



UNIVERSITY of
RWANDA



Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw

College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS(ACEIoT)

Research Thesis Title: IoT-Based System to Monitor and Notify Vehicle Fuel Consumption

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded computing system

Submitted by:

Name: HAKIZIMANA Desire (**Reg No:**221031407)

August, 2024



UNIVERSITY of
RWANDA



Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw

College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS(ACEIoT)

Research Thesis Title: IoT-Based System to Monitor and Notify Vehicle Fuel Consumption

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded computing system

Submitted by:

HAKIZIMANA Desire (Reg No:221031407)

Supervised by:

Dr. Emmy MUGISHA

Dr. Evariste TWAHIRWA

August, 2024

Declaration

I **HAKIZIMANA Desire**, Master 'student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

Names: **HAKIZIMANA Desire**

Ref: **221031407**

Signed:

Date: 08/08/2024

Bonafide certificate

This is to certify that this submitted Research Thesis work report is a record of the original work done by **HAKIZIMANA Desire (Ref. Nu: 221031407)**, MSc. IoT-ECS Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2021/2023.

This work has been submitted under the supervision of **Dr Emmy MUGISHA** and **Dr Evariste TWAHIRWA**

Main Supervisor: **Dr Emmy MUGISHA**

Co-Supervisor: **Dr Evariste TWAHIRWA**

Date: 08 /08/2024

Date: 08 /08/2024

Signature:

Signature:

The Head of Masters and Training

Dr. James Rwigema

Signature :

Date :

Signature.....

Acknowledgements

I give thanks to God for all of my blessings and for bringing me to this moment in my life. I am grateful to the Almighty for my excellent health and the resources that allowed me to start this research project.

I would like to acknowledge the invaluable support offered by my supervisors' Dr Emmy MUGISHA and Dr Evariste TWAHIRWA, My ACEIoT leaders: Dr James Rwigema, Mr Benjamin HAKIZIMANA and Prof Damien Hanyurwimfura. I want to thank you for all of your help and support along this journey. I sincerely appreciate your support and willingness to share your experiences, which have given me a renewed sense of self-assurance and capacity to carry on this research as well as other projects in the future. I will always be grateful for your mentorship because of the priceless lessons I have learned under your watchful eye.

My sincere appreciation goes out to my loved ones, especially Emmanuel Hagenimana and Emile Musoni, as well as my coworkers, Paul Buchana, Philip Sendi, and Dr. Emmanuel Mberabahizi. I also want to express my gratitude to my brothers and sisters for their support and well wishes during this research project. We sincerely appreciate your understanding, moral support, and patience.

I am really grateful for the moral support that the ACEIoT team, my friends, and coworkers have given me. We sincerely appreciate your attendance, encouragement, and suggestions. I would want to thank all of the lecturers that helped me during the course. I want to express my gratitude to everyone who has helped me get this far. I could not have progressed as far as I have without your help. God deserves all praise and thanks for everything.

It is not practical to list all the names of the people that helped me, but I want to thank you everyone. I owe all gratitude and honor to God for having brought me this far.

Abstract

In the sphere of navigator and car shipping, the issues of fuel consumption and its minimization and thus the decrease of costs stay the most challenging. Previous studies have also named possible solutions such as the enhancement of the engine design and the use of lighter materials, better aerodynamics, and multiple forms of fuel. Furthermore, existing fuel monitoring systems present problems of inaccuracies, delays in collecting data and passive style of working which consequently result to fuel wastage an increased fuel related cost. Specific advancements comprise of technology such as direct injection and turbo charging that enhance combustion patterns. However, there are still blank areas in the implementation and the spread of more extensive AFs and the adaptation of new dispensing technologies in current facilities. To this end, the following objectives are being set forward for this project which is to fill up these gaps by creating a new IoT based fuel usage monitoring system. The rapid prototyping concept was applied to incrementally improve the IoT-based system design so that the corresponding elements and features could be tested and validated. The system consists of a microcontroller, GPS module, ultrasonic gasoline tank level sensor, GSM module alongside with the Laravel (Customized PHP), HTML/CSS/JavaScript/Bootstrap/react. The integration of these hardware and software parts was possible to make real time collection and analysis of data and interaction with the users. Some of the key outcomes are the production of a viable working model, the finding that one wastes approximately one gallon of fuel each hour that the car is engaged in idle, and designing of a real time operating fuel optimizing tool. This technology includes location tracking of the vehicles along with the statistics of fuel consumptions, as well as the real time route planning. It also controls fuel consumption, alerts the client when the amounts are low, and helps to find the nearest service station; engaging mobile apps enhance the use.

Keywords: Fleet management, Fuel optimization, IoT-based monitoring, Real-time data analysis, Alternative fuel solutions, Rapid prototyping.

Contents

Declaration	iii
Bonafide certificate	iv
Acknowledgements	v
Abstract	vi
List of Figures.....	ix
LIST OF ACRONYMS	x
CHAPTER 1: INTRODUCTION	11
1.1 Introduction	11
1.2 Problem statement	11
1.3 Research questions	12
1.4 Study objectives	12
1.4.1 Specific objectives	12
1.5 Study Scope	13
1.7 Significance of the Study	13
1.8 Organization of the Study	14
CHAPTER 2: LITERATURE REVIEW	15
2.1 IoT-Based Fuel Monitoring Systems	15
2.2 Sensors for Fuel Monitoring	16
2.3 Integration with GPS Technology	16
2.4 Challenges and Considerations	17
2.5 Research Gaps	18
CHAPTER 3: METHODOLOGY	20
3.1 System Design	20
3.2 IoT based prototype	22
3.3 Data Collection and Transmission	24
3.4 Data Analysis and Visualization	24
3.5 Performance Evaluation	25
CHAPTER FOUR: RESULTS	27
4.1 Hardware and Software Integration	28
4.2 Data Flow and System Structure	30
4.3 System Functionality and results	31
4.4 Web Application Features	32

CHAPTER FIVE: DISCUSSION AND CONCLUSION..... 37
REFERENCES 41

List of Figures

Figure 1: system architecture	21
Figure 2: system flow chart.....	22
Figure 3:fuel level display to LCD	23
Figure 4:Sending data to the cloud	25
Figure 5:System web application dashboard.....	25
Figure 6: New fuel station.....	26
Figure 7:User of the system	32
Figure 8:stakeholder	28
Figure 9:Sending data to the cloud	28
Figure 10: hardware assembly of the prototype.....	30
Figure 11: system web application dashboard.....	30
Figure 12: simplified system structure	31
Figure 13:Cars management.....	32
Figure 14:Cars/Stations locations on map.....	33
Figure 15: Live GPS location of vehicles and Petrol stations	34
Figure 16: fuel level with distance	35
Figure 17: fuel consumption as a function of speed	35
Figure 18: vehicle fuel level time series.....	36

LIST OF ACRONYMS

IoT: Internet of things

ECS: Embedded Computing Systems

GPS: Global positioning system

GSM: Global system for mobile telecommunications

HTML: Hypertext Markup Language

CSS: Cascading Style Sheets

PHP: Personal Home Page

OCC: Occasionally connected computing

Afs: Automatic Finite Scheduling

CHAPTER 1: INTRODUCTION

1.1 Introduction

Internet of Things or IoT is one of the revolutionary technologies that has influenced numerous features of human life, and its presence is rapidly growing in different fields. Regarding such a resource, road transport is one area that has expanded its use far and wide due to the developments in the IoT [9]. To meet the growing need of optimizing fuel consumption an efficient solution is an IoT-based application underpinned by ultrasonic sensor and GPS tracker.

This research presents an Internet of Things (IoT) implemented system that employs the ultrasonic sensor and GPS to supervise and record vehicle fuel consumption in real-time. Using functionality of IoT connectivity, the system offers up-to-date and correct information about the fuel levels allowing for efficient and timely management of the fuel.

The system under consideration calls for the attachment of ultrasonic sensor on the vehicle's fuel tank and the GPS tracker. These types of sensors are used to measure the fuel level and send the data to an IoT main point of interest. Due to integrated connectivity and communication the real time monitoring of fuel level is possible which implies the users are continuously notified of their vehicle's fuel condition consistently.

In addition, the IoT integrated smart system encompasses applications for users' additional convenience and added functionalities. These applications alert the responsible staffs when the fuel levels of the car decrease to a certain level, this requires the staffs to take heed and refuel the car. Also, it has GPS function that provides the navigator which fuel stations are close to the car and how to get there to fill up.

Thus, on the basis of the possibilities of IoT and with the help of the added ultrasonic sensor, this system offers a complete solution to control and optimize the fuel consumption of vehicles. Having real-time from the sensor together with web applications and GPS tracking enables the users to make better decisions, save on fuel and improve operation efficiency.

The rest of the sections of this research will look at the system architecture of this IoT- based system and how it has been implemented, as well as the myriad of advantages associated with the use of smart automotive fuel monitoring and management system.

1.2 Problem statement

In this field of fleet and transportation management it is vital to ensure proper control and measurement of the fuel consumed by vehicles in the fleet in order to improve efficiency and

cut expenses. However, current fuel monitoring solutions can be broadly defined by inaccuracy, a lack of real-time data, and reactive character, which results in numerous inefficiencies and growing fuel-related expenses [3]. Furthermore, methods accompanied with paper and pencil to monitor the fuel level consumes much time and are inaccurate, and thus results in poor management in relation to fuel consumption and replenishment [3]

Besides, it is worth noting that many fuel monitoring solutions of conventional design do not offer efficient interfaces and integration with other working systems; therefore, fuel usage data cannot be combined with other appropriate parameters effectively.

To tackle these issues, it is requisite to develop an IoT based system that effectively and constantly measures the fuel levels of the vehicle using ultrasonic sensor. This kind of system should be responsible for delivering accurate and up-to-date information on fuel status to the users, support effective fuel management, help to make the right decisions, and interact with other organizational systems.

Thus, the problem statement is centered on implementing an IoT system for fuel monitoring that helps in avoiding the deficiencies of the existing approach to fuel monitoring and providing a constant and precise visualization of the fuel consumption of vehicles. They should be able to help users make intelligent decisions regarding fuel consumption, spending patterns, and other measures affecting total functionality of the fleets and transportation sector.

1.3 Research questions

1. What are the most suitable IoT sensors and equipment for accurately measuring and collecting fuel consumption data across a diverse range of vehicles in transport companies?
2. How can a customized IoT solution be developed and deployed to enable real-time tracking and immediate notification of vehicle fuel consumption for transport companies?
3. How can a web-based application be designed and implemented to display prototype results, integrating an IoT-based fuel consumption monitoring system into existing fleet management infrastructure using both agile and waterfall methodologies?

1.4 Study objectives

1.4.1 Specific objectives

1. Assess and choose the IoT sensors and equipment that are most appropriate for precisely measuring and gathering fuel consumption data from transport companies varied range of vehicles.

2. Develop and deploy a customized Internet of Things (IoT) solution uniquely tailored to transport companies, enabling real-time tracking and immediate notification of vehicle fuel consumption.
3. Design and implement a web-based application to display prototype results, integrating an IoT-based fuel consumption monitoring system into existing fleet management infrastructure, utilizing both agile and waterfall methodologies

1.5 Study Scope

This study is focused on Implementing an IoT-based system to monitor and notify vehicle fuel consumption in transport companies by covering the following:

- Design and implementation of an IoT-based system to monitor and notify vehicle fuel consumption in transport companies.
- Generation of reports, deployment and testing a designed IoT system to monitor and notify vehicle fuel consumption to the responsible staffs in Transport companies as well as to display the information in real-time.

1.7 Significance of the Study

The system will be of benefit to the society and the whole country in general in contexts that involve several applications that includes but not limited to; real time monitoring of transportation fuel consumption and generating an alert to the responsible staffs on fuel levels. Besides this GPS tracker of the system, the drivers will receive alert messages concerning the nearest available petrol stations for refueling the vehicle. The advantage is that this is a cheaper ultrasonic sensor and a GPS tracker with GSM technology and thus is an advantage because it costs less to duplicate and to enhance software. As well, with respect to the GSM technology in the present one, the notification (SMS) concerning the remaining fuel level as well as the nearest location of the fuel petrol station is received by the responsible staffs. This work is a cheaper solution for measurement of fuel and location tracking intended for Rwanda it will be the option that many Rwandan's road vehicle transport companies can afford. Besides, the utilization of this solution will enable the vehicle transport companies to minimize on the dishonest loss when it comes to fuel and also avoid the driver to utilize the vehicle on unworthy job.

It provides an economical and comprehensible method through which fuel consumption monitoring can be automated for vehicle fleets. It also equips managers with timely information and notification on how the refueling coordination is done and when fuel burn is too much. Transparency also discourages unauthorized use of the car especially when it has not obtained

permission to do so. It also given an aspect of relief regarding refueling stops to the drivers as the automated petrol station guidance system decreases the various uncertainties.

The major plus with the system is the possibility for most transport organizations Rwandan based to make use of the inexpensive sensors and trackers. It includes the fuel efficiency and cost management, which in turn refers to the accessibility that inspires the industry to innovate. Thus, the system allows for root cause analysis regarding such factors as unsuitable driver practices into which managers can examine consumption trends. He added that companies can use the data to also introduce new methods of pricing for usage-based insurance. This has a connection between premiums and coverage with risk factors such as the number of miles driven in a year. Fascinating such innovations free long-term saver and sustainability of Rwandan road transport. Perhaps even more important, the indicated benefits have been secured by Rwanda relying on its home-grown technical solutions. Adoption helps to create abilities and employment in the IoT domestic market. It also enhances competitive edge and export chances to neighboring countries since global export is a part of the component. Local solutions also aim at satisfying the Africa transport needs in unmatched ways that the global solutions would never be able to afford.

1.8 Organization of the Study

The remainder of this paper is arranged as follows; Section 2 describes the specifications of edge collection of data by sensors. Section 3 describe the architecture and implementation of an IoT for tracking and alerting the fuel consumption of vehicles in transport firms at the edge. Section 4 focuses for the System Analysis and Design, Section 5 contains the Analysis of result. Then, future works and conclusion are discussed in section 6.

This chapter comprises the introduction of this research, the problem statement and the need for conducting this research which is to design and prototype an economical and scalable embedded device for fuel monitoring and vehicle tracking. As part of the research, the literature review was conducted with some emphasis on the applicability of the IoT system to the all the vehicles owned by Transport Companies and the provision of a feasible maintenance strategy for the longevity of the system. Therefore, the dissertation establishes that IoT technology has the potential of bringing drastic change in the management of fuel consumption in transportation. live fuel tracking and alerting may drive Transport companies such as those on fuel costs cutting and hence sustainability. Subsequently, with the development of IoT, it is foreseen that there will be innovations of this technology which seeks to benefit the industry to a greater extent.

CHAPTER 2: LITERATURE REVIEW

Many businesses have improved operational efficiency and decision-making with IoT. IoT fuel monitoring and optimization in transportation has advanced greatly. This literature study discusses IoT-based car fuel monitoring's pros, cons, and tech.

2.1 IoT-Based Fuel Monitoring Systems

IoT fuel monitoring technologies have changed how organizations track and manage car fleets [8]. These systems provide real-time fuel consumption statistics via a network of sensors, communication devices, and data analytics tools. Fuel efficiency and operational decision-making are among the benefits of such systems.

Data collection and real-time transfer are strengths of IoT fuel monitoring devices. They continuously monitor fuel levels, consumption, and vehicle performance [10]. Real-time data helps fleet management optimize fuel replenishment, routes, and maintenance. IoT solutions' seamless connectivity and data integration give fleet managers access to vital information.

Fleet management benefits from IoT-based fuel monitoring systems' real-time data collecting and analysis. First, proactive fuel replenishment is possible. These devices can automatically notify users when fuel levels drop below predefined criteria by continuously monitoring fuel levels. Fleet managers may then move quickly to replenish vehicles, reduce fuel shortages, and optimize fuel consumption.

Second, real-time data improves the routes' optimization within a certain time range. These systems use the GPS tracking along with gasoline consumption data to suggest efficient fuel consumption routes. Less gasoline utilization means less time on the road and better operations.

Third, it becomes possible to conduct predictive maintenance through the IoT. Real-time monitoring of vehicle's performance parameters by the fleet managers can help them in preventing failure and downtime by scheduling repairs.

Besides, the link established between fuel consumption and operations such as weather and traffic help in decision making. Bad weather conditions are also possible to consider to make safe and efficient route changes or needed vehicles' deployment.

However, when IoT technologies are integrated with other sources of operation data, they offer far more important information [5]. Information relating to fuel consumption is thus analyzed alongside details of vehicle diagnostics, weather, and traffic in order to facilitate fleet analysis. It partially explains on how this comprehensive approach assists the firms in identifying areas of waste, cost reduction and environmental sustainability.

2.2 Sensors for Fuel Monitoring

Proper work of the IoT-based fuel monitoring systems is possible only with an accurate sensor that allows measuring the fuel level. High frequency sensors are widely used in this area because of their accuracy, reliability, and versatility.

Ultrasonic sensors are distance measuring instruments that employ use of sound waves. These sensors produce ultra sound waves which in turn interact with the fuel surface to enable the tracking of gasoline. It is used in the measurement of the time it takes some sound waves to cover the distance to the fuel and back in order to come up with the level of the tank's gasoline [6]. This non-invasive approach to the analysis is less stressing to equipment and gives correct results because it does not come into contact with fuel.

CIS ultrasonic sensors are accurate as well as suitable for many gasoline tank sizes and shapes [6]. It can be noted that these gasoline level sensors can be tuned and customized to fit particular fleets ranging from small peck OCC passenger cars to the very large commercial trucks. This flexibility makes ultrasonic sensors suitable to be used in IoT based gasoline monitoring systems because the size and shape of the tanks do not matter to the sensors.

On a similar note, ultrasonic sensors are not restricted to the adaption to tanks only. These sensors are ideal for many operating conditions because they are rather reliable in different conditions. Ultrasonic sensors give accurate quantity of fuel even on extreme temperatures, humidity and tough terrains.

Thus, in summary from this review the ultrasonic sensors are recommended for IoT based gasoline monitoring systems time and again because of the benefits of high accuracy, adaptability depending on the design of the tank and the durability of the environment. The fact that they accurately measure the fuel level without having to come into contact with the fuel surface makes them ideal for various and all kinds of fleets. Fleet management fuel monitoring may also advance with the use of ultrasonic sensors in the future.

2.3 Integration with GPS Technology

Geographical positioning fuel monitoring IoT devices are useful and more important for a company's fleet management.

By so doing GPS technology relays positioning details of fleet cars and fuel consumption of such automobiles to any organization to make efficient routes and avoid the use of excessive gasoline [10]. Fleet managers can learn more about their previous fuel consumption in given routes to plan routes properly. Thus, historically fuel-efficient routes can be determined, which in turn can help firms reduce fuel costs and enhance operational performance.

GPS technology enhances on security and fuel theft [10]. They can track vehicle movement in live conformity in order to identify any unlawful or questionable activity. Fuel theft can be easily identified through GPS data as to the time and place of the occurrence. Then, the obtained information can be useful for subsequent investigations and the recovery process.

Geofencing strategies can be employed with the help of GPS and fuel monitoring data available to the managers of a fleet. Other alerts sent when a vehicle is either entering or departing geofenced areas on a map [10]. Managers are able to constantly track vehicles' movement and get alerts if a car went off route or entered restricted area. Compared to other methods, geofencing makes fleet management more secure and manageable.

GPS accompanied with IoT based fuel monitoring gadgets is extremely advantageous to the fleet management in terms of the following. It assists organizations to find the best routes, reduce expenses on gasoline, enhance protection, and prevent fuel theft. GPS and fuel monitoring data synergy therefore assists in the proper running of the vehicles and in achieving the objectives of the organization. In the future, it will become necessary for the firms to incorporate IoT as well as GPS systems to improve the operations of their fleet and reduce operational costs.

2.4 Challenges and Considerations

However, just like with any other IoT-based applications, several issues arise when integrating car fuel monitoring systems; these are some of the considerations that organizations have to make while applying the system.

In the case of the IoT-based fuel monitoring systems, the security and private data are critical components [7]. Information regarding fuel consumption is always considered to be of a highly sensitive nature and proper measures have to be taken to ensure the security of the information as there is always a high risk of a breach. Encryption, good authentication methods as well as controls to access facilities as well as information are some of the key parts of the security solutions. The protection of the data from the unauthorized viewing or changing from other people is necessary for preserving the accuracy and an appropriate level of confidentiality of fuel consumption data.

Also, as data privacy laws grow and develop, compliance is highly important and even more stringent [7]. Companies with facilities within different geographies need to make sure their IoT-anchored solutions complies with laws on data protection at the country and global levels. The failure to adhere to these standards is punishable by the law, can attract fines, and negatively affects an organization's image. Thus, failing to meet the changes in the regulatory

framework of a country, an organization needs to modify the work of its members and the programs it has implemented in compliance with the new rules.

2.5 Research Gaps

The literature on IoT-based gasoline monitoring systems has produced helpful insights but also highlighted research gaps and prospects for further study:

1. **Scalability and Adaptability:** In the present literature, most research works are centered on a particular type of methodology or application, while IoT-based fuel monitoring systems should be tested across a broad range of vehicle types and industries (NIYIGENA, 2021). Scholarship should analyze its applicability within the sphere of international transportation and the sphere of public transportation because the conditions there may differ. There is a need to engage in research to learn more on how the systems can be adopted to suit different situations and or industries.

2. **Data Analytics and Machine Learning:** IoT devices generate a great amount of data, but there has been relatively research focusing on techniques to extract useful information from such data employing data analysis and machine learning algorithms [5]. Further research could also focus on the enhancement of fuel efficiency and development of prognostic maintenance strategy based on prognostics analytics. Fuel management is a significant area where data analytics also assists the firms in having a better understanding of the same.

3. **Security and Privacy:** IoT systems need to security and privacy rules [2] still fuel monitoring system needs complete guidelines and best practice to protect data. This is important as our laws that brought about data privacy are changing. Shortcomings have to be studied, good security/privacy practices need to be adopted, and disclosed data protection law has to be followed.

4. **Cost-Benefit Analysis:** Since most IoT based fuel monitoring systems solutions enable cost savings in fuel, research cases demonstrate cost benefits in fuel consumption implications; however, more elaborate benefits-cost research are needed to analyze ROI and monetary effects of IoT fuel monitoring systems, particularly on a large scale and varying economic setup (NIYIGENA, 2021). Thus, economic consequences of these systems should be comprehended by the organizations that are thinking about their investment.

5. **Environmental Impacts:** Internet of things-based fuel monitoring system found to be useful in better utilizing the fees usage and minimizing the carbon footprint [8]. They should be researched in terms of their effects in contributing to sustainability agenda the impacts they will potentially have on the vehicle fleet carbon footprints. It can help to realize the extent of

the companies' interconnection with the environment and thus, stress the significance of the topics in question in the context of sustainability.

6. User Experience and Training: Some of the factors that relate to IoT adoption include; User experience and training, [5]. Studies should compare user training and, overall, user redesign procedures. This will enhance the degree of user acceptance and usability since the characteristics and skills of organizational users will be taken into account.

7. Regulatory Structure: It is thus necessary to study the legal constraints and regulations that pertain to different locations and industries for IoT based fuel monitoring system [7]. This research may assist in avoiding such problems and ensure that all the necessary facilities meet the required norms and legislation.

Authors	Contributions	Identified Gaps	Proposed Solutions
Alaba et al. (2017)	Conducted a comprehensive survey on IoT security, highlighting various security threats and solutions in IoT environments.	The study does not focus specifically on IoT-based fuel monitoring systems.	Applying robust security measures such as encryption, authentication, and access control to protect fuel monitoring data.
Deep et al. (2022)	Investigated security and privacy issues in IoT from a layered context, offering a detailed analysis of vulnerabilities.	Specific guidelines and best practices for securing IoT-based fuel monitoring systems are lacking.	Developing comprehensive security frameworks and best practices tailored to IoT-based fuel monitoring.
Fantin Irudaya Raj & Appadurai (2022)	Explored IoT-based smart transportation systems for smart cities, emphasizing the potential for operational efficiency.	Limited focus on fuel monitoring and its integration with IoT in transportation systems.	Integrating IoT-based fuel monitoring with smart transportation systems to enhance fuel efficiency.
Madhukara et al. (2022)	Implemented a vehicle monitoring and accident detection system using IoT, focusing on safety and operational monitoring.	The research does not address fuel monitoring specifically.	Extending IoT applications to include fuel monitoring and optimization in vehicle management systems.
NIYIGENA (2021)	Designed an IoT-based seat occupancy monitoring system for public transport,	Specific application to fuel monitoring and	Applying IoT-based monitoring techniques to fuel consumption and vehicle performance.

	demonstrating the utility of IoT in operational monitoring.	optimization is not explored.	
Pourrahmani et al. (2022)	Reviewed IoT applications in the automotive industry, covering batteries, fuel cells, and engines.	Insufficient focus on comprehensive fuel monitoring systems using IoT.	Developing IoT-based fuel monitoring systems with advanced sensor integration for real-time data collection.
Praveenchan dar et al. (2022)	Utilized IoT for monitoring harmful toxic gases and detecting faults using deep learning techniques.	Lack of research on IoT-based fuel monitoring and its impact on fleet management.	Implementing IoT-based fuel monitoring systems with predictive analytics and machine learning for enhanced decision-making.

CHAPTER 3: METHODOLOGY

3.1 System Design

Requirement Analysis: The first activity performed was the requirement gathering and analysis activity. In order to design a system for a fleet management solution that would satisfy the intended users that include the fleet managers and the vehicle operators, there was the need to establish their functional and non-functional requirements. Consulting with the stakeholders and engaging in discussions with them was crucial in this regard regarding the firm's creation of a scope and direction for the project.

System Architecture: The design phase also wanted the creation of an efficient top level system architecture concept. This architectural framework defined the movement of data and control, connectivity of different system parts and also the integration of hardware and software parts. The architecture of the system is summarized in the figure below:

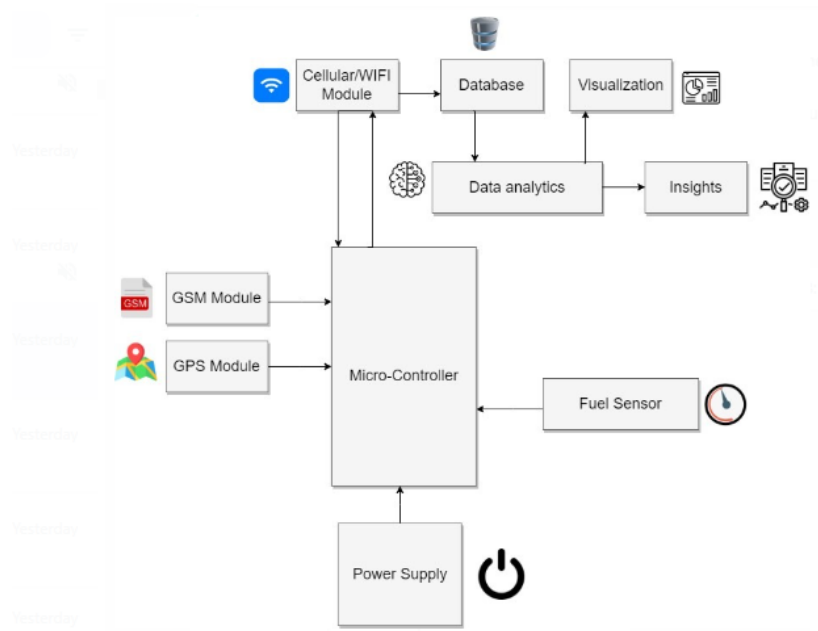


Figure 1: system architecture

As depicted in figure 1 the GSM and GPS modules transmit data to the microcontroller. The microcontroller interfaces with the WIFI/cellular network. The fuel sensor is also interfaced with the microcontroller of the system through the Prototype Circuit Board PCB. Information is then transferred over the network to a database and analyzed originally from the database and then visualized to yield knowledge. The mode of operation is summarized in the system flow chart below:

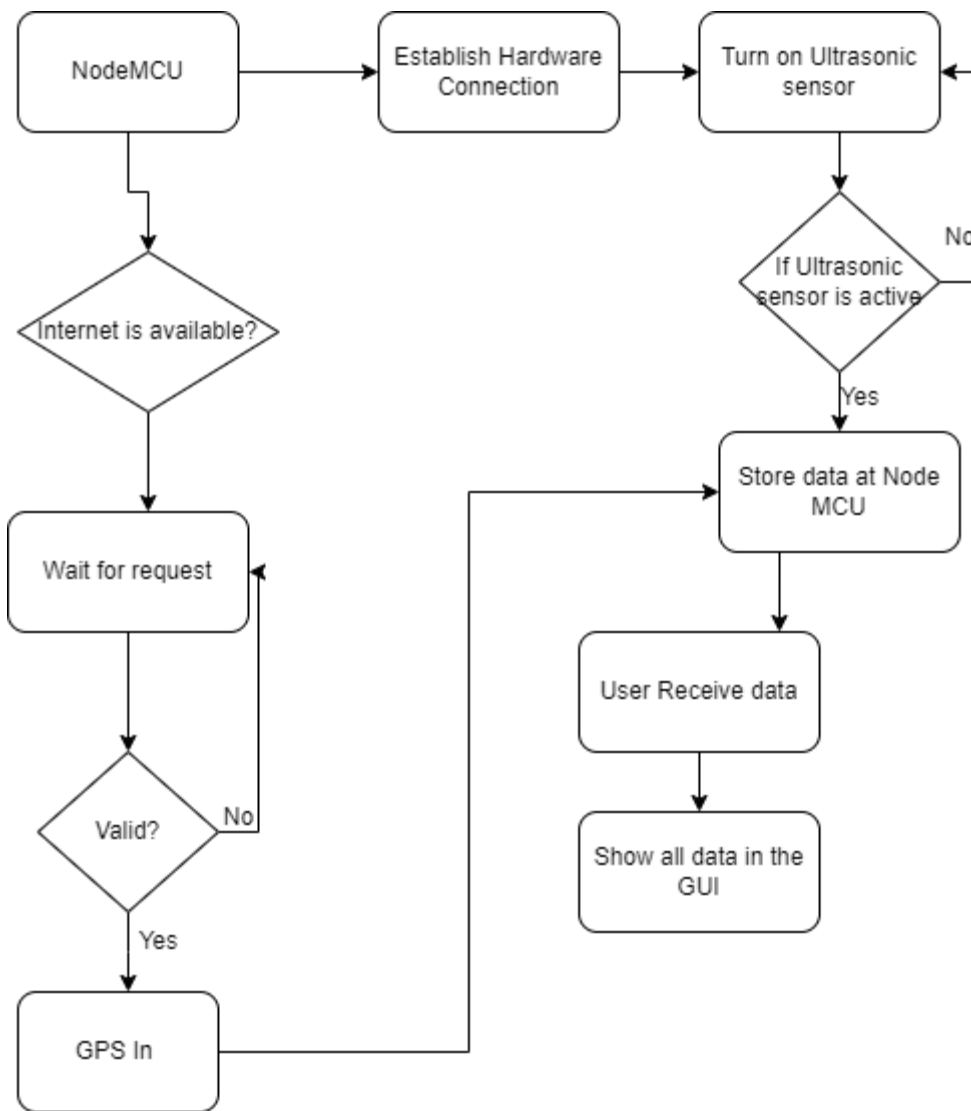


Figure 2: system flow chart

Hardware and Software Selection: In choosing computer hardware and software components, a lot of considerations are given to the system requirements. The components that were included in the hardware ensemble were a microcontroller or commonly known as the Esp 32, GPS module, ultrasonic fuel tank level sensor and the GSM module. To address this, on the software side HTML, CSS, JavaScript, Bootstrap and react were adopted for the frontend while Laravel (PHP) for the backend. The following selections were crucial in shifting the alignment of technology stack to the goal of the project.

3.2 IoT based prototype

The following stage that arrived power the blueprint of the system design brought the initiation of both the hardware and software components. The implementation process was well planned

in phases so as to be methodical in performances in order to avoid compromise on the set standards.

Hardware Integration: The final acquisition of the selected hardware components appeared neat and incorporated in to the prototype. This process involved integrating the microcontroller to the GPS/GSM modules and casually interfacing the ultra-sound fuel tank level sensor.



Figure 3: fuel level display to LCD

Firmware Development: Firmware was then created to help connect the two groups, by being hardware enough to access the hardware's data structures, and yet having the programs' capabilities to process data. This software layer helped in proper interaction of the microcontroller with other hardware components of the system. It was able to enable the microcontroller get fuel sensor data then send it to the database using the GSM module.

Backend and Frontend Development: At the same time, the software portions of the system were deliberately set up. The Laravel-based backend was the main constituent that contributed to data reception, further processing, and storage. Frontend which was created using HTML, CSS, JavaScript, Bootstrap, and react offered a friendly and easy to use design and visibility. The dynamic data visualization, and the users' interaction were implemented utilizing the features of React, a JavaScript framework.

Calibrating fuel monitoring systems with ultrasonic sensors: This ensures that fuel levels are accurately detected. Static calibration involves plotting sensor measurements against known fuel quantities, whereas dynamic calibration accounts for gasoline sloshing while in motion. Mathematical models account for irregular tank forms and sensor location, while temperature compensation corrects for temperature-induced variations in sound speed. Advanced

approaches, such as multi-point and self-calibration, improve accuracy by combining many sensors and learning-based models.

3.3 Data Collection and Transmission

One of the project goals was to obtain data on fuel consumption and the approximate location of the vehicle in real time.

Data Sensors: In this regard, the ultrasonic fuel tank level sensor was the centerpiece. Always, it overwatched fuel in the tanks in the vehicle and the GPS facility which gave real-time location information. These parameters were collected at equal time intervals to build the system's real-time feedback.

Data Transmission: ESP32 microcontroller acted as the bridge between the data sensors and the network of the system. Later, it successfully sent the collected data over the network with the help of the GSM module. The collected data reached its final place in the database that is specifically assigned to store and organize the necessary data for analysis.

3.4 Data Analysis and Visualization

Data Processing: Processing of the data that enters the system was handled by the backend of the system. It systematically collected and categorized important data about the fuels, vehicles' locations, and performance metrics.

Analysis Algorithms: Special algorithms were used for the analysis of the collected data. These algorithms provided the basis for the system in computing such things as fuel efficiency, and suggestions on the best way to get from one point to another.

Data Visualization: The frontend of the system implemented contained the information analysis results that remains transparent to the users. It offered a real-time dashboard through which one could get data, read various charts of information, and check maps in real-time. The visualization of the data was a significant component in executing the project as it helped the users to understand details regarding their vehicle fleet.

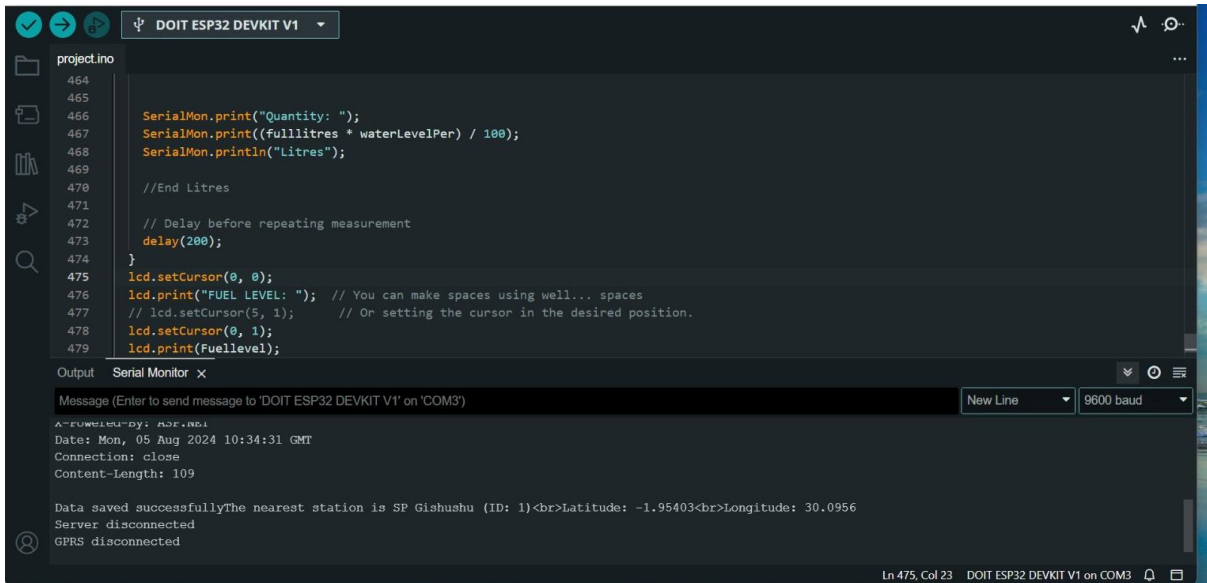


Figure 4: Sending data to the cloud

3.5 Performance Evaluation

The last stage of the described methodology was focused on the comprehensive assessment of the performance of the created system. Several criteria were meticulously assessed:

Accuracy: In order to increase the confidence in the developed system the precision of fuel level measurements and GPS location was analyzed. Relative comparisons were made aiming at giving details about the precision of the system.

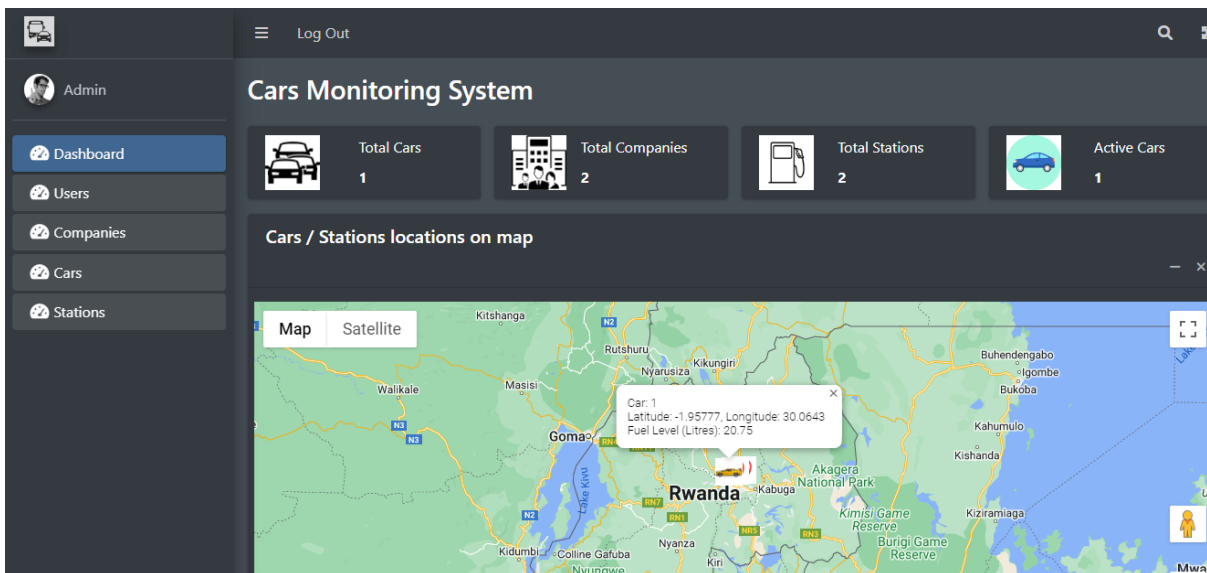


Figure 5: System web application dashboard

User Testing: A test questionnaires was administered on users with the aim of establishing the usability as well as functionality of the web application. Testing was one critical activity that accompanied the development of the system where user feedback was given considerations to improve the system and align with the users' demands.

Route Optimization: There were several goals of the system, one of them was to suggest a path which requires minimal amount of fuel. The identification of cost savings opportunities and the commendation of vehicle route was analyzed comparatively, using actual and recommended routes.

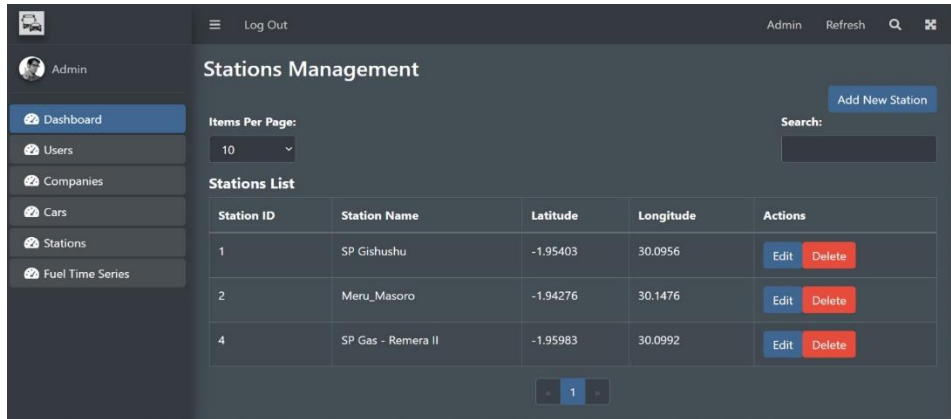


Figure 6: New fuel station

CHAPTER FOUR: RESULTS

In this section thus, a comprehensive discussion of the results and observations of the IoT – based fuel consumption monitoring system project shall be made. The details that will be discussed include the combined design of the hardware and the software, how data flows through the system and how structured, what functionalities the system has, critical findings that were made when developing the web application, and what features the web application possesses. These conclusion and findings are therefore significant to managers of fleets as well as the operators of vehicles.

A summary of the key findings as per the objectives is:

Objective 1: Identify and select the IoT sensors and equipment that adequately measures and collects fuel consumption from the transport companies' diverse fleet of vehicles.

- **Results:** Conducting a literature and empirical review of the study, it was found that the ultrasonic fuel tank level sensor is the most effective for the measurement of the fuel level. The selected type deserves consideration due to its high accuracy, versatility in terms of sizes and shapes of tanks, and element stability in rather different climates. Due to its ability to deliver the location information in real time, GPS module was selected to offer location inform

Objective 2: Implement an innovative IoT solution fully aligned to the transport companies that, for the first time, tracks vehicle fuel consumption in real-time and automatically sends out notifications about fuel use.

- **Results:** A tailored IoT solution was designed and implemented and it connects microcontroller, GPS, Ultrasonic fuel tank level sensor and GSM module. It had a real time tracking feature and one could be notified on the fuel consumption status as it progressed. Effective notifications included low fuel levels with a means to assist in the identification of fuel stations nearby which improved operation efficiency.

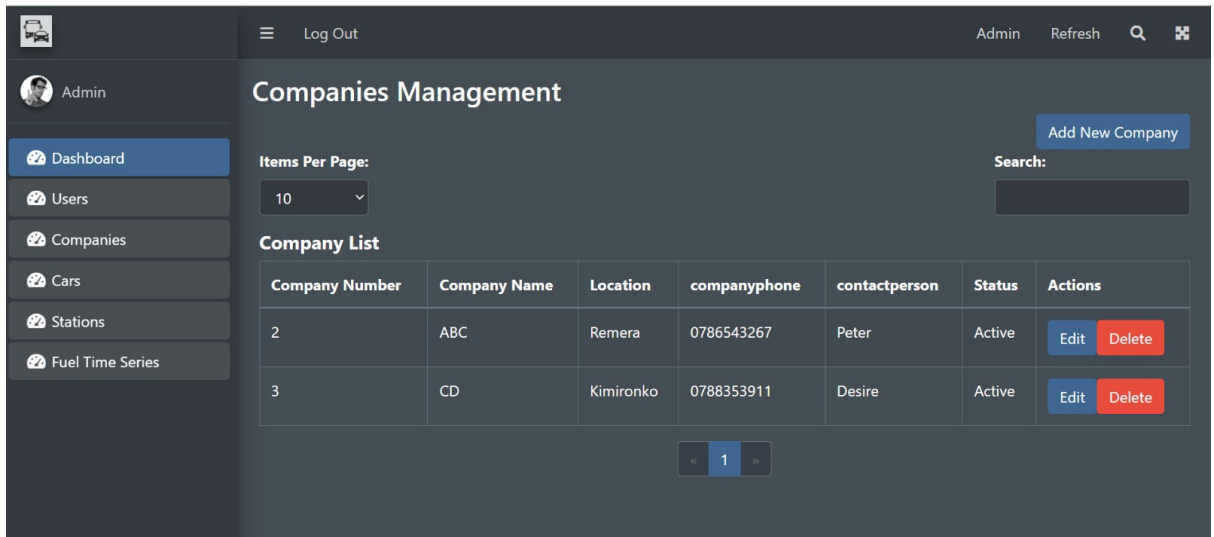


Figure 7:stakeholder

Objective 3: Develop and sustain a website for prototype demonstration; incorporate elements from an IoT concept of a fuel consumption monitoring system with existing fleet management system, use both the agile and waterfall development methods.

- **Results:** For the development of the Front end and back end, PHP was used with the Laravel framework, HTML, CSS, JavaScript, Bootstrap, React. By using this application, the real-time data gathered from the IoT system in the fleet of vehicles could be shown to the fleet managers in order to note easily the fuel utilized, the places the vehicles are in, and the performance rates. The use of both agile and waterfall methodologies help in the development of the application and it's effective as it can be externally used.

```
Car Location: https://www.google.com/maps?q=-1.93109,30.1033
Car Number: 1

Distance: 28.61 cm
Distance: 28.61 cm
Level: 27%
Quantity: 1.00Litres
```

Figure 8:Sending data to the cloud

4.1 Hardware and Software Integration

The hardware components, including the Micro-controller (Esp32), GPS module, Ultrasonic fuel tank level sensor, and GSM module, represent the physical infrastructure that makes our IoT system possible.

The table below shows the components used and their functions:

Component	Description	Importance
-----------	-------------	------------

Microcontroller	The central unit that processes data from sensors and manages communication between hardware components.	Critical for data processing and control of the IoT system, ensuring efficient operation and real-time data handling.
GPS Module	Provides real-time location data of vehicles.	Essential for route optimization, tracking vehicle movements, and enhancing security by detecting unauthorized activities.
Ultrasonic Fuel Tank Level Sensor	Measures the fuel level in the tank using ultrasonic waves.	Key to accurate and non-invasive fuel level measurement, adaptable to various tank sizes and shapes.
GSM Module	Enables wireless communication for data transmission and alerts.	Important for real-time data transmission to the web-based application and for sending notifications to fleet managers.
Laravel (PHP)	A web framework used for developing the backend of the web application.	Facilitates efficient development of the server-side application, ensuring robust data management and integration.
HTML, CSS, JavaScript, Bootstrap, React	Technologies used for developing the front-end of the web application.	Crucial for creating a user-friendly, responsive, and interactive web interface for fleet managers.

A picture of the hardware prototype developed is shown in the figure below:



Figure 9: hardware assembly of the prototype

As for the software component LAMP was employed while the backend was implemented with the help of Laravel (PHP) In front end it was decided to use HTML, CSS, JavaScript, Bootstrap, and React. The combination of the availability of the hardware and software subsystems prevents the creation of the complex and unintuitive interface while providing high processing capabilities for the data. The dashboard of the web application developed is shown below:

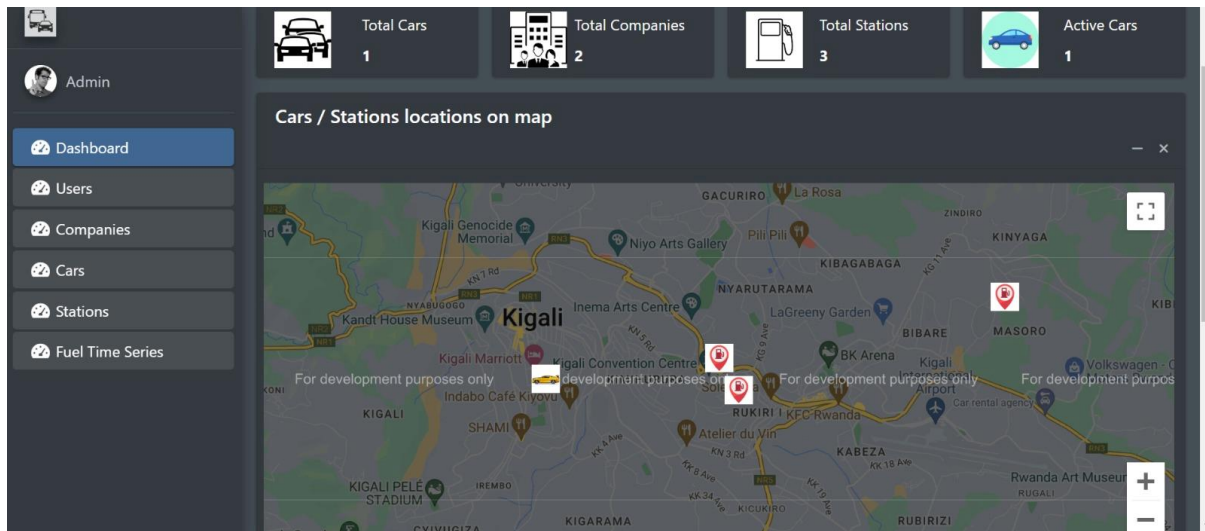


Figure 10: system web application dashboard

With such elements combined, driving and managing data acquisition and analysis as well as user engagement were met to empower the efficient fuel consumption management.

4.2 Data Flow and System Structure

There is also an efficient flow of data and a system's organization which is also a part of its formation. This architecture enables it is possible to translate data gathered by different sensors into valuable information to the users. The system structure is summarized below:

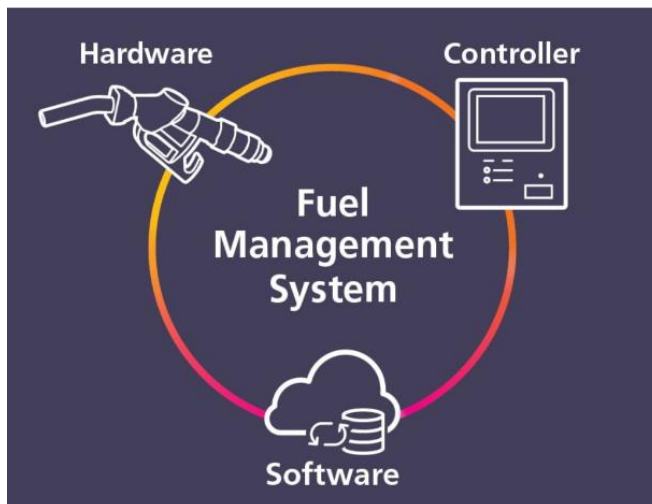


Figure 11: simplified system structure

The Micro controller plays the role of the main control unit of the system in this data flow diagram. It is used to manage the flow of data which is received from the GSM and GPS modules continually. Their aim is to collect information on the vehicular position and the quantity of fuel in the tanks in real time.

The Ultrasonic fuel tank level sensor is in itself a piece of technology and boasts of the accuracy and contactless method of measuring the fuel quantities. This sensor together with Micro-controller assists in the monitoring of fuel levels without coming into direct contact with the fuel.

Thus, it is clear that while the Micro-controller's responsibilities would comprise of data gathering, they also embrace data transportation. It gets in touch with a WiFi or cellular connection so as to establish a secure mode of transferring data to a referenced data base. Thus, in this database, all the new data whatsoever enter with great care and establish the beginning of the following stage.

In the exact Database, data is not only stored, but it is laid down for analysis; the Data is arranged in an analytical format. The core of our backend based on Laravel (PHP) and Laravel appear to sort the received information. Such a processing creates a basis for the data to be subjected to strenuous analysis, which is one of our systems' strengths.

4.3 System Functionality and results

Throughout the project's development and testing phases, several pivotal functionalities and discoveries came to light:

- *Prototype Fabrication:* The design and fabrication of the working prototype within our project was also an achievement towards the project goal. This tangible prototype was helpful

in proving the possibility of our design and showing the efficiency of the integration of the hardware and software.

- *Idling Fuel Consumption:* One of the revelations that elicited a profound effect was the fact that an engine that is left on uses as much as one gallon of fuel in every one hour. This eye-opening revelation underlined the need to manage idle time in fuel management strategies translating into better and healthier ways of cutting costs greatly with even better impacts on the environment.

- *Route Optimization in Action:* The fuel optimization system which was only an idea on paper transformed to a functional idea. Apart from the tracking of vehicles, it provided real-time information on a vehicle’s fuel consumption and integrated this into planning the most effective routes. This capability manifested in savings in fuel costs and better operations on the part of Deutsche Telekom.

ation for optimizing the routes, and in monitoring movements of the vehicles.

Figure 12:User of the system

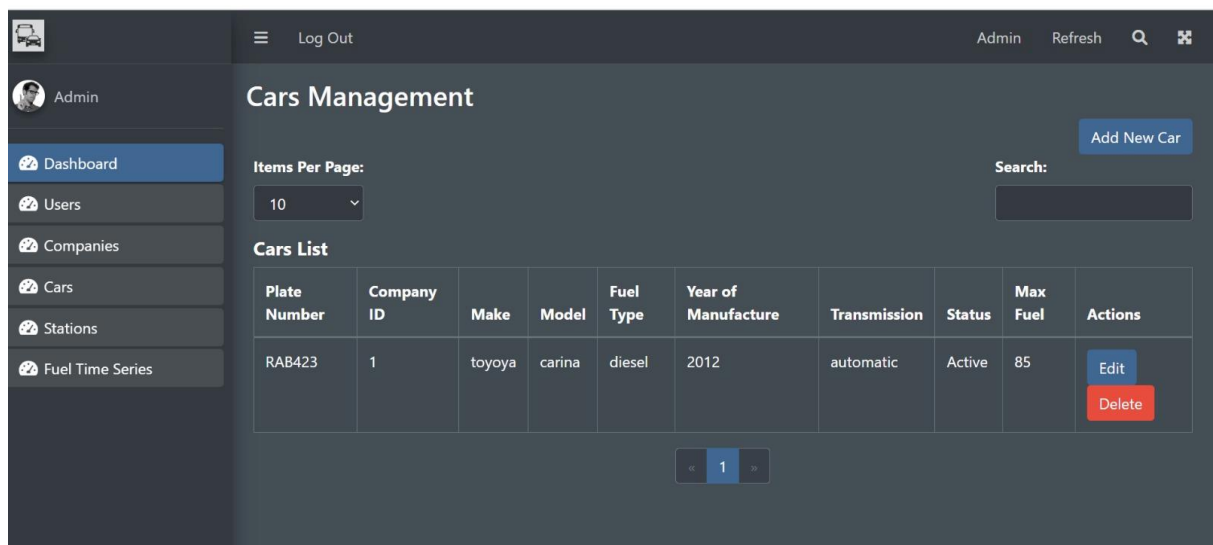


Figure 13:Cars management

4.4 Web Application Features

The web application allowed users to enter the system, explore and use the data produced by the system in a more realistic framework. The dashboard incorporated a multitude of features, each contributing to a user-friendly and informative experience:

- *Secure User Login:* The login page included into the system made it secure with authorized personnel to access the system only hence enhancing security of the data.

- *User Profile Information:* Among them, the system enabled users to input and modify their own details; improving the usability and data quality of the system.
- *Insights into Fuel and Distance:* One of the most essential ones was, as for the remaining fuel and the distance one can cover with the remaining stock. It allowed users to make informed decisions as to when and where to refuel and plan their routes for potentially massive savings. This information is displayed as shown in the figure below:

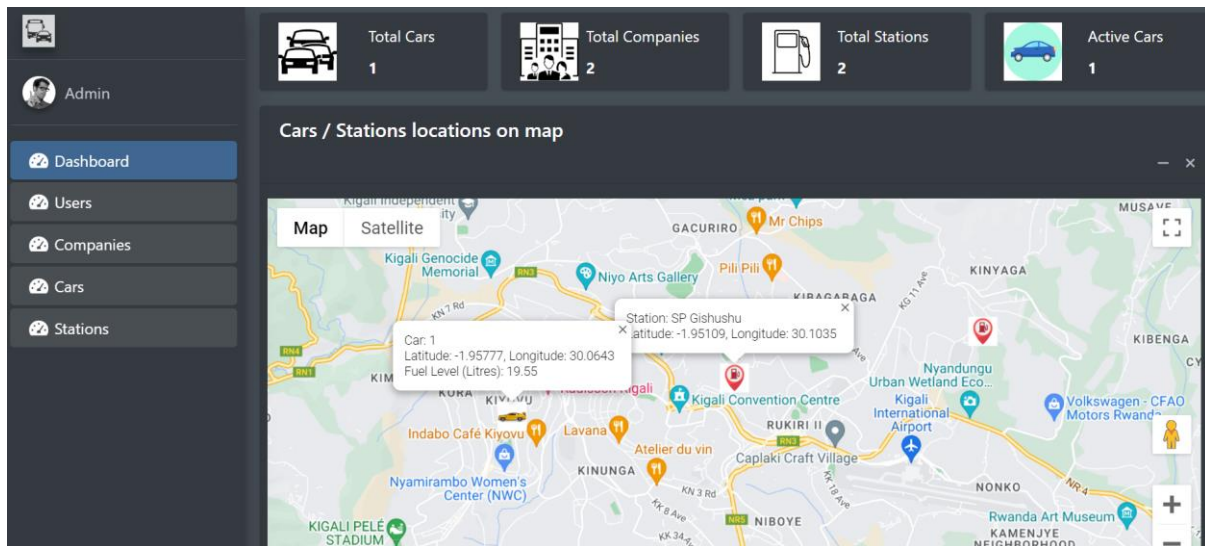


Figure 14: Cars/Stations locations on map

- *In-depth Fuel Data:* Thus, the users could observe even the smallest information on the fuel consumption and the fuel tank level without any doubt regarding the car's fuel usage. The inherent excellence in this compact of assembly came at the right level of detail, which was vital for making accurate decisions.
- *Live GPS Mapping:* One of them was a dynamic map which allowed to observe the actual location of a car, so it was easier to manage the route. Of this feature, the fleet

management was the most enhanced by this feature. An example of a map obtained during the testing phase is shown below:



Figure 15: Live GPS location of vehicles and Petrol stations

- *Odometer Readings:* Some of the additions to this design included such fields as vehicle odometer readings which was beneficial in assessing vehicle performance and when making recommendations for their maintenance. It enabled the monitoring of the status of the vehicle and the schedule for performing some basic tasks.
 - *Fuel Level Graph:* The graphical representation depicted fuel levels on the y-axis while on the x-axis, the number of kilometers read by the car's odometer was recorded as fuel was consumed making tracking of fuel consumption quite easy. The above illustration ensured that the users were able to easily determine trends in fuel consumption over time. The fuel level as a function of the odometer was shown as depicted in the figure below:

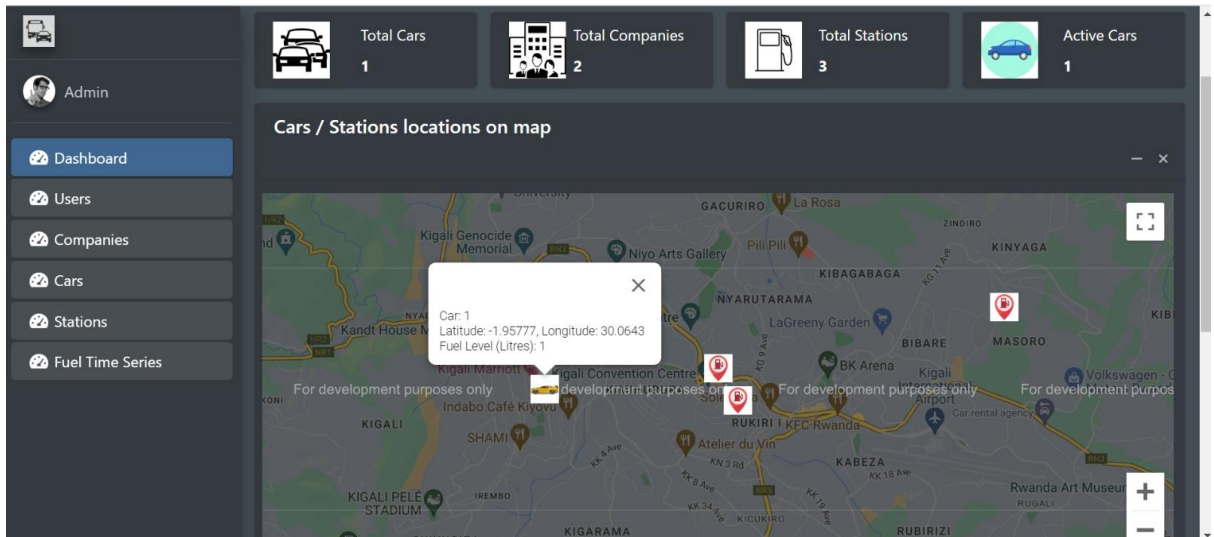


Figure 16: fuel level with distance

Going by the figure it is evident that the fuel level reducing steadily as it corresponded with the distance the vehicle had to travel. In addition, the dosage of the fuel in km/lit contributing the speed was achieved with a graph. Obtained. This is shown in the figure below:

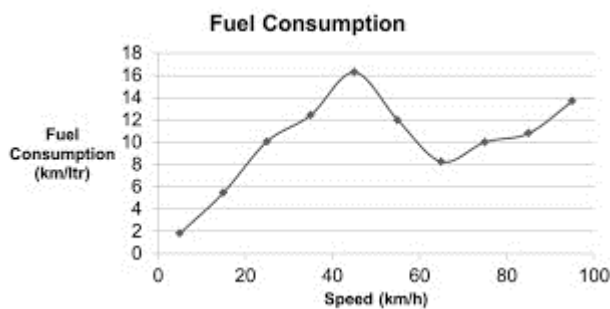


Figure 17: fuel consumption as a function of speed

The fuel consumption was proportional to the speed as the graph depicted since the vehicle would use more fuel as the speed was raised.

- *Vehicle Summary:* Through the system it was possible to obtain an account of all monitored vehicles. This summary involved the names of the vehicles, time stamps, duration of monitoring, and the locations of the fleet for convenient overview by the users. The figure below shows how the summary was displayed:

CHAPTER FIVE: DISCUSSION AND CONCLUSION

One of the significant sub-processes in our IoT-based fuel consumption monitoring system was the connection of hardware and software parts. From this category, we had the Micro-controller (Esp32), GPS module, Ultrasonic fuel tank level sensor, and GSM module which were the structural framework that supported our system's running. This integration of hardware and software helped in developing a system where the clients have the option of real time data collection and analysis.

Cooperation of these elements of hardware and software defined an efficiency of the system for fuel consumption monitoring. Hence, integrating the features of Micro-controller, GPS module, Ultrasonic fuel tank level sensor, and GSM module helps me in developing a complete solution for tracking and monitoring the fuel usage of vehicles.

In our IoT-based system, data flow and the structure of the system's architecture were important characteristics. The flow of data and the structure of the system was thought in a very detailed way, guaranteeing that data harvested from different sensors were smoothly turned into relevant information for the final users. The broad and general structures and design of the system were especially essential in achieving an optimum reliability of the entire system as was witnessed.

The primary data flow within the framework of this system was the Micro-controller, which served as the control point in the system. They were very central in managing the persistent stream of data that was received from the GSM and GPS modules. These modules actively collected geographical position data of vehicles and fuel amount with necessary updates as soon as possible, so users could receive the information about status of their vehicles.

The Ultrasonic fuel tank level sensor which was already a splendid technology exhibited in an independent capacity due to accuracy and in-contact measurement of fuel levels. This sensor was connected to the Micro-controller so that fuel levels were measured without any physical touch with fuel. Since this was a non-instrumental method of measuring fuel levels, it cut on the amount of wear and tear on the equipment and on top of that provided accurate results.

This means that in addition to data analysis, the Micro-controller was also responsible for information transfer. This was implemented through a WiFi or cellular network, whose help the Micro-controller ensured safe transfer of data to a central database. This was important since it made all the incoming data to be recorded in a proper manner and with ease for further analysis.

Touched upon previously, data was stored not just in databases but was preprocessed for analysis. Our backend that was developed using Laravel (PHP), was critical in handling and

organizing the data that we were receiving. While backends were critical for all data processing since the data had to be provided in forms that could be subjected to intensive analysis, the same was true for the foundations of our system.

Several important functionalities and finds were revealed when the project was being developed and tested. These were imperative for evaluating effectiveness of system under study and how suitably it aligned to the objectives stated in this research.

The achievement of a working prototype was a major accomplishment in our project. This hardware embodiment provided proof of the workability of the design and the workability of the consideration of hardware and software as an integrative organization. The actual fabrication of the prototype allowed us to remain confident in the system as it made fabrication possible as planned.

In a number of cases already discussed some of the most startling findings dealt with idling fuel usage. From the learning it was seen that approximately one gall of fuel is burnt when an engine is left idle for an hour. It also highlighted the aspect of idle time in fuel optimization which mandates a possible approach towards cutting down on the time wastage in an effort to save costs and the environment in the long run. Given the potential that this discovery has on fuel efficiency also resulting in reduction of costs, this is something monumental.

The case reflects the fuel optimization system that is considered as one of the critical components of the IoT-based solution and that has been turned from the conceptual level to the actual one. More than tracking vehicles' location, it effectively collected information on fuel usage and incorporated this into the routing processes in real time. This capability was accomplished in terms of lowering fuel usage and improving operational performance, hence were in line with objective of decreasing fuel usage and increasing operational performance.

The web application plays the basic role of the interface where people can interact with the data produced by the system in terms of access the visualization. It presented a number of features that were quite easy to use for the intended user and made data much more useful and meaningful.

The login page of the web application made sure that only those who have been authorized were granted entry into the web application and hence kept security and important information safe. This security measure was indeed important to make sure that the data of the system was very secure and private.

The system enabled the users to view and amend their information that made interacting with the system enjoyable and effective while at the same time creating and maintaining accurate

user information. Having this much control from the part of the user and the ability to tune the system for one's particular needs was a design requirement.

One of the most appreciated options of the web application was the presentation of the remaining fuel and the range in kilometers that can be covered with remaining fuel. This information helped the users to take informed decisions regarding the refueling and the optimized path thus enabling them to save a huge amount of money and at the same time improving the fuel efficiency.

Users could check every small data from the fuel consuming rate to the Fuel Tank Indicator, and they had full control over the fuel usage of their car. These capabilities proved very valuable in the precise decision-making, such as when and where a car will refuel, and how it could best expend its fuel.

The system also allowed for the updating of an auto-map wherein the location of the vehicles was accurately indicated thereby enhancing planning and monitoring of routes on the vehicles. Another useful function of this feature was that with the help of this data it is possible to determine on which territories and how often the cars belonging to the fleet are now located, which can be useful for fleet managers when making decisions about the dispatching of their cars.

Another element that was incorporated was the use of vehicle checksums which served to enrich the data for vehicle diagnostics and performance. It enabled the usage parameter to be monitored and facilitate the development of the schedule for maintenance and tune up thereby improving the operations of vehicles and safety of users.

The second one was in form of a graph on which fuel quantities were plotted against the number of kilometers traveled so as to ascertain trends in fuel usage. This tool ensured that the users were in a position to estimate general utilization of the fuel so that they could easily detect certain patterns with fuel consolidation.

Thus, the findings of the present research have important implications for fleet management and vehicle operators. The proposed IoT system for monitoring fuel consumption has a chance to increase fuel economy, reduce spending, optimize processes, and introduce preventive maintenance. These implications correlate with the concerns of the fleet managers; aspects like the enhancement of operation costs, safety and security of fleets, and increased efficiency. The proposed system has the ability to become implemented in the real world since the IoT-based model can become a solution in resolving fleet management issues and at the same time reduce cost and adverse effects on the environment. The smooth interaction of the hardware and software components, optimal data flow, important findings, as well as clarity and convenience

of using the web application's interfaces collectively set a harmonic presence, which holds promising real-world application. Thus, the data obtained in our study possesses real-world relevance and can impact various aspects of fleet management and vehicles' functioning.

REFERENCES

- [1] Alaba, F. A., Othman, M., Hashem, I. A. T., & Alotaibi, F. (2017). Internet of Things security: A survey. *Journal of Network and Computer Applications*, 88, 10-28.
- [2] Deep, S., Zheng, X., Jolfaei, A., Yu, D., Ostovari, P., & Kashif Bashir, A. (2022). A survey of security and privacy issues in the Internet of Things from the layered context. *Transactions on Emerging Telecommunications Technologies*, 33(6), e3935.
- [3] Fantin Irudaya Raj, E., & Appadurai, M. (2022). Internet of things-based smart transportation system for smart cities. In *Intelligent Systems for Social Good: Theory and Practice* (pp. 39-50). Singapore: Springer Nature Singapore.
- [4] Madhukara, S., Varsha Singh, V., Veena, M., Vidya, V., & Vidyashree, M. (2022). Implementation of Vehicle Monitoring and Accident Detection system Using Internet Of Things. *International Research Journal of Modernization in Engineering, Technology and Science. e-ISSN*, 2582-5208.
- [5] NIYIGENA, I. (2021). Design of an IOT-Based seat occupancy monitoring system for public transport: Case study: Rwanda (Doctoral dissertation, College of science and technology).
- [6] Pourrahmani, H., Yavarinasab, A., Zahedi, R., Gharehghani, A., Mohammadi, M. H., & Bastani, P. (2022). The applications of Internet of Things in the automotive industry: A review of the batteries, fuel cells, and engines. *Internet of Things*, 100579.
- [7] Praveenchandar, J., Vettrithangam, D., Kaliappan, S., Karthick, M., Pegada, N. K., Patil, P. P., ... & Umar, S. (2022). IoT-Based harmful toxic gases monitoring and fault detection on the sensor dataset using deep learning techniques. *Scientific Programming*, 2022.
- [8] Rana, A., Rawat, A. S., Afifi, A., Singh, R., Rashid, M., Gehlot, A., ... & Alshamrani, S. S. (2022). A Long-Range Internet of Things-Based Advanced Vehicle Pollution Monitoring System with Node Authentication and Blockchain. *Applied Sciences*, 12(15), 7547.
- [9] Muthuramalingam, S., Bharathi, A., Rakesh Kumar, S., Gayathri, N., Sathiyaraj, R., & Balamurugan, B. (2019). IoT based intelligent transportation system (IoT-ITS) for global perspective: A case study. *Internet of Things and Big Data Analytics for Smart Generation*, 279-300.
- [10] Hamid, A. H. F. A., Chang, K. W., Rashid, R. A., Mohd, A., Abdullah, M. S., Sarijari, M. A., & Abbas, M. (2019). Smart vehicle monitoring and analysis system with IoT technology. *International Journal of Integrated Engineering*, 11(4).

