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Development of a Fleet IoT-Based System Management in Institutions

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Abstract:- IoT-based systems are increasingly important for managing assets and activities, and implementing such a system can greatly benefit institutions like WASAC. The purpose of this system is to effectively manage WASAC's fleet, improving vehicle tracking, dispatching, fuel management, maintenance planning, driver behavior and safety, accident reduction, vehicle lifespan, customer service, unauthorized vehicle usage control, and data analysis and reporting. Currently, WASAC relies on paper-based methods for data recording and fuel management, resulting in financial losses and inadequate driver monitoring. By developing an IoT-based system, several sensors and devices such as a CAN adapter FMB140, automatic alcohol test sensor, fuel sensor, relay, I-button, and buzzer will be employed. These devices and sensors will be connected to the FMB140 IoT device, which will capture data and store them in a server database. This data will then be used to create an interactive web-based application using socket programming for fleet managers and the monitoring team. The application will be developed using PHP and React technologies. By implementing this IoT in fleet management will enhance safety and security measures for institutions specifically within the WASAC fleet management system, Real-time tracking, geofencing, prevention of fuel theft, driver behavior monitoring, and remote engine cut-off will significantly improve driver and vehicle safety while boosting fleet productivity. Overall, the IoTbased system will streamline operations, reduce costs, and enhance efficiency for WASAC's fleet management.

Keywords:- *Iot-Based Fleet Management System, Real-Time Tracking, Fuel Management, Maintenance Planning, Driver Behavior And Safety.*

I. INTRODUCTION

The integration of Internet of Things (IoT) technology has catalyzed transformative changes across various sectors, notably transportation and logistics. In this context, this study delves into the application of IoT in fleet management, with a specific focus on its implementation within the Water and Sanitation Corporation (WASAC). Efficient fleet management stands as a linchpin for WASAC's mission to deliver clean water and sanitation services effectively. However, the existing fleet management system confronts challenges such as limited real-time monitoring capabilities, suboptimal resource allocation, and reliance on manual data entry and processing. Addressing these challenges necessitates a comprehensive, technology-driven solution.

The core variables under scrutiny in this research encompass fleet management, IoT, and system management. Fleet management encompasses the orchestration, supervision, and governance of vehicles, spanning their acquisition, operation, maintenance, and disposal. IoT, on the other hand, refers to the intricate network of physical objects imbued with sensors and software, facilitating data collection and exchange for real-time monitoring and automation. System management encompasses the design, execution, and upkeep of a framework overseeing and directing the entire fleet management system.

Presently, WASAC's fleet management relies heavily on manual processes, culminating in delays, inaccuracies, and a lack of real-time visibility. This leads to suboptimal resource utilization, delays in maintenance and repair, and compromised accuracy in reporting. The absence of real-time monitoring exacerbates challenges in tracking vehicle locations, optimizing routes, and effectively allocating resources. Neglected maintenance and inaccurate reporting further inflate costs and impede productivity. While the history of fleet management traces back to the early 20th century, the advent of IoT technology has revolutionized this domain by enabling real-time vehicle monitoring and data analysis.

However, within the confines of WASAC, limited research and implementation of IoT-based fleet management systems have been observed. Hence, this study endeavors to bridge this gap by conceptualizing and implementing an IoT-based system management solution tailored to the unique requisites and obstacles faced by WASAC. Leveraging IoT technology holds the promise of augmenting WASAC's fleet management practices, streamlining operations, and enhancing service delivery.

- *Significance*

The development of a fleet IoT-based system management in Water and Sanitation Corporation (WASAC) carries profound academic and practical implications. Academically, this study advances the understanding of IoT-based system management within the realm of fleet operations, particularly in the water and sanitation sector. It furnishes insights into the application of IoT technologies, delineating their impact on fleet management efficiency, cost-effectiveness, and environmental sustainability.

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Practically, the findings of this study hold significance for WASAC and akin organizations vested in fleet management. The implementation of an IoT-based system management promises several tangible benefits. It promises improved fleet efficiency by identifying and advocating optimized fleet management practices facilitated by IoT technologies. Additionally, it enables cost reduction through data-driven decision-making, thereby optimizing preventive maintenance, fuel consumption, and route planning. Furthermore, it fosters environmental sustainability by curbing carbon emissions through route optimization and fuel consumption monitoring. Ultimately, real-time monitoring and decision-making capabilities enhance WASAC's responsiveness, customer service, and resource allocation efficiency.

In summary, the development of a fleet IoT-based system management in WASAC transcends mere academic curiosity; it holds practical implications for enhancing efficiency, reducing costs, and fostering environmental sustainability within the water and sanitation industry in Rwanda

II. LITERATURE REVIEW

This chapter critically examines the existing literature pertinent to the development of fleet IoT-based system management. It aims to pinpoint weaknesses, gaps, and contributions within the literature while discussing relevant theories or models. Additionally, this chapter establishes the variables, methods, objectives, and research questions of the study. Lastly, a conceptual framework is formulated to depict the relationships among the concepts and variables analyzed to meet the study's objectives. (Lee, 2017)

A. Fleet Management Systems in the Water and Sanitation Sector

Literature on fleet management systems within the water and sanitation sector underscores the significance of efficiently managing vehicles, equipment, and resources to ensure reliable service delivery. Studies address challenges faced by water and sanitation corporations, including aging fleets, maintenance issues, fuel consumption, route optimization, and real-time tracking. A notable contribution involves integrating IoT technologies such as sensors, GPS, and data analytics to enhance fleet management operations. (Musanzikwa, 2022)

B. Empirical Evidence on IoT-Based Fleet Management Systems

➢ *Improved Fuel Efficiency*

IoT-based fleet management systems excel in monitoring and optimizing fuel consumption through GPS tracking and data analytics. By analyzing vehicle routes, speed, and engine performance, fleet managers identify inefficient driving behaviors and rectify them. Empirical studies, such as one conducted by the Aberdeen Group, reveal that implementing IoT-based systems can lead to a significant reduction in fuel costs, with companies achieving an average of 14% savings by optimizing routes and driver behavior. (DZIUBA, 2023).

➢ *Enhanced Safety*

IoT-based systems contribute to improved safety for drivers and vehicles by providing real-time monitoring of driver behavior and alerting fleet managers to potential safety hazards. Empirical evidence, exemplified by a study from Verizon Connect, indicates a reduction in accidents and related costs by 14% and 15%, respectively, for companies utilizing IoT-based safety monitoring. (Khan, 2020)

➢ *Maintenance Cost Reduction*

Predictive maintenance capabilities offered by IoT-based systems, through continuous monitoring of vehicle health and components, lead to substantial cost savings. A case study by IBM on a large trucking fleet demonstrated that predictive maintenance reduced maintenance costs by up to 50% and increased vehicle uptime by 30%, emphasizing the significant impact of IoT on reducing maintenance expenses. (Corporation, 2022)

C. Internet of Things (IoT) in Fleet Management

The IoT has emerged as a transformative technology in fleet management, enabling real-time monitoring, remote diagnostics, predictive maintenance, and enhanced decision-making. Literature underscores the applications of IoT in fleet management, emphasizing increased visibility, operational efficiency, and cost reduction. The IoT Fleet Management Market is projected to grow substantially, indicating its pivotal role in revolutionizing fleet management. (BADNAKHE, IoT in Fleet Management-Use Cases and Benefits, 2023)

D. Challenges and Opportunities of IoT-Based Fleet Management

Despite numerous advantages, implementing IoT-based fleet management systems poses challenges such as data security concerns, interoperability issues, and the need for skilled personnel. However, literature also highlights opportunities including improved asset utilization, reduced downtime, proactive maintenance, and enhanced customer service. (BADNAKHE, IoT in Fleet Management-Use Cases and Benefits, 2023)

➢ *Fleet Maintenance*

IoT-based fleet management systems face challenges including data security and connectivity reliability but offer opportunities like real-time monitoring and predictive maintenance. (Dziuba, 2022)

➢ *Vehicle Monitoring*

Sensor-equipped fleets enhance vehicle tracking, real-time monitoring, predictive maintenance, fuel efficiency optimization, and safety. (Takyar, 2022)

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- *Cargo Management*

Technologies like telematics with temperature monitoring optimize route planning, reduce costs, and improve operational efficiency, despite facing challenges such as data security and connectivity issues. (BADNAKHE, blog/iot-in-fleet-management-use-cases-and-benefits/, 2023)

- *Passenger Information*

IoT-enabled systems enhance passenger experience through real-time information updates, optimized routing, and predictive maintenance, while facing challenges like data security and device compatibility. (BADNAKHE, IoT in Fleet Management-Use Cases and Benefits, 2023)

- *Environmentally Conscious Operation*

IoT technologies contribute to sustainability initiatives through energy efficiency, emissions reduction, and optimized routes, despite challenges such as data security and connectivity issues. (Nagalia, 2022)

- *Automation*

Automation through IoT-based fleet management systems offers benefits such as enhanced efficiency and customer satisfaction, despite challenges in scalability and performance. (Fleetroot, 2023)

E. Theoretical Frameworks and Models

Several theoretical frameworks and models, including the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Service Profit Chain (SPC) model, are discussed in the literature. These models provide insights into users' acceptance of IoT technologies, factors influencing technology adoption, and the relationship between customer satisfaction, employee satisfaction, and financial performance.

F. Conceptual Framework

A conceptual framework is developed based on identified variables and relationships, highlighting fleet management efficiency, IoT implementation, operational performance, customer satisfaction, and financial performance. This framework guides data collection, analysis, and interpretation in subsequent chapters.

G. Research Gaps

Despite advancements in IoT technology, gaps remain in addressing interoperability, scalability, and performance in fleet management systems. Standardized protocols, scalable architectures, and optimized algorithms are needed to ensure smooth communication, support large fleets, and maintain system performance.

III. METHODOLOGY

A. Research Design

This study adopts a combination of Descriptive and Case Study research designs to investigate 'The Development of a Fleet IoT-Based System Management in Institutions.' Descriptive research offers an overview of the fleet IoT-based system management, delineating its components and functionalities. Additionally, Case Study research delves into specific institutional contexts, analyzing challenges and outcomes. This dual approach facilitates a comprehensive understanding, benefiting theory and practice.

B. Sample Size Determination

The study population comprises 344 drivers and 18 employees responsible for fleet management at WASAC Headquarters, overseeing 312 vehicles nationwide. Sample size is determined using Taro Yamen's formula (1967), considering a 5% marginal error and 95% confidence level.

C. Sampling Strategy

Given the nature of the study, no specific study population is required. The focus is on addressing the identified gap in WASAC's fleet management through IoT-based solutions without direct employee involvement.

D. Data Collection Methods

Interviews, surveys, and document analysis are employed. Interviews gather qualitative insights from key stakeholders, while surveys collect quantitative data from staff. Document analysis scrutinizes existing fleet management records. Closed questionnaires ensure comparable data from 190 respondents.

E. Data Processing

Collected data undergo processing using statistical analysis software and qualitative data analysis tools. Organizing, cleaning, coding, and transforming raw data are essential steps.

F. Data Analysis

Qualitative data from interviews and document analysis are thematically analyzed. Quantitative data from surveys undergo descriptive and inferential statistical analysis to derive insights.

G. Limitations

Challenges may arise due to respondents' busy schedules, but their direct involvement is unnecessary. Communication methods such as phone calls and emails, along with access to archives, mitigate these challenges.

H. Ethical Considerations

Research ethics dictate establishing rapport with respondents and obtaining informed consent. Permission from organization management and ensuring confidentiality are paramount. Freedom for respondents during data collection is maintained to prevent coercion.

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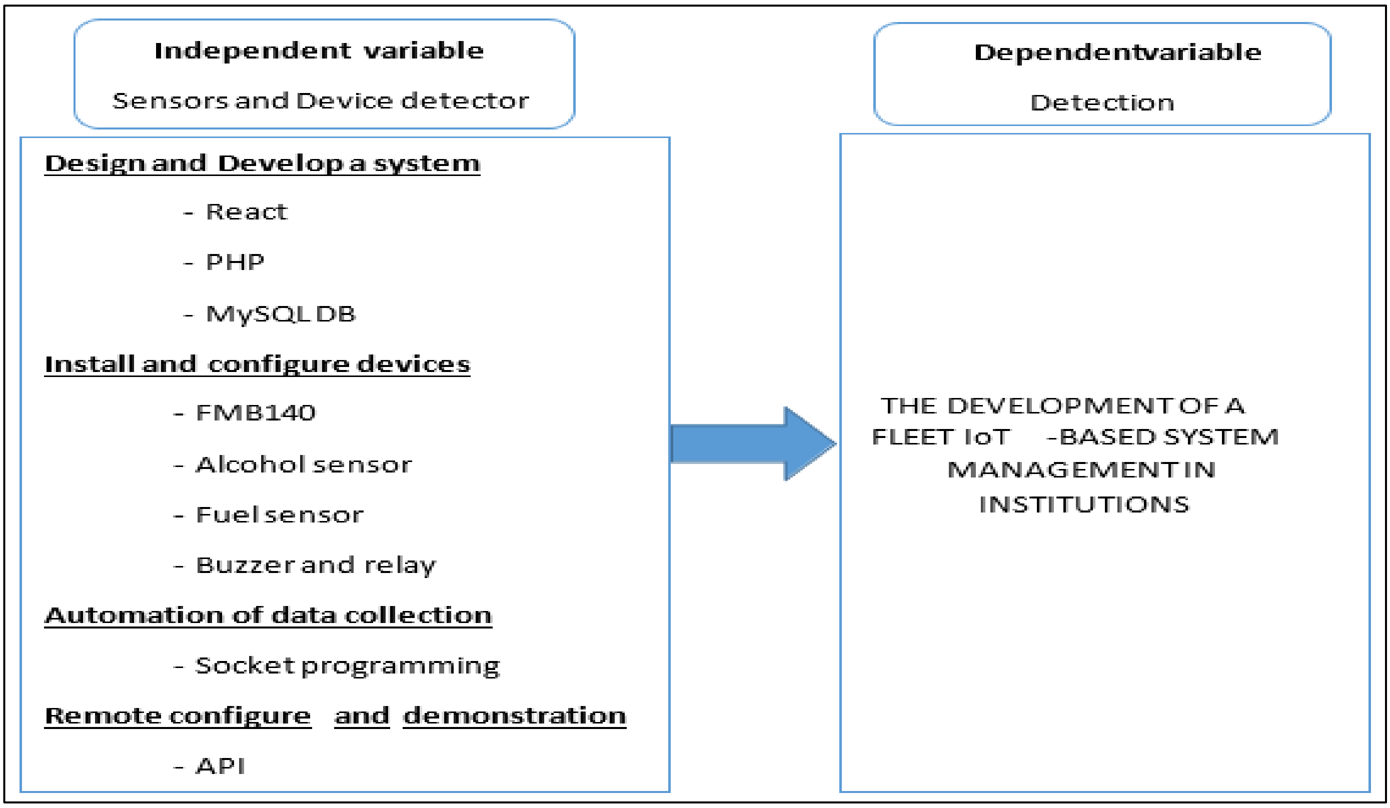

Fig 1: Conceptual Framework

IV. PRESENTATION, ANALYSIS AND INTERPRETATION OF FINDINGS

A. Introduction

This chapter presents the data collected and provides interpretations of the findings regarding the contribution of a Fleet Management System based on the Internet of Things (IoT) in institutions, specifically in the case of WASAC. The data were analyzed with respect to the objectives of the study, resulting in the development of an IoT-based fleet management software. Additionally, this chapter includes an overview of the technologies employed in creating the application, its operation, applied tests, identified weaknesses in the current Fleet Management System, screenshots illustrating the system's functionality, and software and hardware compatibility requirements.

B. Fleet IoT-Based System Management Presentation

This section outlines the configuration process of the Fleet IoT Management System, detailing the manual input required from users to set up the system for vehicle monitoring. It describes the system's functions, including remote monitoring capabilities.

➢ *Technology Used and Tools for the IoT-Based Fleet Management System*

The development of the IoT-Based Fleet Management System necessitates the utilization of various technologies and tools. React and Node.js and PHP serve as primary programming technologies for the user interface and server-side logic, respectively. Web Sockets technology enables real-time data synchronization between the system and connected IoT devices. MySQL database is utilized for structured data storage. These technologies, along with IoT hardware, ensure real-time tracking, remote diagnostics, and performance optimization. Below are the tools to use:

Fig 2: IoT GPS Device


Fig 3: Breathalyzer Alcohol Test

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Fig 4: Fuel Sensor

➢ *Flow Chart Diagram*

A flowchart illustrates the user journey within the Fleet Management System, beginning with user login and leading to various functionalities such as GPS monitoring, reporting, fuel management, maintenance management, and alerts and notifications. The flowchart streamlines user interactions and facilitates efficient navigation throughout the system.

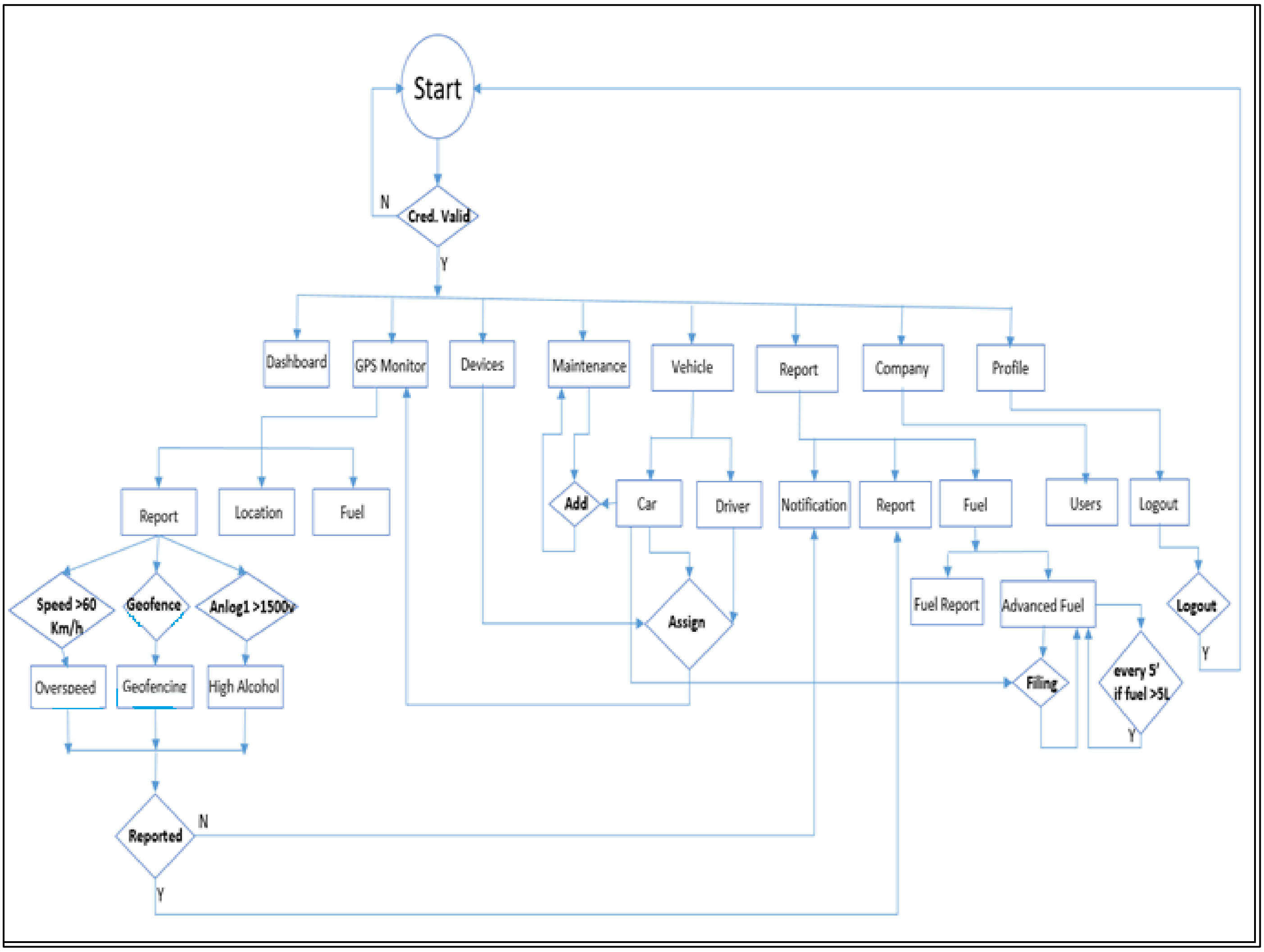

Fig 5: Flow Chart

➢ *Presentation and Findings*

The Fleet IoT-Based System Management Presentation offers insights into an advanced system designed to optimize fleet management using IoT technology. The system empowers fleet managers with real-time monitoring, proactive maintenance, and insightful reporting capabilities. Screenshots of the sign-in page, dashboard, GPS monitor, device management, maintenance tracking, vehicle overview, report generation, and company management pages demonstrate the system's functionality and user interface.

- *Sign in Page*

The sign-in page employs a user's email and password for authentication.

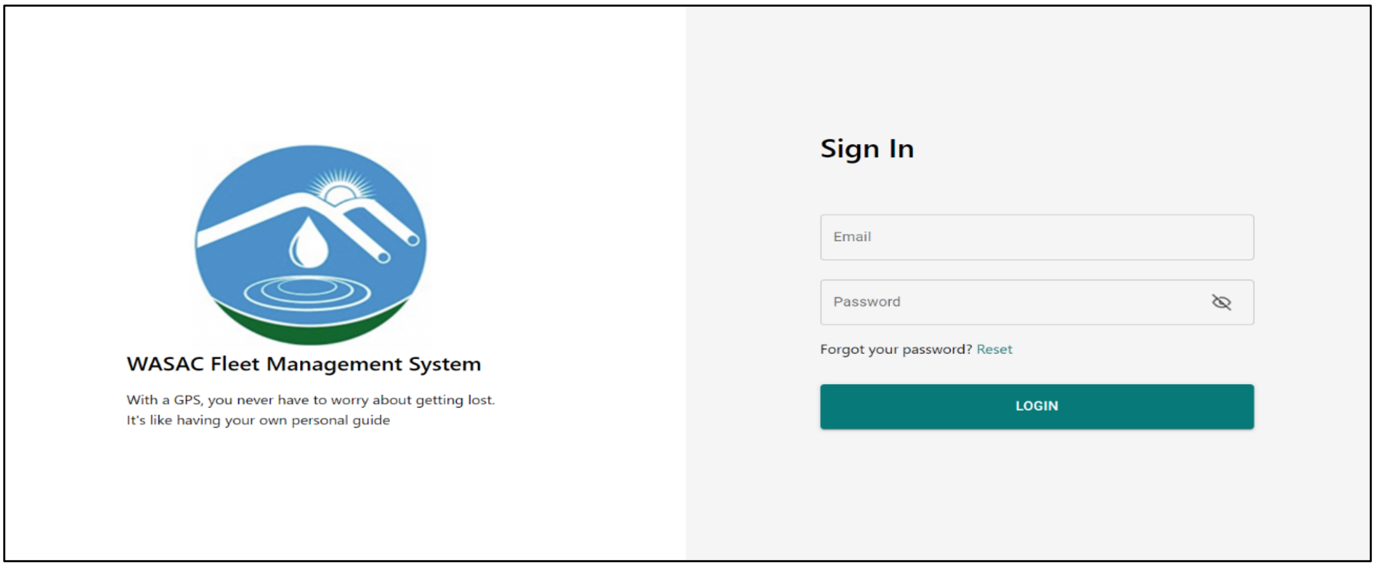

Fig 6: Sign in Page

* *Dashboard Page*

The dashboard serves as a comprehensive summary of essential information and features within the Fleet IoT-Based System Management, providing users with at-a-glance insights into device status, maintenance statistics, reporting data, vehicle details, and real-time monitoring capabilities.

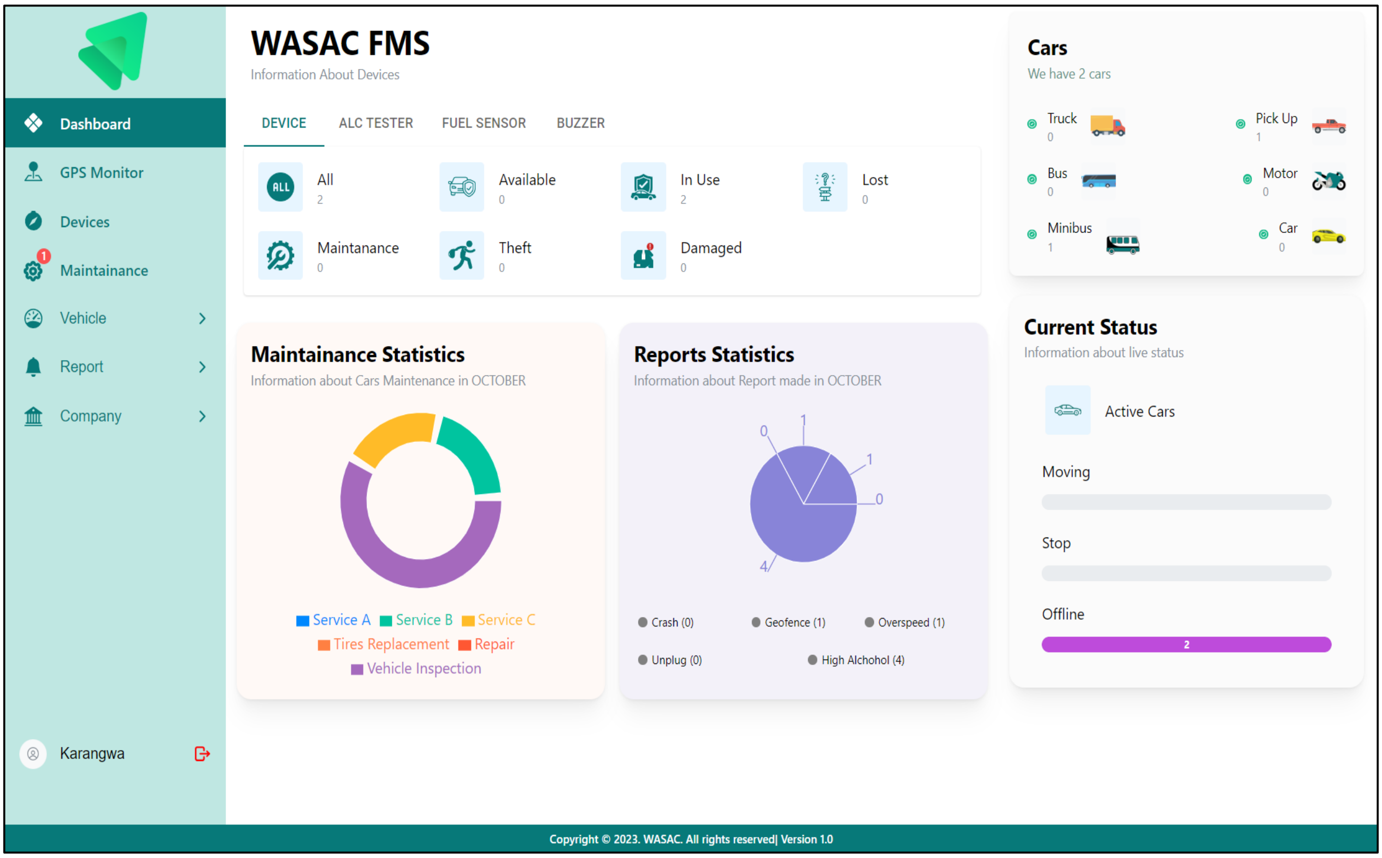

Fig 7: Dashboard Page

* *GPS Monitor page*

The GPS monitoring feature empowers users to track and manage their fleet vehicles efficiently. It enables real-time vehicle tracking by plate, device, and location, offers playback and reporting functionalities, and ensures over-speed alerts and geo-fencing capabilities for enhanced fleet management and security.

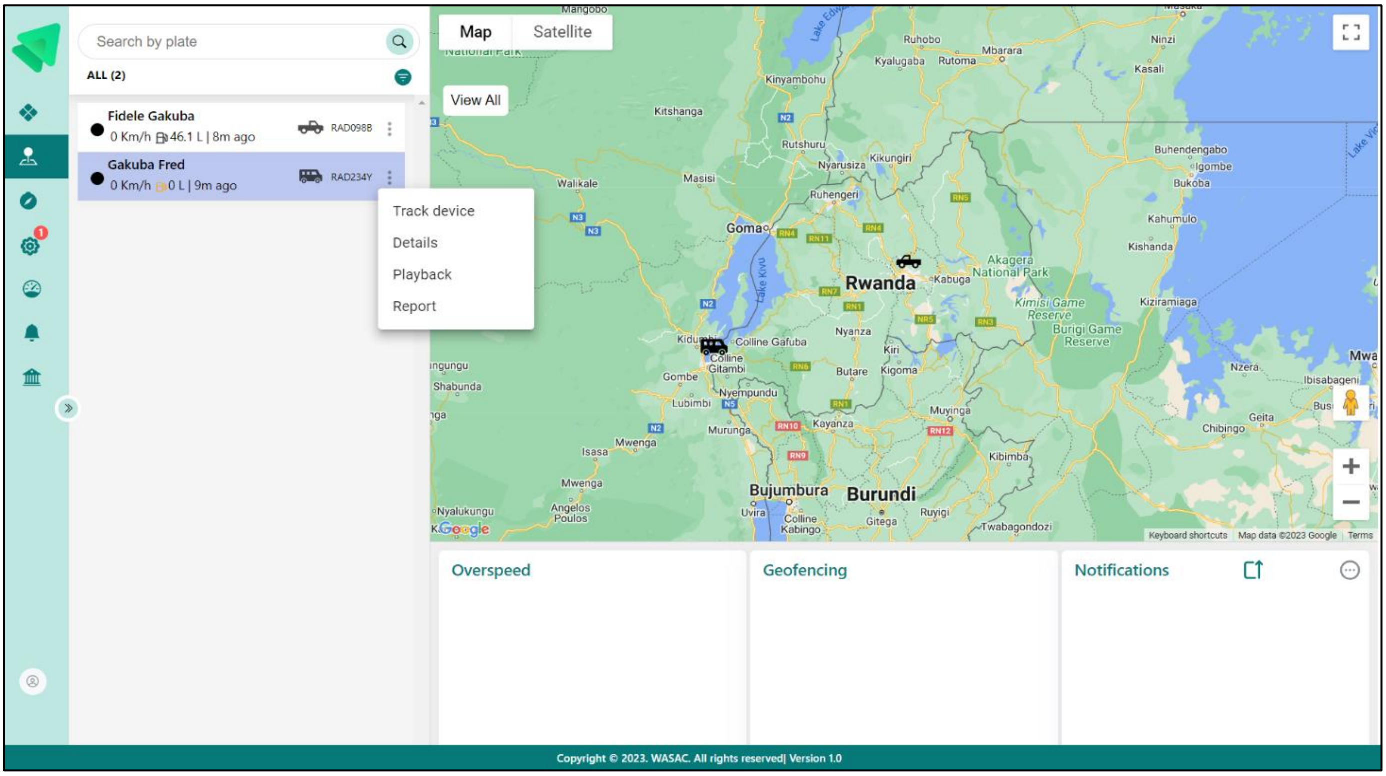

Fig 8: GPS Monitoring Page

- *Maintenance Page*

The maintenance page serves as a centralized hub for managing and tracking maintenance activities related to fleet vehicles. Users can effortlessly add maintenance records, view maintenance history, and take necessary actions such as editing or updating the status of maintenance tasks. This feature aids in optimizing vehicle performance and safety by ensuring that maintenance tasks are executed efficiently and on schedule.

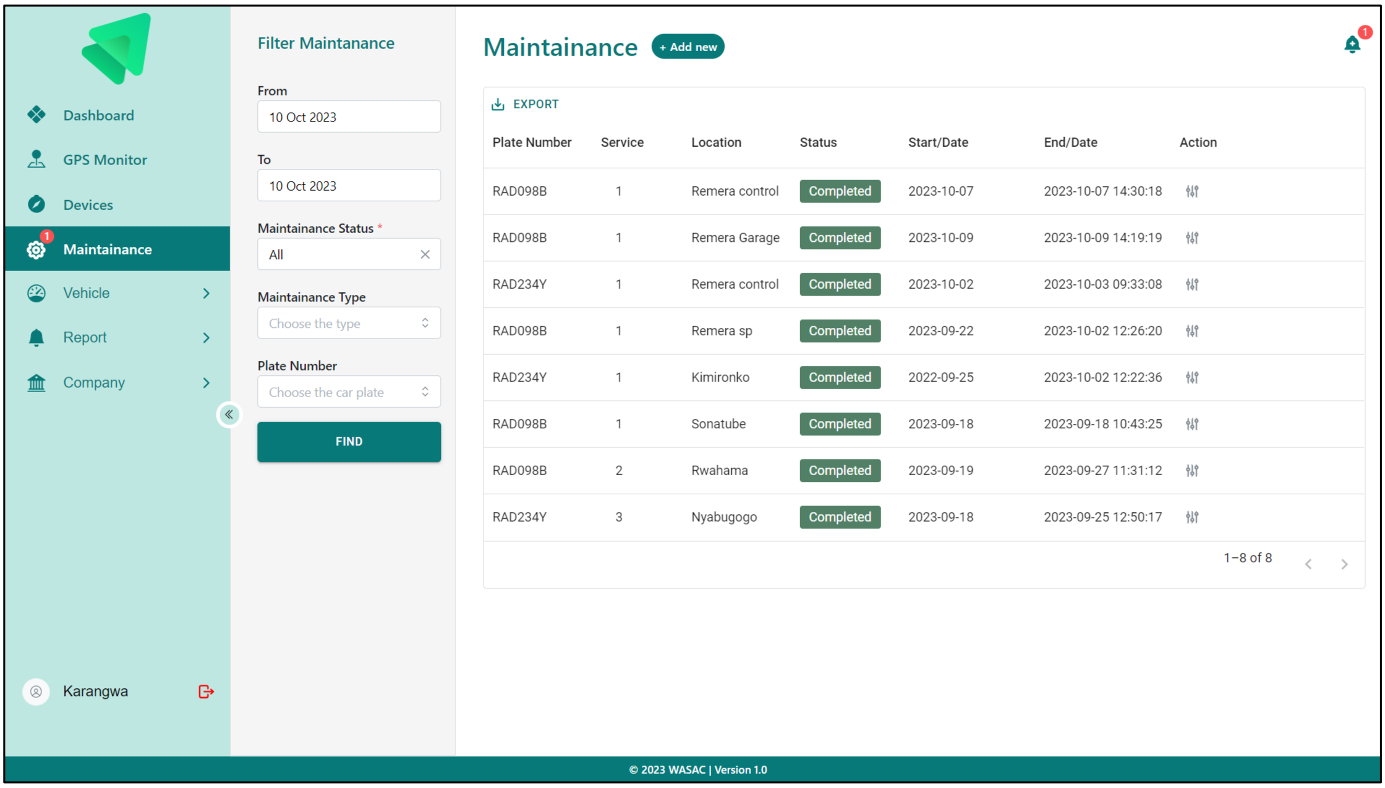

Fig 9: Maintenance Page

- *Report Page*

The report page is a vital component of the Fleet Management System, offering users the ability to generate various reports for critical insights and decision-making. Users can access functions like notification reports, full historical print reports, and fuel reports. These reports provide essential data on vehicle and driver performance, maintenance history, and fuel consumption. The information is presented in a user-friendly format, such as tables and charts, making it easy for users to analyze and take actions based on the insights provided by these reports.

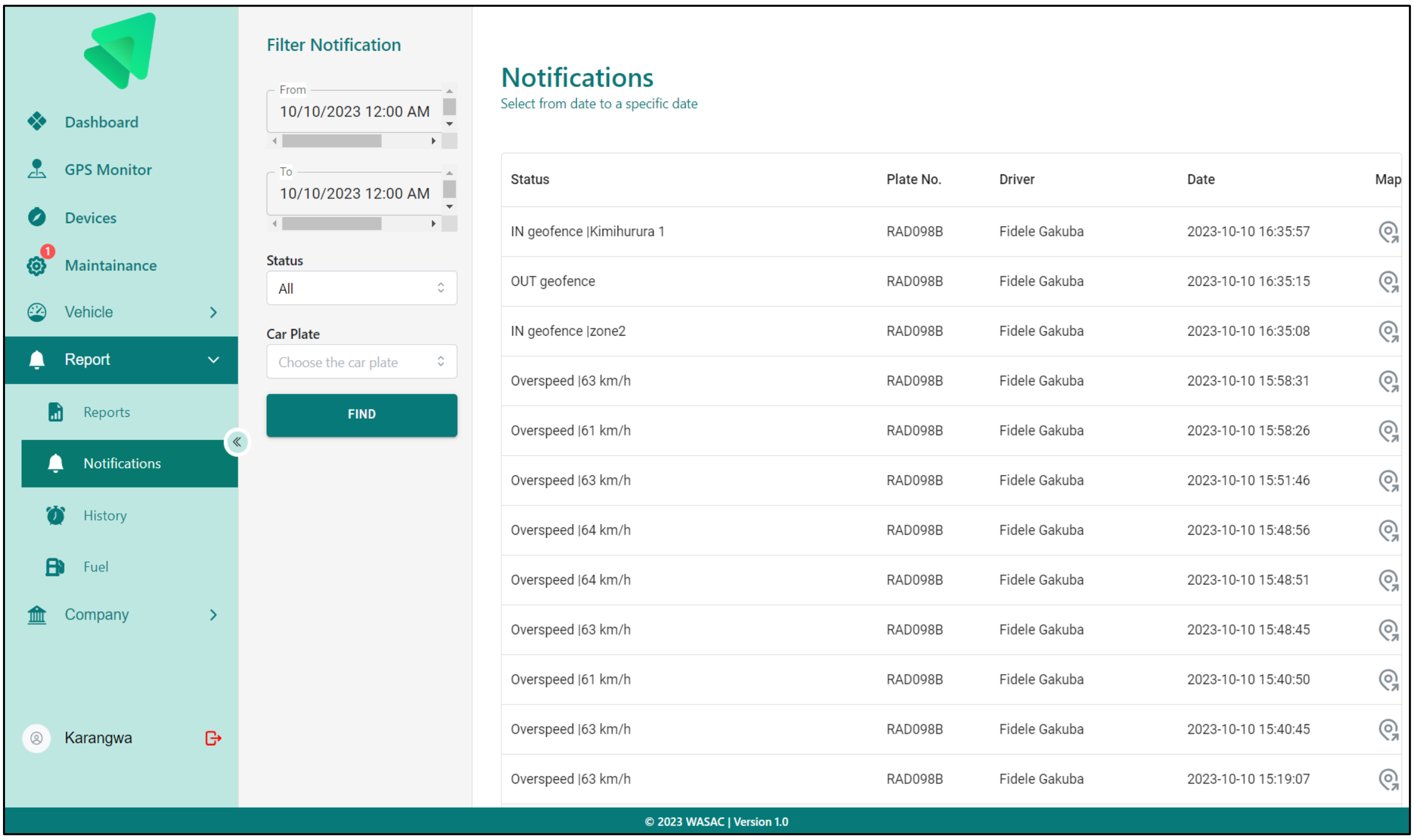

Fig 10: Report Page

C. *Analysis and Interpretation*

The presentation of the Fleet IoT-Based System Management highlights the integration of IoT technology to streamline fleet operations. By leveraging real-time data synchronization and comprehensive reporting functionalities, the system enables efficient vehicle tracking, maintenance scheduling, and performance optimization. The utilization of React, Node.js, Web Sockets, and MySQL database ensures robust system architecture and reliable data management. The flowchart diagram illustrates a user-friendly interface that simplifies navigation and enhances user experience. Overall, the findings suggest that the IoT-Based Fleet Management System offers a promising solution for institutions like WASAC, facilitating improved efficiency, cost savings, and operational control over vehicle fleets.

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

The development of this system include the design, installation, automation, and remote configuration aspects of an IoT-based fleet management system tailored for the Water and Sanitation Corporation (WASAC). Addressing four key research questions (RQs), it outlines practical steps and benefits in integrating IoT technology for improved operational efficiency and decision-making processes within the fleet.

- Designing the IoT-based system involves careful sensor selection, robust network establishment, and centralized platform development for real-time data collection, analysis, and monitoring. Integration of GPS and vehicle sensors enables precise tracking, while analytics tools offer insights for optimizing routes and maintenance, thus enhancing operational efficiency and decision-making.
- Effective installation and configuration of IoT devices entail selecting appropriate hardware, ensuring secure mounting, establishing reliable network connections, customizing device settings, implementing centralized data management, securing data through encryption, and regularly monitoring device health. Integration with fleet management software ensures seamless control and insights.
- Leveraging automation in the IoT-based fleet management system streamlines tasks like maintenance, route optimization, and fuel monitoring, reducing manual effort, downtime, and operational costs. Real-time data from IoT sensors facilitates informed decision-making,

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enhancing route planning, fuel efficiency, and overall fleet performance, thus improving operational efficiency.

- Remote device configuration through API integration demonstrates the system's agility and efficiency, enabling real-time adjustments to device settings for enhanced operational control and minimized downtime. This capability optimizes fleet performance, reduces maintenance costs, and ensures a seamless, responsive IoT ecosystem, enhancing productivity

VI. CONCLUSION

The implementation of the IoT-based Fleet Management System at WASAC demonstrates its effectiveness in improving fleet operations. The system's adaptability, user interface, real-time monitoring capabilities, and data insights contribute to enhanced efficiency and safety. The conclusions highlight the system's potential for broader implementation across Africa, offering long-term benefits in cost savings, safety improvements, and service quality.

RECOMMENDATIONS

- Future research should delve deeper into IoT technologies to further enhance fleet operations, with a focus on driver-centric approaches to improve safety, well-being, and job satisfaction.
- University of Kigali, particularly in Information Technology, should incorporate IoT projects and courses into their curriculum to provide students with practical experience in applying IoT technology.
- Promotion of research and development activities focused on IoT technology for fleet management, potentially establishing dedicated research centers and labs, to drive future advancements and innovations in IoT.

These recommendations aim to foster continued research, educational development, and technological innovation in IoT for fleet management.

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