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Predictive Vehicle Maintenance Scheduling And Gis-Integrated Service Recommendation System Using A Machine Learning Approach

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Abstract

Vehicle maintenance plays a vital role in ensuring vehicle reliability, operational efficiency, and road safety. Conventional maintenance practices often rely on fixed schedules, manual inspections, or reactive approaches, which may lead to delayed issue detection, unexpected breakdowns, and increased maintenance costs. To address these challenges, this study developed a Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System Using a Machine Learning Approach. The study aimed to design and develop a mobile-based intelligent vehicle maintenance system capable of real-time vehicle monitoring, anomaly detection, GIS-based repair shop recommendations, and automated maintenance notifications. The study employed a project-based developmental research design guided by the Design and Creation Model and utilized the Iterative Prototyping Model for system development. Real-time vehicle diagnostic data, including engine RPM, coolant temperature, battery voltage, fuel level, engine load, vehicle speed, and GPS coordinates, were collected through an OBD-II Bluetooth device connected to an Android mobile application. The gathered diagnostic data were processed and analyzed using the Isolation Forest machine learning algorithm to detect anomalous vehicle conditions and generate predictive maintenance alerts and recommendations. Geographic Information System (GIS) technology was integrated to identify and recommend nearby repair shops, while email and SMS services were utilized to provide automated notifications to users. The developed system was evaluated by fifty (50) private vehicle owners in Misamis Occidental using selected ISO/IEC 25010 software quality characteristics, namely Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, and Security. Evaluation results revealed an overall weighted mean of 4.48, interpreted as Very Satisfactory, indicating a high level of user acceptance. The findings indicated that the developed system is functional, reliable, secure, and highly acceptable for predictive vehicle maintenance monitoring and GIS-integrated service recommendations. The study demonstrates the potential of integrating machine learning, OBD-II diagnostics, and GIS technologies to support proactive vehicle maintenance, improve maintenance decision-making, enhance vehicle reliability, and promote road safety.

Keywords: *anomaly detection, GIS, machine learning, OBD-II, predictive maintenance, vehicle monitoring.*

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1. Introduction

Vehicle maintenance is essential for ensuring road safety, vehicle reliability, operational efficiency, and extended service life. However, many vehicle owners still rely on fixed maintenance schedules, personal judgment, or visual inspections to determine when maintenance is required. Such practices may result in delayed servicing, unexpected breakdowns, increased repair costs, and safety risks. Although modern vehicles generate valuable diagnostic information, many owners lack access to intelligent systems that can continuously monitor vehicle conditions and provide timely maintenance recommendations.

Recent advances in machine learning have enabled predictive maintenance by identifying abnormal patterns and potential failures before they occur. This approach supports proactive maintenance strategies that reduce downtime, minimize repair costs, and improve reliability (Carvalho et al., 2019; Çınar et al., 2020). Likewise, the On-Board Diagnostics II (OBD-II) standard provides access to real-time vehicle data such as engine RPM, coolant temperature, engine load, battery voltage, vehicle speed, fuel status, and diagnostic trouble codes. Studies have shown that integrating OBD-II data with machine learning techniques improves vehicle health monitoring and supports early fault detection (Massaro et al., 2020; Michailidis et al., 2025). In addition, Geographic Information System (GIS) technology has become increasingly important in transportation and location-based services. GIS enables users to identify nearby facilities and supports location-aware recommendations that improve accessibility and decision-making (Zaroujtaghi et al., 2025).

Previous studies indicate that predictive maintenance provides significant advantages over traditional preventive maintenance by utilizing vehicle condition data to identify potential failures before they occur. Research has shown that machine learning algorithms can analyze vehicle sensor data to improve maintenance planning, reduce downtime, and enhance vehicle reliability (Jain et al., 2022; Raj & Sharma, 2024; Johnson et al., 2024). Furthermore, the integration of OBD-II technology and IoT-based monitoring enables continuous collection of vehicle diagnostic information and supports predictive maintenance and fault detection (Çınar et al., 2020; Michailidis et al., 2025; Massaro et al., 2020). GIS technologies have likewise been applied in transportation and spatial decision-support systems to provide location-based recommendations and improve service accessibility (Zaroujtaghi et al., 2025).

Despite these advancements, many existing vehicle maintenance applications primarily focus on diagnostics, maintenance logging, mileage tracking, or scheduled reminders. Current systems often lack the integration of machine learning-based predictive maintenance, GIS-enabled repair shop recommendations, and automated notification mechanisms within a single platform (Shetty et al., 2023). Existing vehicle maintenance systems generally rely on preventive schedules, manual monitoring, and reactive diagnostics, which may lead to delayed maintenance interventions and unexpected vehicle failures. Consequently, vehicle owners often have limited support in identifying potential maintenance concerns and locating appropriate service centers promptly.

To address these limitations, this study developed a Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System using a machine learning approach. The system integrates OBD-II vehicle diagnostics, machine learning-based anomaly detection, GIS-enabled repair shop recommendations, and automated email and SMS notification services within a unified mobile platform. Specifically, the study aimed to: (1) collect and compile relevant vehicle and diagnostic data; (2) design and develop a mobile-based application for vehicle monitoring and maintenance management; (3) integrate a GIS-based service recommendation feature capable of identifying nearby repair shops; (4) incorporate a machine learning-based predictive maintenance component for anomaly detection; (5) implement automated email and SMS notification services; and (6) evaluate the developed system in terms of Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, and Security based on ISO/IEC 25010:2011 standards.

Materials and Methods

- Research Design

This study employed a project-based developmental research design guided by the Design and Creation Model. The Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System was developed using the Iterative Prototyping Model, which facilitated continuous refinement through planning, design, implementation, testing, and evaluation phases.

- Participants

The study involved fifty (50) purposively selected private vehicle owners from Misamis Occidental. The participants owned gasoline- and diesel-powered vehicles equipped with standard OBD-II interfaces and had experience in routine vehicle operation and maintenance activities. They served as evaluators of the developed Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System and assessed its Functional Suitability, Performance Efficiency, Usability, Reliability, Compatibility, and Security based on ISO/IEC 25010:2011 software quality standards.

- Instruments

Data were collected using a researcher-made questionnaire based on selected ISO/IEC 25010:2011 software quality characteristics, namely Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, and Security. The instrument underwent face and content validation by information technology experts. A pilot test involving twenty (20) vehicle owners was conducted to assess reliability using Cronbach’s Alpha. Feedback from the pilot test was used to refine the questionnaire before its administration to the fifty (50) actual respondents. Additional data sources included OBD-II diagnostic readings, maintenance records, system-generated logs, and GIS location data.

Online ISSN: 3082-5121
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https://journals.aloysianpublications.com
Volume 2 Issue 6 (2026)

- Procedure

The study commenced with requirements gathering through interviews, surveys, consultations, and observations involving vehicle owners and automotive service providers. The system was then designed, developed, and tested. Real-time vehicle diagnostic data were collected using an OBD-II Bluetooth adapter and analyzed through the Isolation Forest machine learning algorithm for anomaly detection. GIS functionality was integrated to identify nearby repair shops using GPS coordinates and the Haversine Formula. Following prototype testing, respondents evaluated the developed system using the validated questionnaire.

- Data Analysis

Quantitative data collected through the ISO/IEC 25010:2011 evaluation questionnaire were analyzed using weighted mean and standard deviation to determine the respondents' assessment of the developed system. The interpretation of the evaluation scores was based on a 5-point Likert scale. Reliability of the survey instrument was assessed using Cronbach's Alpha to determine its internal consistency. The computed weighted means and standard deviations were used to evaluate the system in terms of Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, and Security based on the ISO/IEC 25010:2011 software quality model.

2. Results

The Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System was successfully developed and implemented as a mobile-based platform that integrates OBD-II vehicle diagnostics, machine learning-based predictive maintenance analysis, GIS-enabled repair shop recommendations, and automated notification services. The system allows vehicle owners to monitor vehicle conditions, receive maintenance alerts, and locate nearby repair facilities based on their geographic location.

Figure 1.

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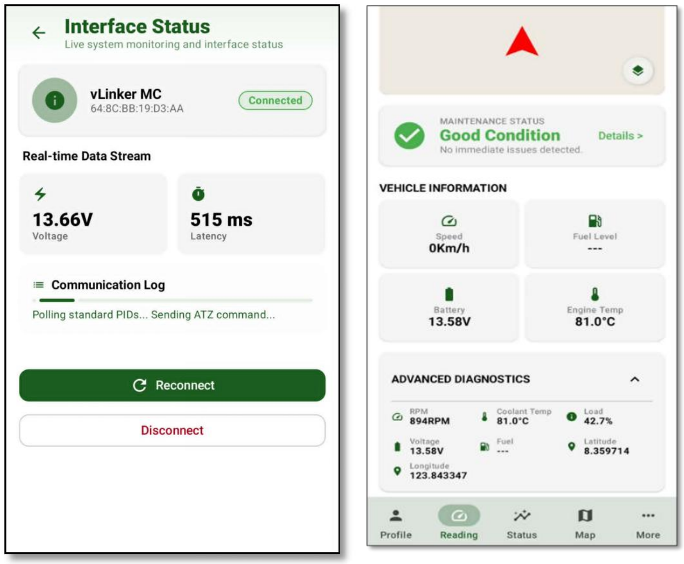
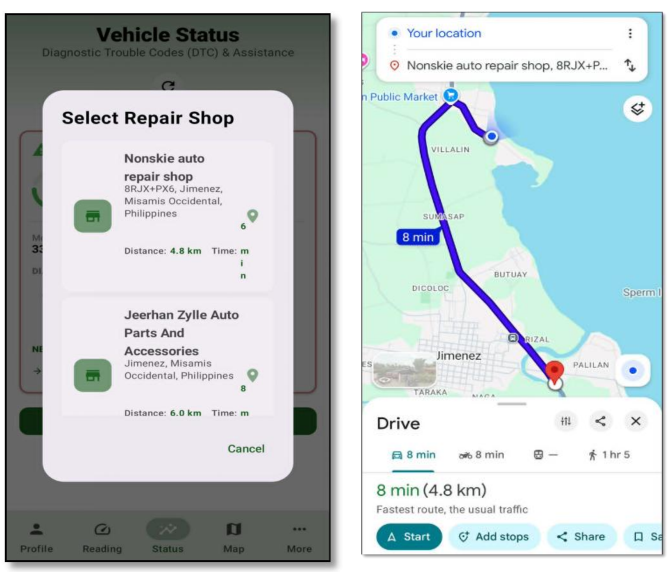
Volume 2 Issue 6 (2026)



This interface shows the Real-Time Vehicle Monitoring feature of the system. Through the OBD-II Bluetooth adapter, the application collects real-time vehicle data such as RPM, coolant temperature, battery voltage, fuel level, engine load, vehicle speed, and GPS coordinates. These data are displayed to the user and simultaneously transmitted to the backend server for analysis using the Isolation Forest algorithm. Based on the analysis, the system determines the vehicle's maintenance condition and generates predictive maintenance alerts when abnormalities are detected.

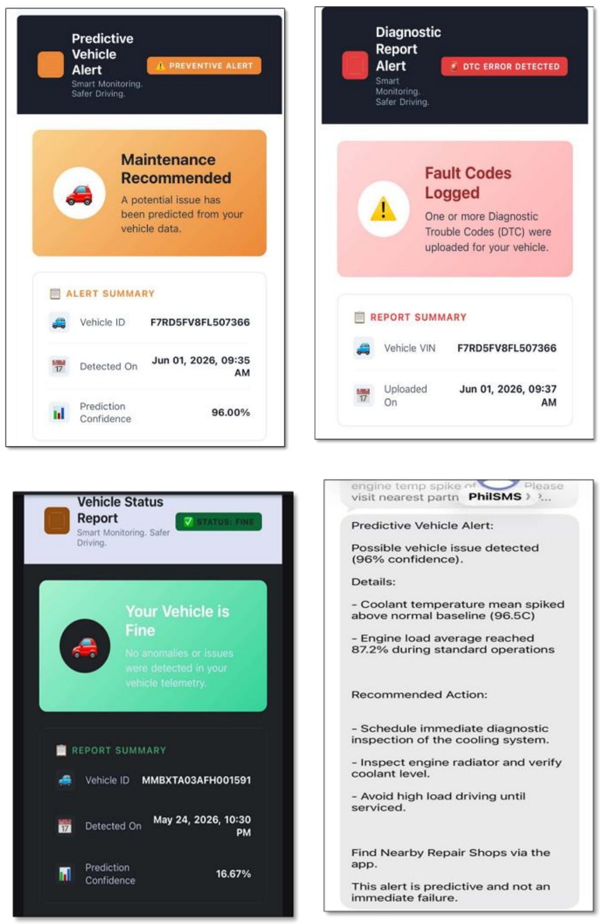
Figure 2.



Online ISSN: 3082-5121
https://journals.aloysianpublications.com
Volume 2 Issue 6 (2026)

This interface shows the GIS-Based Service Recommendation feature. When a maintenance issue or anomaly is detected, the system uses the user's GPS location and the Haversine Formula to identify the nearest repair shops. The user can view available service centers, their distances, and select a preferred shop. The system then displays the route, travel distance, and estimated travel time using MapLibre and Mapbox mapping services. This helps users quickly locate nearby repair facilities whenever maintenance is needed.

Figure 3.



This interface shows the Automated Notification feature of the system. When the machine learning model detects an anomaly or when a diagnostic trouble code is identified, the system automatically generates maintenance alerts and sends notifications through the mobile application, email, and SMS. If no issues are detected, the system can also send a normal vehicle status report. These notifications provide users with real-time information, recommended maintenance actions, and nearby repair shop suggestions, supporting proactive vehicle maintenance.

Online ISSN: 3082-5121
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System Evaluation

To evaluate the quality and acceptability of the developed system, fifty (50) vehicle owners participated in the user evaluation using selected ISO/IEC 25010:2011 software quality characteristics, namely Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, and Security.

Table 1. Overall System Evaluation Results

Characteristic	Mean	Standard Deviation	Interpretation
Functional Suitability	4.55	0.671	Very Satisfactory
Performance Efficiency	4.30	0.721	Very Satisfactory
Compatibility	4.34	0.664	Very Satisfactory
Usability	4.47	0.573	Very Satisfactory
Reliability	4.61	0.571	Excellent
Security	4.65	0.543	Excellent
Overall Weighted Mean	**4.48**	**0.623**	**Very Satisfactory**

The results indicate that the developed system achieved an overall weighted mean of 4.48, interpreted as Very Satisfactory, demonstrating a high level of user acceptance and system quality. Among the evaluated characteristics, Security obtained the highest weighted mean score (M = 4.65), followed by Reliability (M = 4.61), indicating that respondents perceived the system as secure, dependable, and capable of protecting user and vehicle information. Conversely, Performance Efficiency obtained the lowest weighted mean score (M = 4.30), although it remained within the Very Satisfactory range.

Functional Suitability obtained a weighted mean of 4.55 (SD = 0.671), indicating that the system effectively performs its intended predictive maintenance and GIS-based recommendation functions. Performance Efficiency achieved a weighted mean of 4.30 (SD = 0.721), suggesting that the system provides acceptable response time and processing performance. Compatibility and Usability obtained weighted means of 4.34 (SD = 0.664) and 4.47 (SD = 0.573), respectively, reflecting positive user perceptions regarding system integration and ease of use. Reliability obtained a weighted mean of 4.61 (SD = 0.571), while Security achieved the highest weighted mean of 4.65 (SD = 0.543), both interpreted as Excellent. These findings suggest that the developed system consistently performs its intended functions and effectively safeguards user accounts, vehicle records, and maintenance information.

Online ISSN: 3082-5121
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https://journals.aloysianpublications.com
Volume 2 Issue 6 (2026)

3. Discussion

Interpretation of Findings

The findings indicate that the Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System successfully achieved its intended objectives. The overall evaluation result of 4.48 (Very Satisfactory) demonstrates a high level of user acceptance and indicates that the system effectively supports vehicle maintenance monitoring and decision-making. Security obtained the highest evaluation score (M = 4.65), followed by Reliability (M = 4.61), suggesting that respondents perceived the system as secure, dependable, and capable of protecting sensitive vehicle and user information.

The results further suggest that the integration of machine learning-based anomaly detection, real-time OBD-II diagnostics, GIS-enabled repair shop recommendations, and automated notification services provides a practical approach to proactive vehicle maintenance. By identifying potential maintenance concerns and delivering timely recommendations, the system may assist vehicle owners in addressing vehicle issues before they develop into major mechanical failures.

Comparison to Existing Studies

The findings support previous studies that emphasized the effectiveness of machine learning in predictive maintenance applications. Carvalho et al. (2019), Jain et al. (2022), and Çınar et al. (2020) reported that machine learning techniques improve maintenance planning through early fault detection and predictive analysis. Similarly, the developed system utilized machine learning-based anomaly detection to identify potential maintenance concerns and generate preventive maintenance alerts.

The results also support the findings of Shetty et al. (2023) and Michailidis et al. (2025), who highlighted the value of OBD-II-based vehicle monitoring systems in improving vehicle diagnostics and maintenance management. Furthermore, the integration of GIS functionalities aligns with the studies of Solanki and Dhall (2017), Li and Zeng (2022), and Zaroujtaghi et al. (2025), which emphasized the effectiveness of location-based technologies in improving accessibility and service recommendations. Unlike many existing systems that focus primarily on diagnostics or maintenance tracking, the developed system integrates predictive maintenance, GIS-based recommendations, and automated notifications within a single mobile platform.

Implications for Practice and Policy

The study demonstrates the practical application of machine learning, OBD-II diagnostics, and GIS technologies in vehicle maintenance management. The developed system may assist vehicle owners in adopting a proactive approach to maintenance through continuous monitoring, predictive alerts, and location-based service recommendations. Such capabilities may reduce unexpected vehicle breakdowns, improve maintenance efficiency, and enhance road safety.

Online ISSN: 3082-5121
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From an industry perspective, automotive repair shops and maintenance service providers may benefit from improved customer accessibility through GIS-enabled recommendations and automated maintenance notifications. The findings also provide a foundation for future intelligent transportation and predictive maintenance solutions that support data-driven maintenance decision-making.

Study Limitations

This study was limited to gasoline- and diesel-powered vehicles equipped with standard OBD-II interfaces and excluded heavy-duty, hybrid, and electric vehicles. The developed prototype was deployed, tested, and evaluated only on Android devices. The machine learning component utilized the Isolation Forest algorithm and relied on the availability, quality, and completeness of OBD-II diagnostic data. The GIS-based recommendation feature depended on GPS accuracy, internet connectivity, and geographic location data. Furthermore, the system was evaluated by fifty (50) vehicle owners from Misamis Occidental and was limited to prototype development and academic evaluation rather than large-scale real-world implementation.

4. Conclusion

The study successfully developed and evaluated a Predictive Vehicle Maintenance Scheduling and GIS-Integrated Service Recommendation System using a machine learning approach. The system integrated OBD-II vehicle diagnostics, machine learning-based anomaly detection, GIS-enabled repair shop recommendations, and automated notification services within a unified mobile platform for vehicle maintenance monitoring.

Evaluation results revealed an overall weighted mean of 4.48, interpreted as Very Satisfactory, indicating a high level of user acceptance. The findings demonstrate that the developed system is functional, reliable, secure, and acceptable for predictive vehicle maintenance monitoring and GIS-integrated service recommendation. The integration of machine learning, OBD-II diagnostics, and GIS technologies provides a practical approach to supporting proactive vehicle maintenance, improving maintenance decision-making, and reducing the likelihood of unexpected vehicle failures.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com
Volume 2 Issue 6 (2026)

Recommendation

Future studies may enhance the machine learning component by utilizing larger and more diverse vehicle diagnostic datasets to improve anomaly detection accuracy and maintenance forecasting reliability. Researchers may also explore the use of advanced machine learning and deep learning algorithms to compare predictive performance and improve maintenance prediction capabilities.

Future system development may include support for additional vehicle categories such as motorcycles, heavy-duty vehicles, hybrid vehicles, and electric vehicles. The integration of cloud-based technologies and Internet of Things (IoT) functionalities may further improve real-time monitoring, data synchronization, and system scalability.

The GIS-based recommendation feature may be enhanced by incorporating repair shop ratings, service costs, waiting times, customer reviews, and service availability to provide more intelligent and personalized recommendations. Additional security and privacy mechanisms may also be implemented to strengthen the protection of vehicle diagnostic data, user information, and location-based services.

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