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DEPARTMENT OF COMPUTER SCIENCE

TOPIC: IoT BASED SYSTEM FOR ROAD RISK PREVENTION AND ACCIDENT MONITORING

Case study: Ndjamena, Chad

DONE BY

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A DISSERTATION SUBMITTED TO THE KIGALI INDEPENDENT UNIVERSITY, SCHOOL OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF SCIENCE IN COMPUTER SCIENCE.

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DECLARATION

I, NOUBA-ASRA GOURSAM TRESOR, hereby declare that this dissertation titled "**IoT-based System for Road Risk Prevention and Accident Monitoring**" is my original work and has not been submitted previously for any degree award to any other university. All sources and references used in this dissertation have been duly acknowledged.

Signature……………………………

Date: ……/……. /…………

NOUBA-ASRA GOURSAM TRESOR

APROVAL

This dissertation titled "**IoT-based System for Road Risk Prevention and Accident Monitoring**" **Supervisor Approval**" has been done under my supervision and submitted for examination with my approval.

Signature……………………………

Date: ……/……. /…………

Dr. MUSABE JEAN BOSCO (PhD)

DECLARATION

This research is dedicated to my beloved parents, NGUEALOUM NOËL NADJINGAR and ADOUMDENE VICTOIRE, whose unwavering support and encouragement have been the driving force behind my academic pursuits. Their love, guidance, and sacrifices have shaped me into the person I am today, and I am eternally grateful for their belief in me.

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LIST OF ACRONYMS

AI: Artificial Intelligence

CSS: Cascading Style Sheets

DHT11: Digital temperature and humidity.

ESP32Board: Espressif Board.

ERD: Entity-Relationship Diagram

GPS: Global Positioning System

GSM: Global System for Mobile Communications.

HTML: HyperText Markup Language

IDE: Integrated Development Environment

IoT: Internet of Things

JS: JavaScript

KPI: Key Performance Indicator

LCD: Liquid Crystal Display

MQ3: An alcohol sensor commonly used in breathalyzers to detect the presence of alcohol in the air.

MySQL: Structured Query Language

PCB: Printed Circuit Board

SMS: Short Message Service

SSADM: Structured Systems Analysis and Design Method

WHO: World Health Organization

Abstract

Traffic accidents remain a significant threat on roads worldwide despite various actions taken by the World Health Organization (WHO) and many other organisms and researchers around the world. Real-time Internet of Things (IoT) systems offer a promising approach to both preventing accidents and improving response to those that occur. In this study, we propose a comprehensive road safety system that combines sensor technology, real-time monitoring, and data storage.

The system utilizes a temperature sensor to detect fire in the vehicle, an alcohol sensor to determine whether the driver was intoxicated, a gyroscope sensor to record data if the vehicle tilted or overturned during an accident, a GPS and GSM modem to send an SMS with the GPS coordinates of the incident, and an ultrasonic sensor to measure the distance between the driver and the obstacle before alerting the driver to monitor the speed of the vehicle. By analyzing this data, the system can predict potential accidents and trigger warnings for drivers. Additionally, the system can automatically detect accidents and send alerts to emergency services, minimizing response times and saving lives, saves all sensor data on a cloud in the event that any sensor detects aberrant behavior, allowing the investigating team to retrieve. Overall, data is accessible via the dashboard.

Keywords: IoT (Internet of Things) Systems, Road Risk Prevention, Accident Monitoring, Predictive Analytics (accident prediction), Driver Warnings, Automatic Accident Detection, Emergency Response Services, Data storag

CHAPITRE ONE: GENERAL INTRODUCTION

1. Introduction

Road transport offers numerous benefits to both nations and individuals, facilitating the movement of people and goods and providing increased access to job opportunities, economic markets, education, entertainment, and healthcare. These factors directly and indirectly contribute to positive influences on population health. However, the expansion of road transport has also brought about significant health burdens, including road traffic injuries, respiratory diseases, and reduced physical activity levels**.**

Every year, approximately 1.19 million lives are tragically lost due to road traffic crashes worldwide, sending shockwaves through families, communities, and nations at large. However, behind these grim statistics, lies a staggering number of non-fatal injuries—ranging from 20 to 50 million annually—often resulting in disabilities that profoundly affect individuals' quality of life and productivity (World Health Organization and the United Nations Regional Commissions, 2021).

In addition to health concerns, the growth in road transport has raised various negative economic, social, and environmental issues. These include air pollution, greenhouse gas emissions, depletion of limited resources, community disruption, and noise pollution.

Research by Ma et al., 2022 examined the causes of death from road traffic accidents in China and proposed practical measures to improve road safety, such as regular vehicle inspections, driver education, and stricter penalties for violations like drunk driving and speeding. Byun, Shin, Moon, Kang, & Choi, 2021 developed an algorithm to evaluate vehicle speeds from videos, a major factor in road traffic accidents in United States and South Korea, aiming to assist traffic police in handling collision cases more effectively**.**

The distribution of road traffic fatalities reveals a stark imbalance: despite high-income countries accounting for only around 60% of the world's vehicles, 92% of fatalities occur in low- and middle-income nations. Among these, the WHO African Region bears the heaviest burden, reporting the highest road traffic death rates, while the European Region boasts the lowest rates. Vulnerable groups, particularly children and young adults aged 5–29 years, bear a disproportionate brunt. Males are three times more likely to succumb to road crashes than females, and socioeconomic disparities exacerbate risks even within affluent countries (World Health Organization, 2023).

Road traffic safety represents a multifaceted puzzle, intricately shaped by various factors including drivers, vehicles, roads, ancillary facilities, driving environments, and traffic management. It responds to a complex interplay of driving behaviors, vehicle characteristics, road conditions, and broader transportation contexts**.**

Viewed from two perspectives, road traffic safety resembles both an elaborate blueprint and a dynamic system in operation. It involves not only designing vehicles with advanced safety features and constructing roads to minimize risks but also hinges on driving habits, adherence to traffic regulations, and rigorous enforcement of safety protocols (World Health Organization, 2021, 2023)

However, relying solely on isolated interventions falls short. The road traffic system is a dynamic network where risks persist despite preventive efforts. Accidents are never completely avoidable due to the system's inherent complexity. To devise effective solutions, we must delve into the underlying safety risks at every juncture, exploring both macro and micro levels of driving hazards and implementing targeted prevention strategies.

In this endeavor, understanding the root causes and transmission patterns of risks assumes paramount importance. And when accidents occur, swift response and effective emergency rescue operations become indispensable in safeguarding lives and property.

1.1 Background of the project

Chad faces significant road safety challenges, including inadequate road maintenance, poor signage, insufficient lighting, and a critical lack of driver education and awareness. The situation is further aggravated by the prevalence of overloaded vehicles, limited emergency services, and restricted access to medical facilities. Our project aims to address these pressing issues within the Chadian context by collaborating with local stakeholders to enhance road safety (World Bank’s Global Road Safety Facility, 2020).

In our interconnected world, road safety is an urgent concern. Road traffic accidents claim millions of lives each year, causing immense suffering and placing a considerable strain on healthcare systems and economies. Vulnerable road users—such as pedestrians, cyclists, and motorcyclists—bear the brunt of these tragedies.

Although some progress has been made through existing measures like traffic regulations, speed limits, and awareness campaigns, significant gaps remain. Enforcement of these measures is often inconsistent, and reactive responses to accidents frequently fail to minimize casualties and property damage effectively.

Our project envisions a comprehensive approach to road safety. We aim to establish a data-driven ecosystem that proactively identifies risks, prevents accidents, and enables swift responses to incidents. This initiative transcends isolated efforts, requiring collaboration, the integration of technology, and robust policy frameworks. It is crucial to understand that road safety is not just the responsibility of individuals; it demands a collective commitment and concerted action from all stakeholders.

To facilitate this collective action, we will engage with local communities, government agencies, and international organizations to foster a culture of safety. Training programs will be developed to enhance driver education and raise awareness about road safety. Additionally, we will advocate for improved infrastructure and emergency services, ensuring that all road users are better protected and equipped to respond to potential hazards.

Moreover, our project will leverage technology to gather and analyze data on road traffic incidents, helping us identify high-risk areas and trends. By utilizing geographic information systems (GIS) and other analytical tools, we can inform policy decisions and prioritize interventions that will have the greatest impact on reducing accidents. This holistic approach aims to create safer roads in Chad, ultimately saving lives and improving the quality of life for all residents.

1.2 Statement of the Problem

Road traffic accidents continue to claim lives globally, posing significant challenges to public health, economies, and social well-being. Existing road safety measures, while valuable, exhibit gaps in enforcement, risk assessment, and emergency response. Moreover, specific contexts, such as Chad, face unique challenges due to inadequate road infrastructure and limited awareness. To address these issues, our project aims to develop and implement an integrated system that proactively identifies risks such us obstacle in front of the vehicle, high vibration, fire incident, enhances preventive measures like alerting the driver on the distance between the vehicle and the obstacle, and ensures swift responses during accidents by sending SMS alert to emergency services. By bridging gaps in evidence, technology, and collaboration, we aspire to create safer roads for all.

1.3 Objective of the project

Our study aims to improve road safety by addressing critical gaps in risk prevention and accident monitoring. We seek to proactively identify hidden safety risks within the road traffic system, enhance preventive measures, implement real-time monitoring technologies, and establish swift emergency response protocols. Additionally, we recognize the unique challenges faced by specific regions, such as Chad, and aim to tailor context-specific solutions. Ultimately, our purpose is to create safer roads through evidence-based strategies, collaboration, and technology.

1.3.1 General objective

The general objective of the project "**IoT-based System for Road Risk Prevention and Accident Monitoring**" is to design the real time accident monitoring system.

1.3.2 Specific objectives

i. Incorporate sensors in the PCB.
ii. Implement an alert system using GSM.
iii. Design a database for keeping sensors data.
iv. Develop a dashboard for further data analysis.

1.4 Research Questions

i. How to integrate sensor in the PCB?
ii. How to effectively implement the alert method?
iii. Which database structure will be suitable for the system?
iv. What will the appropriate approach for the dashboard development?

1.5 Scope of the project

1.5.1 Content Scope

Our project covers risk assessment, preventive measures, real-time monitoring, and emergency response. It includes awareness campaigns, sensor deployment, and data analytics.

1.5.2 Geographical Scope

Initially, we focus on the study area (N'djamena, Chad) with unique challenges. Scalability to other regions is a long-term goal.

1.5.3 Time Scope

The timeframe of this project will center on the period between 2020 and 2024, encompassing the current situation within its boundaries.

1.6 Project methodology

This project will utilize a combination of methodologies to ensure efficient development and implementation: sensors for data collection and agile methodology for iterative development of our admin dashboard. A structured system analysis and design method (SSADM) will be used to define system requirements.

1.7 Significance of the project / Interest in the tin project

The significance of this project lies in its potential to address a pressing global issue - road traffic accidents. By developing and implementing an integrated system for road risk prevention and accident monitoring, this project could significantly contribute to public health, economic stability, and social well-being, particularly in contexts like N'Djamena, Chad.

1.7.1 Personal Interest

On a personal level, this project provides an opportunity to apply and enhance my skills in risk assessment, technology development, and collaborative problem-solving. It also aligns with my personal commitment to improving public safety and quality of life.

1.7.2 Institutional Interest

From an institutional perspective, this project could bolster our reputation as a leader in innovative, impactful research. Success in this project could also attract additional funding and partnerships, further advancing our institutional goals.

1.7.3 Public Interest

In terms of public interest, the project's outcomes could benefit a wide range of stakeholders. For road users in N'Djamena and similar contexts, the project could enhance safety and peace of mind. For policymakers and enforcement agencies, it could provide valuable data and tools to improve road safety measures. For the broader public, the project could contribute to a safer, more secure society.

1.8 Limitations of the Project

While we endeavor to ensure the efficacy of our project, it's crucial to recognize potential limitations that may affect the generalizability of our findings. These limitations extend beyond conventional constraints such as time and budget: data availability and quality, technological constraints as well as adoption of the system by relevant authorities.

Despite these challenges, we remain confident in the potential of our project to significantly enhance road safety in N'Djamena and offer valuable insights for similar initiatives elsewhere. We are committed to learning from these limitations and adjusting our approach as needed to realize our goal of safer roads for all.

1.9 Organization of the Project

This research will contain five organized as follows:

Chapter One: General Introduction; in this chapter, we talked about the reason that motivates us to develop this system according to the existing problems and possible solutions that are expected to be done. We stated where this system is going to be used and we talked briefly about some other topics that belong to the next chapter and the period during which we are supposed to finish

Chapter Two: Literature review; this chapter will handle with all theoretical concepts within the project.

Chapter Three: System Analysis and Design, this chapter is all about the system used to design the software and focuses on the requirements that need to be fulfilled.

Chapter Four: System implementation; It is in this chapter where all information regarding the implementation of the new system is highlighted using charts, screenshots, tables, and so on.

Chapter Five: Conclusion and recommendations; this is the chapter dedicated to the designer's general conclusion about the system and what can be.

CHAPITRE TWO: LITTERATURE REVIEW

2. Introduction

In this chapter, we delve into the existing body of knowledge surrounding road risk prevention and accident monitoring. By examining relevant studies, reports, and scholarly work, we aim to identify key insights, gaps, and trends. This literature review will inform our approach as we move forward in addressing road safety challenges.

2.1 Definition of concepts

Risk Assessment: Identifying potential hazards and assessing their impact on road safety.

Preventive Measures: Implementing strategies to prevent accidents and minimize risks.

Real-Time Monitoring: Using technology to monitor road conditions, traffic flow, and incidents.

Emergency Response: Establishing protocols for swift and effective responses during accidents.

Awareness Campaigns: Educating the public about safe road practices.

Sensor Deployment: Using sensors to collect data for analysis.

Data Analytics: Analyzing data to inform decision-making and improve road safety.

2.2 Theoretical review

This section will explore the theoretical underpinnings of the project, focusing on the themes of real-time data acquisition, cloud integration, and their applications in intelligent transportation systems.

2.3 Real-Time Data Acquisition and Processing

The effectiveness of this project hinges on its ability to collect and process data in real-time. Studies by Xia et al., 2023, Saddik, Latif, El Ouardi, Elhoseny, & Khelifi, 2022 highlight the growing importance of real-time data acquisition in various fields. (Priyanka, Maheswari, & Thangavel, 2020) emphasizes the role of real-time data in enabling proactive decision-making and optimizing resource allocation. Similarly, (Shafqat et al., 2020) explores the use of real-time data analytics for improving efficiency and safety in complex systems .

2.4 Cloud Integration and Scalability

The cloud platform will play a crucial role in data storage, analysis, and visualization. Research by (Almurisi & Tadisetty, 2022) demonstrates the advantages of cloud-based solutions for IoT systems. Cloud platforms offer scalability, allowing the system to handle increasing data volumes as the user base grows (Sandhu, 2022). Additionally, cloud storage ensures data accessibility and security, as highlighted by (Yang, Xiong, & Ren, 2020).

2.5 Theoretical Framework and Application to the Study

Building upon the concepts of real-time data acquisition and cloud integration, this project aims to develop a system that leverages these principles to improve security response times, optimize and monitor smart transportation systems. The theoretical framework will be further refined based on the chosen system analysis and design method SSADM to ensure a well-defined and achievable set of functionalities.

2.6 Human Factor Risks

Studies on drunk driving (Anthony, Varia, Kapadia, & Mukherjee, 2021), (Kumar & Nandal, 2022), fatigue driving (Al-mekhlafi, Nizam, Isha, Mohammed, & Naji, 2020), distracted driving (Dunn, Dingus, Soccolich, & Horrey, 2021), (Choudhary, Pawar, Velaga, & Pawar, 2020), and characteristics of elderly and young drivers (Isabelle & Simon, 2020) and (Ayuso, Sánchez, & Santolino, 2020) fall within this category. Findings reveal that alcohol impairs driver response time and reduces overall action ability. Fatigue leads to inattention, miscalculation, and neglect of driving conditions. Additionally, physiological decline in elderly drivers affects their driving ability, collectively posing significant threats to road safety.

2.7 Vehicle Factor Risks

Researching driver assistance systems (Ayyasamy, 2022), predicting vehicle collision risks (Lyu, Wen, Duan, & Wu, 2022), and ensuring vehicle-lane-changing safety (Luo et al., 2021) are all centered on vehicle-related risks. The accomplishments in this area encompass the development of driving assistance systems, algorithms for avoiding collisions in autonomous vehicles, assessing risks associated with lane changes, and the implementation of decision-making technologies. These advancements play a crucial role in improving vehicle safety and advancing intelligent transportation systems (ITS).

2.8 Road Factor Risk

Studies addressing road alignment safety (Wei, He, Meng, & Gao, 2021), climbing lane safety (Rivelino Duta Muhammad, Yogandari, & Aunurrofiq, 2022), and related topics explore road infrastructure risks. Researchers derive safety design indicators under varying conditions, laying theoretical foundations for improving road standards. These insights guide road planners and engineers in creating safer road networks.

2.9 Comprehensive Risk Management Approach

Certain scholars adopt a holistic perspective, considering the complete process of managing road traffic risks. This encompasses the perception (Ha, Kim, Seo, & Lee, 2020), evaluation (Zhou, Zhao, Shen, Yang, & Cai, 2020), forecasting (Wang & Chen, 2021), adaptation (Calvo-Poyo, Navarro-Moreno, & de Oña, 2020), and prevention of driving hazards (Michelaraki, Sekadakis, Katrakazas, Ziakopoulos, & Yannis, 2023). By combining these elements, professionals can devise successful tactics to reduce risks.

Conclusion

To sum up, extensive research efforts have yielded successful results in road traffic risk prevention and control. Our present study analyzes existing literature, contextualizes development trends, and identifies research priorities using bibliometrics. By clarifying future directions, we aim to enhance road safety and promote intelligent traffic management.

CHAPTER THREE: SYSTEM ANALYSIS AND DESIGN

3. Introduction

In the realm of road traffic safety, effective systems play a pivotal role in preventing accidents, minimizing risks, and ensuring swift responses during critical incidents. The process of system analysis and design involves a structured approach to understanding existing processes, identifying shortcomings, and proposing feasible enhancements. By examining the intricate interplay of components—ranging from sensors and algorithms to communication modules—we can create an integrated system that proactively detects risks, alerts stakeholders, and stores crucial data for investigation. In this chapter, we delve into the intricacies of analyzing and designing such a system, aiming to enhance road safety and mitigate the economic and human costs associated with traffic accidents.

3.1 Analysis of the current system

3.2 Problem of the current system

The existing system faces delays in responding to rescue accident victims promptly. Additionally, there is a lack of an efficient alert mechanism that can instantly notify relevant parties when signs of an accident or potential risks emerge. These delays and inefficiencies contribute to increased risks and hinder timely interventions during critical incidents.

The current system relies on traditional accident reporting methods, often involving manual intervention or passive monitoring. When an accident occurs, there is no immediate alert mechanism to notify emergency services, vehicle owners, or loved ones. As a result, rescue efforts are often delayed, impacting the well-being of accident victims. Furthermore, the absence of real-time data collection and proactive risk detection hinders effective accident prevention and response.

3.3 Analysis of the new system

3.3.1 Introduction

As we embark on designing an advanced road traffic safety system, our focus lies in addressing critical gaps and enhancing the existing framework. The new system aims to revolutionize accident prevention, swift response, and risk detection. By integrating cutting-edge sensors, real-time data capture, and instant alert mechanisms, we aspire to create a proactive and intelligent solution. In this analysis, we delve into the intricacies of our system, exploring its components, functionalities, and potential impact on road safety.

3.3.2 System requirements

The **functional** and **non-functional requirements** for our road traffic safety system:

Functional Requirements

Table 1 Functional requirements

Requirement	**Description**
Real-Time Risk Detection	Continuously monitor parameters (fire, vibration) to detect potential risks (any impact force or heavy vibrations, gyroscope sensor to record data if vehicle tilted or turned over during accident). Trigger alerts when risk thresholds are exceeded.
Emergency Alert Mechanism	Instantly send SMS alerts to relevant parties (emergency services, vehicle owner, family members) upon detecting imminent risks (collision, fire).
Data Logging and Storage	Record all relevant data during an accident (sensor readings, GPS coordinates, vehicle status). Store data for later investigation.
Driver Behavior Monitoring	Detect drunk driving (via alcohol sensors).
Admin Interface and Feedback	Provide clear visual alerts to the driver. Display relevant information on a dashboard screen.
Scalability and Adaptability	Accommodate different vehicle types (cars, trucks). Easily scale for widespread adoption.

Privacy and Security	Protect user privacy (personal data, location information). Prevent unauthorized access to sensitive information.
Latency and Real-Time Processing	Minimize delays in risk detection and alert delivery.

Table 2 Non-Function requirements

Requirement	Description
Performance	Real-time risk detection within milliseconds. Handle large concurrent users and data streams.
Reliability	Minimize false positives/negatives. Built-in redundancy for continuous operation.
Security	Protect sensitive information. Prevent tampering of sensor data.
Usability	Intuitive user interface for quick understanding.
Scalability	Accommodate future growth and additional sensors.
Maintainability	Modular design for easy updates and bug fixes.
Compatibility	Integrate with existing vehicle systems and communication protocols.
Privacy and Security	Protect user privacy and prevent unauthorized access.

3.3.3 Functional Diagram

Function diagrams show the relationship between the principal parts of a total system and are well-suited for process or drive control.

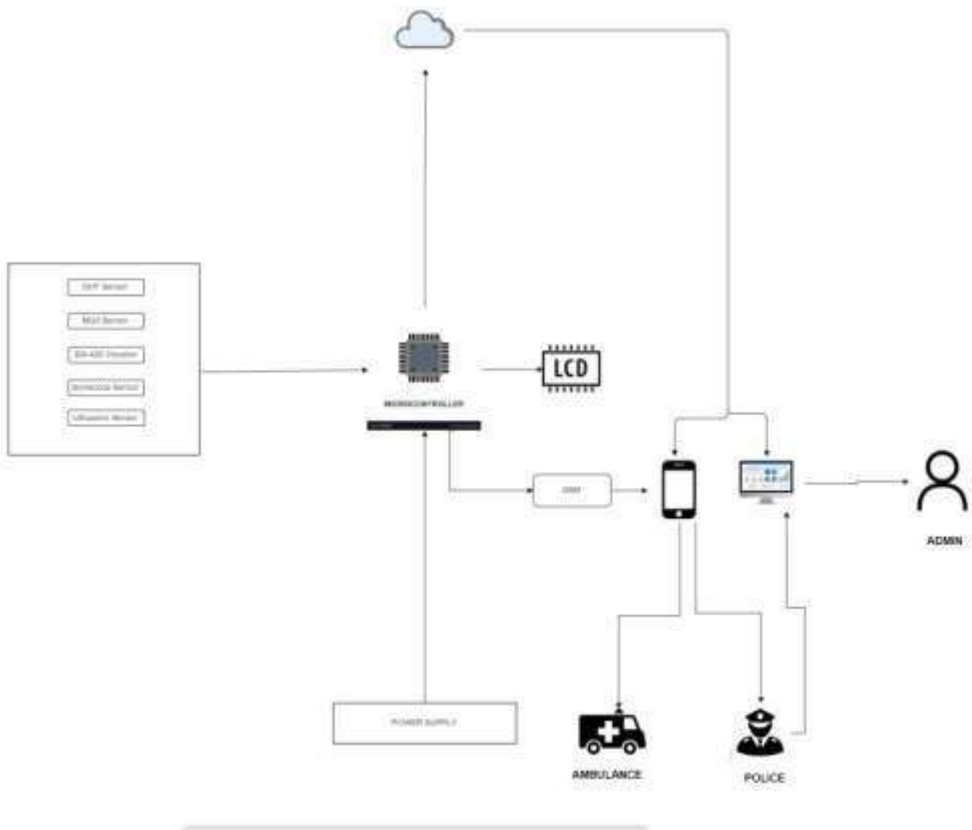


Figure **1** Functional Diagram

3.3.4 Methodological approach

3.3.5 Data collection techniques

For our research, the data collection technique employed was documentation. Specifically, we utilized data from existing records provided by reputable sources such as the World Health Organization (WHO), road safety journals, and other relevant publications. These records serve as valuable repositories of historical data, statistics, and insights related to road safety.

3.3.6 Software Development Methodology

Figure 2 Agile Model

The five steps of the Agile model in the context of designing our advanced road traffic safety system:

i. **Evaluation and Monitoring:**

Scenario: Imagine our team assessing the current road safety framework. We analyze accident data, response times, and existing risk detection mechanisms.
Agile Approach: We set Key Performance Indicators (KPIs) related to accident rates, response efficiency, and risk alerts. Regularly, we monitor whether the system is meeting these targets.

ii. **Strategies for Optimization:**

Scenario: Recognizing gaps, we strategize improvements. Our focus is on integrating cutting-edge sensors and real-time data capture.

Agile Approach: We collaborate with stakeholders (city planners, engineers) to choose optimal technologies. Iteratively, we refine our approach based on feedback.

iii. Application Design Together with Client:

Scenario: We engage with city officials and safety experts. Together, we envision the new system's design, considering user needs and safety requirements.

Agile Approach: Frequent interactions with stakeholders ensures alignment. We co-create wireframes, mockups, and user stories, adapting as we learn.

iv. Application Construction, Implementation, and Testing:

Scenario: Our development team starts building the system. We integrate sensors, develop algorithms, and create real-time alert mechanisms.

Agile Approach: In short sprints, we deliver functional components. We test each feature, iterate, and refine. The system evolves incrementally.

v. Mapping Processes to Determine the Starting Point ('Actual State'):

Scenario: We map existing infrastructure, identifying where enhancements fit. Our goal is a seamless transition to the new safety system.

Agile Approach: We assess the current state—what works well and what needs improvement. This informs our roadmap for implementation.

Agile allows us to iteratively enhance road safety by addressing critical gaps, integrating advanced technologies, and ensuring collaboration among stakeholders.

3.3.7 System Design Methodology

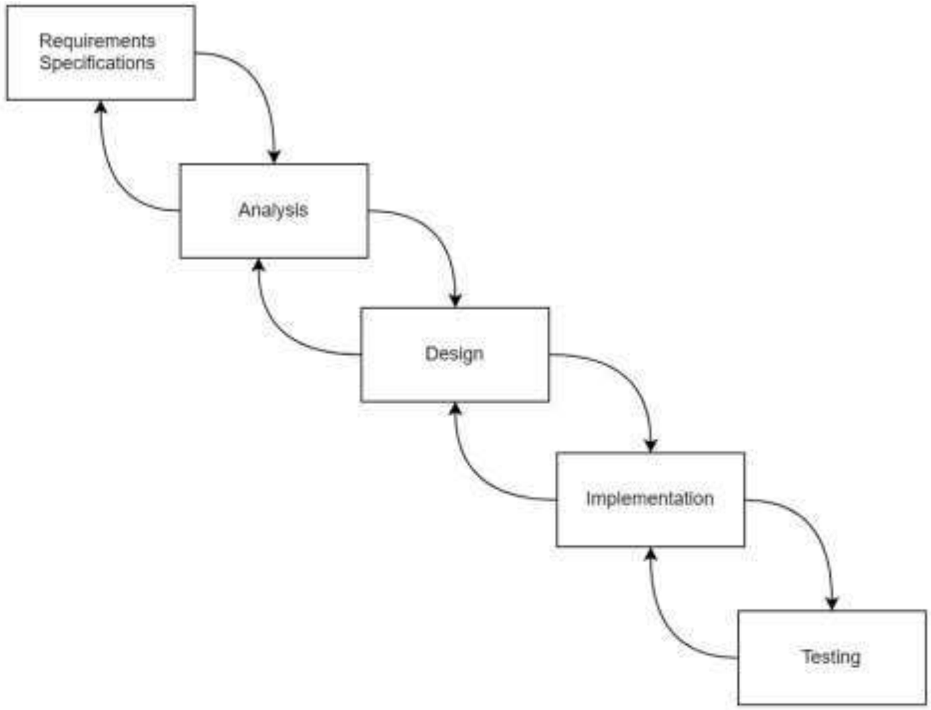


Figure 3 **System Analysis and Design**

For our project, Structured System Analysis and Design Methodology (SSADM) is a well-established approach for developing information systems. Its structured nature ensures a systematic and rigorous process. SSADM involves stages like feasibility study, requirements analysis, logical design, and physical implementation. It’s particularly suitable for complex projects where clarity, documentation, and step-by-step refinement are essential. By following SSADM, your team can ensure a thorough understanding of system requirements, minimize risks, and create robust solutions.

i. Context diagram (Level0)

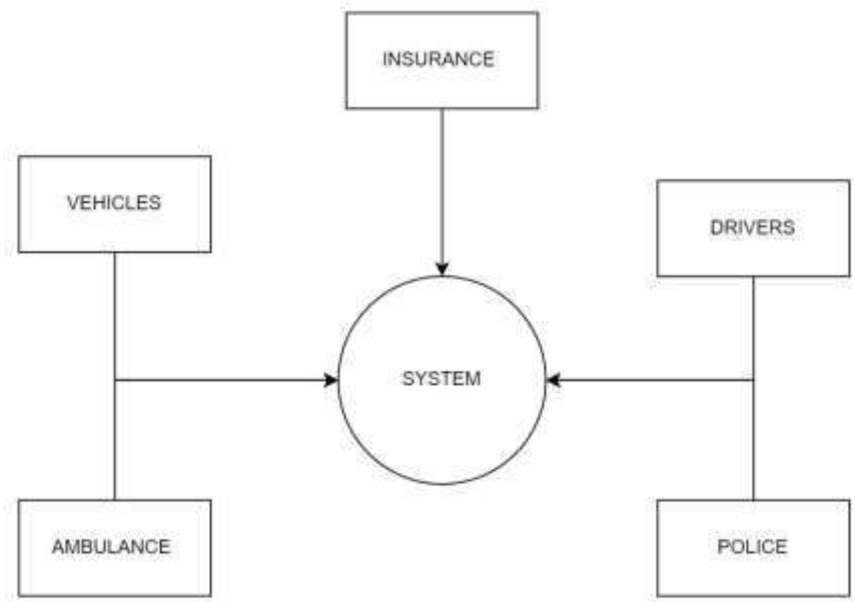


Figure **4** Dataflow Diagram Level 0

An IoT-based accident prevention and monitoring system that communicates with several external entities is depicted in the context diagram. The primary components communicating with the system are:

Vehicles: These give the system real-time data (including position, speed, and condition) to monitor and identify possible problems or accidents.

Insurance: This organization probably communicates with the system to follow coverage details and claims, or to confirm car information in the event of an accident.

Ambulance: In order to facilitate a quicker reaction to crises, the system interacts with ambulances to notify them of accidents.

Drivers: In order to avoid collisions, the system keeps an eye on driver behavior (such as weariness and speeding). It might also warn drivers of impending hazards or infractions.

Police: The system alerts the police for prompt reaction and investigation in the case of an accident or traffic infraction.

ii. Dataflow diagram (Level1)

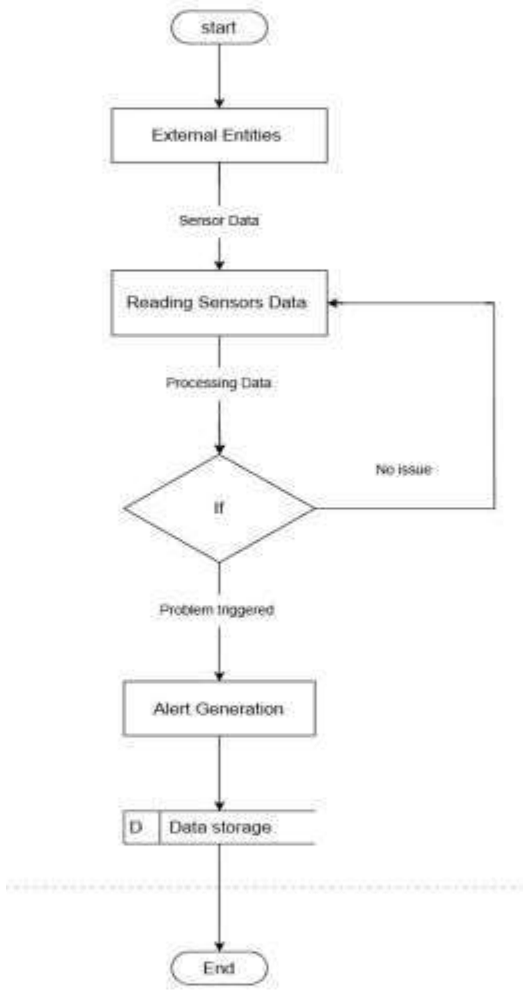


Figure **5** : Dataflow Diagram Level1

Level 1 DFD Explanation (For Sensor Data Processing):

The Level 1 DFD delves into the details of the Sensor Data Processing process within the vehicle monitoring system, illustrating the specific steps and interactions.

a) Step 1

Read Sensors: The system continuously reads data from the following sensors:

- Alcohol Sensor
- Fire Sensor
- Vibration Sensor
- ADXL335 Sensor
- Ultrasonic Sensor

b) Step 2

Process Sensor Data: Each type of sensor data is processed to detect specific conditions:

- Process Alcohol Data: Checks for the presence of alcohol.
- Process Fire Data: Checks for fire detection.
- Process Vibration Data: Checks for heavy vibrations indicating a potential collision.
- Process Gyroscope Data: Checks for tilting or overturning of the vehicle.
- Process Ultrasonic Data: Checks for obstacles in front of the vehicle.

c) Step 3

Alert Generation: If any abnormal condition is detected, the system generates SMS alerts:

- Vehicle Owner/Police/Emergency services: Receives SMS alerts.
- Web-based Dashboard: Also receives SMS alerts for real-time monitoring.

d) Step 4

- Data Storage: The system stores all relevant sensor data on an SD card for post-accident investigation.

iii. Entity Relationship Diagram (ERD)

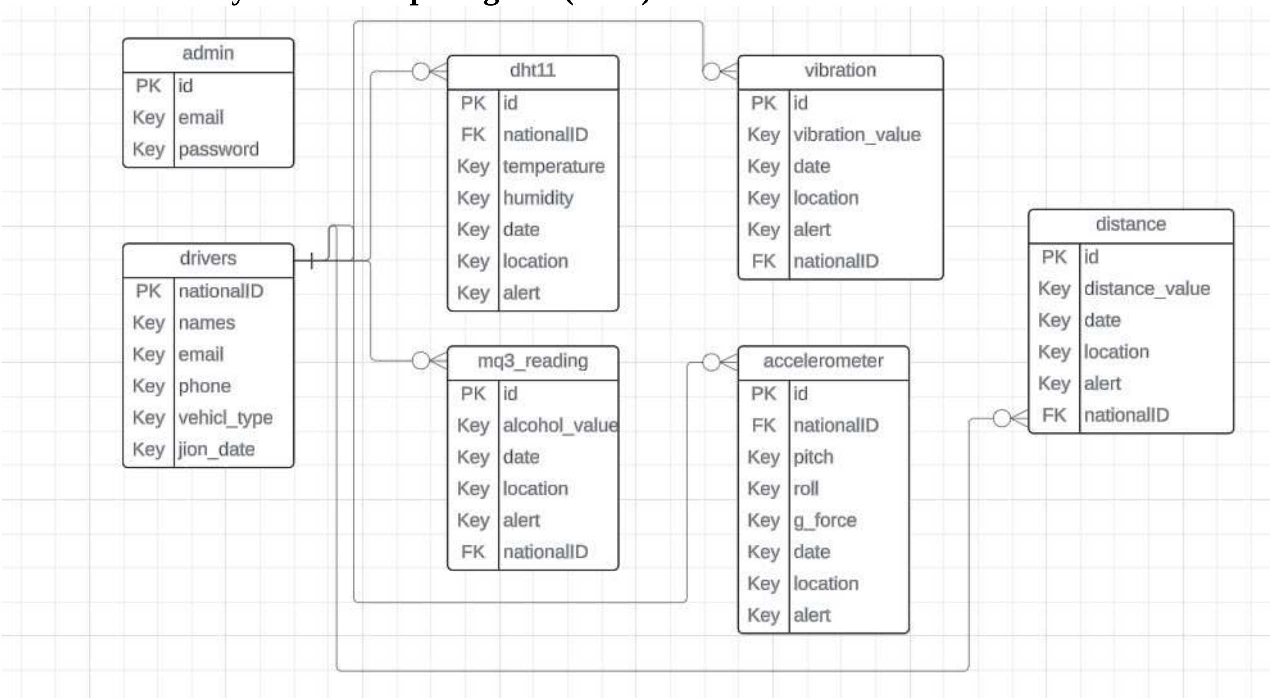


Figure 6 **Entity Relationship Diagram**

Description

This Entity Relationship Diagram (ERD) represents a system where different sensor readings (such as temperature, vibration, alcohol detection, and accelerometer data) are captured and associated with users and administrators.

Each sensor table has fields for `date` and `alert` to track the timing of the reading and whether an alert was triggered. All readings are linked to specific users through foreign key constraints, creating relationships between the `users` and the sensor tables. The diagram effectively models how sensor data is collected and related to users and managed by administrators.

iv. Data dictionary

Table 3 Sensor table

Field Name	Data Type	Data Format	Field Size	Description
Sensor_id	Integer	NNNN	11	Unique ID for sensor
Recorded_Date	Date/Time	DD/MM/YYYY	10	Date when sensor data is recorded
Alcohl_value	Float		4	triggered alcohol Value
Temperature_value	Float		2	triggered temperature Value
Accelerometer_value	Integer		3	triggered axes Value
Vibration_value	Integer		3	triggered vibration Value
Speed_value	Integer		3	triggered speed Value
Distance	Integer		4	Distance between vehicle and obstacles
Message	Varchar		100	Warning message

Table 4 Vehicle table

Field Name	Data Type	Data Format	Field Size	Description
Vehicle_id	Integer		11	Unique ID for vehicle
Vehicle_name	Varchar		10	Type of vehicle
User_id	Integer		11	Vehicle owner

Table 5 Users table

Field Name	Data Type	Data Format	Field Size	Description
user_id	Integer		11	Unique ID for users
user_name	Varchar		50	Name of the system's user
Relative_name	Varchar		50	Person to alert
Relative_phone	Varchar		15	Phone number of the person to alert
Registered_Date	Date/Time	DD/MM/YY	10	User registered date into the system

Table 6 Admin table

Field Name	Data Type	Data Format	Field Size	Description
admin_id	Integer		11	Unique ID for the dashboard user(administrator)
name	Varchar		39	System Admin Name

email	Varchar	example@gmail.com	20	Admin email
Password	Varchar	xxxxxxx	16	Admin password

Table 7**:** Vibration sensor table

Field Name	**Data Type**	**Data Format**	**Field Size**	**Description**
id	Integer		11	Unique ID for sensor
Vibration_value	float		50.00	Value received from sensor
Date	Date/Time	DD/MM/YY	10	Sensor abnormal date

Table 8**:** DHT11 sensor table

Field Name	**Data Type**	**Data Format**	**Field Size**	**Description**
id	Integer		11	Unique ID for sensor
humidity_value	float		50.00	Value received from sensor
temperature_value	float		50.00	Value received from sensor
Date	Date/Time	DD/MM/YY	10	Sensor abnormal date

Table 9**:** Alcohol sensor table

Field Name	**Data Type**	**Data Format**	**Field Size**	**Description**
id	Integer		11	Unique ID for sensor
alcohol_value	float		50.00	Value received from sensor

Date	Date/Time	DD/MM/YY	10	Sensor abnormal date

Table 10**:** Accelerometer sensor table

Field Name	**Data Type**	**Data Format**	**Field Size**	**Description**
id	Integer		11	Unique ID for sensor
pitch_value	float		50.00	Value received from sensor
roll_value	float		50.00	Value received from sensor
g_value	float		50.00	Value received from sensor
Date	Date/Time	DD/MM/YY	10	Sensor abnormal date

CHAPTER FOUR: SYSTEM ANALYSIS AND DESIGN

4. Implementation and Coding

4.1 Introduction

The process of implementing a designed system is known as system implementation. This phase entails integrating several components, converting the functional and technical requirements of the system into actual functioning code, and making sure the system performs as intended. It also entails testing the system to make sure it satisfies the specifications and is error- and bug-free.

This chapter covers the procedures for setting up a car monitoring system, which is intended to notify the owner, ambulance, police, family members of any possible accidents or unusual activity picked up by several sensors. An ESP32 microcontroller is used in the development of the system to regulate the input data from sensors such as the alcohol, fire, vibration, accelerometer, and ultrasonic sensors. A GPS module is integrated to transmit the vehicle's location data, and a GSM module is utilized to deliver SMS notifications. Additionally, data from anomalous occurrences is kept for future research needs.

The implementation entails creating the web-based dashboard for real-time monitoring, integrating the various hardware parts, and coding the software to govern sensor readings and SMS messaging. This part will go over the coding techniques, programming logic, and system architecture that go into making sure the system runs smoothly and consistently.

4.2 Description of Implementation tools and technology

The vehicle monitoring system is implemented by merging a number of hardware and software components. Each component is critical to ensure the system's proper operation, from recognizing abnormal events to sending alerts. Here is a thorough summary of the tools and technology utilized in the implementation:

ESP32Board

The ESP32 is a low-cost, low-power microcontroller with integrated Wi-Fi and Bluetooth functionality. It is often utilized in IoT projects due to its adaptability, which allows the system to not only monitor sensor data but also wirelessly interface with other devices. In this project, the ESP32 acts as the central processing unit (CPU), collecting data from sensors and controlling communication via the GSM modules.

Ultrasonic-Sensor

An ultrasonic sensor measures the distance between the vehicle and any impediments. It operates by producing ultrasonic waves and measuring the reflected signal when they bounce off an object. This sensor is essential to the system's obstacle recognition feature, which sends out notifications when a nearby item poses a hazard of collision.

DHT11(Digital-Temperature-and-Humidity-Sensor)

The DHT11 sensor monitors the temperature and humidity conditions within the car. It delivers precise digital data and is widely used in environmental monitoring systems. In this project, the DHT11 can detect fires or extreme conditions within the vehicle, so aiding in accident prevention or early warning systems.

MQ3(Metal Oxide Q-Chemistry) Sensor: The MQ3 sensor detects the presence of alcohol in the air, especially surrounding the driver. It is extremely sensitive to ethanol and is commonly used in breathalyzer devices. If the alcohol levels reach a certain threshold, the device will issue an alarm indicating possible drunk driving, informing the vehicle owner or emergency contacts.

ADXL335(Analog-Digital-Axis-Low-Power-Sensor)

The ADXL335 is a three-axis accelerometer that monitors vehicle acceleration along the X, Y, and Z axes. This sensor can detect rapid motions, tilts, and orientation changes. It can help determine whether the vehicle has flipped or is exhibiting aberrant driving habits, prompting relevant alerts.

The SW-420 vibration sensor detects mechanical vibrations and shocks. It generates a signal when vibration levels reach a predetermined threshold, making it helpful for detecting crashes, bumps, and other impacts. This sensor is crucial for accident detection, allowing the system to promptly notify necessary parties when an accident happens.

SIM808: GSM (Global System for Mobile Communication) Module.

The SIM808 is a GSM, GPRS, and GPS module that enables communication and position tracking. It is in charge of delivering SMS notifications to the vehicle's owner or loved ones with information such as the nature of the event (accident, fire, or alcohol detection) and GPS coordinates for convenient monitoring. It enables the system to operate independently of external network infrastructure.

The 4WD Smart Robot Car serves as the physical platform for the system's movement and obstacle detection tests. Equipped with four wheels, this vehicle can simulate real-world driving scenarios and help demonstrate how the system responds to various events, such as over-speeding or obstacle detection.

L298NMotorDriver

The L298N is a dual H-Bridge motor driver that can control the speed and direction of two DC motors or a single stepper motor. In this project, it is used to control the speed and direction of the robotic car's wheels, emulating the vehicle's behavior during an accident or obstacle detection.

Double-sided PCB (Printed Circuit Board): The double-sided PCB features copper rails on both sides, allowing for more intricate circuitry. In this system, it is utilized to install and connect numerous hardware components, ensuring smooth data flow between sensors, the microcontroller, and the GSM module.

LCD (liquid crystal display): An LCD displays real-time sensor data and system status updates. It offers a user-friendly interface for the system operator to see sensor readings, vehicle speed, and notifications. The LCD is necessary for on-site monitoring and diagnostics.

Lithium-Ion Battery: The entire system is powered by a rechargeable lithium-ion battery, allowing for portability and continued operation even when no external power sources are available. Li-ion batteries are preferred because of their high energy density and depend ability in powering embedded systems.

Jumper sand Power Supplies: Jumpers are needed to link different components on the PCB, and a reliable power supply guarantees that all hardware components receive enough power to operate smoothly. These are necessary for establishing the physical connections required to run the system efficiently.

Arduino IDE

The Arduino IDE is an open-source integrated development environment that allows you to write and upload programs to Arduino-compatible boards, such as the ESP32 in this project.

The code is mostly written in C++ (ccp), and it manages all hardware components, including sensors and communication modules. The IDE includes built-in libraries and tools for programming the ESP32 for real-time data collection, processing, and alarm creation.

Dashboard Implementation

The dashboard is a web-based application that displays real-time information from the vehicle's monitoring system. Several technologies were utilized for its implementation:

The dashboard's material is structured using:

HTML (Hypertext Markup Language). The user interface is built on HTML, which allows for the display of sensor data, alarms, and GPS information.

CSS (Cascading Style Sheets): Styles the dashboard so that it is visually pleasing and easy to browse. CSS controls the layout, colors, and general style of the interface.

Bootstrap is a popular front-end framework for creating responsive, mobile-first designs. Bootstrap components were used to create a sleek and professional-looking dashboard that adapts well to various screen sizes.

JavaScript (JS) enables dynamic information and interactive features on the dashboard. It provides for real-time updates to sensor data, alert notifications, and other system actions without reloading the entire page.

PHP (Hypertext Preprocessor) is a server-side programming language used to perform backend tasks such as receiving data from a car monitoring system and communicating with a MySQL database. PHP handles the logic that drives data insertion, retrieval, and alerts on the dashboard.

MySQL is a relational database management system that stores all data linked to the vehicle monitoring system. This comprises sensor data, alert records, GPS locations, and other important information. MySQL ensures that data is saved correctly and can be efficiently queried for inquiry and reporting.

Apache: A web server that hosts the dashboard and allows users to access it using a web browser. Apache serves HTML, CSS, JavaScript, and PHP files, as well as queries to and from the MySQL database.

Git is a version control system for tracking changes and collaborating during the development process. Git allows several developers to work on the dashboard at the same time, tracking different versions of the code and making updates and problem fixes easy to handle.

Together, these tools provide a powerful system that effectively monitors vehicle activity, generates alarms, and provides a user-friendly interface for investigation and reporting.

4.3 Software and hardware required

4.3.1 Circuit Diagram

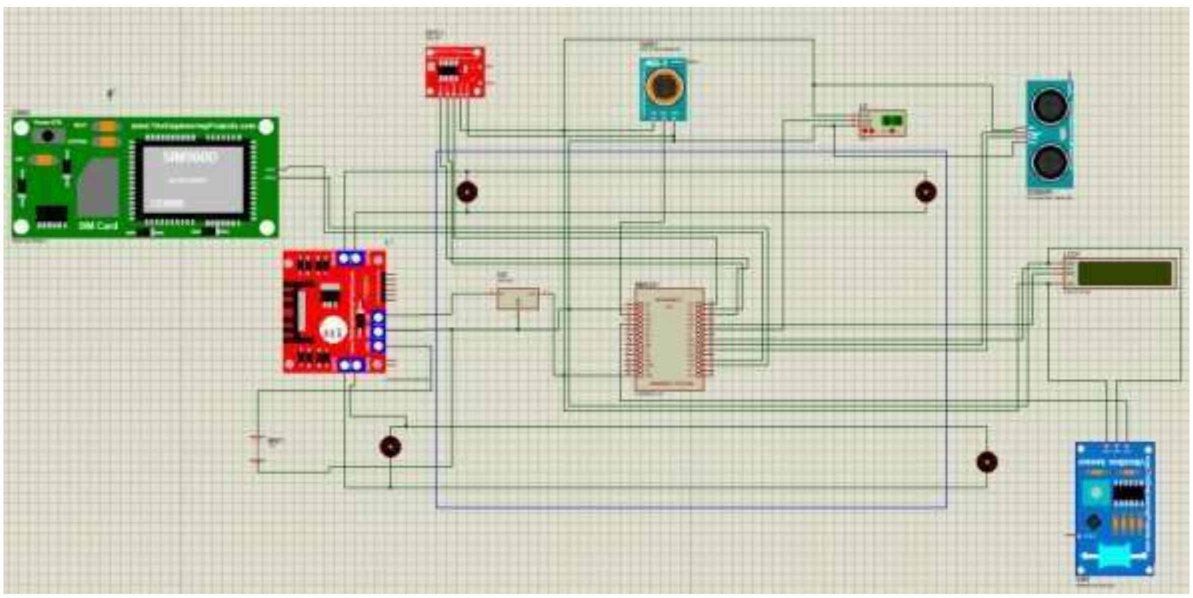


Figure 7 Circuit Diagram

4.3.2 Software

Arduino IDE: The Arduino IDE is a user-friendly platform designed for programming Arduino boards. It provides an intuitive interface for writing, compiling, and uploading code directly to microcontroller boards, making it ideal for beginners and hobbyists in electronics and robotics.

Visual Studio Code: Visual Studio Code is a versatile and highly customizable code editor used by developers for various programming languages. With its wide range of extensions, integrated Git, debugging tools, and robust IntelliSense, it's a powerful environment for both professional developers and learners alike.

Draw.io: Draw.io is a popular web-based diagramming tool used for creating flowcharts, network diagrams, and other visual representations. Its drag-and-drop interface, along with cloud storage integration, makes it a great choice for quickly designing and sharing visual content in collaborative settings.

Lucidchart: is a powerful web-based diagramming tool that allows users to create flowcharts, diagrams, wireframes, and other visual representations. It is highly intuitive, offering a drag-and-drop interface to design complex diagrams quickly.

4.3.3 Hardware

Personal computer (PC): A personal computer (PC) is a versatile device used for general-purpose computing tasks, programming, and development.

SP32 board: The ESP32 board is a powerful microcontroller with built-in Wi-Fi and Bluetooth, ideal for IoT and embedded projects.

PCB: A Printed Circuit Board (PCB) provides the physical platform to connect electronic components through conductive pathways.

DHT11: The DHT11 is a basic, low-cost digital temperature and humidity sensor for simple environmental monitoring applications.

MQ3: The MQ3 sensor detects alcohol concentration in the air, commonly used in breathalyzer systems.

Ultrasonic: An ultrasonic sensor measures distance by emitting sound waves and detecting their reflection, used in robotics and obstacle avoidance.

Accelerometer sensor: An accelerometer sensor detects changes in motion or orientation by measuring acceleration forces.

Vibration sensor: A vibration sensor detects physical movement or vibrations, often used for shock detection and monitoring machinery.

L298N Motor Driver: The L298N motor driver is a dual H-bridge module used to control the speed and direction of DC motors.

4-wheel robot car: A 4-wheel robot car is a mobile platform used in robotics projects, typically driven by DC motors and controlled via microcontrollers.

SIM808: The SIM808 module combines GSM, GPS, and Bluetooth functions, making it useful for communication and location tracking in IoT projects.

Lithium-Ion Battery - 12V: A 12V Lithium-Ion battery provides a reliable and rechargeable power source for various electronic and robotics applications.

Power supply 5-12 V: A power supply that delivers 5 to 12 volts is commonly used to power electronic circuits and microcontrollers.

Cable: A cable transmits electrical signals or power between components in an electronic system.

Jumper wires: Jumper wires are used for making temporary connections between components on a breadboard or circuit.

3.3 V AMS1117: The AMS1117 is a voltage regulator that steps down higher voltages to a stable 3.3V for powering low-voltage devices.

1.1 Screen shots and source codes

Super Admin Panel

Figure 8 Registration page

This page is used by the super Admin of our system to add an admin which will be responsible for managing the dashboard.

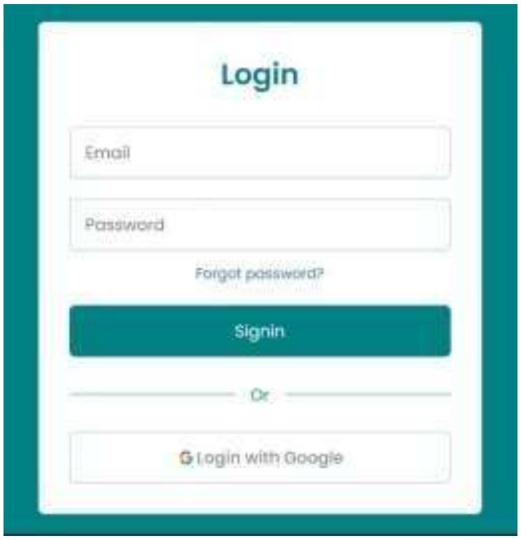


Figure 9 Login page

This page will be used by our system administrator to access the dashboard.

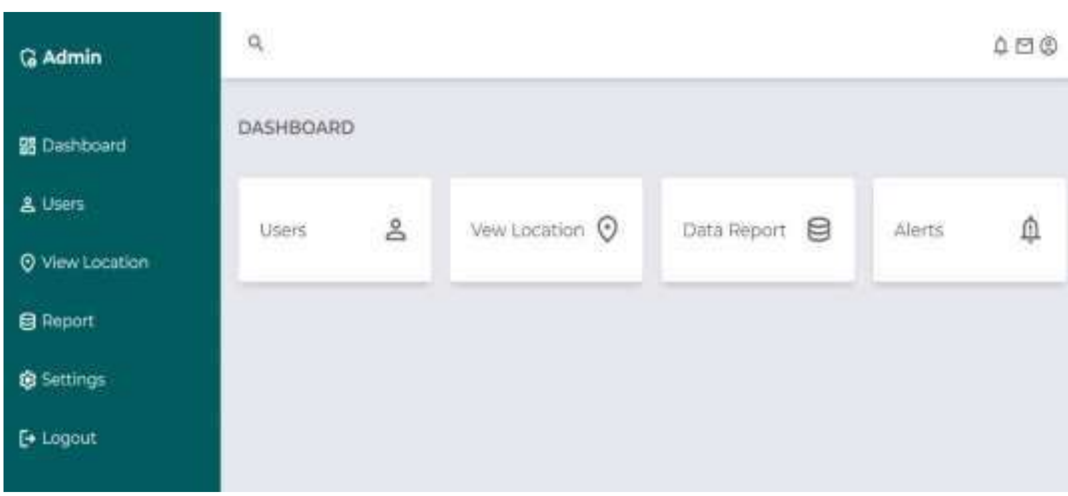


Figure 10 Dashboard

This is our dashboard that allow the administrator to add new users, to view the location of the vehicle whenever an abnormal activity occurs. Here, we can also generate report which is all about sensors data in order to know how many accidents have occurred along a period of time and where do the accidents mostly happen.

1.2 Testing.

1.2.1 Introduction.

The major purpose of the testing phase is to confirm that the system performs as expected and meets all of the requirements. The system goes through a series of tests to ensure that it successfully takes sensor data, issues warnings quickly, saves data correctly, and presents it suitably on the dashboard. Testing also includes testing the system's capacity to handle aberrant conditions such as accidents, and high vibrations, as well as ensuring that SMS alerts are sent reliably and shown on the web dashboard.

This project's testing consists of unit, integration, and system testing. Each test is aimed to check various components of the system's hardware and software, ensuring that the complete system functions properly. To assess the system's responsiveness and performance, the testing environment simulates real-world circumstances like as accidents, fire outbreaks, and driving beyond the speed limit.

Ultrasonic sensor Test outputs

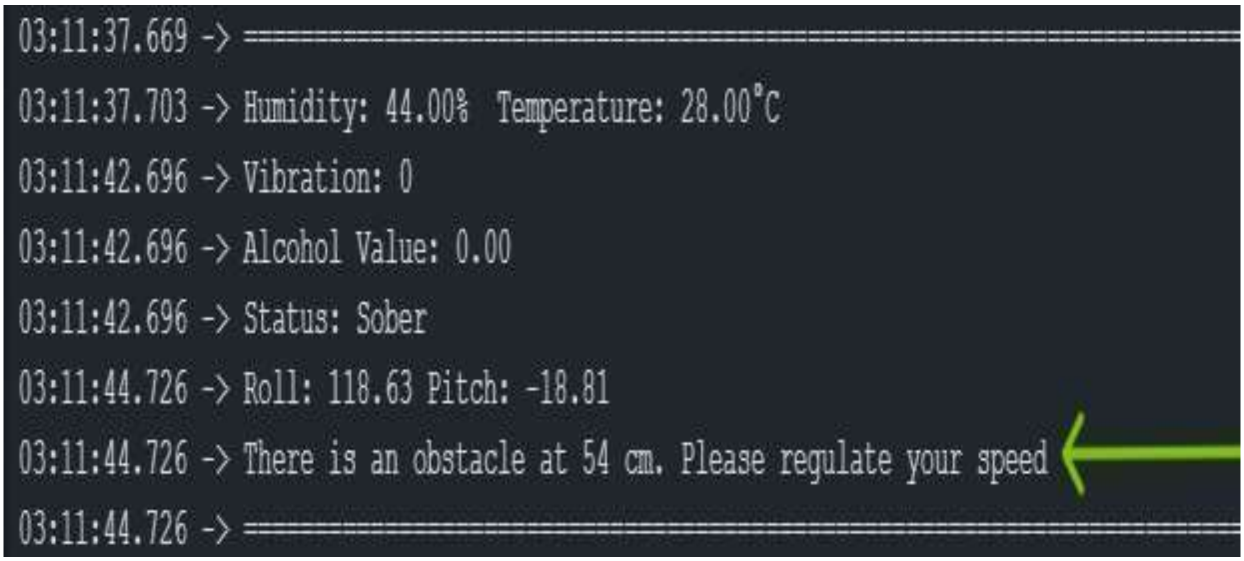
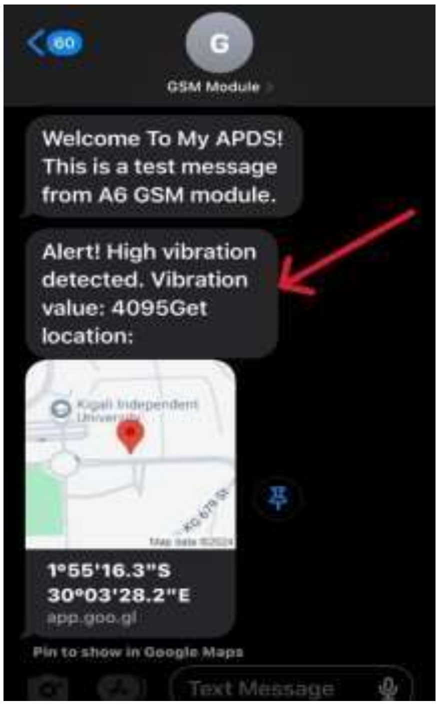


Figure **11** Ultrasonic test

Vibration & DHT11 sensor Test outputs



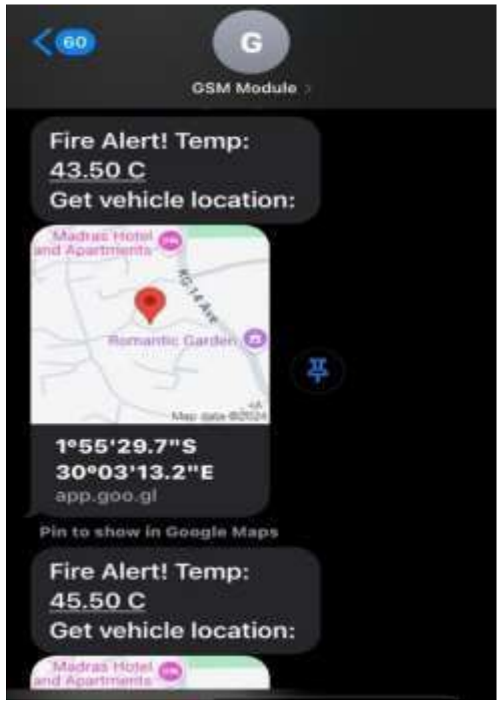
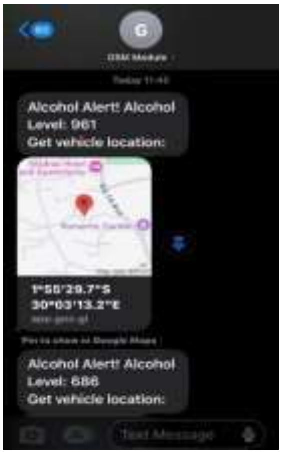


Figure 12 Temperature sensor test

Figure 13 Vibration sensor test

Alcohol & Accelerometer sensor Test outputs



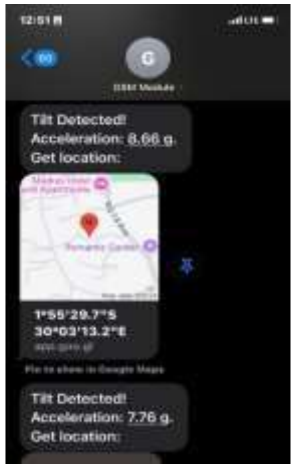


Figure 14 Accelerometer sensor test

Figure 15 Alcohol sensor test

Integration Testing Results

Integration testing investigates how individual components (sensors, GSM module, GPS, and dashboard) interact as a cohesive system. It ensures that the data collected by the sensors is properly processed, warnings are issued, and the data is displayed accurately on the online dashboard. This testing guarantees that all modules work together seamlessly.

Test Case ID	Test Description	Components Involved	Expected Result	Pass/Fail
ITC-001	Check sensor data collection and transmission	Vibration sensor, GSM module, Dashboard	Data from sensor is sent via GSM and displayed online	Pass
ITC-002	Validate GPS location data display	GPS module, Dashboard	Accurate location displayed on dashboard	Pass

ITC-003	Verify vibration alerts sent via SMS	Vibration sensor, GSM module, Mobile	SMS alert sent when vibration exceeds threshold	Pass
ITC-004	Ensure alcohol sensor data processed and displayed	Alcohol sensor, GSM module, Dashboard	Sensor data transmitted and displayed on dashboard	Pass
ITC-005	Test full system integration under normal operating conditions	All sensors, GSM, GPS, Dashboard	All components function together as expected	Pass
ITC-006	Simulate loss of network connectivity	GSM module, Dashboard	System retries to send data, alerts shown on dashboard	Pass
ITC-007	Check system response to high tilt value detection	Tilt sensor, GSM module, Dashboard	Alert sent via GSM and displayed on dashboard	Pass

ITC-008	Test GSM module's ability to send multiple alerts	GSM module, Dashboard, Mobile	Multiple alerts sent when multiple events are triggered	Pass
ITC-09	Check system operation under low power conditions	All components	System operates correctly or provides a warning	Pass

4.5.1 Functional and System Testing

Functional testing determines whether the system performs the desired functions, such as acquiring sensor data, producing warnings, and displaying real-time dashboard updates. System testing validates the system's overall performance, ensuring that it can handle different real-world scenarios and produce accurate results under a variety of inputs and conditions.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

1. Conclusion.

To summarize, our project has successfully created a car accident detection and alert system. The system identifies accidents and anomalous occurrences such as fire, over-speeding, or drunk driving using a variety of sensors including a vibration sensor, ultrasonic sensor, MQ3 alcohol sensor, gyroscope, and temperature sensor. When detected, an SMS alert is issued to registered contacts, and the data is saved for future examination. The Arduino Uno-based system, combined with a GSM and GPS module, enables real-time monitoring and location tracking. This technology provides considerable benefits for accident prevention and post-accident analysis. It can significantly cut response time and aid in the prevention of similar occurrences by evaluating stored data.

2. Recommendations

Improve sensor accuracy: Higher-grade sensors, particularly those for alcohol detection and impact force measurement, should be investigated for more accurate detection.
User interface improvements: The web-based dashboard should be improved to provide additional visual insights from sensor data and better analysis tools for investigators.
Battery optimization: In distant places where power sources are not widely available, implementing a more efficient power management system or solar-powered solutions may improve system reliability.

3. Future Work

Integration of advanced AI. Incorporating machine learning approaches to identify impending accidents or dangerous driver behavior using sensor data could be a future improvement. This would enable the system to take preventative action and avoid accidents.
Cloud storage and remote access: The system might store data in a cloud database, making it accessible from anywhere and lowering the risk of data loss in the event of a hardware failure.
Real-time data analysis: Future systems may use real-time data analysis to detect accident-prone behaviors, such as erratic driving patterns, and notify the driver promptly.

Obstacle recognition and avoidance: The system could be improved to identify and recognize impediments (such as pedestrians, other cars, and stationary objects). This information would be provided to the driver in order to help them manage their behavior, perhaps preventing crashes and other harmful circumstances.

Future research could include linking this system with a smart city grid to provide automatic reporting to local authorities, traffic management, and hospitals.

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APPENDICES

a. Overall system

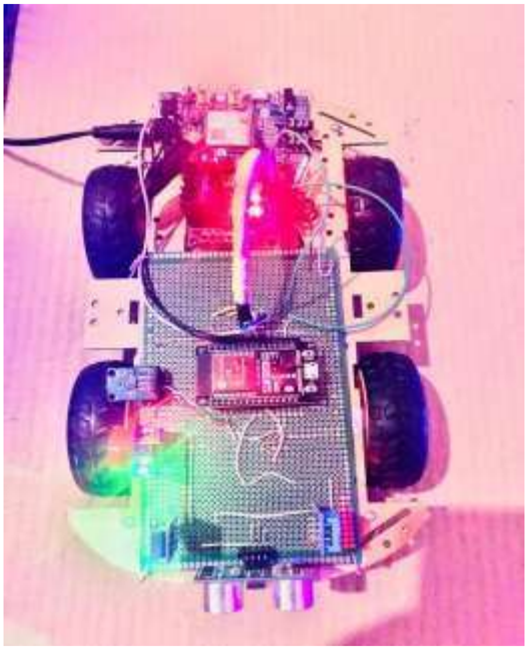


Figure 16 Working system

b. Time Frame

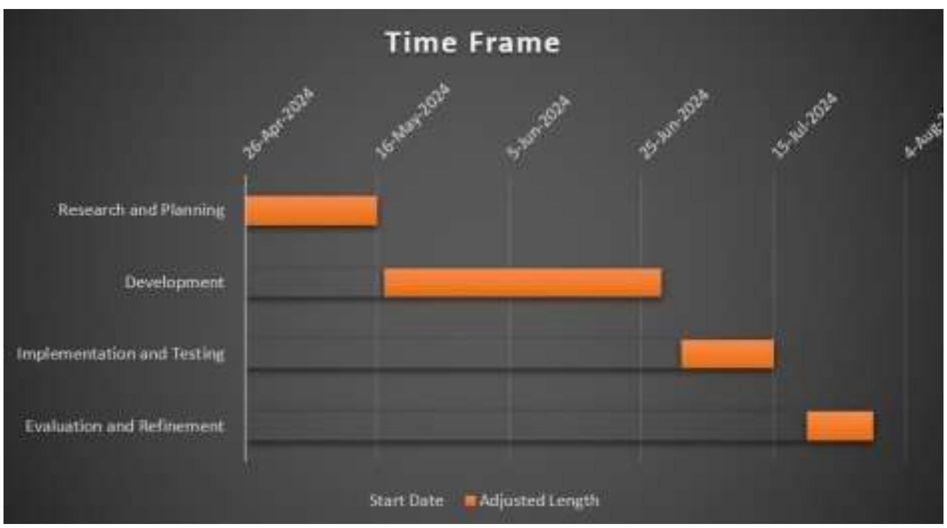
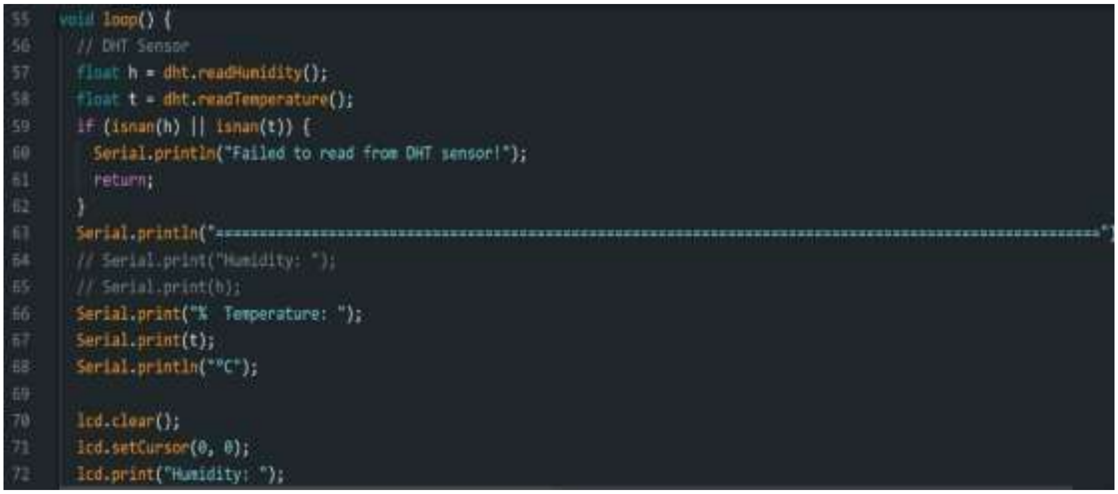


Figure **17 Time Frame**

c. Arduino code

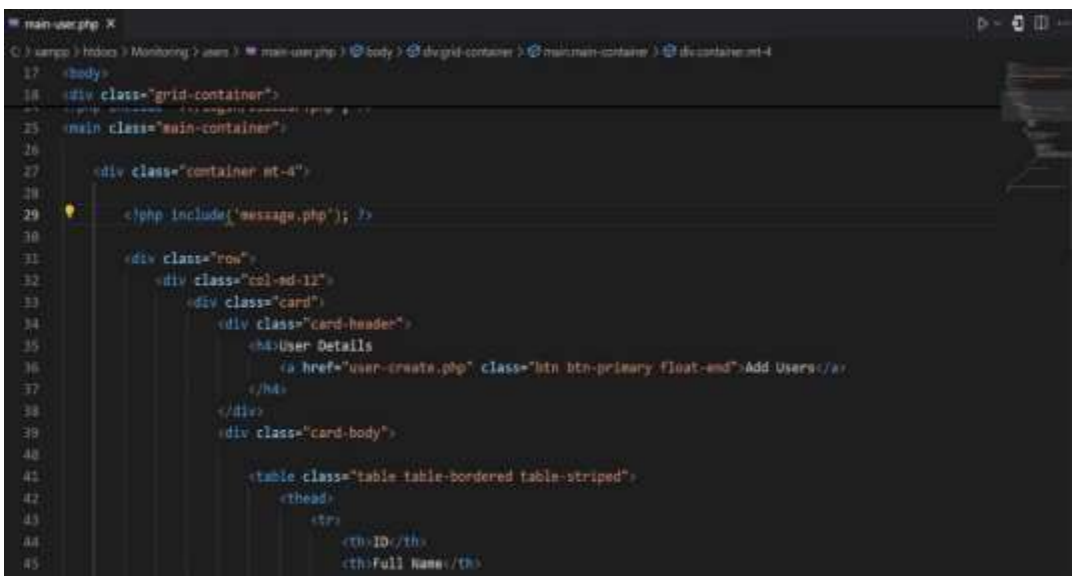


```
void loop() {
  // DHT Sensor
  float h = dht.readHumidity();
  float t = dht.readTemperature();
  if (isnan(h) || isnan(t)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }
  Serial.println("==========================================================================================================");
  // Serial.print("Humidity: ");
  // Serial.print(h);
  Serial.print("%  Temperature: ");
  Serial.print(t);
  Serial.println("°C");

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Humidity: ");
```

Figure **18: Arduino sketch**

d. Dashboard Code



```
<body>
<div class="grid-container">
<main class="main-container">

    <div class="container mt-4">

        <?php include('message.php'); ?>

        <div class="row">
            <div class="col-md-12">
                <div class="card">
                    <div class="card-header">
                        <h4>User Details
                            <a href="user-create.php" class="btn btn-primary float-end">Add Users</a>
                        </h4>
                    </div>
                    <div class="card-body">

                        <table class="table table-bordered table-striped">
                            <thead>
                                <tr>
                                    <th>ID</th>
                                    <th>Full Name</th>
```

e. Add users

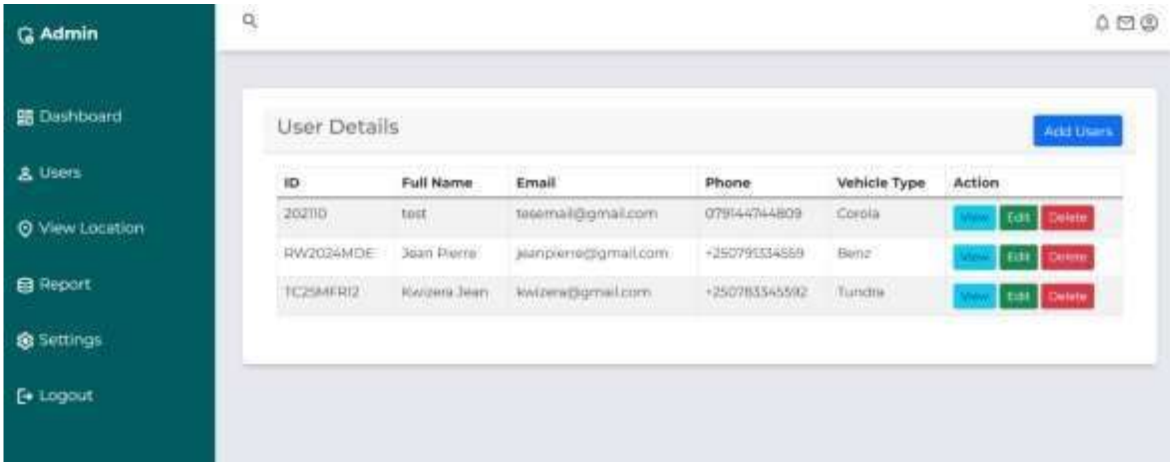


Figure 19: Add users