

Design and Development of IoT Based Fleet Management and Smart Vehicle Monitoring 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

1.INTRODUCTION

Fleet management plays a crucial role in industries that depend heavily on transportation, such as logistics, public transit, delivery services, and construction. As organizations expand and the demand for timely, safe, and cost-efficient transport grows, traditional fleet management methods often fall short in providing real-time visibility and data-driven insights. Managing large fleets manually not only increases the chances of human error but also makes it difficult to ensure fuel efficiency, driver safety, and timely maintenance. To overcome these challenges, modern technologies like the Internet of Things (IoT), cloud computing, and intelligent data analytics are transforming how fleet operations are monitored and controlled. The proposed IoT-based Fleet Management System (FMS) aims to automate and optimize fleet operations through a seamless integration of hardware and software components. At its core, the system utilizes the ESP32 microcontroller, which serves

as the central unit for data acquisition and communication. Various sensors including GPS, fuel level, and speed sensors are interfaced with the controller to continuously capture key vehicle parameters. This real-time data is processed and transmitted to a cloud server via the Internet, enabling fleet managers to access critical information through a secure web or mobile application.

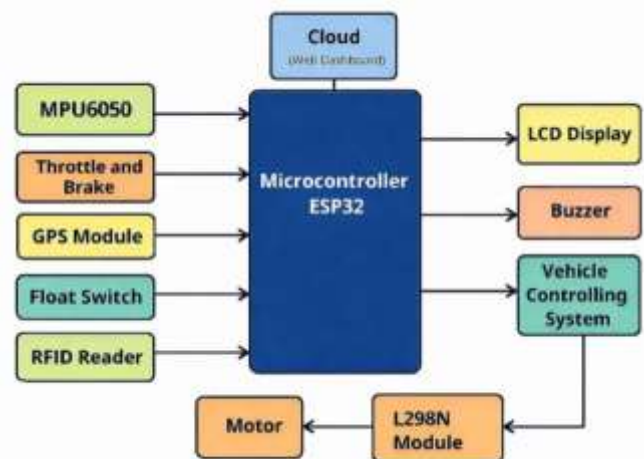


Figure 1: Block Diagram of Proposed System

The system is also equipped with RFID-based trip management to ensure secure access control and accurate trip recording, minimizing unauthorized vehicle usage and data manipulation. Furthermore, the integration of GPS tracking and cloud-based dashboards enhances route management by providing live location updates, route history, and alerts for deviations or unusual behavior. The inclusion of driver behavior analysis allows monitoring of parameters such as speed variations, braking patterns, and idle time, which are crucial for improving safety and fuel economy. Through predictive maintenance features, the system can analyze usage trends to schedule maintenance proactively, thereby preventing costly breakdowns and improving vehicle lifespan. By combining IoT technology with cloud analytics and intelligent automation, the developed Fleet Management System provides a comprehensive, scalable, and user-friendly solution. It not only enhances

operational efficiency but also supports data-driven decision-making for businesses managing large vehicle fleets. Overall, this research contributes to the development of a smart and sustainable fleet management approach that aligns with Industry 4.0 objectives emphasizing connectivity, automation, and intelligent monitoring for improved productivity and reduced operational costs.

2. LITERATURE REVIEW

Several research efforts have focused on intelligent vehicle monitoring, fleet management, and speed-control systems using optimization techniques, IoT frameworks, and advanced control strategies.[1] Rahman et al. investigated fleet speed profile optimization for autonomous and connected vehicles. Their approach improved energy efficiency and coordination among electric vehicles; however, it primarily addressed optimization at the fleet level rather than real-time safety control at the individual vehicle level. An IoT-based vehicle monitoring and tracking system was proposed by Dewan and Agarwal [2], employing GPS, GSM, and vibration sensors to detect accidents and send real-time alerts. While the system was effective for monitoring and notification, it lacked active control mechanisms such as automatic speed regulation or preventive safety intervention.

Furthermore, in another study we [3] explored the aggregation of electric vehicles for primary frequency control in industrial microgrids using Vehicle-to-Grid communication. Their work highlighted the importance of real-time coordination and bidirectional communication in large-scale vehicular systems but did not focus on driver behaviour or speed safety. In another paper, we studied about [4] demonstration of the effectiveness of machine learning in optimizing fleet operations based on energy consumption and control effort, though it emphasized operational efficiency rather than real-time vehicle safety.

Security and reliability issues in vehicle tracking systems were examined by Narain et al. [5], who highlighted vulnerabilities such as GPS spoofing, jamming, and data manipulation. Their work emphasized the need for secure sensor fusion and data integrity mechanisms, often implemented using Kalman filtering techniques. Reinforcement learning approaches for optimizing ride-hailing and routing decisions in electric vehicle fleets were discussed by Shi et al. [6], showing improvements

in operational decision-making and route efficiency through AI-based models. On the hardware and sensing side, [7] there was a system which was made to detect motion-based human-computer interaction system using an MPU6050 sensor and microcontroller, validating its accuracy in detecting tilt and motion. This supports the applicability of such sensors for driver behaviour and motion monitoring. Motor speed control techniques were addressed by Curys [8], who demonstrated the effectiveness of Pulse Width Modulation for Brushless DC motor speed regulation, ensuring smooth and efficient operation. Finally, Gowda and Gopalakrishna [9] developed a real-time fleet management and vehicle security system using GPS and GSM technologies. While the system provided reliable tracking and data logging, it lacked predictive intelligence and automated safety control.

3. 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.

4. METHODOLOGY

4.1 Components

1. Microcontroller – ESP32

The ESP32 serves as the central controller responsible for interfacing with all sensors, processing real-time data, and managing communication with the Firebase cloud. It coordinates inputs from the GPS, RFID, fuel sensor, and motion sensors while generating outputs to the buzzer and motor driver.

2. RFID Module – MFRC522

Used for secure driver authentication before vehicle operation. The RFID reader scans the driver's card and verifies it against the stored database, ensuring only authorized personnel can access or start the vehicle.

3. GPS Module – NEO-7M

The NEO-7M provides real-time vehicle location, speed, and route data. This information is continuously transmitted to the cloud for live tracking and trip history analysis.

4. Motion Sensor – MPU6050

The MPU6050 monitors vehicle orientation, vibration, and acceleration. It helps detect unsafe motion events like sudden tilts, sharp turns, or collisions, enhancing driver safety and post-event analysis.

5. Ultrasonic Sensor – HC-SR04

The HC-SR04 is used for non-contact fuel level measurement by calculating the distance from the sensor to the fuel surface. It enables accurate fuel monitoring and low-fuel alert generation.

6. Throttle and Brake Sensors – Analog Potentiometers

Two potentiometers are employed to simulate throttle and brake inputs. They convert pedal movement into analog voltage signals, allowing the system to interpret acceleration and braking behavior digitally.

7. Motor Driver – L298N

The L298N module controls the motor's direction and speed during vehicle simulation. It executes commands from the ESP32 to replicate movement or stop operations under unsafe conditions.

8. Active Buzzer

The buzzer provides immediate sound feedback for system alerts such as RFID authentication success, tilt detection, low fuel, or unauthorized access events.

4.2 Working

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 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.

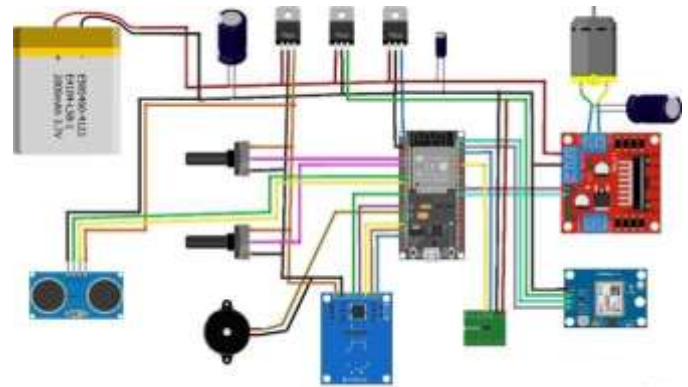


Figure 2: Circuit Diagram of Proposed System

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.

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.

4.4. Flow Chart:

The flowchart of FMS represents the logical operation and data flow from sensor initialization to real-time monitoring. It ensures efficient and continuous fleet supervision by integrating sensing, validation, cloud communication, and alert mechanisms.

The process begins with the initialization of sensors, where all the connected modules such as the ADC, RFID, GPS, MPU6050 (tilt sensor), ultrasonic sensor, throttle, and brake sensors are activated. Once initialized, the system moves to the sensor data reading stage, where it collects real-time information on key parameters including vehicle location, fuel level, speed, tilt angle, driver RFID authentication, and timestamp. After the data is collected, the system performs a validation and authentication check to confirm that the received information is accurate and the driver is authorized. If the data is valid and authenticated, it is logged as trip data for record-keeping and analysis. However, if the data is found invalid or the driver authentication fails, the system immediately triggers an “Invalid/Unauthenticated” alert to prevent unauthorized operation or false readings. For valid inputs, the system proceeds to transmit real-time data to the Firebase cloud using the ESP32’s Wi-Fi connectivity. This ensures that all fleet parameters are continuously updated in the cloud database. The synchronized data is then displayed on the web dashboard, where the fleet manager or operator can monitor the vehicle’s live status, performance, and safety parameters. Finally, the system incorporates an alert mechanism that activates whenever a defined threshold is crossed for example, in cases of excessive speed, abnormal tilt, or low fuel level. These alerts are immediately reflected on the dashboard, enabling timely response and enhanced operational safety. In summary, this flow ensures that every stage from sensor activation

to data validation and cloud synchronization—is performed efficiently, providing an intelligent, automated, and secure fleet management solution.

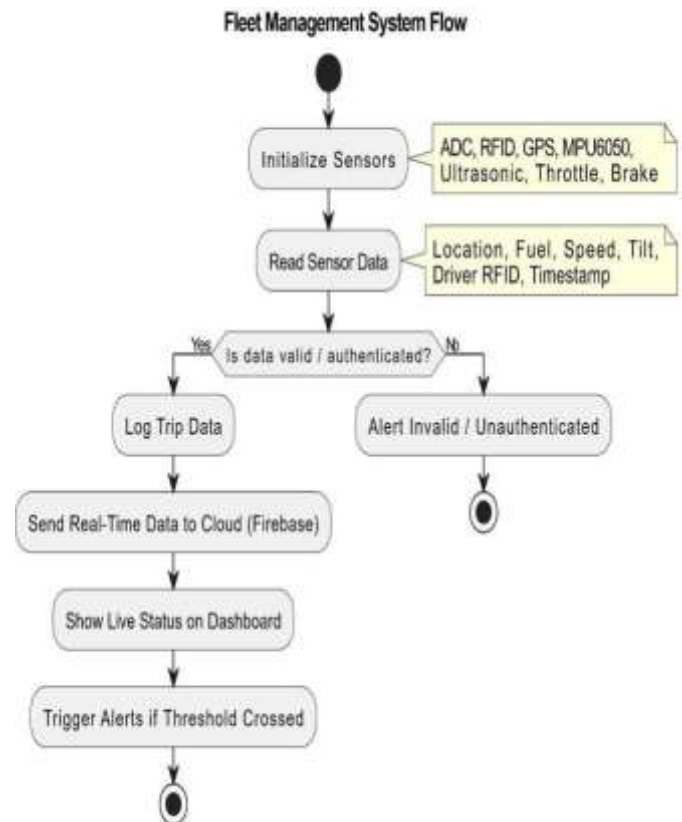


Figure 3: Flowchart

5.RESULTS

The results obtained from the proposed IoT-Based Fleet Management System demonstrate effective real-time monitoring, accurate data collection, and reliable cloud communication. The system successfully integrated GPS tracking, RFID authentication, sensor monitoring, and web-based visualization into a single platform. During testing, all modules operated continuously without major interruption, confirming stable system performance. Real-time vehicle parameters such as speed, location, fuel status, and motion data were accurately updated on the dashboard through Wi-Fi communication. The implemented alert mechanism also responded properly to abnormal conditions, improving overall vehicle safety and monitoring efficiency. The system also demonstrated quick

response and smooth data synchronization between the hardware modules and the cloud-based monitoring platform.

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 1: System Performance Parameter

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 m/s	Stable cloud communication
Fuel Sensor Accuracy	$\pm 3\%$ error margin	Accurate fuel monitoring
Tilt Detection Accuracy	$\pm 0.5^\circ$ deviation	Sensitive motion detection
Alert Response Time	< 10 m/s	Instant notification response

5.1. 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.



Figure 4: Dashboard Description

Trip Summary: This image also 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. The Trip Summary section stores important trip-related information such as Driver ID and Trip ID for proper monitoring and record management. Driver ID helps identify the assigned driver, while Trip ID provides a unique reference for each

journey. This information improves trip tracking, data organization, and overall fleet management efficiency.

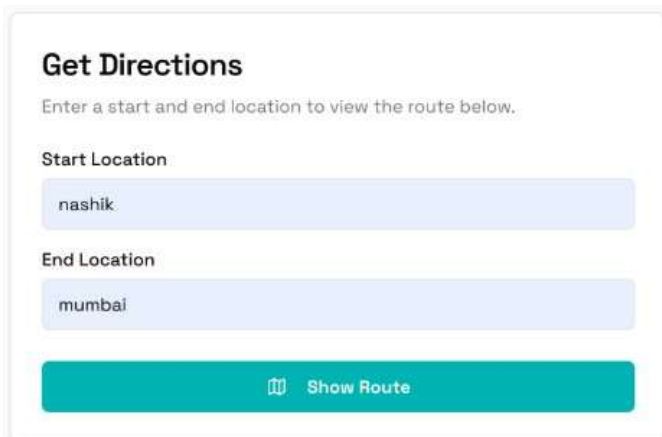


Figure 5: Trip planning

Route Mapping: This 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.



Figure 6: Route Planning

The system continuously collects real-time data from vehicles using GPS trackers and IoT sensors installed in the fleet. This data is transmitted to the cloud server, where the route information is processed and displayed on the monitoring dashboard. The map interface shows the vehicle's travel path, estimated travel time, distance coverage, and available route options. By analyzing this information, fleet managers can identify the most efficient route, avoid traffic congestion, reduce fuel consumption, and improve overall trip management. The system also helps in monitoring route deviations and ensuring that vehicles follow the planned path accurately.

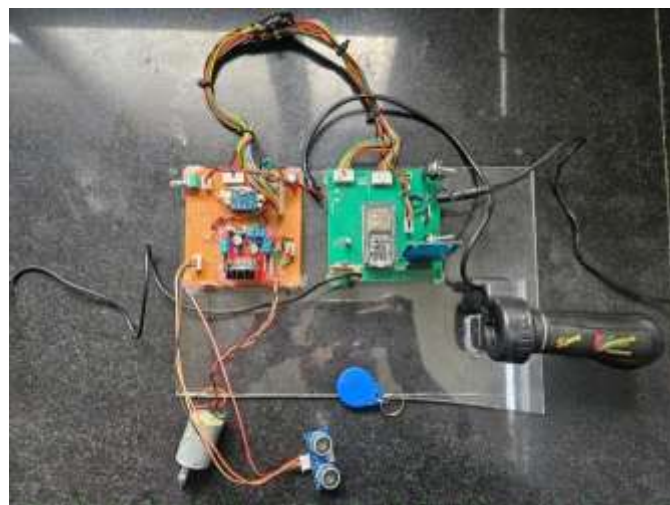


Figure 7: Hardware Setup

5.2. 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. The hardware setup is compact, reliable, and suitable for real-time fleet monitoring applications. All connected sensors and modules communicate efficiently with the ESP32 controller to ensure accurate data collection and smooth system

operation. The prototype can also be upgraded with additional IoT features for future enhancements.



Figure 8: Speed over Time Graph Description

Speed Over Time Graph Description

The graph continuously records and displays the vehicle speed data collected through IoT sensors and GPS-based monitoring modules. Initially, the vehicle starts at a lower speed and gradually accelerates as the trip progresses. The speed reaches a peak value of approximately 52 km/h, indicating normal vehicle acceleration under monitored conditions. After reaching the maximum speed, the vehicle speed decreases gradually, representing deceleration or stopping conditions. This graphical analysis helps in real-time monitoring of driver behaviour, vehicle performance, and speed regulation. It also assists fleet operators in identifying over-speeding events, unsafe driving patterns, and trip efficiency. The collected speed data is stored in the cloud/database for future analysis, reporting, and decision-making.

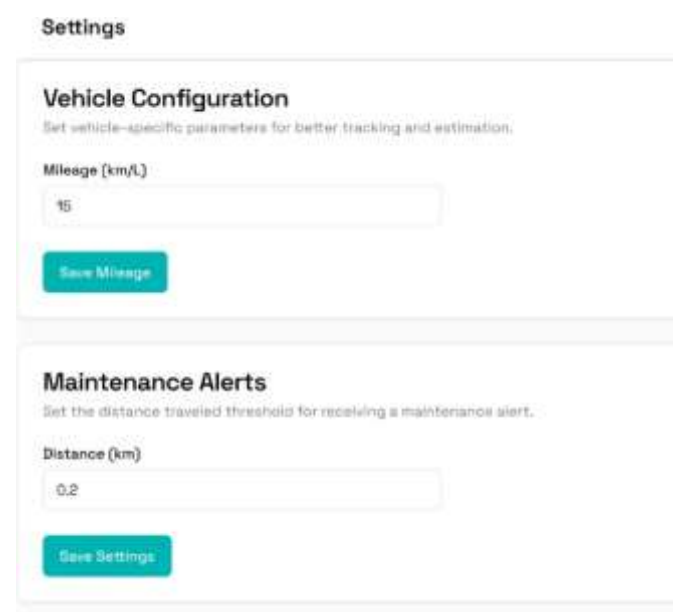


Figure 9: Settings Module Description

Settings Module Description

This module allows the user or fleet administrator to configure important vehicle parameters for accurate monitoring, tracking, and maintenance management. The Vehicle Configuration section is used to enter the vehicle mileage value in km/L. This information helps the system estimate fuel consumption, travel efficiency, and overall vehicle performance during trips. By storing vehicle-specific parameters, the system can provide more precise monitoring and analytics. The Maintenance Alerts section enables the user to set a predefined travel distance threshold for maintenance notifications. Once the vehicle travels the specified distance, the system automatically generates a maintenance alert to remind the user about servicing requirements. This feature helps in preventive maintenance, reduces the risk of vehicle breakdown, and improves fleet reliability. The settings are stored in the database/cloud platform and can be updated anytime through the web dashboard. This module enhances the flexibility, efficiency, and reliability of the smart vehicle monitoring system by enabling real-time configuration and automated maintenance management.

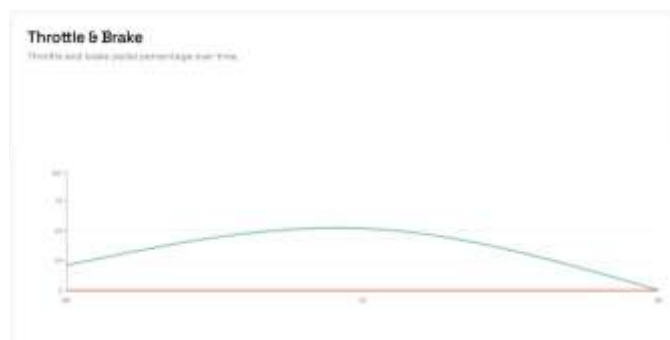


Figure 10: Throttle and Brake Graph Description

Throttle and Brake Graph Description

This graph is used to analyze driver behaviour and vehicle control performance during a trip. The throttle curve gradually increases from the initial stage, indicating acceleration of the vehicle as the driver applies more throttle input. The throttle percentage reaches a peak value of approximately 50%, representing the maximum acceleration condition during the trip. After reaching the peak, the throttle value decreases gradually, indicating reduction in vehicle speed or transition towards stopping conditions. The brake line remains nearly constant at the lower level, showing minimal brake application during the monitored interval. This indicates smooth vehicle

operation without sudden braking events. The system continuously collects throttle and brake data using IoT-enabled sensors and transmits it to the monitoring dashboard for real-time analysis. This graphical representation helps fleet operators identify harsh acceleration, sudden braking, unsafe driving patterns, and overall driving efficiency. The data can also be stored for performance evaluation, safety analysis, and predictive maintenance purposes.

6. CONCLUSIONS

The ESP32 Fleet Management System effectively showcases an advanced IoT-driven solution for modern fleet monitoring and control, overcoming the drawbacks of conventional manual tracking methods. Through the integration of real-time sensor data, RFID-based trip authentication, GPS tracking, and cloud-based analytics, the system delivers a unified and transparent view of vehicle performance, driver activities, and overall operational efficiency. Its modular and scalable architecture enables effortless deployment across multiple vehicles and industries such as construction, logistics, and corporate transportation. By incorporating features like predictive maintenance, driver behaviour evaluation, and intelligent route optimization, the system helps minimize operational expenses, enhance safety standards, and optimize resource usage. The inclusion of centralized cloud storage and a dynamic dashboard empowers fleet managers to access real-time data for informed decision-making, leading to improved productivity and compliance with safety protocols. Overall, this project demonstrates how IoT and cloud computing technologies can revolutionize fleet management delivering a cost-efficient, reliable, and intelligent solution that supports the evolution toward smarter, connected, and data-driven transportation systems of the future.

Future Scope

The system can be enhanced with Artificial Intelligence (AI) and Machine Learning (ML) algorithms to enable predictive analytics, allowing accurate forecasting of maintenance needs, fuel consumption, and optimal route planning based on historical and real-time data.

- Integration with Smart City infrastructure and Vehicle-to-Infrastructure (V2I) communication can improve traffic coordination, minimize travel delays, and help

reduce carbon emissions through intelligent transport management.

- Future developments may include support for autonomous and semi-autonomous fleet operations, enabling coordinated control and monitoring of multiple vehicles with minimal human input.

- An advanced mobile application can be developed to provide real-time notifications, performance insights, and route optimization for both drivers and fleet managers, improving accessibility and decision-making.

- The incorporation of data analytics for environmental sustainability can promote eco-friendly driving, optimize routes for energy efficiency, and lower the overall carbon footprint of fleet operations.

- Enhancing system scalability will allow seamless integration with large commercial fleets, public transport systems, and global logistics networks, making the system adaptable for broader applications.

- The use of blockchain technology can ensure secure, tamper-proof records, facilitate automated billing, and improve supply chain transparency through smart contracts.

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