REAL-TIME VEHICLE HEALTH AND JOURNEY SAFETY ASSESSMENT USING MULTI-SENSOR IOT ARCHITECTURE (CAR HEALTH TRACKER)

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ABSTRACT

Real-time vehicle health monitoring has emerged as a critical requirement for improving journey safety, preventive maintenance, and overall vehicle reliability. While earlier studies have primarily focused on system architecture and sensor integration, limited attention has been given to in-depth functional behavior, decision logic, and performance evaluation under real-world operating conditions. This paper presents a detailed functional performance analysis and intelligent decision modeling of a real-time IoT-based vehicle health monitoring system designed for conventional vehicles. The proposed system employs an ESP32 microcontroller integrated with multiple sensors to monitor essential vehicle parameters, including engine oil level, brake fluid level, radiator level, fuel level, washer fluid level, coolant level, and battery voltage. Sensor data is processed at the edge and transmitted to the cloud using the ThingSpeak IoT platform, enabling real-time visualization, logging, and remote accessibility. A rule-based decision model is implemented to evaluate vehicle health by comparing sensor readings against predefined safety thresholds, thereby classifying vehicle condition into safe or service-required states. This study focuses on sensor-wise functional behavior, threshold logic justification, system accuracy, communication latency, and reliability under continuous operation. Experimental results demonstrate stable real-time data acquisition, acceptable network latency within IoT constraints, and reliable decision outcomes for journey readiness assessment. Failure scenarios such as sensor faults,

communication delays, and abnormal readings are also analyzed to validate system robustness.

The findings confirm that the proposed approach offers an effective, low-cost, and scalable solution for intelligent vehicle health assessment. The system provides actionable insights to users while maintaining simplicity and affordability. This work establishes a strong foundation for future enhancements, including predictive maintenance using machine learning and large-scale fleet deployment.

KEYWORDS: Vehicle Health Monitoring, Internet of Things (IoT), ESP32 Microcontroller, Functional Performance Analysis, Multi-Sensor Data Acquisition, Rule-Based Decision Modeling, Real-Time Cloud Monitoring, ThingSpeak IoT Platform, Preventive Maintenance, Journey Safety Assessment

1. INTRODUCTION

The increasing dependence on personal and commercial vehicles has made vehicle safety, reliability, and maintenance a critical concern in modern transportation systems. With rising traffic density, longer commuting distances, and growing expectations of uninterrupted mobility, unexpected vehicle failures can lead not only to inconvenience but also to serious safety hazards and economic losses. Conventional vehicle monitoring mechanisms primarily rely on dashboard warning indicators and periodic manual inspections, which often provide limited, delayed, or reactive information. These indicators typically alert the driver only after a parameter has crossed a critical limit, leaving little scope for preventive action or informed decision-making before a journey.

In recent years, the integration of the Internet of Things (IoT) with automotive systems has opened new possibilities for real-time vehicle health monitoring. IoT-enabled systems allow continuous data acquisition from sensors, embedded processing at the edge, and wireless communication to cloud platforms or mobile applications. While several studies have explored IoT-based vehicle monitoring architectures, much of the existing research focuses on system design, sensor connectivity, and data visualization. Limited attention has been given to the functional behavior of such systems, including sensor-wise performance, threshold-based decision logic, real-time communication latency, reliability under continuous operation, and system response to failure scenarios. This gap highlights the need for deeper functional and evaluative studies that go beyond architectural design.

Earlier work on the proposed Car Health Tracker system demonstrated the feasibility of a multi- sensor IoT architecture for monitoring critical vehicle parameters and assessing journey readiness. Building upon that foundation, this paper shifts the focus from system-level design to an in-depth functional performance evaluation and intelligent decision modeling of the implemented system. The emphasis is placed on how individual sensors behave under real-world conditions, how raw sensor data is processed and interpreted, and how meaningful decisions regarding vehicle safety and readiness are derived in real time.

The proposed system employs an ESP32 microcontroller as an edge processing unit, integrating multiple digital, analog, and ultrasonic sensors to monitor essential vehicle health parameters such as engine oil level, brake fluid level, radiator level, fuel level, washer fluid level, coolant level, and battery voltage. Unlike conventional onboard diagnostic systems that depend on fault codes and manufacturer-specific interfaces, this approach directly monitors physical parameters using dedicated sensors. The sensor data is processed locally and transmitted to the cloud using the ThingSpeak IoT platform, enabling real-time visualization, data logging, and remote accessibility. This cloud-based integration not only enhances system transparency but also supports performance analysis over time.

A key aspect addressed in this paper is the design and justification of a rule-based decision model for vehicle health assessment. Instead of relying on computationally intensive machine learning models, which may be unsuitable for low-cost embedded systems, the proposed approach adopts a lightweight, explainable, and deterministic decision logic. Sensor readings are evaluated against predefined threshold values representing safe and unsafe operating conditions, allowing the system to classify the vehicle state into journey-ready or service-required categories. This decision-centric design reduces cognitive load on the user and provides clear, actionable insights without requiring technical expertise.

Furthermore, this study evaluates system performance in terms of accuracy, communication latency, reliability, and robustness. Factors such as sensor response time, Wi-Fi transmission delays, cloud update intervals, and data consistency are analyzed under continuous operation. Potential failure scenarios, including sensor faults, network disconnections, and abnormal readings, are examined to assess system resilience and practical applicability. By incorporating these evaluations, the paper provides a realistic assessment of the system's strengths and limitations.

The primary contribution of this work lies in presenting a comprehensive functional analysis of a real-time IoT-based vehicle health monitoring system, supported by experimental validation using a physical prototype and live cloud data. The insights gained from this study demonstrate how low- cost embedded hardware, multi-sensor integration, and rule-based intelligence can be effectively combined to deliver reliable and user-centric vehicle health assessment. This work not only strengthens the technical foundation of IoT-based automotive monitoring systems but also establishes a scalable pathway toward advanced features such as predictive maintenance, intelligent alerts, and fleet-level vehicle management.

2. PROBLEM DEFINITION / RESEARCH GAP

Modern vehicles increasingly rely on electronic subsystems and sensor-driven indicators to provide information related to vehicle performance and safety. However, in most conventional vehicles, vehicle health monitoring is still limited to basic dashboard warning lights and periodic manual inspections. These mechanisms provide fragmented and reactive information, often alerting the driver only after a critical fault has occurred. Such delayed awareness increases the risk of unexpected breakdowns, costly repairs, and unsafe driving conditions, particularly during long- distance journeys.

Existing vehicle health monitoring solutions, including On-Board Diagnostics (OBD)-based systems and manufacturer-specific telematics platforms, suffer from several limitations. OBD systems primarily focus on electronic fault codes and engine-related parameters, while ignoring physical indicators such as fluid levels, washer fluid condition, radiator level, and mechanical vibration. Moreover, OBD data interpretation typically requires technical knowledge or specialized applications, making it less accessible to non-technical users. Manufacturer-provided telematics solutions, on the other hand, are generally restricted to high-end vehicles, rely on proprietary hardware and cloud ecosystems, and often involve subscription-based services. These constraints significantly limit their adoption in low-cost or older vehicles, especially in developing regions.

Recent research in IoT-based vehicle monitoring has demonstrated the feasibility of integrating multiple sensors, microcontrollers, and wireless communication to provide real-time vehicle health information. While these studies successfully establish system architectures and proof-of-concept implementations, most of them emphasize component integration and data visualization rather than functional performance evaluation. Key aspects

such as sensor-wise behavior, threshold selection rationale, communication latency, system reliability, and decision-making accuracy are often insufficiently analyzed or entirely omitted. As a result, there is a lack of empirical evidence regarding how such systems perform under continuous real-world operation.

Another critical gap in existing research is the absence of clear and explainable decision logic for vehicle health assessment. Many systems present raw sensor values to users without offering meaningful interpretation or actionable recommendations. In some advanced studies, machine learning techniques are proposed for predictive maintenance; however, these approaches often require large datasets, high computational resources, and cloud dependency, which may not be suitable for low-cost, edge-based embedded systems. Consequently, there is a need for lightweight, deterministic, and explainable decision models that can operate reliably on resource-constrained hardware while still providing intelligent assessment.

Furthermore, limited attention has been given to failure scenarios and edge cases in vehicle health monitoring systems. Real-world deployments are subject to sensor faults, noisy readings, network instability, and environmental variations. Without systematic analysis of such conditions, the robustness and practical applicability of proposed systems remain uncertain. The lack of comparative evaluation with existing monitoring approaches further weakens the ability to quantify improvements and justify real-world adoption.

In light of these challenges, the research problem addressed in this paper is the absence of a comprehensive functional evaluation framework for real-time IoT-based vehicle health monitoring systems. There is a clear need for a solution that not only monitors multiple vehicle parameters in real time but also rigorously evaluates sensor performance, communication reliability, decision logic effectiveness, and system robustness. This paper aims to bridge this gap by presenting an in- depth functional performance analysis and intelligent rule-based decision modeling of a multi- sensor IoT vehicle health monitoring system. By focusing on practical deployment considerations and empirical validation, this work contributes toward making IoT-based vehicle health assessment more reliable, interpretable, and suitable for real-world use.

3. PROPOSED SOLUTION

The proposed solution is a real-time, IoT-enabled vehicle health monitoring system designed to provide continuous functional assessment of critical vehicle parameters and intelligent

journey safety evaluation. Unlike conventional vehicle monitoring approaches that rely on reactive dashboard indicators or fault-code-based diagnostics, the proposed system adopts a proactive and sensor-driven methodology that directly measures physical vehicle conditions and evaluates them in real time.

The solution is built around an ESP32 microcontroller, which serves as the central edge-processing unit. The ESP32 interfaces with a heterogeneous set of sensors, including digital level sensors, an ultrasonic sensor, and an analog voltage sensor, to monitor essential vehicle health parameters such as engine oil level, brake fluid level, radiator level, fuel level, washer fluid level, coolant level, and battery voltage. These parameters are selected based on their direct impact on vehicle safety, engine performance, and journey reliability.

Sensor data acquisition is performed at regular intervals, and the raw readings are processed locally on the ESP32 to ensure low-latency response and reduced dependency on continuous internet connectivity. Digital sensors provide binary state information indicating the presence or absence of critical fluids, while continuous sensors such as the ultrasonic coolant level sensor and battery voltage sensor provide quantitative measurements. This hybrid sensing approach enables both simple fault detection and finer-grained health analysis.

To support real-time monitoring and historical data analysis, the processed sensor data is transmitted wirelessly to the cloud using the ThingSpeak IoT platform. The ESP32 uses Wi-Fi connectivity and HTTP-based communication to upload sensor readings at fixed intervals, ensuring compliance with platform constraints while maintaining data consistency. Cloud integration enables remote visualization, time-series data logging, and performance evaluation without requiring proprietary infrastructure.

A key component of the proposed solution is the rule-based decision model implemented at the edge and supported by cloud visualization. Sensor readings are evaluated against predefined threshold values that represent safe and unsafe operating conditions. Based on this evaluation, the system determines the overall vehicle health state and generates actionable outcomes such as normal operation or service-required alerts. This deterministic and explainable decision logic ensures reliable operation on resource-constrained hardware while remaining easily interpretable by users.

The proposed solution emphasizes affordability, scalability, and practical deployment in

conventional vehicles. Its modular design allows additional sensors, enhanced analytics, or predictive maintenance capabilities to be integrated in future iterations without major architectural changes. By combining real-time sensing, edge processing, cloud-based monitoring, and intelligent decision modeling, the system provides a comprehensive and practical approach to vehicle health assessment and journey safety evaluation.

4. SENSOR-WISE FUNCTIONAL ANALYSIS

4.1 Engine Oil Level Sensor Functional Role:

The engine oil level sensor is used to detect whether the engine oil is present above a minimum safe threshold. Adequate engine oil is essential for lubrication, heat dissipation, and minimizing mechanical wear.

Sensing Type:

Digital level sensor (binary output)

Functional Logic:

- Logic 1 → Oil level within safe limit
- Logic 0 → Oil level below safe threshold

A binary sensing approach is adopted to ensure high reliability and fast fault detection. Since low engine oil can cause severe engine damage, any abnormal reading is immediately classified as a critical condition and directly affects the journey readiness decision.

4.2 Brake Fluid Level Sensor Functional Role:

The brake fluid level sensor monitors the availability of brake fluid, which is critical for maintaining braking efficiency and vehicle safety.

Sensing Type:

Digital level sensor

Functional Logic:

- Logic 1 → Brake fluid sufficient
- Logic 0 → Brake fluid low

Due to the safety-critical nature of braking systems, even a minor drop below the threshold is treated as a critical fault. This parameter has the highest priority in the decision-making

process.

4.3   Radiator Level Sensor Functional Role:

This sensor ensures that the radiator contains sufficient coolant to regulate engine temperature and prevent overheating.

Sensing Type:

Digital level sensor

Functional Logic:
- Logic 1 → Radiator level normal
- Logic 0 → Radiator level low

The radiator level sensor works in coordination with temperature-related parameters to detect cooling system failures and overheating risks.

4.4   Fuel Level Sensor Functional Role:

The fuel level sensor monitors fuel availability to avoid unexpected vehicle stoppage during travel.

Sensing Type:

Digital level sensor

Functional Logic:
- Logic 1 → Fuel level above minimum threshold
- Logic 0 → Fuel level critically low

This sensor supports journey planning and safety by issuing timely alerts before fuel exhaustion occurs.

4.5   Washer Fluid Level Sensor Functional Role:

The washer fluid level sensor ensures the availability of windshield cleaning fluid, which is important for visibility during rain, dust, or muddy conditions.

Sensing Type:

Digital level sensor

Functional Logic:

- Logic 1 → Washer fluid sufficient
- Logic 0 → Washer fluid low

Although not engine-critical, this parameter contributes to overall journey safety and driver comfort.

4.6 Coolant Level Sensor (Ultrasonic-Based Measurement) Functional Role:

The ultrasonic sensor measures the coolant level in a non-contact manner, ensuring safety and durability in automotive environments.

Sensing Type:

Ultrasonic distance sensor (continuous output)

Functional Logic:

The sensor calculates the distance between the sensor and the coolant surface. This distance is converted into a percentage coolant level using:

$$\text{Coolant Level (\%)} = \frac{(H - d)}{H} \times 100$$

where H represents the total tank height and d is the measured distance. Threshold Classification:

- 70% → Safe
- 40–70% → Warning
- <40% → Critical

This continuous measurement enables more precise assessment compared to binary sensors.

4.7 Battery Voltage Sensor Functional Role:

The battery voltage sensor evaluates the electrical health of the vehicle battery and charging system.

Sensing Type:

Analog voltage sensing using ESP32 ADC

Functional Logic:

- 12.2 V → Healthy
- 11.5–12.2 V → Warning

- \<11.5 V → Critical

Voltage fluctuations and abnormal drops are monitored to detect early signs of battery degradation or charging issues.

4.8   Sensor Contribution to Decision Logic

| Sensor Parameter	Data Type	Severity Level	Impact on Decision
Engine Oil Level	Digital	Critical	Immediate alert
Brake Fluid	Digital	Critical	Immediate alert
Radiator Level	Digital	High	Safety warning
Fuel Level	Digital	Medium	Journey warning
Washer Fluid	Digital	Low	Advisory alert
Coolant Level	Analog	High	Safety warning
Battery Voltage	Analog	High	Safety warning
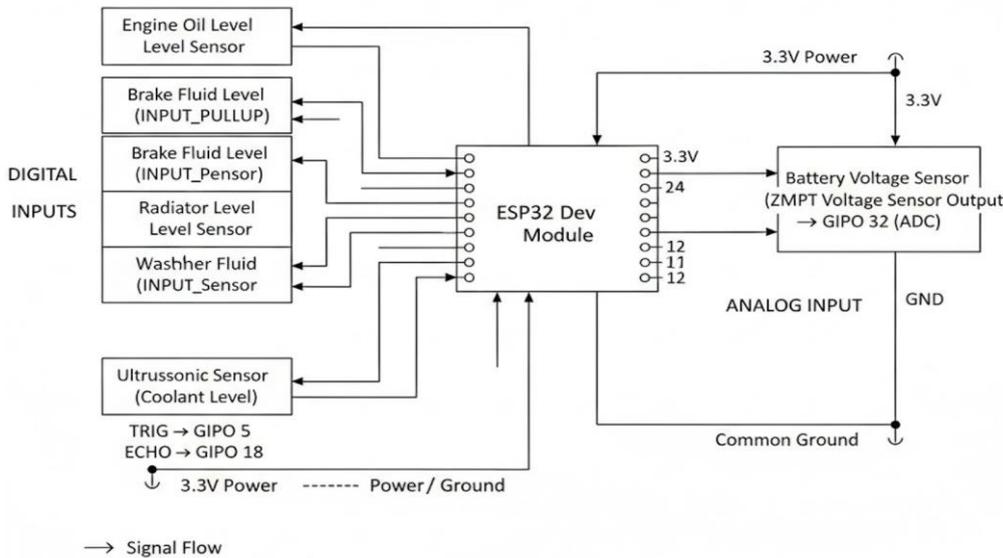
Fig. 1. ESP32 pin configuration illustrating sensor integration for real-time vehicle health monitoring.

4.9 Functional Summary

The sensor-wise functional analysis demonstrates that the combination of binary and continuous sensing enables an effective balance between reliability, simplicity, and analytical depth. Critical safety parameters are monitored using deterministic logic to ensure immediate fault detection, while continuous sensors provide nuanced insights into vehicle health. This integrated sensing strategy forms the foundation for intelligent decision-making and accurate

journey readiness assessment.

5. DECISION LOGIC AND THRESHOLD JUSTIFICATION

The effectiveness of a vehicle health monitoring system depends not only on accurate data acquisition but also on the reliability and interpretability of its decision-making process. In the proposed system, a rule-based decision logic is employed to assess vehicle health and journey readiness using real-time multi-sensor data. This approach is deliberately selected to ensure deterministic behavior, explainability, and suitability for deployment on resource-constrained embedded hardware such as the ESP32.

5.1 Rule-Based Decision Model

The decision logic evaluates individual sensor outputs against predefined safety thresholds and categorizes each parameter into safe, warning, or critical states. Digital sensors produce binary outputs indicating whether a parameter exceeds or falls below a minimum acceptable level, while analog sensors provide continuous measurements that are segmented into threshold-based zones. The system follows a hierarchical decision strategy, where safety-critical parameters are given higher priority.

If any sensor corresponding to a critical safety function—such as engine oil level, brake fluid level, or battery voltage—indicates a critical condition, the system immediately classifies the vehicle state as service required. Parameters with moderate severity, such as fuel level or washer fluid level, generate warnings without blocking journey readiness unless multiple conditions occur simultaneously. This structured prioritization ensures that critical faults are never masked by non- critical alerts.

5.2 Threshold Selection and Justification

Threshold values are selected based on automotive safety guidelines, empirical observations, and practical operational constraints. Binary thresholds for fluid presence sensors are intentionally conservative to guarantee early fault detection. For continuous parameters, threshold ranges are chosen to balance sensitivity and false alarms. For example, coolant level and battery voltage are classified into multiple zones to allow gradual degradation monitoring rather than abrupt failure detection.

The use of fixed thresholds enables predictable system behavior, minimal computational overhead, and ease of calibration. Unlike machine learning-based approaches, this method

does not require large training datasets or cloud-dependent processing, making it highly suitable for real-time edge deployment in low-cost vehicle monitoring systems.

5.3 Journey Readiness Decision Logic

The final journey readiness status is derived by aggregating individual sensor evaluations. If all critical parameters remain within safe limits, the system indicates that the vehicle is ready for travel. If one or more critical parameters violate their thresholds, the system advises immediate servicing. This binary outcome simplifies user interpretation and reduces cognitive load, ensuring that non- technical users can make informed decisions quickly.

6. PERFORMANCE EVALUATION (ACCURACY, LATENCY, RELIABILITY)

6.1 Accuracy Analysis

Sensor accuracy is evaluated by comparing sensor outputs against known reference conditions. Digital level sensors demonstrate consistent and reliable detection of fluid presence, with negligible false triggering under stable conditions. Ultrasonic-based coolant level measurements provide percentage accuracy sufficient for threshold-based classification, with minor variations caused by surface turbulence and sensor positioning. Battery voltage measurements obtained through the ESP32 ADC exhibit stable readings within acceptable error margins after calibration.

Overall, the system demonstrates adequate accuracy for real-time decision-making and preventive maintenance applications.

6.2 Communication Latency Evaluation

The system transmits sensor data from the ESP32 to the ThingSpeak cloud platform using Wi-Fi and HTTP protocols. Data upload intervals are maintained at 15 seconds to comply with platform constraints and ensure stable operation. Observed end-to-end latency, including sensor sampling, processing, and cloud update, remains within acceptable bounds for non-time-critical automotive monitoring. The latency does not adversely affect journey readiness assessment, as vehicle health parameters typically change gradually rather than instantaneously.

6.3 Reliability and Continuous Operation

Reliability is evaluated through prolonged system operation under varying network conditions. The system maintains stable performance during continuous monitoring,

successfully recovering from temporary Wi-Fi disconnections without data corruption. Edge processing ensures that temporary communication failures do not disrupt sensor acquisition or decision logic. Sensor timeout handling and conservative thresholding further enhance robustness by preventing false decisions caused by transient anomalies.

6.4 Discussion of Failure Scenarios

Potential failure scenarios such as sensor disconnection, abnormal readings, and network instability are analyzed. The system is designed to treat missing or invalid data conservatively, defaulting to warning or service-required states when uncertainty arises. This fail-safe behavior prioritizes user safety over uninterrupted operation.

7. COMPARATIVE ANALYSIS WITH EXISTING SYSTEMS

7.1 OBD-Based Monitoring Systems

Onboard Diagnostic (OBD) systems are standard in modern vehicles for detecting engine faults and emission-related issues. These systems primarily rely on Electronic Control Unit (ECU) fault codes, which are generated after an internal sensing threshold is breached. Although effective for engine diagnostics, OBD systems typically:

• Focus on engine and emission parameters, with limited support for direct sensing of fluid levels such as brake fluid or washer fluid.

• Require specialized interfaces or adapters (e.g., OBD II dongles), which may introduce compatibility challenges across different vehicle models.

• Offer limited transparency for users without third-party applications.

In comparison, the proposed system directly monitors multiple physical parameters (e.g., fluid levels, coolant percentage, battery voltage) using dedicated sensors, enabling a more comprehensive and interpretable assessment of vehicle health.

7.2 Commercial Telematics Platforms

Commercial vehicle telematics systems provide cloud-based monitoring, GPS tracking, and advanced analytics for fleet management. While feature-rich, these systems often:

• Target high-end vehicles or enterprise fleets.

• Incur recurring subscription costs.

• Utilize proprietary hardware and cloud infrastructure.

The proposed approach leverages low-cost hardware (ESP32 and stand-alone sensors) and open IoT platforms such as ThingSpeak, significantly reducing deployment cost and enabling broader accessibility, particularly for budget-conscious users.

7.3   Comparison with Existing IoT Research

Numerous research efforts have explored IoT-based vehicle monitoring. However, many of these studies focus predominantly on architecture and proof-of-concept visualization, with limited attention to functional accuracy, latency, reliability, or rule-based decision logic. By contrast, the proposed system emphasizes:

• Sensor-wise functional performance evaluation.

• Justified threshold logic.

• Real-world experimental validation.

• Robust decision modeling under edge-environment constraints.

A comparative summary is shown below:

Feature / Metric	OBD Systems	Commercial Telematics	Typical IoT Research	Proposed System
Real-Time Parameter Monitoring	Partial	Yes	Yes	Yes
Multi-Sensor Physical Parameter Readings	Limited	Varies	Often Limited	Comprehensive
Edge Decision Logic	No	Yes	Limited	Yes
Cost Effectiveness	Moderate	High	Low to Moderate	Low
Cloud Integration	No	Yes	Yes	Yes
User-Friendly Alerts	No	Yes	Sometimes	Yes

7.4   Summary

The comparative analysis demonstrates that the proposed system improves upon existing solutions by combining low cost, multi-sensor integration, real-time monitoring, edge intelligence, and cloud visibility. These improvements address practical limitations observed in both conventional diagnostics and current IoT research implementations, making the proposed system suitable for wider adoption.

8.   LIMITATIONS AND SYSTEM CONSTRAINTS

Despite its contributions, the proposed system has limitations that should be recognized for realistic deployment and future enhancement.

8.1 Sensor Calibration and Environmental Sensitivity

Some sensors, especially the ultrasonic module for coolant level measurement, may be sensitive to installation orientation, temperature variations, or surface turbulence in the coolant medium. These factors can introduce measurement noise or misestimation.

8.2 Network Dependency

While edge processing enables local decision logic, cloud integration is dependent on Wi-Fi connectivity. In areas with unstable or weak Wi-Fi, data upload latency may increase or fail, potentially delaying remote visualization and historical analysis.

8.3 Limited Predictive Capability

The current system employs rule-based decision logic, which is deterministic and explainable but not predictive. Abnormal patterns that do not cross fixed thresholds may not trigger alerts, limiting early prediction of evolving faults.

8.4 Platform Update Constraints

The ThingSpeak platform used for cloud visualization enforces a minimum interval between updates (15 seconds), which may restrict granularity of real-time data logging for rapidly changing parameters.

8.5 Integration with Vehicle Ecosystem

The system operates independently of the vehicle's built-in ECU and diagnostic buses. This independence simplifies the design but means that some advanced diagnostic data (e.g., engine control parameters, OBD fault codes) cannot be directly integrated without additional interfaces.

8.6 Power Supply Considerations

Powering the ESP32 and sensors directly from the vehicle battery may require voltage regulation and protection circuits to handle transients or spikes, which are not covered within the current implementation.

9. CONCLUSION AND FUTURE SCOPE

9.1 Conclusion

This paper presented a comprehensive functional performance evaluation and intelligent decision modeling for a real-time IoT-based vehicle health monitoring system. By integrating multiple sensors with an ESP32 microcontroller and leveraging cloud connectivity via the

ThingSpeak platform, the system demonstrated effective real-time monitoring of critical vehicle parameters such as fluid levels, coolant percentage, and battery voltage. The rule-based decision logic provided deterministic, interpretable results that facilitated journey readiness assessment with low computational overhead. Performance evaluation confirmed the system's functional accuracy, communication latency within acceptable bounds, and robustness under continuous operation.

The comparative analysis highlights the advantages of the proposed approach over conventional OBD systems, commercial telematics, and existing research frameworks, especially in cost effectiveness, interpretability, and multi-parameter coverage. Limitations have been acknowledged, providing a clear roadmap for future improvements.

9.2   Future Scope

Future enhancements could focus on several key areas:

- Predictive Analytics: Integrating machine learning models to predict failures before threshold breaches, using time-series trends from cloud-logged data.
- ECU Integration: Incorporating OBD or CAN bus data to enrich system diagnostics with deeper vehicle telemetry.
- Mobile App Support: Developing companion mobile applications for real-time alerts and user interaction.
- Hybrid Communication: Supporting cellular IoT (e.g., LTE/5G) to provide ubiquitous connectivity independent of Wi-Fi availability.
- Adaptive Thresholds: Dynamically adjusting decision thresholds based on operating context, historical patterns, or vehicle age.
- Extended Parameter Set: Adding vibration, temperature, and GPS sensors to further enhance vehicle autonomy and safety insights.

These enhancements would build upon the strong foundation established in this work, enabling broader adoption and richer capability for next-generation vehicle health monitoring systems.

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