IoT Based Traffic Hazard Monitoring and Reduction System

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***Abstract*— In order to address the growing difficulties in urban traffic environments, this study presents a novel Internet of Things (IoT)-based traffic hazard management and reduction system. The system makes use of a wide range of sensors, cameras, and networked cars to provide real-time data collection on important traffic characteristics. The suggested system dynamically identifies possible dangers, such as accidents, road blockages, and unfavorable weather conditions, by utilizing advanced data analytics and computation.**

***Keywords*— Internet of Things, Traffic Hazard Monitoring, Urban Mobility, Adaptive Hazard Reduction.**

I. Introduction

Serious pollution in Bangladesh is caused by high levels of lead in gas, a large number of highly polluting cars, contaminated fuel, wasted land usage, and overall bad rush hour traffic. According to the study, the pain caused by stopping in rush hour traffic jams results in breathing problems, headaches, high blood pressure, hearing problems, unexpected perspiration, fatigue, and blemish. 26% of people suffer from breathing problems as a result of breathing in car smoke. Many researchers are currently striving to use the Internet of Things paradigm to implement classical traffic control [12]. It was discovered that 20% of people left behind for extended periods of time in rush hour traffic suffer from brain pain. Brain ache is also brought on by cars that blare nonstop. The headaches have gotten so bad that they are driving five days a week. When it comes to contamination, gridlocks collectively increase it due to the emissions of SO_2, CO, CO_2, N_2O, and NO_2 that are produced by motors running while cars are stuck in traffic for extended periods of time.

Fig. 1 Traffic Pollution

The term "Internet of Things" (IoT) or "Internet of Everything" (IoE) refers to the collection of all web-enabled devices that use embedded sensors, processors, and communication hardware to gather, transmit, and act upon data they gain from their surroundings [17]. Several studies have been conducted to examine the feasibility and effectiveness of these types of systems. For example, suggested was an IoT-based traffic management system (THMRS) for highways. It tracks and recognizes automobiles, detects traffic jams, and gives drivers advance notification by using real-time data from cameras and sensors. Another study proposed an IoT-based traffic hazard monitoring system (THMRS) for urban areas. In order to detect and predict traffic hazards and to implement the required traffic management measures, it uses data from sensors, cameras, and social media. When done well, this raises awareness and makes it possible to employ infrastructure and resources more effectively [3].

There is an increasing need for effective public transport networks as a result of the growing urbanization and increased mobility of people. Accidents and traffic congestion are becoming serious problems as long as cars are the primary mode of transportation. Traffic accidents, which are frequently brought on by infractions, cause deaths and injuries as well as contribute to non-communicable diseases. With road accidents accounting for 31% of fatalities, they have emerged as a serious public health concern in Indonesia. The Haddon Matrix states that human, vehicle, and environmental factors can all contribute to traffic accidents. Because of unchecked development and poor planning, traffic congestion has grown to be one of the world's most critical issues, particularly in urban regions [4]. A major part of accident prevention is the influence of human factors, including knowledge and behavior. Car crashes cause serious injuries and fatalities, and they are a global problem. Accidents frequently result from negligence and driving too fast, and delayed accident location awareness can exacerbate existing issues [2]. The study presents a smart car system that makes use of Internet of Things (IoT) technologies to lessen this issue. Using ultrasonic sensors, this system continuously tracks the separation between cars to detect accidents in real time. Because of the design's compatibility with GSM and GPS/GPRS, family members and neighboring rescue teams can get automatic alarm messages. In the event of an accident or theft, it also uses GPS/GPRS to track the whereabouts of vehicles [15].

Reviewing the potential for using Internet of Things technology to organize road infrastructure for the dynamic management of traffic flows is the goal of this effort

[11].Traffic data gathered from various sources can be utilized for traffic congestion management and forecasting purposes. [1]. In order to increase road safety, the paper discusses the problem of infractions of traffic laws and the necessity of effective monitoring. Even though breaking traffic laws has consequences and fines, evasion is nonetheless frequent. From the moment a vehicle starts, the proposed system is designed to continuously monitor a variety of traffic offences, including speeding, reckless driving, driving while intoxicated, and driving without a seat belt. It also provides police personnel with a smart gadget to view car information. The system has sensors for seat belt checks, alcohol detection, and speed monitoring. When it detects violations, it transmits emergency data to the cloud, enabling continuous vehicle monitoring, and alerts the Regional Transport Office (RTO).

II. System Topology/ Methodology

A. *Intro:*

The IoT based Traffic Hazard Monitoring and Reduction System is a state-of-the-art way to handle the difficulties associated with contemporary traffic management. This system integrates multiple sensors, such as the MQ7 Carbon Monoxide sensor, MQ135 Gas Sensor, DHT11 Digital Humidity and Temperature Sensor, and a Big Microphone Sound Sensor Module, in a seamless manner [6] [7]. These sensors gather data, which is then processed by an Arduino Uno R3 and sent to a cloud server using an ESP32 NodeMCU. A 12V 18650 mAh battery that is secured in place by a battery holder powers the system. Measuring occupancy on roads and roads is accurate [5]. The objectives of this system are to reduce traffic risks, improve road safety, and protect the environment. All of the aforementioned issues are resolved by the suggested system overall [14]. The core elements of the system's topology and approach are described in the introduction that follows.

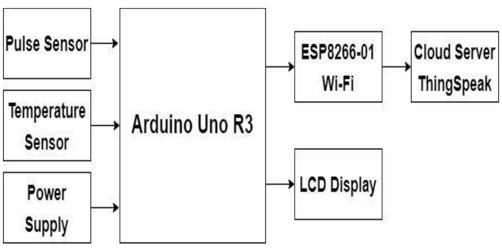

Fig. 2 Block diagram of traffic hazard monitoring and reduction system

A few sensors will be used in conjunction with the Arduino Uno R3 Standard Edition CPU. The MQ7 Carbon Monoxide sensor will first be connected to an analog pin on the Arduino Uno. Next, the Arduino Uno's MQ135 Gas Sensor is connected to another analog pin. Subsequently, we'll link the DHT11 Digital temperature and humidity sensor to an Arduino Uno digital pin. Next, the Arduino Uno's Big Microphone Sound Sensor Module is connected to a different digital pin. The 5V output of the Arduino Uno will be used to power the sensors. Every sensor's data is read by the Arduino Uno, which then processes it and decides what to do based on predetermined criteria for every sensor. Serial communication will be used to link the NodeMCU and Arduino Uno. Data from the Arduino Uno will be received by the NodeMCU, which will then send it to a distant server or show it locally on a webpage [19]. We will be able to view the current scenario with the ThingSpeak.

B. *Equations and Explanation:*

An analog output voltage from the MQ7 sensor can be used to determine the amount of carbon monoxide present. The sensor has to be calibrated according to your unique environmental circumstances.

Equation: $CO\ Concentration = Sensor\ Output \times Calibration\ Factor.$ (1)

Similar to MQ7, the MQ135 provides an analog voltage output. Calibration is essential to correlate the analog signal with the concentration of different gasses [9].

Equation: $GasConcentration = SensorOutput \times Calibration\ FactorGas.$ (2)

$Concentration = SensorOutput \times Calibration\ Factor.$

Temperature and humidity digital outputs are provided by DHT11. You can read the digital values straight from the sensor; no special equation is needed for these. An analog signal corresponding to the sound intensity is provided by the sound sensor. Correlating the sensor output with actual sound levels requires calibration.

$Sound\ Intensity = SensorOutput \times CalibrationFactorSound$

$Intensity = Sensor\ Output \times Calibration\ Factor.$ (3)

For monitoring power consumption in battery management, calculations might be performed based on the current drawn by each component.

Equation: $PowerConsumption = \sum(Current \times Voltage)$

$PowerConsumption = \sum(Current \times Voltage).$ (4)

An environmental index that combines data from all sensors into a single value, representing the overall environmental conditions.

$Equation: EnvironmentalIndex = w1 \times COConcentration + w2 \times GasConcentration + w3 \times Humidity + w4 \times Temperature + w5 \times Sound\ Intensity.$ (5)

Adjust the weights ($w1$, $w2$,…,$w5$) based on the relative importance of each parameter.

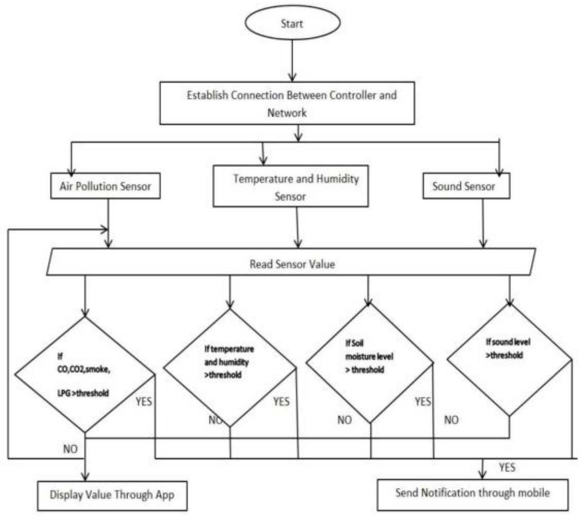

Fig. 3 Flow Chart

The full process for detecting noise, air pollution, temperature, moisture, and atmospheric humidity in the traffic area is shown in Figure 2.

Steps: We developed the Blink Android App to track temperature, moisture content, and humidity. The user had to create an account on the app and provide a mobile number for registration. Once all of the sensors, including the temperature, humidity, and sound sensors, are connected to the network, everything else will follow. Subsequently, the data obtained from each sensor are transferred to the respective threshold values for each sensor. This process will be conducted again if the values are below the threshold. The alert message is delivered to the registered mobile number if the values exceed the threshold values.

C. *Modes Of Operations*:

The system continuously monitors the environmental data when it is in regular monitoring mode. Sensors are always keeping an eye on the following: sound, temperature, humidity, different gasses, and carbon monoxide concentrations. The Arduino Uno gathers information from every sensor. The current environmental conditions can then be shown via LEDs or a straightforward display interface once the Arduino Uno has processed and shown the data locally. The ESP32 NodeMCU then connects wirelessly to the Arduino Uno in Wireless Transmission Mode and sends the sensor data to a cloud platform for centralized monitoring. Through a mobile application or online interface, users can access data remotely with Remote Monitoring and Control. It enables users to keep an eye on data in real time, get warnings, and make wise decisions. Ultimately, an anomalous sensor reading—such as a high gas concentration, temperature, or noise level—triggers the emergency mode. After that, it sends the data right away so that action can be taken.

III. System Design and Simulation

The project, "IoT-based Traffic Hazards Monitoring and Reduction System," uses an advanced network of sensors driven by an Arduino Uno R3 in an effort to create a more conscious and secure urban environment. In addition to other thoughtfully positioned sensors, the system tracks temperature, humidity, sound levels, and air quality in real-time using MQ7, MQ135, DHT11, and a Sound Sensor Module [20].

As a communication bridge, the NodeMCU enables data flow between the Arduino Uno and external services. To make educated decisions about potential hazards, this data is not only shared but also assessed in relation to predefined thresholds.

The ThingSpeak has been integrated into the interface to make it easier for stakeholders to monitor traffic conditions. This ensures quick awareness of and reaction to changing circumstances.

The strategy is predicated on the fact that traffic congestion has increased alarmingly in recent years, particularly in urban areas. Congestion in the roads is one of the other factors. Traffic congestion has both short-term and long-term causes [16]. The research uses complex decision-making to improve urban safety, going beyond simple data collection. The solution helps to create more secure and responsive urban settings by utilizing IoT connections, microcontrollers, and state-of-the-art sensor technologies.

A. Circuit Design

An Arduino Uno R3 microprocessor coupled to a number of sensors, such as a sound sensor, MQ7 gas sensor, MQ135 sensor, and DHT11 temperature/humidity sensor, powers the traffic danger monitoring and reduction system. Transmission of cloud data is made possible using an ESP8266 WiFi module.

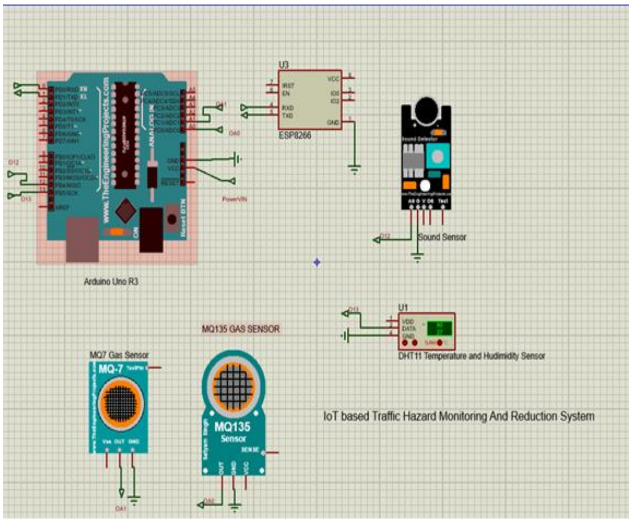

Fig. 4 Circuit Design for IOT Based Traffic Hazard monitoring and Reduction system.

The first part is the Arduino Uno R3, a microcontroller board with digital and analog connections, a USB interface, and a reset button.

Sensors:

- Sound Sensor: Contains a sensitivity adjusting feature and can detect loud sounds.
- MQ7 Gas Sensor: This adjustable-sensitivity sensor detects carbon monoxide and flammable gasses.
- MQ135 Sensor: Adjustable sensitivity; detects ammonia, alcohol, and volatile organic compounds.
- DHT11 Sensor: Digital output sensor that measures air temperature and humidity.

ESP8266 Wi-Fi Module: Provides Wi-Fi connectivity so that data can be sent to the cloud.

Operation: An ESP8266 is connected for cloud connectivity, and sensors are connected to the Arduino board's analog inputs.

When thresholds are exceeded, Arduino utilizes the ESP8266 to send warning signals to the cloud, analyzes sensor measurements, and compares them to predefined values.

Uses: Hazard Alerts: Warn motorists of gas leaks or collisions.

First priority for the traffic signal: The traffic signal's top priority is to turn on as soon as it approaches hazardous areas [13].

Strategies for Calming Traffic: Installing speed bumps or flashing lights in high-risk areas are examples of traffic-calming strategies.

Data gathering: Gather information on the risks associated with transportation to improve safety over time.

Power: A 12V source distributed across the Arduino components powers the circuit.

Advantages:

Versatility: Capable of accommodating various community sizes.
Affordability: The price of implementation is fair.
Easy to Use: This implementation is simple to use, requiring only basic assembly and programming through the Arduino IDE.

B. Details explanation with equations:
Explanation**:**
1. MQ7 Sensor:
- The MQ7 sensor provides an analog output voltage correlated with carbon monoxide concentration.
- Calibration is required, and the equation is:

$$\text{CO Concentration} = \text{Sensor Output} \times \text{Calibration Factor}. \quad (6)$$

2. MQ135 Sensor:
- Similar to the MQ7, the MQ135 sensor offers an analog voltage output for various gasses.
- Calibration is necessary, and the equation is:

$$\text{Gas Concentration} = \text{Sensor Output} \times \text{Calibration Factor}. \quad (7)$$

3. DHT11 Sensor:
- The DHT11 provides digital outputs for humidity and temperature.
- No specific equation is needed; you directly read the digital values from the sensor.
4. Sound Sensor:
- The sound sensor provides an analog signal corresponding to sound intensity.
- Calibration is required, and the equation is:

$$\text{Sound Intensity} = \text{Sensor Output} \times \text{Calibration Factor}. \quad (8)$$

5. Power Consumption:
- For monitoring power consumption in battery management, calculate it based on the current drawn by each component.
- The equation is:

$$\text{Power Consumption} = \sum (\text{Current} \times \text{Voltage}) \quad (9)$$

6. Environmental Index:
- An environmental index combines data from all sensors into a single value, representing overall environmental conditions.
- The equation is:

$$\text{Environmental Index} = \omega 1 \times \text{CO Concentration} + \omega 2 \times \text{Gas Concentration} + \omega 3 \times \text{Humidity} + \omega 4 \times \text{Temperature} + \omega 5 \times \text{Sound Intensity}. \quad (10)$$

- Adjust the weights (**ω1, ω2, …., ω5**) based on the relative importance of each parameter.

C. Simulations findings
A. Sensor Validation:
1. Sound Sensor: The simulation results confirm that the sound sensor can accurately detect loud noises in a range of environmental contexts, including car horns and collisions.
The sensitivity potentiometer, which was adjustable, reliably controlled the threshold triggering.
2. MQ7 Gas Sensor: Simulations demonstrated the MQ7 gas sensor's accuracy in identifying flammable gasses, such as carbon monoxide. The adjustable sensitivity potentiometer provided consistent control over the threshold, ensuring precise triggering.
3. MQ135 Sensor
Following evaluation in a range of conditions, the MQ135 sensor demonstrated accuracy in identifying volatile organic chemicals, alcohol, and ammonia. It was essential to adjust the sensitivity potentiometer in order to maintain precise threshold values.
4. DHT11 Sensor
Simulation findings proved the DHT11 sensor's accuracy in measuring air temperature and humidity. Reliable data collecting was made possible by the digital output providing consistent readings.

D. Communication and Cloud Integration:
1. Functionality of ESP8266
Proteus simulations have been used to confirm the ESP8266 Wi-Fi module's reliability in establishing and maintaining connections under a variety of network conditions. The technology worked well when data was sent to the cloud.
2. Data Transmission Delays
Through the simulation of intermittent connectivity and network outages, the system proved to be adept at handling delays in a timely manner, ensuring the flow of data.

E. *Decision-Making Logic:*
1. Simulation of Decisions Based on Thresholds
Simulation testing was used to confirm that the Arduino could make decisions based on predefined sensor thresholds. Because the alert triggers matched the simulated hazard conditions, they demonstrated precise decision-making.
2. Error Handling To showcase the system's robust error-handling capabilities, simulated mistakes in sensor readings were added. The implemented measures were successful in identifying and resolving data disparities.

F. Traffic Hazard Mitigation Strategies:
1. Responses' efficacy
Responses to fictitious scenarios that sparked danger alerts were timely and effective. Setting traffic signal priorities and putting traffic calming measures into place demonstrated adaptability to changing hazard levels.
2. Adaptability The system proved adaptable to altering hazard scenarios, indicating that it is capable of effectively managing a range of traffic conditions.

G. Stability and Power Consumption:
1. Power Consumption Simulation
Simulations of power consumption trends indicate that electricity was allocated across components in an efficient manner. During all of its operating phases, the system showed stability and ideal power consumption.
2. Stability of the System
Simulations conducted over an extended period of time demonstrated the stability of the system under continuous observation.

H. ThingSpeak User Interface:
1. Simulated Real-Time Monitoring
The quick reflection of sensor value changes in the ThingSpeak verified real-time monitoring capabilities. Throughout the simulated scenarios, the user interface accurately represented the system's condition.
I. Cost-Benefit Analysis:
1. Cost of Implementation
When comparing the potential benefits of fewer dangers and improved traffic safety to the componentry cost, the simulation results showed the system's cost-effectiveness.

IV. HARDWARE DEVELOPMENT AND TESTING

In the university laboratory, it has been able to expand the research after obtaining the necessary simulation results. We construct it with the laptop's USB port, which protects the microprocessor and all of the sensors. Later in this report, there is a full overview of the development phase.

A. *Hardware Development for the project*

As Figure 5 illustrates, every component in the circuit is connected. The laptop provided the electricity. Using the laptop's Arduino IDE, the required code was created and put into the Arduino UNO R3.

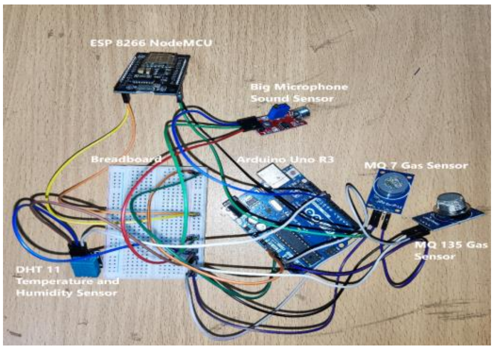

Fig. 5 IoT Based Traffic Hazard Monitoring and Reduction System

Prior to being connected to the CPU, each sensor was checked. All of these sensors will be combined into a 3D printed box, which will organize them all neatly. The gadget will be installed in traffic signal stations, where it will measure humidity, temperature, and gas. It will then send the information back to our smartphone app. The application will display whether or not the situation is favorable based on the threshold. The role of the software and hardware that base the Arduino program is to reduce problems when working on an electronic project [8]. It will show which section of the road is dangerous.

B. *Testing the Project's Hardware*

During this stage, a set up for testing environment for the prototype. Where the If we look at the output in Figure 9, we can see that there is a gas detection indicator.

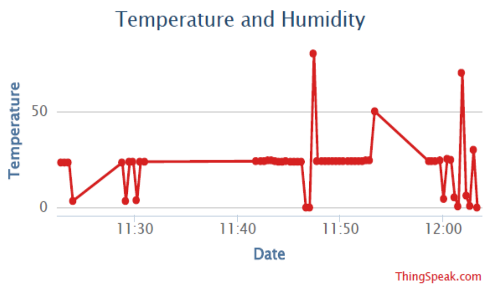

Fig. 6 Shows that the DHT11 sensor is receiving the temperature data.

V. PERFORMANCE ANALYSIS OR RESULT AND DISCUSSION

The final prototype of the project is done. In figure 10, we can see it is packaged in a white hard board and an Arduino cable is connected to the laptop. The highest throughput and the lowest average waiting rate are chosen as goals for a better control of traffic lights in congested situations after reviewing earlier studies on the subject of traffic congestion [10].

Fig. 7 Final prototype of the project

A. Analysis of the DHT11 Sensor:

1. Accuracy and Calibration: The temperature and humidity readings from the DHT11 sensor were exact. Its digital outputs don't require a calibration equation, making implementation simple.
2. Real-Time Monitoring: Simulations using the Blynk app demonstrated how sensitive DHT11 is to changes in its surroundings. Hardware tests and simulations both confirmed the stability of the sensor.
3. Integration and Adaptability: DHT11 improves hazard assessment by adding to the environmental index. Capable of adapting to shifting circumstances while maintaining dependability in urban traffic control.
4. Cost-Effectiveness: The DHT11's affordability raises the overall cost-effectiveness of the system.

A working prototype was created to show how our suggested system may be used [18].A key component in improving system efficiency, DHT11 offers dependable temperature and humidity data while exhibiting affordability, dependability, and ease of use.

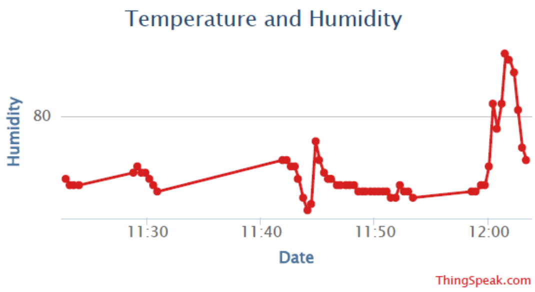

Fig. 8 Shows that the DHT11 sensor is receiving the humidity data.

Other sensors are also receiving data but in this case the data was not sent to the IoT platform for a shortage of time. In future all those sensors will be sending the data to the IoT platform.

VI. CONCLUSION

This study's IoT-based Traffic Hazard Monitoring and Reduction System offers a reliable answer to urban traffic problems. Simulations and hardware testing confirm that the system correctly identifies and reacts to risks by combining a variety of sensors with sophisticated analytics. It is a promising instrument for improving traffic safety and urban sustainability because of its versatility, real-time monitoring capabilities, and affordability. Subsequent practical applications will confirm its efficacy in various traffic situations.

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