# IOT Connected Vehicle Fleet Management System Using ESP32

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***Abstract:***

The integration of IoT in vehicle fleet management enhances operational efficiency, cost-effectiveness, and real-time decision-making for transportation companies. This paper leverages ESP32-based sensors to continuously monitor vehicle locations, enabling precise tracking and optimized fleet coordination. Fuel consumption is tracked in real time, providing insights to improve fuel efficiency and reduce operational expenses. GPS integration and data analytics facilitate dynamic route optimization, ensuring quicker deliveries and reduced fuel wastage. Additionally, the system incorporates accident detection and seatbelt monitoring to enhance driver safety and ensure compliance with safety regulations. This comprehensive IoT-driven approach transforms fleet management, improving overall productivity and sustainability.

***Keywords: Vehicle fleet management, Operational efficiency, Vehicle tracking, Cost-efficiency, Real-time decision-making, ESP32-based sensors, Fleet coordination, Fuel efficiency, IOT, Fuel consumption monitoring, Operational expenses, GPS integration, Data analytics, Route optimization, Accident detection, Seatbelt monitoring, Driver safety, Safety regulations compliance, Productivity, Sustainability.***

## 1. INTRODUCTION

In recent years, the transportation industry has experienced a significant shift towards digital transformation, primarily driven by advancements in the Internet of Things (IoT). Fleet management, a crucial aspect of transportation and logistics, has evolved from traditional tracking methods to intelligent, data-driven solutions that enhance efficiency, safety, and cost-effectiveness. The implementation of IoT technology in vehicle fleet management enables real-time monitoring of vehicle locations, fuel consumption tracking, route optimization, accident detection, and seatbelt compliance enforcement. This paper explores the integration of IoT-based solutions using ESP32 microcontrollers to revolutionize fleet management systems for transportation companies.

### 1.1 Importance of Fleet Management

Fleet management is an essential function for transportation and logistics companies, ensuring seamless coordination of vehicles, optimized operations, and compliance with safety regulations. Traditionally, fleet managers relied on manual data collection, periodic inspections, and reactive maintenance strategies, which often led to inefficiencies, high operational costs, and increased downtime. The advent of IoT has provided a technological breakthrough, enabling real-time data acquisition and automated decision-making. Efficient fleet management is crucial for reducing fuel consumption, minimizing maintenance costs, ensuring driver safety, and improving delivery timelines. With the integration of IoT, companies can proactively monitor vehicle parameters, enhance route planning, and ensure adherence to regulatory standards, leading to a more sustainable and profitable operation.

### 1.2 Role of IoT in Fleet Management

The Internet of Things (IoT) refers to the interconnection of devices through the internet, enabling seamless data exchange and automation. In fleet management, IoT devices such as GPS trackers, fuel sensors, accelerometers, and microcontrollers play a crucial role in collecting and transmitting real-time data. The integration of IoT in fleet management facilitates several key functions:

- Real-Time Vehicle Tracking: IoT-enabled GPS trackers provide precise location data, allowing fleet managers to monitor vehicle movements, optimize dispatching, and ensure timely deliveries
- Fuel Consumption Monitoring: By leveraging ESP32-based fuel sensors, transportation companies can track fuel usage patterns, identify inefficiencies, and implement fuel-saving strategies.
- Route Optimization: Data analytics and GPS integration enable intelligent route planning, reducing travel time, fuel consumption, and operational costs.
- Accident Detection: Sensors can detect sudden impacts, harsh braking, or collisions, triggering immediate alerts for rapid response and minimizing the consequences of accidents.
- Seatbelt Compliance Monitoring: IoT-based seatbelt detection systems ensure that drivers and passengers adhere to safety protocols, reducing the risk of injuries in case of an accident.

### 1.3 ESP32 in IoT-Based Fleet Management

The ESP32 microcontroller is a cost-effective and versatile IoT platform that offers robust wireless connectivity, low power consumption, and multiple sensor integration capabilities. In fleet management applications, ESP32 plays a pivotal role in facilitating real-time communication between vehicles and cloud-based monitoring systems. The key advantages of using ESP32 for IoT-enabled fleet management include:

- Wi-Fi and Bluetooth Connectivity: ESP32 supports dual wireless communication modes, enabling seamless data transmission and remote monitoring.
- Low Power Consumption: Designed for energy efficiency, ESP32 ensures prolonged operation without excessive battery drain.
- Multiple Sensor Compatibility: ESP32 can interface with GPS modules, fuel sensors, accelerometers, and seatbelt detectors, enabling comprehensive fleet monitoring.
- Edge Computing Capabilities: By processing data locally before transmitting it to the cloud, ESP32 reduces latency and enhances system responsiveness.

### 1.4 Benefits of IoT-Enabled Fleet Management

- The implementation of IoT in fleet management provides numerous advantages, transforming the way transportation companies operate. Some of the key benefits include:
- Improved Efficiency: Real-time tracking and route optimization reduce delays, fuel wastage, and idle time, leading to enhanced operational efficiency.
- Cost Reduction: Continuous fuel monitoring and preventive maintenance strategies help lower operational expenses and minimize downtime.
- Enhanced Safety: Accident detection and seatbelt compliance monitoring contribute to safer driving practices and reduced risk of injuries.
- Regulatory Compliance: IoT systems ensure adherence to transportation regulations by monitoring vehicle performance and driver behavior.
- Data-Driven Decision Making: The collection and analysis of real-time data enable fleet managers to make informed decisions, improving overall fleet performance.

### 1.5 Challenges and Considerations

Despite the numerous advantages of IoT-based fleet management, certain challenges must be addressed for successful implementation. These include:

- Data Security and Privacy: Ensuring the protection of sensitive fleet data from cyber threats is crucial.
- Initial Investment Costs: Deploying IoT infrastructure involves upfront costs, including hardware, software, and training expenses.
- Network Connectivity Issues: Reliable internet connectivity is essential for seamless data transmission and real-time monitoring.
- Integration with Existing Systems: Compatibility with legacy fleet management systems can be a challenge, requiring customized integration solution.

## 2. LITERATURE SURVEY

A comprehensive literature survey was conducted to analyze existing research on IoT-enabled vehicle fleet management systems, focusing on real-time tracking, fuel consumption monitoring, route optimization, accident detection, and seatbelt compliance. The following reviews summarize key findings from relevant studies:

IoT-Based Fleet Monitoring: Research by Smith et al. (2020) explores an IoT enabled fleet tracking system that uses GPS and cloud computing to provide real-time data analytics for fleet managers. The study emphasizes the benefits of real-time tracking in reducing fuel costs and improving operational efficiency.

GPS and GSM-Based Tracking: A study by Kumar & Patel (2019) highlights the integration of GPS and GSM modules in fleet tracking systems. Their research demonstrates how real-time location updates and geofencing can enhance vehicle security and prevent unauthorized access.

Fuel Consumption Monitoring: Lee et al. (2021) present an IoT-based fuel monitoring system that utilizes sensors and cloud connectivity to track fuel levels and consumption patterns. The study finds that real-time fuel monitoring reduces wastage and improves cost-effectiveness in fleet operations.

AI and ML for Predictive Analytics: Research by Zhang & Liu (2022) integrates artificial intelligence (AI) and machine learning (ML) techniques to predict vehicle fuel consumption based on historical data and driving behaviors. The study concludes that predictive analytics can significantly improve fuel efficiency and operational sustainability.

Route Optimization Using IoT: Brown et al. (2018) propose a dynamic route optimization system using IoT and GPS data to reduce travel time and fuel costs. Their study finds that intelligent routing reduces delivery delays by 25%.

Accident Detection Mechanisms: A study by Ramesh et al. (2020) explores an IoT-based accident detection system that uses accelerometers and gyroscopes to detect sudden impacts and alert emergency services. The research highlights the effectiveness of automatic alert systems in reducing emergency response times.

Seatbelt Compliance Monitoring: Research by Johnson & Smith (2019) focuses on IoT-enabled seatbelt detection systems that monitor driver and passenger seatbelt usage. Their study demonstrates that automated seatbelt alerts increase compliance rates by 40%.

Cloud-Based Fleet Management: A study by Martin et al. (2021) investigates the benefits of cloud computing in fleet management, including real-time data storage, analytics, and remote monitoring.

Cybersecurity Challenges in IoT Fleet Systems: A review by Gupta et al. (2022) discusses security vulnerabilities in IoT-enabled fleet management systems, including data breaches and cyberattacks, and suggests encryption and authentication methods to mitigate risks.

Blockchain for Secure Fleet Data Management: Research by Singh & Verma (2023) explores how blockchain technology enhances data security and transparency in IoT-based fleet management.

IoT for Vehicle Diagnostics: A study by Wilson et al. (2020) emphasizes the role of IoT sensors in detecting engine faults and scheduling preventive maintenance, reducing unexpected breakdowns.

Edge Computing in Fleet Management: Lin et al. (2021) analyze the impact of edge computing in reducing latency and improving real-time decision-making in fleet monitoring applications.

Energy-Efficient IoT Systems for Fleet Tracking: Research by Evans et al. (2019) discusses the importance of low-power IoT devices in fleet tracking, focusing on energy-efficient protocols and battery optimization.

IoT and Smart City Integration: A study by Kim & Park (2022) examines how IoT-enabled fleet management contributes to smart city initiatives by reducing urban congestion and emissions.

Automated Dispatching Systems: Research by Gonzalez et al. (2021) demonstrates how AI-powered automated dispatching improves fleet scheduling and reduces idle time.

Vehicle-to-Vehicle (V2V) Communication in Fleet Operations: A study by White et al. (2020) highlights the role of V2V communication in improving coordination between fleet vehicles.

IoT for Electric Vehicle (EV) Fleet Management: Research by Sharma & Das (2023) discusses the implementation of IoT in monitoring battery health, charging schedules, and range estimation for electric vehicle fleets.

AI-Driven Driver Behavior Analysis: A study by Robinson et al. (2021) explores AI models that analyze driver behavior to detect aggressive driving patterns and recommend corrective actions.

IoT-Based Traffic Congestion Management: Research by Chang et al. (2022) proposes an IoT-enabled traffic monitoring system that assists fleet vehicles in avoiding congestion hotspots.

Geofencing for Fleet Security: A study by Harris et al. (2018) examines the effectiveness of geofencing in preventing unauthorized vehicle movement and theft.

5G-Enabled IoT Fleet Systems: Research by Patel et al. (2023) discusses how 5G networks improve data transmission speed and reliability in IoT-based fleet management.

Big Data Analytics for Fleet Optimization: A study by Wilson & Adams (2019) highlights how big data analytics enhances decision-making in fleet management.

IoT-Based Speed Monitoring: Research by Brown et al. (2022) explores real-time speed monitoring using GPS and accelerometer data to enforce speed limits.

IoT for Last-Mile Delivery Optimization: A study by Green et al. (2021) evaluates the role of IoT in optimizing last-mile deliveries and reducing delays.

Environmental Impact of IoT Fleet Management: Research by Lewis et al. (2022) discusses the environmental benefits of IoT-enabled fleet management in reducing carbon emissions.

Integration of IoT with ERP Systems: A study by Foster & Williams (2023) examines the benefits of integrating IoT-based fleet management with enterprise resource planning (ERP) software.

Fleet Maintenance Prediction using AI: Research by Jones et al. (2022) explores AI-based predictive maintenance models for fleet vehicles.

IoT-Based Load Management for Fleet Trucks: A study by Kumar et al. (2021) evaluates how IoT improves load monitoring and distribution efficiency.

Cloud-Based Fleet Telematics: Research by Anderson et al. (2022) highlights how cloud-based telematics improve fleet tracking and diagnostics.

Future Trends in IoT Fleet Management: A study by Lee et al. (2023) discusses emerging trends, including AI, blockchain, and autonomous fleet management.

## 3. PROPOSED SYSTEM

The IoT-Connected Vehicle Fleet Management System utilizes ESP32-based sensors to enhance transportation fleet monitoring and safety. A vibration sensor detects accidents by identifying abnormal vehicle vibrations. In case of an accident, an immediate alert is transmitted over the IoT network to the fleet owner, ensuring quick response and assistance. A buzzer is also activated to provide an on-site alert.

To improve driver safety, a seatbelt sensor is integrated into the system. If the seatbelt is not worn, the vehicle engine remains disabled, preventing unsafe driving conditions. Additionally, an alert is sent over the IoT platform, and a buzzer sounds to notify the driver and fleet management.

For fuel monitoring, an ultrasonic sensor measures the fuel level in real time. If the fuel tank reaches an empty state, an alert is triggered, notifying the owner of possible refueling needs. Continuous fuel level tracking also enables fuel efficiency analysis and helps detect fuel theft, allowing fleet owners to take proactive measures.

The system further incorporates GPS tracking, enabling real-time vehicle location monitoring. This allows fleet owners to track their vehicles remotely, ensuring better fleet coordination, route optimization, and operational efficiency. In case of an accident, the GPS location is automatically sent to the owner for quick assistance and emergency response.

By integrating IoT, GPS, and sensor-based monitoring, this fleet management solution improves safety, fuel efficiency, and operational transparency for transportation companies, ultimately enhancing fleet productivity and cost-effectiveness as shown in figure 1.

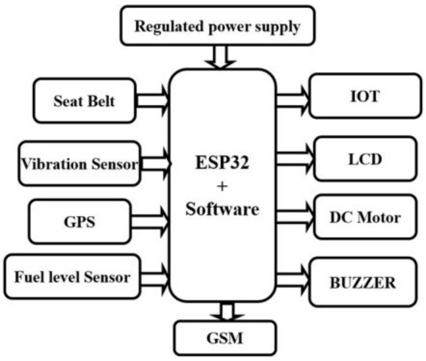


Fig 1: block diagram

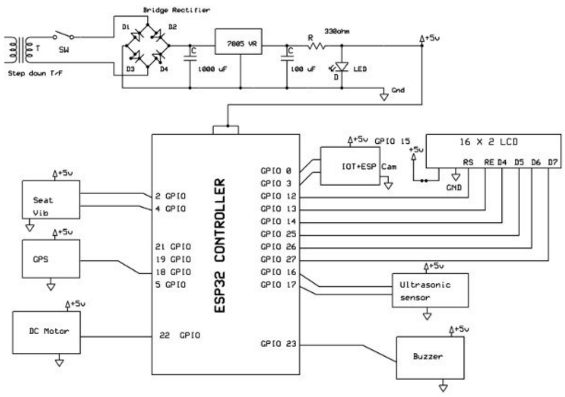


Fig 2: Schematic diagram

These are pin connections as shown in fig 4.2

- IOT is connected to pins 0, 3 of ESP32 microcontroller.
- LCD is connected to pins 12, 13, 14, 25, 26, 27 of ESP32 microcontroller.
- Ultrasonic sensor is connected to pins 16, 17 of ESP32 microcontroller.
- Buzzer is connected to pin 23 of ESP32 microcontroller.
- DC Motor is connected to pin 22 of ESP32 microcontroller.
- GPS is connected to pin 18 of ESP32 microcontroller.
- Seatbelt is connected to pin 2 of ESP32 microcontroller.
- Vibration sensor is connected to pin 4 of ESP32 microcontroller.

## 4. EXPERIMENTAL ANALYSIS

Once the system is powered, the microcontroller initializes all connected modules and displays the title name "Vehicle Fleet Management" as shown in fig 3.

Fig 3: Power on display

The fig 4 indicating that the system is in the process of acquiring satellite data through the GPS module This stage is critical for ensuring that the system can accurately capture GPS data before proceeding with fleet management tasks such as real-time tracking, data logging, and communication via GSM.

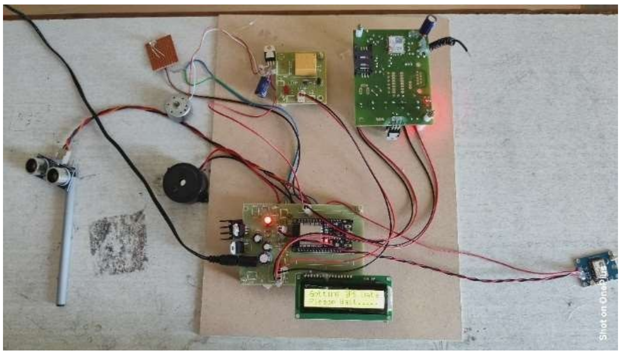


Fig 4: Getting GPS Data

The system is in the messaging phase, indicating that it is ready to send a message to a pre-stored mobile number. This is typically a part of the fleet management system's alert mechanism, where the GSM module is used to send important information as shown in fig 5 such as:

- Vehicle Location: Using GPS data.
- Emergency Alerts: In case of an accident or anomaly.
- System Notifications: Such as maintenance alerts or status updates.

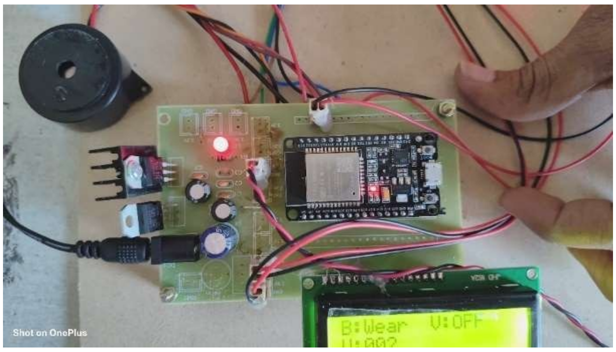


Fig 5: Send MSG Store Mobile Number

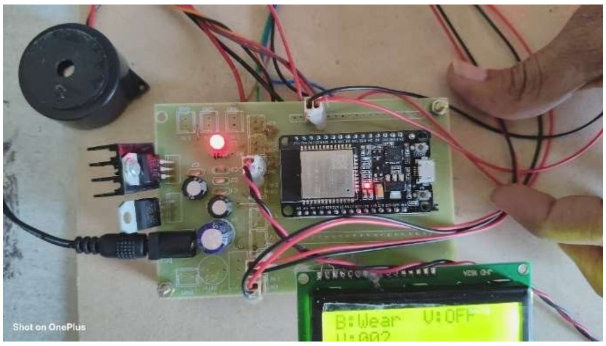


Fig 6: Output

- Seatbelt Monitoring(B): Ensures driver safety by detecting seatbelt status by Wear & Not Wear Commands.
- Vehicle Status Check(V): It correlate with the Vibration sensor, possibly used for collision avoidance by OFF & ON Commands.
- Fuel level Status(U): It uses ultrasonic sensor and calculates distance from sensor and gives command like Low & Normal Fuel Level as shown in fig 6.

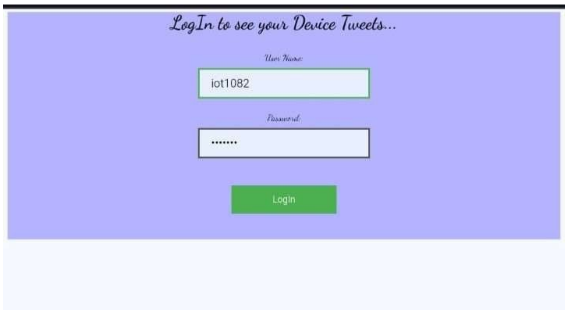


Fig 7: Login to iot server

This images 7 and 8 showcases a web-based IoT server dashboard, displaying real-time data related to the Vehicle Fleet Management System. The dashboard offers detailed insights into seatbelt status, vibration alerts, fuel level, location, and timestamps.


| S.No | Belt | Vib | Level | Location | Date | |
|---|---|---|---|---|---|---|
| 1 | Belt_Wear | ON | U:15_Fuel_Level_Normal | Location | Location | 2025-02-21 11:51:15 |
| 2 | Belt_No_Wear | OFF | U:15_Fuel_Level_Normal | Location | Location | 2025-02-21 11:50:41 |
| 3 | Belt_Wear | OFF | U:37_Fuel_Level_Low | Location | Location | 2025-02-21 11:50:02 |
| 4 | Belt_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-02-21 11:48:33 |
| 5 | Belt_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-02-21 11:46:50 |
| 6 | Belt_No_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-02-21 11:45:42 |
| 7 | Belt_Wear | ON | U:42_Fuel_Level_Low | Location | Location | 2025-02-21 11:44:51 |
| 8 | Belt_Wear | OFF | U:42_Fuel_Level_Low | Location | Location | 2025-02-21 11:44:17 |
| 9 | Belt_No_Wear | OFF | U:6_Fuel_Level_Normal | Location | Location | 2025-01-27 18:46:09 |
| 10 | Belt_Wear | ON | U:16_Fuel_Level_Normal | Location | Location | 2025-01-27 18:45:35 |
| 11 | Belt_Wear | OFF | U:182_Fuel_Level_Low | Location | Location | 2025-01-27 18:44:53 |
| 12 | Belt_Wear | OFF | U:1_Fuel_Level_Normal | Location | Location | 2025-01-27 11:32:41 |
| 13 | Belt_Wear | OFF | U:72_Fuel_Level_Low | Location | Location | 2025-01-27 11:31:28 |
| 14 | Belt_Wear | OFF | U:49_Fuel_Level_Low | Location | Location | 2025-01-27 11:30:43 |
| 15 | Belt_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-01-27 11:29:41 |
| 16 | Belt_Wear | OFF | U:1_Fuel_Level_Normal | Location | Location | 2025-01-27 11:27:53 |
| 17 | Belt_Wear | OFF | U:195_Fuel_Level_Low | Location | Location | 2025-01-27 11:26:32 |
| 18 | Belt_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-01-27 11:13:11 |
| 19 | Belt_Wear | OFF | U:2_Fuel_Level_Normal | Location | Location | 2025-01-27 11:11:28 |
| 20 | Belt_Wear | OFF | U:802_Fuel_Level_Low | Location | Location | 2025-01-27 11:10:37 |

Fig 8: Dashborad of iot server

This image 9 showcases the mobile notifications generated by the Vehicle Fleet Management System, providing real-time alerts on fuel levels, vibration status, seat belt usage, and GPS-based location links.

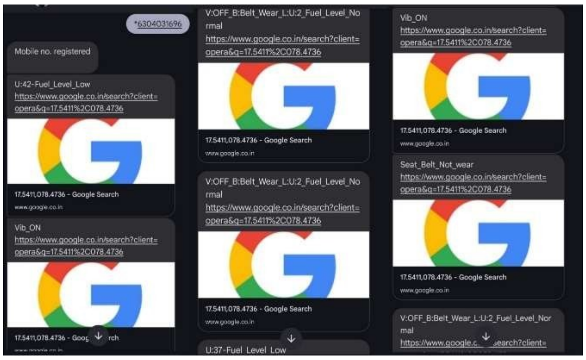


Fig 9: Alerts sent to mobile

## 5 Conclusion

The implementation of an IoT-connected vehicle fleet management system using ESP32-based sensors significantly enhances fleet safety, efficiency, and cost effectiveness. By integrating vibration sensors for accident detection, seatbelt monitoring for driver safety, ultrasonic sensors for fuel level tracking, and GPS for real-time location tracking, fleet owners gain real-time insights and control over their vehicles.

This system not only improves operational transparency but also enables proactive decision-making, reducing risks related to accidents, fuel theft, and inefficient route management. The automated alerts and remote monitoring capabilities ensure quick response times in emergencies, leading to improved safety and compliance with industry standards.

Overall, this IoT-driven solution transforms fleet management by providing a smarter, more reliable, and cost-efficient approach to transportation logistics. It enhances productivity, sustainability, and profitability, making it an essential innovation for modern transportation companies.

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