URBAN GUARD-Smart IoT Solutions for Safer Cities

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***Abstract*—Urban areas face critical challenges such as flooding, electrical hazards, inefficient energy use, and poor air quality, impacting public safety and sustainability. This project, UrbanGuard, presents an IoT-based smart city solution integrating Arduino and ESP32 microcontrollers for real-time monitoring and automated response. The system includes a two-tier flood detection mechanism that alerts officials and citizens via SMS, electrical hazard prevention using a continuity sensor to shut down power in flooded areas, smart street lighting with LDR-based automation and fault detection, and air quality monitoring using DHT11 and MQ135 sensors. Data is processed and transmitted to the ThingSpeak IoT cloud, enabling real-time analytics for efficient urban management.**

***Keywords*—Smart city, IoT, Arduino, ESP32, flood detection, electrical hazard prevention, smart street lighting, air quality monitoring, ThingSpeak, real-time monitoring, urban safety, energy efficiency, disaster management, environmental monitoring, automation.**

I. Introduction

Smart cities face major challenges, including flooding, electrical hazards, inefficient energy usage, and poor air quality, which impact public safety, infrastructure management, and environmental sustainability. Traditional monitoring and response systems are often reactive, leading to delays in disaster management and inefficient resource utilization. The rise of IoT-based technologies offers an opportunity to enhance urban safety and operational efficiency through real-time monitoring and automation.UrbanGuard is an integrated IoT-based solution that leverages Arduino and ESP32 microcontrollers to address multiple urban challenges simultaneously. The system incorporates a two-tier flood detection mechanism that provides early warnings to officials and sends evacuation alerts to citizens. A continuity sensor ensures electrical safety by detecting fallen power lines in floodwaters and shutting down the power supply. Smart street lighting is optimized using LDR sensors for automated control and includes a fault detection system for quick maintenance. Additionally, air quality monitoring is achieved using DHT11 and MQ135 sensors, allowing city administrators to track pollution levels and implement necessary interventions.

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II. The Implemented Modules

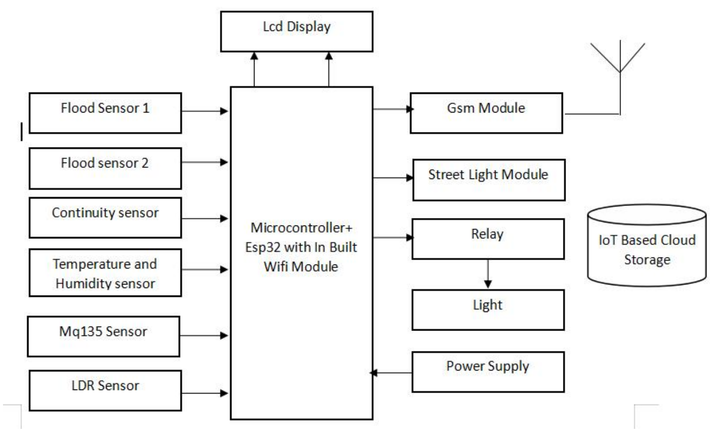

Figure 1: Prototype System

1. Water Level Sensor:

   Detects rising water levels to identify potential flooding, The first sensor triggers an alert to officials for early action. The second sensor, placed at a higher level, sends evacuation alerts via SMS when the situation becomes critical.

2. Continuity sensor:

   Detects fallen power lines in floodwater, Automatically shuts down the electricity supply in the affected area to prevent electrocution

3. LDR Sensor:

   Senses ambient light levels, Automatically turns streetlights on at night and off during the day to optimize energy use.

4. MQ135 Air quality gas sensor:

   Detects harmful gases and pollutants in the air, Helps city officials monitor pollution levels and take preventive actions.Helps city officials monitor pollution levels and take preventive actions.

Identify applicable funding agency here. If none, delete this text box.

III. WORKING

This Smart City Monitoring System enhances urban safety and efficiency through automated flood detection, electrical hazard prevention, smart street lighting, and air quality monitoring.The project utilizes ESP32, Arduino Uno, GSM modules, water level sensors, gas sensors, relays, and LDRs, interconnected through appropriate wiring and communication protocols. The system is powered by a regulated power supply and can operate in multiple modes based on real-time conditions.

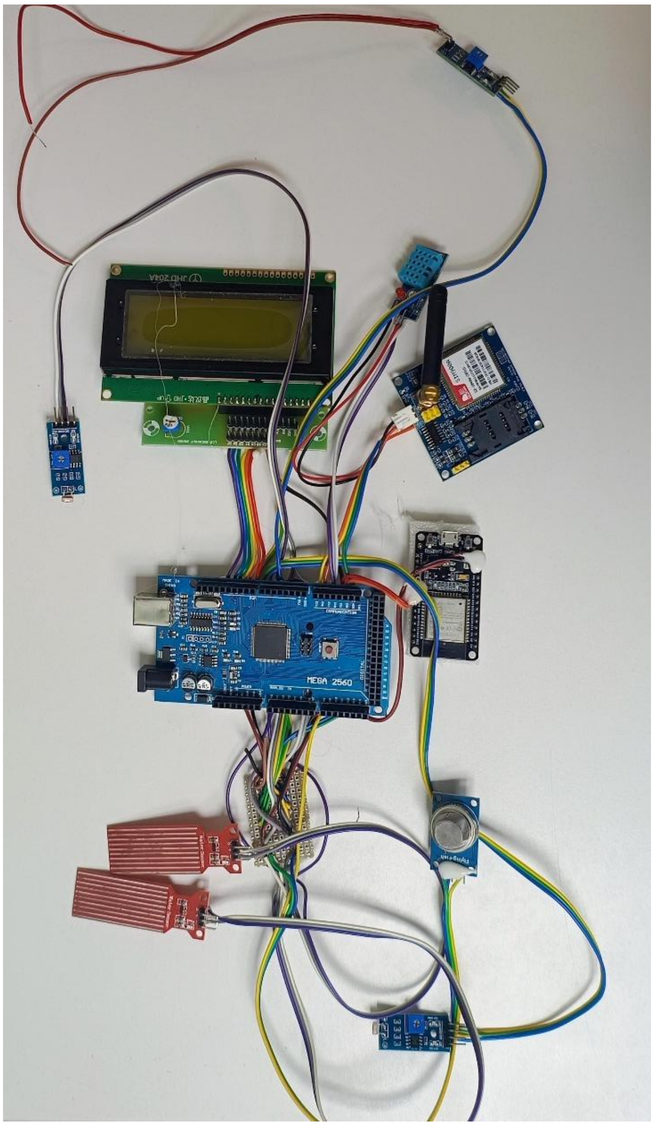

Figure 2: Hardware ImplementationThe Urban Guard-Smart IoT Solutions For Safer Cities

Case 1: Normal Monitoring Mode

- **Objective:** Maintain routine environmental monitoring while conserving energy.
- **How It Works:**
  - Sensors for water level, air quality, and electrical leakage operate in a low-power state to minimize energy consumption.
  - Data is periodically transmitted to the cloud dashboard or local government authorities for passive monitoring.
  - The **smart street lights** adjust based on ambient light conditions using **LDR sensors**.
  - If no emergency conditions are detected, the system remains in this energy-efficient mode.

Case 2: Flood Detection and Early Warning

- **Objective:** Detect rising water levels and alert authorities before flooding occurs.
- **Steps:**
  1. **Activation:**
     - Water level sensors continuously monitor flood-prone areas.
     - If water crosses a predefined safety level, the flood detection system activates.
  2. **Flood Risk Analysis:**
     - The sensor sends real-time water level data to the microcontroller.
     - If levels increase rapidly, the system triggers a multi-tier alert mechanism.
  3. **Alert Mechanism:**
     - **Stage 1 (Warning):** Initial alerts sent to **l**ocal authorities and dashboard.
     - **Stage 2 (Emergency):** If levels continue rising, the system:
     - Sends SMS alerts via GSM to residents.

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Case 3: Electrical Hazard Detection in Flooded Areas

- **Objective:** Prevent electrocution risks in waterlogged zones.
- **Steps:**
  1. **Hazard Detection:**
     - **Continuity sensors** monitor electrical circuits in flood-prone areas.
     - If water enters an **active circuit**, it detects abnormal current leakage.
  2. **Automatic Power Cut-off:**
     - The **relay module** immediately **disconnects power** in affected regions.
     - A **buzzer alarm** warns people nearby.
  3. **Alert Mechanism:**
     - Authorities receive **real-time alerts via GSM** for maintenance actions.

Case 4: Smart Street Lighting System

- **Objective:** Optimize energy consumption and ensure proper street lighting.
- **Steps:**
  1. **Daytime Mode:**
     - **LDR sensors detect sunlight levels** and keep lights **OFF** during daylight hours.
  2. **Night Mode Activation:**
     - As ambient light drops, the **streetlights automatically turn ON**.
  3. **Motion-Based Lighting (Energy Conservation):**
     - **PIR motion sensors detect movement**, activating lights only when needed.
  4. **Fault Detection & Maintenance Alerts:**
     - If any streetlight **malfunctions**, the system logs it and sends a **maintenance request** to authorities.

Case 5: Air Quality Monitoring & Public Health Alerts

- **Objective:** Detect air pollution levels and alert residents about health risks.
- **Steps:**
  1. **Data Collection:**
     - **Gas sensors (MQ-135, PM2.5)** measure air pollutants (CO_2, CO, NO_2, etc.).
  2. **Analysis & Index Calculation:**
     - The system calculates the **Air Quality Index (AQI)** based on sensor readings. **Alert System:**
     - If AQI exceeds safe limits:
       - **Public notifications** are sent via GSM and IoT dashboard.

Case 6: Emergency Mode & Remote Control

- **Objective:** Enable authorities to take manual control of the system in critical situations.
- **Steps:**
  1. **Activation:**
     - A central command unit allows **municipal authorities** to trigger **manual override mode**.
  2. **Flood & Electrical Hazard Response:**
     - Officials can **remotely shut down** power in dangerous zones.
  3. **Air Quality Emergency Actions:**
     - If pollution levels spike, **traffic restrictions** or **factory shutdown requests** can be issued.

Case 7: Passive Mode (Power-Saving)

- **Objective:** Reduce energy consumption when no risks are detected.
- **How It Works:**
  - The system **lowers sensor activity** and switches to **low-power mode**
  - Smart streetlights operate on **motion-based activation only**.
  - **Data transmission frequency** is reduced to conserve **network bandwidth and power**.

This Smart City Monitoring System enhances urban safety and efficiency through automated flood detection, electrical hazard prevention, smart street lighting, and air quality monitoring. The IoT-based architecture ensures real-time data collection, analysis, and alert dissemination, aiding authorities in disaster prevention and city management.

IV. Algorithm for Flood Detection System:

1. Start.
2. Power on the system.
3. Initialize the Arduino/ESP32.
4. Activate the water level sensors.
5. Continuously monitor for water levels:
   - If water level is below the alert threshold, return to step 4.
   - If water level exceeds the safe threshold, proceed to step 6.
6. Trigger alert mechanism:
   - Low-level warning: Send SMS notifications via GSM to authorities.
   - High-level flood warning: Activate sirens, LED indicators, and government dashboard alerts.
7. If emergency escalates, cut off electrical supply in affected areas.
8. Repeat the process in a loop.
9. End.

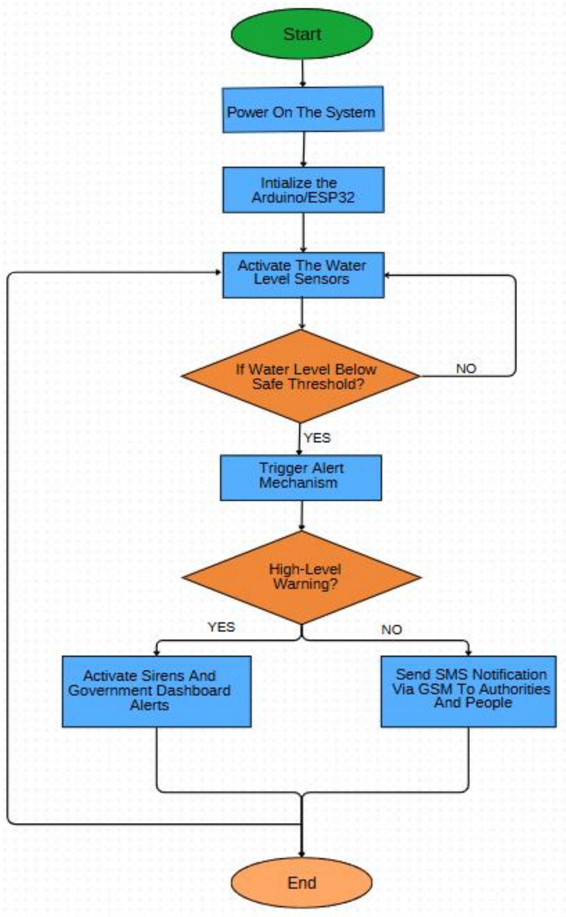


Figure 3: Flowchart for Flood Detection System

V. Algorithm for Electrical Hazard Prevention System

1. Start.
2. Initialize the electrical leakage detection circuit.
3. Continuously monitor for abnormal current flow in flooded areas.
   - If no leakage is detected, return to step 3.
   - If leakage is detected, proceed to the next step.
4. Activate the emergency shutdown system:
   - Relay module automatically cuts off power supply in the affected area.
   - Buzzer alarm warns the public.
5. Send real-time alerts to authorities via GSM and IoT dashboard.
6. Repeat the process in a loop.
7. End.

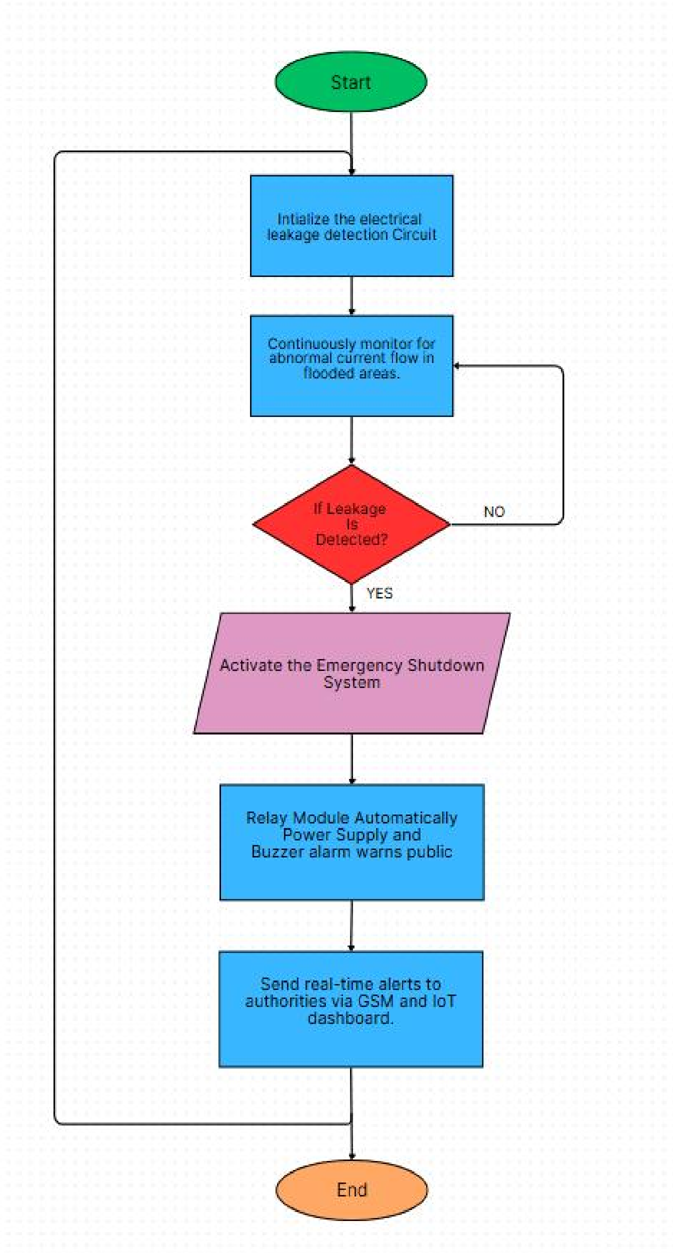


Figure 4: Flowchart for Electrical Hazard Prevention System

VI. Experimental Analysis of the Proposed System

In this project, The implementation of the proposed smart city system involves integrating multiple IoT-based solutions using Arduino and ESP32 microcontrollers to address urban challenges such as flood detection, electrical hazard prevention, smart street lighting, and air quality monitoring. Each subsystem is designed to function independently while contributing to the overall system through real-time data sharing and centralized management via the ThingSpeak IoT cloud platform. The hardware setup includes water level sensors for flood detection, a continuity sensor for electrical hazard prevention, LDR sensors for smart street lighting, and DHT11 and MQ135 sensors for air quality monitoring.The Arduino microcontroller processes sensor data and controls alert mechanisms, while the ESP32 microcontroller transmits the collected data to the ThingSpeak cloud for storage and analysis.

1. Smart City Setup:

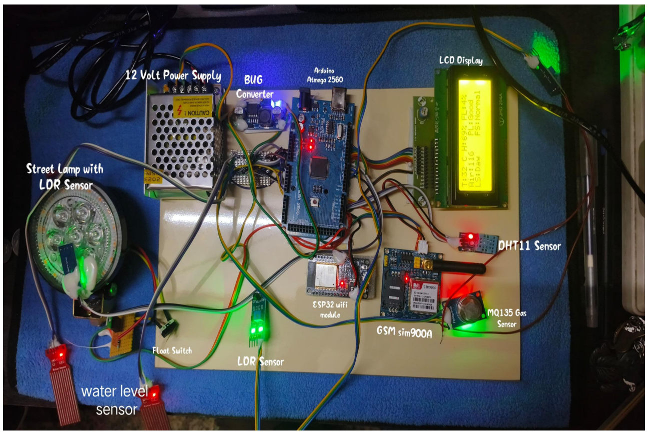


Fig 5: Smart City Setup

The Smart City Setup integrates multiple modules and sensors to ensure real-time monitoring and automated responses for urban safety and efficiency. The setup consists of:

- The two-tier flood detection mechanism was implemented by positioning water level sensors at different heights. The first sensor alerts officials via notifications when initial flooding is detected, while the second triggers SMS alerts to residents using a GSM module in critical situations.
- For electrical safety, the continuity sensor detects live wires submerged in water and automatically shuts down power in affected areas.
- The smart street lighting system was implemented with LDR sensors to control lights based on ambient light levels. A fault detection mechanism was added to identify malfunctioning lights and their locations.
- Environmental monitoring was achieved by integrating DHT11 and MQ135 sensors to measure temperature, humidity, and air quality. All subsystems were tested individually before being integrated into a unified platform.

2. Flood DetectionTesting:

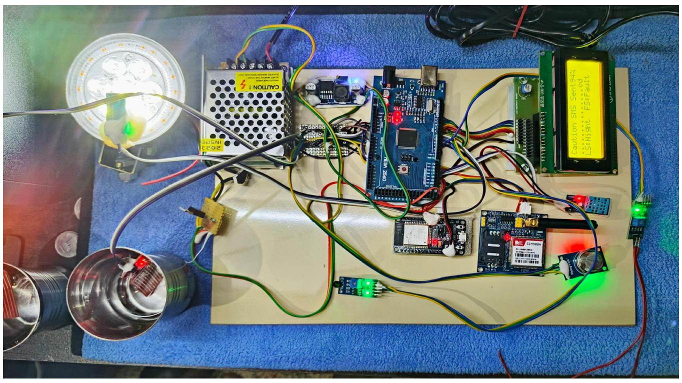


Fig 6: Flood Detection Testing

The water sensor is placed in varying water levels to test its accuracy and responsiveness. The ESP32 detects the water presence and transmits the data to the receiver. Upon detecting a flood condition, the GSM module sends an SMS alert to the authorities. The system is monitored to ensure consistent and reliable performance.

2. Electrical Hazard Prevention Testing

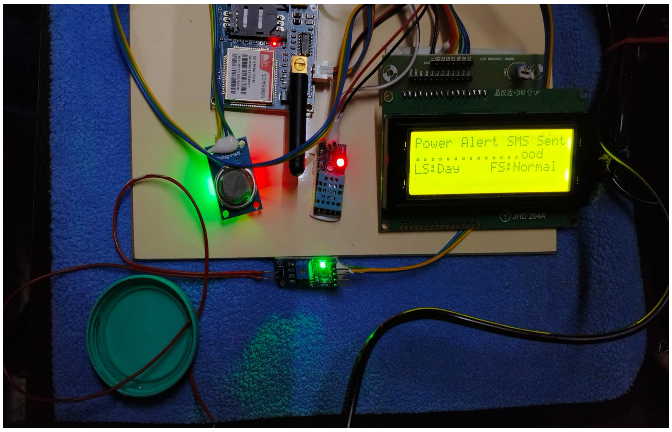


Fig 7: Electric Hazard Prevention Testing

The continuity sensor is tested by creating open and closed circuit conditions to simulate faults. The system detects breaks or continuity loss and displays the fault status on the LCD. Simultaneously, the GSM module sends an alert message when a hazard is detected. Multiple tests are conducted to confirm reliable fault detection.

4. Street Light Monitoring Testing

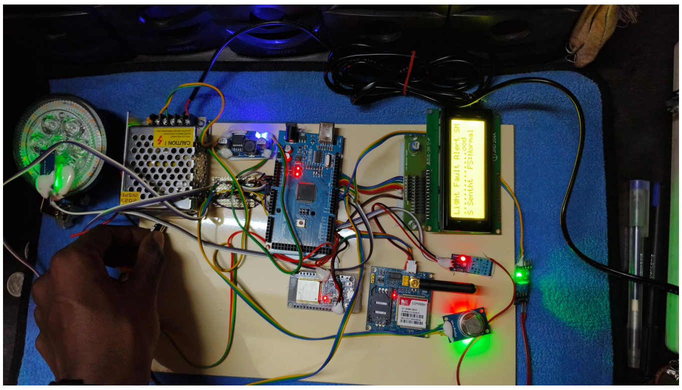


Fig 8: Street Light Monitoring Testing

The LDR sensor is tested by exposing it to different light intensities. During low light, the street light is automatically activated, and it turns off in brighter conditions. The status is displayed on the LCD screen.When float switch is Applied to the 2nd LDR the light has made faultThe message will be sent to the officals

5. Air Quality Monitoring Testing:

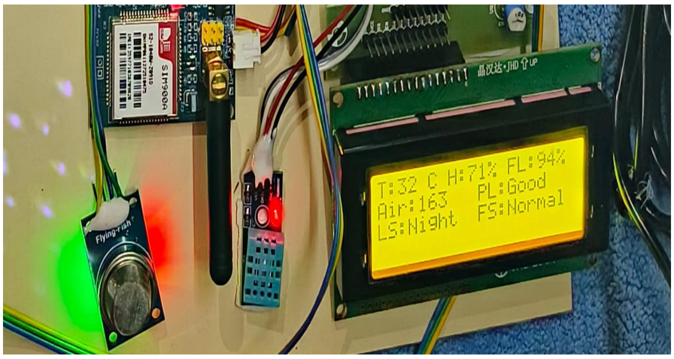


Fig 9: Air Quality Monitoring Testing

The LDR sensor is tested by exposing it to different light intensities. During low light, the street light is automatically activated, and it turns off in brighter conditions. The status is displayed on the LCD screen. The system is tested repeatedly to ensure proper light sensitivity and switching accuracy.

VII. RESULT

The proposed system is fully automated, with the readings being recorded in a controlled environment, which may vary slightly in real-world conditions. The following images display the outputs generated by the system, including mobile alerts, data displayed on the serial monitor, and the activation of streetlights and hazard detection systems.

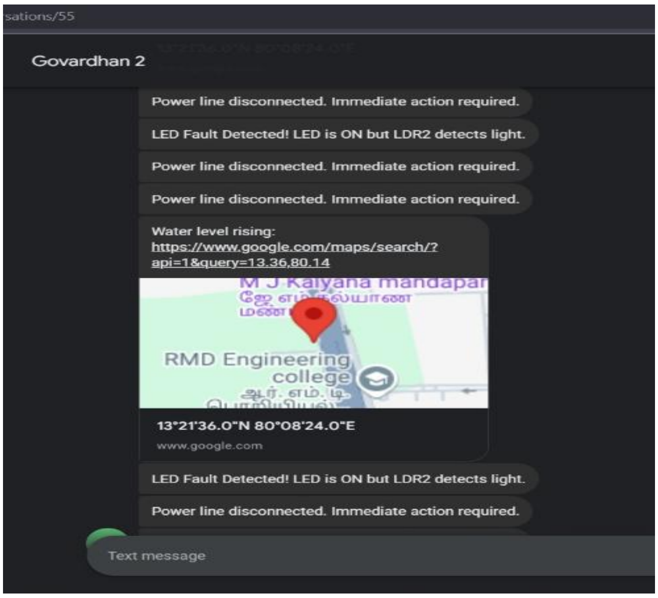
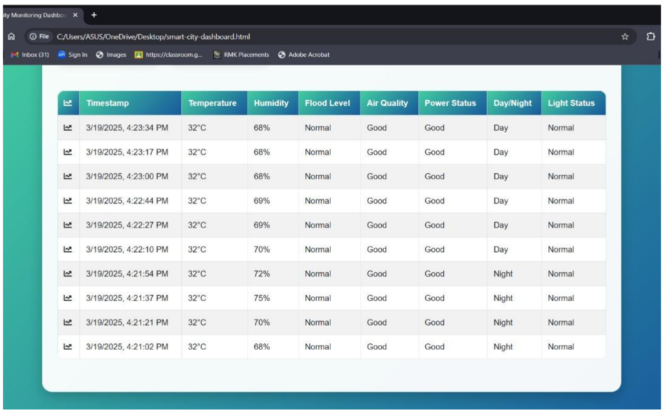


Fig 10: GSM Module Alert Notification

The implemented system successfully performs real-time monitoring using IoT technology. The collected data from various sensors, including flood detection, air quality monitoring, electrical hazard detection, and streetlight control, is transmitted to a web-based platform. The system displays live data readings on a webpage, providing remote access for continuous monitoring. This real-time visualization allows users to track environmental parameters and receive instant alerts, enhancing the efficiency and reliability of the smart city setup.



Timestamp	Temperature	Humidity	Flood Level	Air Quality	Power Status	Day/Night	Light Status
3/19/2025, 4:23:34 PM	32°C	68%	Normal	Good	Good	Day	Normal
3/19/2025, 4:23:17 PM	32°C	68%	Normal	Good	Good	Day	Normal
3/19/2025, 4:23:00 PM	32°C	68%	Normal	Good	Good	Day	Normal
3/19/2025, 4:22:44 PM	32°C	69%	Normal	Good	Good	Day	Normal
3/19/2025, 4:22:27 PM	32°C	69%	Normal	Good	Good	Day	Normal
3/19/2025, 4:22:10 PM	32°C	70%	Normal	Good	Good	Day	Normal
3/19/2025, 4:21:54 PM	32°C	72%	Normal	Good	Good	Night	Normal
3/19/2025, 4:21:37 PM	32°C	75%	Normal	Good	Good	Night	Normal
3/19/2025, 4:21:21 PM	32°C	70%	Normal	Good	Good	Night	Normal
3/19/2025, 4:21:02 PM	32°C	68%	Normal	Good	Good	Night	Normal

Fig 11: Real Time Monitoring Using Iot

The implemented system effectively displays real-time flood status on the IoT dashboard. Before detecting a flood, the system shows the "Flood Level: Normal" status, indicating safe water levels.

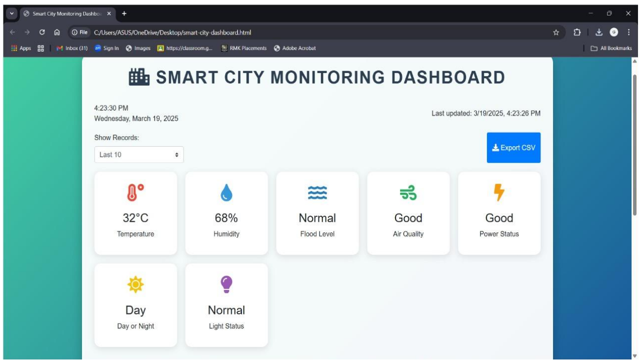


Fig 12: Before Flood Detection in City

However, when the water level crosses the predefined threshold, the system immediately updates the status to "Flood Level: Danger", signaling a potential flooding event. This real-time status change is reflected on the webpage, allowing for quick identification of hazardous conditions and enabling timely preventive measures.

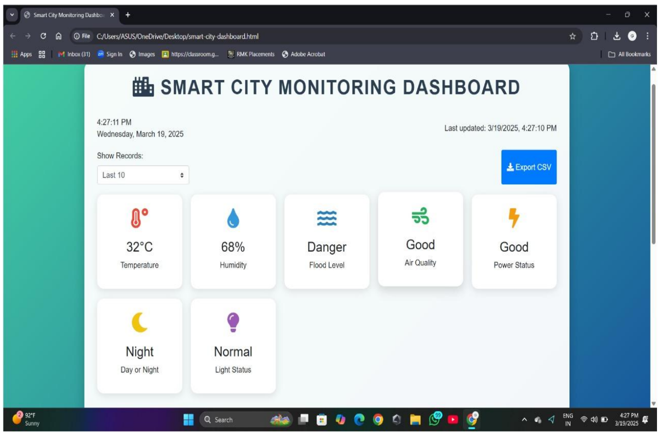


Fig 13: After The Flood Detection in City

VIII. Conclusion

In conclusion, The proposed smart reservoir management system integrates IoT-driven solutions to enhance flood control, public safety, and efficient water management.

- **Enhanced Flood Control**: The system efficiently monitors water inflow and outflow, preventing sudden surges and minimizing flood risks in urban and residential areas.
- **Real-Time Hazard Detection**: By integrating continuity sensors, the system identifies electrical hazards in flood-prone regions and automatically shuts down power to prevent accidents.
- **Early Warning System**: The GSM module provides timely alerts to authorities and residents, allowing them to take necessary precautions during emergencies.
- **Smart Street Lighting Management**: The automated lighting system optimizes energy consumption and detects faults in real-time, ensuring uninterrupted functionality.
- **Air Quality Monitoring**: The system continuously tracks environmental parameters like temperature, humidity, and pollutant levels, aiding in proactive urban planning and public health measures.

By integrating these smart technologies, the proposed system enhances urban safety, optimizes resource management, and strengthens disaster preparedness in smart cities.

This smart city project successfully integrates multiple urban solutions, including flood detection, electrical hazard prevention, smart street lighting, and air quality monitoring, using IoT-based technologies. By leveraging microcontrollers, sensors, and real-time data transmission, the system enhances public safety, improves urban infrastructure efficiency, and enables proactive disaster management. The two-tier flood detection mechanism ensures early warnings and timely public alerts, minimizing loss of life and property damage. The electrical hazard detection system prevents electrocution risks during floods by automatically cuttingpower in affected areas. The smart street lighting solution optimizes energy usage while incorporating a fault detection system for quicker maintenance. Additionally, the air quality monitoring module provides valuable environmental data for health and pollution control measures.

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