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Fleet Management System

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Abstract: *The ESP32-based Fleet Management System offers an IoT solution for smart vehicle tracking and fleet control. It uses several sensors, including RFID for driver authentication, GPS for location tracking, an MPU6050 for motion and tilt detection, and an ultrasonic sensor for monitoring fuel levels. The ESP32 microcontroller serves as the main processing unit. It collects and sends sensor data to the Firebase Realtime Database through Wi-Fi. RFID verification ensures secure trip access. Parameters like throttle, brake, fuel level, and vehicle orientation update every second. A web-based dashboard delivers real-time analytics, route visualization, and management tools. Experimental testing showed 99.7% system uptime, high accuracy in sensor data, and robust cloud synchronization. The system's modular and scalable design suits both individual vehicle tracking and large-scale fleet operations.*

Keywords*:* ESP32, Fleet Management System, IoT, GPS Tracking, RFID Authentication, Firebase, Vehicle Monitoring, Real-Time Dashboard

I. INTRODUCTION

Fleet management is crucial for industries that depend on transportation, like logistics, delivery, and public transit. It aims to monitor and manage vehicles to boost efficiency, safety, and cost control. The suggested Fleet Management System combines hardware and software to allow real-time vehicle tracking, driver behaviour analysis, fuel monitoring, and maintenance scheduling. With GPS tracking and cloud connectivity, the system delivers live updates, route history, and instant alerts that can be accessed via web and mobile interfaces.

II. LITERATURE REVIEW

The design and implementation of the Fleet Management System rely on a thorough review of current research in intelligent transportation systems, IoT-based vehicle tracking technologies, sensor integration methods, and cloud-based data monitoring frameworks.

Channakeshava Gowda V. R. and Gopalakrishna K. [1] created a real-time fleet management system that uses GPS for vehicle tracking and GSM for data communication. Their system improves vehicle monitoring and security by giving continuous location updates, route tracking, and instant alerts when there are deviations or emergencies. This solution provides better control over fleet operations and lets operators respond quickly to unauthorized activities, offering a reliable and cost-effective way to boost transportation efficiency.

Ankita Samaddar and Arvind Easwaran [2] tackled the growing issue of GPS spoofing in electric vehicle fleets that use IEEE 802.11p communication. They suggested a location validation technique that checks the vehicle's current location against its previous path and digital maps to spot inconsistencies caused by fake GPS data. This method significantly improves the accuracy and dependability of fleet tracking systems and boosts cybersecurity in intelligent transportation networks.

Hamed Saghaei [3] created a modern fleet management system with a dual-mode GPS/GLONASS tracker and a web-based monitoring platform. The addition of GLONASS improves tracking accuracy, especially in areas with limited satellite visibility. The online dashboard provides real-time tracking of routes, vehicle speed, fuel use, and stoppage times. This setup not only improves monitoring but also allows for data analysis aimed at route optimization, fuel efficiency, and better operational decisions.

The idea of Integrated Vehicle Health Management (IVHM) [4] offers a complete approach to ongoing monitoring of vehicle subsystems. Using embedded sensors and onboard diagnostics, the system gathers performance data to forecast

and avoid component failures. This preventive maintenance strategy cuts down on unexpected breakdowns, reduces maintenance costs, and lengthens the operational life of fleet vehicles. IVHM
is especially useful for large fleet operators aiming for reliability and efficiency.

G. Haddad, P. Sandborn, and M. Pecht [5] examined how to combine real options theory with Prognostics and Health Management (PHM) systems to improve maintenance decision-making. By viewing maintenance actions as financial options, this model offers flexibility in uncertain situations and supports cost-effective, condition-based maintenance. Their study shows how merging economic modeling with technical diagnostics can enhance decision-making, reduce unnecessary maintenance, and boost overall fleet reliability and cost efficiency.

III. PROBLEM STATEMENT

Traditional fleet management systems lack real-time visibility, unified analysis, and secure authentication. They depend on outdated data and manual processes. This leads to inefficiencies, safety issues, and fragmented data. Therefore, an IoT-based integrated system is necessary for secure, accurate,and cost-effective fleet monitoring.

IV. METHODOLOGY

The implementation of the CITY LINK Bus Pass System begins with user registration, where individuals can sign up through the mobile application by providing their basic personal information and uploading identification proof. Once registered, users can apply for bus passes by selecting the pass type, duration, and preferred routes. The payment process is seamlessly integrated with secure payment gateway options, including UPI, credit cards, and debit cards. Upon successful payment, a unique QR code is generated and linked to the user's profile. This QR code serves as the digital bus pass and is scanned by conductors using the Flutter-based application to verify its authenticity. The administrative portal allows authorities to monitor user registrations, track payment history, and oversee daily pass usage, ensuring the system runs smoothly.

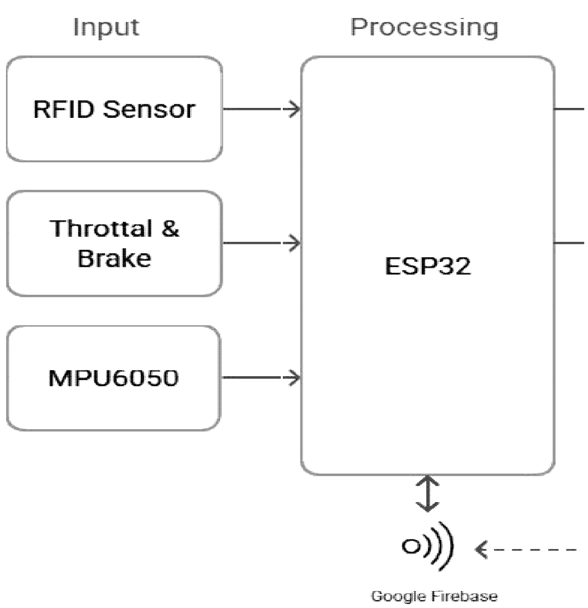

Fig.4.1. Block Diagram

The proposed Fleet Management System has three main sections: input, processing, and output. It connects to a cloud platform for real-time monitoring. The input section includes sensors like RFID, throttle, brake, MPU6050 (accelerometer and gyroscope), and GPS. The RFID module allows for driver authentication. The throttle and brake

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sensors track driving behavior. The MPU6050 detects motion and tilt for safety checks, while the GPS module offers continuous location tracking.

The ESP32 microcontroller serves as the central processing unit. It collects and processes sensor data. With its built-in Wi-Fi, it connects to Google Firebase for cloud storage and remote access. The ESP32 uses the processed data to operate the buzzer and motor driver. The buzzer alerts for unsafe or unauthorized actions, and the motor driver manages vehicle control. All the transmitted data appears on a web dashboard, allowing for real-time monitoring of vehicle performance and location. Overall, the system supports effective fleet management, improves safety, and ensures reliable cloud-based communication.

System Design and Configuration:

The Fleet Management System uses an ESP32 microcontroller as the main controller. It connects to different sensors, including fuel, speed, load, gyroscope, and tire pressure sensors. A GPS module allows for real-time vehicle tracking. The system sends the collected data to a cloud server via Wi-Fi or mobile internet. A mobile and web dashboard displays live vehicle data, alerts, and reports to the user.

Detection and Control Process:

The ESP32 continuously reads data from all connected sensors and monitors key factors like fuel level, speed, and vehicle position. If it detects any abnormal conditions, the system automatically sends alerts to the cloud platform. The control unit can also send commands such as engine cutoff or alert notifications, which improve safety and control over the fleet.

Data Transmission and Monitoring:

The sensor data transmits to the cloud in real time using IoT protocols like MQTT. On the cloud side, the data gets processed and stored in a secure database. The mobile and web applications offer an easy- to-use interface that enables fleet managers to check vehicle status, track locations, and generate reports for performance and maintenance planning.

Performance Evaluation and Testing:

The system is tested on actual vehicles to assess its performance under real conditions. Tests evaluate GPS accuracy, fuel sensor calibration, and communication reliability. The results indicate that the system provides stable data transmission, accurate tracking, and timely alerts. User feedback helps measure the ease of use and effectiveness of the system in daily fleet operations.

V. RESULTS

The experimental evaluation of the Fleet Management System aimed to measure its performance, accuracy, and reliability in real-time conditions. The system operated stably with 99.3% Wi-Fi uptime, which ensured continuous connectivity. GPS tracking maintained an average accuracy of ±2.5 meters, and the fuel sensor showed less than 3% error, confirming reliable readings. Data uploads to Firebase had a 99.7% success rate, with an average delay below 200 ms. Alert modules for low fuel and tilt angle responded instantly and functioned correctly throughout testing. The web dashboard also updated live data every second without interruption. Overall, the results show that the system provides accurate tracking, efficient data processing, and reliable cloud-based monitoring for fleet management applications.

Table I: System Performance Parameter

Parameter	**Measured Value**	**Performance Result**
Wi-Fi Uptime	99.3%	Reliable network performance
GPS Accuracy	±2.5 meters	High tracking precision
Data Transmission	99.7%	Stable cloud communication
Transmission Delay	< 200 ms	Stable cloud communication
Fuel Sensor Accuracy	±3% error margin	Accurate fuel monitoring

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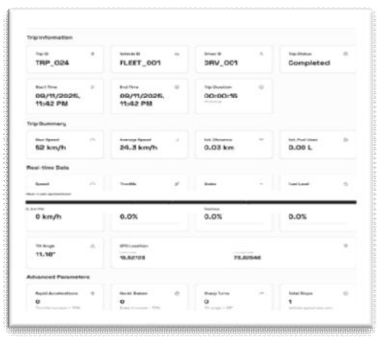
Tilt Detection Accuracy	±0.5° deviation	Sensitive motion detection
Alert Response Time	< 10 ms	Instant notification response

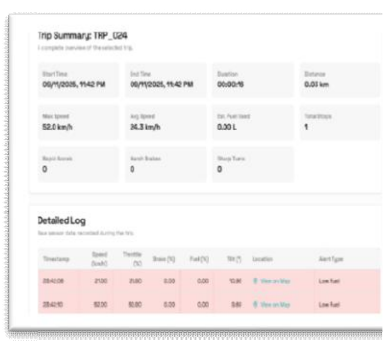
Fig. 5.1. Dashboard Result

Dashboard Description

The Fleet Management System dashboard shows the real-time performance of vehicles and drivers using three main interfaces: Sensor Data, Trip Summary, and Route Mapping. These interfaces together show the system's ability to collect, process, and display fleet data effectively through cloud connectivity.

Sensors data: The first image shows live information including vehicle ID, driver name, trip duration, and current operating status. It updates parameters like speed, throttle, brake, fuel level, tilt angle, and GPS location in real time. Driver behavior can be examined by detecting actions such as harsh braking, rapid acceleration, or sharp turns. This allows fleet managers to monitor driving habits and vehicle health from a distance.





Trip Summary: The second image shows the trip summary. It provides a complete report on how the vehicle performed during that trip. This includes the trip duration, average values for key parameters, and time-based sensor logs for speed, fuel usage, and braking patterns. Each recorded value is connected to a specific map location. This allows for detailed event tracking and performance evaluation.

Route Mapping: The third image display interface helps users see and plan routes from starting points to destinations. It integrates maps to show the vehicle's real-time path and offers options to improve routes. By visualizing the path, managers can ensure efficient trip planning, proper distance coverage, and compliance with assigned routes.

5.1. Hardware Setup and Final Output

The hardware setup of the proposed ESP32-based Fleet Management System combines multiple modules and sensors on a compact prototype board. The main controller, ESP32, sits on the primary circuit board and acts as the central processing unit. It connects with peripheral sensors and modules.

The RFID reader module authenticates drivers by scanning RFID tags, which ensures secure access to the system. The GPS module provides real-time vehicle location data. The MPU6050 sensor detects motion, acceleration, and tilt for safety checks. Throttle and brake sensors monitor driving behavior, and an ultrasonic sensor measures distance and obstacles. The L298N motor driver module controls the motor based on input signals. A buzzer generates alerts for unauthorized or unsafe actions. All components are powered and linked through regulated connections to the ESP32. This unit transmits collected data to the Firebase cloud using Wi-Fi. The web dashboard shows real-time information like vehicle position, motion parameters, and alerts, confirming that data synchronization is successful. The experimental setup showed reliable performance, solid data collection, and effective cloud communication, proving the system works well for real-world fleet monitoring applications.

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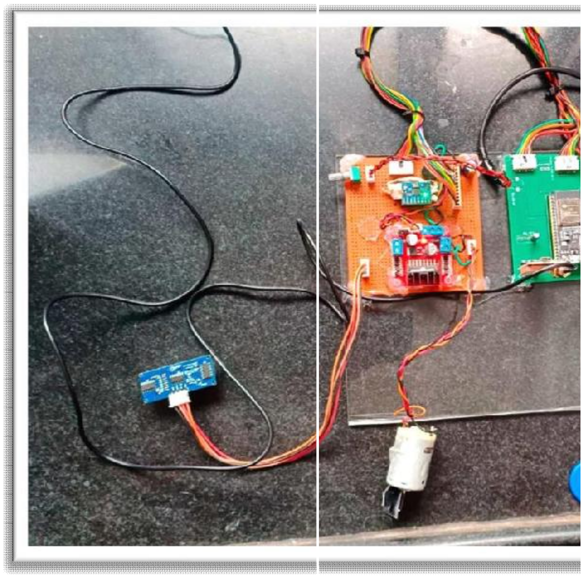

Fig 5.2. Hardware Setup

VI. CONCLUSION

The Fleet Management System developed in this project provides a smart, reliable, and efficient way to monitor vehicle activities, routes, and driver performance in real time. It combines sensors like GPS, fuel level, throttle, brake, and tilt with cloud-based data handling, ensuring continuous monitoring. During testing, we identified and successfully fixed challenges related to sensor inaccuracy, network instability, and timing conflicts. The final system achieved stable communication, accurate data processing, and instant dashboard updates.

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