adaptive lighting control and optimized lighting levels provide a better user experience for pedestrians, drivers, and residents. It creates well-lit and safe environments, enhancing the livability and attractiveness of the urban space.

Overall, the IoT-based Weather Adaptive Street Lighting System brings numerous advantages, including increased safety, energy efficiency, cost savings, environmental sustainability, and improved user experience. By leveraging IoT technologies and data-driven approaches, it offers a smart and efficient solution for urban lighting management.

Disadvantages:

Initial Cost: Implementing an IoT-based system requires upfront investment in hardware, sensors, connectivity infrastructure, and software development. The initial costs of installation and deployment can be significant, particularly for large-scale implementations.

Technical Complexity: Developing and managing an IoT system involves complex technologies, including sensor integration, data transmission, and cloud connectivity. It requires expertise in IoT architecture, data analytics, and cybersecurity. Maintaining and troubleshooting the system may require specialized skills and resources.

Connectivity Reliability: The system relies on stable and reliable internet connectivity for data transmission and communication between devices. In areas with poor network coverage or intermittent connectivity issues, the system's performance may be compromised, affecting real-time data collection and control capabilities.

Data Security and Privacy: IoT systems gather and process large amounts of data, including real-time weather data, lighting control information, and user feedback. Protecting this data from unauthorized access, cyber threats, and maintaining user privacy requires robust security measures and compliance with data protection regulations.

Dependency on Power Supply: IoT devices and sensors require a continuous power supply to operate effectively. Power outages or disruptions in the electrical grid can impact the functionality of the system. Implementing backup power solutions, such as battery backups or alternative energy sources, may be necessary to ensure continuous operation.

Integration Challenges: Integrating the IoT-based lighting system with existing street lighting infrastructure, control systems, or other smart city components can present technical challenges. Ensuring compatibility, interoperability, and seamless integration with legacy systems may require additional effort and customization.

Maintenance and Upkeep: While predictive maintenance capabilities can help identify issues early, maintaining and servicing an IoT-based system still requires regular inspections, software updates, and hardware maintenance. Ensuring proper upkeep of the system and addressing potential failures or malfunctions can incur additional costs and resource allocation.

Reliance on Weather Data Accuracy: The accuracy and reliability of weather data are crucial for effective adaptive lighting control. Inaccurate or outdated weather information can lead to incorrect lighting adjustments and suboptimal performance. Ensuring access to reliable and up-to-date weather data sources is essential for the system's effectiveness.

User Acceptance and Adaptation: Introducing new technology and changing the way street lighting operates may require user education and acceptance. Some users may be resistant to change or unfamiliar with the concept of adaptive lighting. Ensuring effective communication, user training, and addressing concerns can help promote user acceptance and adoption.

Environmental Impact: While the system aims to improve energy efficiency, the manufacturing, installation, and disposal of IoT devices and infrastructure can have an environmental impact. It is important to consider the life cycle of the system and implement sustainable practices throughout its implementation and operation.

These disadvantages highlight some of the challenges and considerations associated with implementing an IoT-based Weather Adaptive Street Lighting System. Proper planning, risk assessment, and addressing these concerns can help mitigate potential drawbacks and maximize the benefits of the system.

8.Conclusion:

In conclusion, an IoT-based Weather Adaptive Street Lighting System offers significant advantages in terms of safety, energy efficiency, cost savings, and user experience. By dynamically adjusting lighting levels based on real-time weather conditions, the system enhances visibility, reduces accidents, and improves overall urban safety. The optimization of energy consumption leads to substantial energy savings, cost reduction, and environmental sustainability.

However, it is important to consider the potential disadvantages associated with implementing such a system, including the initial costs, technical complexity, connectivity reliability, data security and privacy concerns, and maintenance requirements. Addressing these challenges through proper planning, expertise, and robust implementation strategies is essential for successful deployment and operation.

Despite the challenges, an IoT-based Weather Adaptive Street Lighting System offers a smart and efficient solution for urban lighting management. It leverages the power of IoT technologies, data-driven insights, and adaptive lighting control to create well-lit and safe environments while promoting energy efficiency and sustainability. By integrating with other smart city infrastructure, the system enhances overall urban efficiency, coordination, and safety.

To maximize the benefits and overcome the potential disadvantages, collaboration among stakeholders, ongoing monitoring, and continuous improvement are essential. With careful planning, effective implementation, and user engagement, an IoT-based Weather Adaptive Street Lighting System can greatly contribute to creating safer, more sustainable, and livable cities for residents, businesses, and visitors alike.

9.Future Scope:

The future scope of an IoT-based Weather Adaptive Street Lighting System is promising, with several potential advancements and opportunities:

Advanced Predictive Analytics: The system can evolve to incorporate advanced predictive analytics algorithms. By analyzing historical weather data, traffic patterns, and user behavior, the system can anticipate lighting requirements and proactively adjust lighting levels, further optimizing energy consumption and improving efficiency.

Machine Learning and Artificial Intelligence: Implementing machine learning and artificial intelligence techniques can enhance the system's capabilities. The system can learn from real-time data, identify patterns, and dynamically adapt lighting control strategies to optimize performance based on evolving weather conditions and user needs.

Integration with Smart City Ecosystems: The integration of the lighting system with other smart city components can unlock synergistic benefits. For example, integrating with traffic management systems can enable dynamic lighting adjustments based on traffic flow, improving road safety and reducing congestion.

Sensor Fusion: Integrating additional sensors, such as motion sensors or cameras, with the lighting system can enable a more comprehensive understanding of the environment. This allows for context-aware lighting control, where lighting levels can be adjusted based on factors like pedestrian presence or specific events, further enhancing safety and user experience.

Mobile Applications and User Engagement: Developing mobile applications that allow users to interact with the system, report issues, and provide feedback can enhance user engagement and participation. This enables a more collaborative approach to urban lighting management and fosters a sense of ownership among the community.

Edge Computing: Utilizing edge computing technology can enhance real-time data processing and reduce reliance on cloud connectivity. By processing data closer to the edge devices, the system can improve responsiveness, reduce latency, and ensure continuous operation even in situations with limited connectivity.

Integration with Renewable Energy Sources: As renewable energy technologies advance, the system can integrate with more efficient and cost-effective renewable energy sources, such as advanced solar panels or wind turbines. This reduces reliance on the electrical grid and further enhances the system's sustainability.

Smart Grid Integration: Integrating the lighting system with the smart grid infrastructure can enable bi-directional communication and energy exchange. This allows for optimized energy management, load balancing, and even the potential for energy generation from street lighting infrastructure.

Augmented Reality and Virtual Reality Integration: Augmented reality (AR) and virtual reality (VR) technologies can be integrated with the system to provide immersive visualizations and simulations. This enables urban planners and decision-makers to experience and evaluate the impact of lighting designs and adjustments before implementation.

Collaborative Data Sharing: Collaborative data sharing between cities can provide insights and benchmarks for performance comparison and best practices. This allows for cross-city collaboration and knowledge sharing, leading to continuous improvement and innovation in the field of adaptive street lighting.

The future scope of an IoT-based Weather Adaptive Street Lighting System is exciting, with advancements in technology, data analytics, and user engagement. By embracing these opportunities, cities can create smarter, more sustainable, and user-centric urban environments.

10. APPENDIX

Source Code:

https://youtu.be/wVrWEAGHVKk