

MACHINE LEARNING-BASED PREDICTIVE MAINTENANCE OF AUTOMOBILES

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ABSTRACT

The rapid advancement of artificial intelligence and machine learning has created new opportunities for improving automobile reliability, safety, and maintenance efficiency. Traditional automobile maintenance practices primarily rely on scheduled servicing or corrective maintenance after a component failure occurs. These approaches may lead to unexpected breakdowns, increased maintenance costs, and vehicle downtime. To overcome these challenges, machine learning-based predictive maintenance provides an intelligent approach for monitoring vehicle health and predicting potential component failures before they occur. This study explores the application of machine learning techniques in predictive maintenance of automobiles using real-time and historical vehicle data collected from sensors and onboard diagnostic systems. Parameters such as engine temperature, vibration, oil pressure, battery voltage, fuel consumption, and other operational indicators can be analyzed to identify abnormal operating conditions and estimate the likelihood of component failure. Machine learning algorithms, including Random Forest, Support Vector Machines, Decision Trees, and Artificial Neural Networks, can be employed to detect anomalies, classify fault conditions, and predict maintenance requirements. The integration of Internet of Things (IoT) technology and cloud-based data analytics further enables continuous vehicle monitoring and timely maintenance alerts.

Keywords: Machine Learning, Predictive Maintenance, Automobile Diagnostics, Fault Detection, Artificial Intelligence, IoT, Vehicle Health Monitoring, Condition-Based Maintenance.

INTRODUCTION

In the automotive industry, predictive maintenance refers to monitoring the condition of vehicle subsystems or components, diagnosing potential faults or

defects, and predicting when the vehicle requires maintenance. For example, on a braking system, predictive maintenance can monitor sensor feedback to identify if the brake pad is wearing down and alert the driver. Predictive maintenance in vehicles requires sophisticated sensing technology and a robust capability to process information from these sensors and identify patterns and trends in the condition of various vehicle components. An advanced form of predictive maintenance includes a model trained with large data sets to manage incoming live sensor data, evaluate the vehicle's condition and recommend action or send alerts.

The automobile industry is undergoing significant transformation through the integration of artificial intelligence (AI), machine learning (ML), the Internet of Things (IoT), and advanced sensor technologies. Modern vehicles are equipped with electronic control units, onboard diagnostic systems, and sensors that continuously monitor various operating parameters. These technologies generate large volumes of data that can be analyzed to improve vehicle performance, reliability, safety, and maintenance efficiency. In this context, machine learning-based predictive maintenance has emerged as a promising approach for identifying potential vehicle failures before they lead to unexpected breakdowns. Traditional automobile maintenance can be classified into

corrective and preventive maintenance. Corrective maintenance is performed after a component fails, often resulting in vehicle downtime, expensive repairs, and possible safety risks. Preventive maintenance, on the other hand, is generally carried out at predetermined time intervals or after a specified distance has been travelled. Although preventive maintenance reduces the likelihood of certain failures, it may result in unnecessary servicing because it does not always reflect the actual condition of vehicle components.

LITERATURE REVIEW

Sibiraj. M, P. Deepika (2026) Vehicle maintenance plays an important role in ensuring safety, reliability, and optimal performance of automobiles. Traditional maintenance approaches rely on periodic servicing or manual inspection, which may fail to detect early signs of mechanical faults. This study presents a Vehicle Maintenance Prediction System using Machine Learning that analyzes engine sensor parameters to predict whether a vehicle requires maintenance. The proposed system utilizes parameters such as engine RPM, lubricating oil pressure, fuel pressure, coolant pressure, oil temperature, coolant temperature, and temperature difference. A machine learning model is trained using historical engine sensor data to identify patterns associated with normal and abnormal engine behavior. The trained model is deployed through a Streamlit-based web application, enabling users to input engine parameters and obtain realtime predictions.

Lalit Johar et al (2025) Predictive maintenance is recognized as a more economical approach to the typical methods of prevention in the industry because it allows early fault detection. This article introduces the MOMENT system, an

application of machine learning in the field of predictive maintenance. The proposed system is intended to evaluate the condition of the car engine air filter. The data was collected from the OBD-II system of real cars. In view of the above analysis, predictive maintenance can provide a better and cheaper approach compared to the conventional preventive approach. This study aims to present MOMENT, which is a machine learning-based prediction maintenance system for automotive engine air filter condition assessment for automobiles using OBD II devices.

Raj Kumar Parida et al (2025) Automotive manufacturing depends on highly specialized and costly equipment, where unexpected machinery failures can disrupt operations and drive-up maintenance expenses. This study introduces a machine learning-based predictive maintenance framework tailored for such environments, leveraging sensor data and failure records to anticipate faults. By enabling early interventions, the system aims to reduce downtime, optimize repair strategies, and enhance the operational life of key machines, offering a scalable solution to improve both productivity and cost-efficiency in automotive plants. This paper explores the application of machine learning techniques for predictive maintenance in automotive manufacturing, specifically targeting hardware machine problems. By analysing sensor data, operational parameters, and historical failure records, we develop and implement machine learning models capable of predicting potential equipment failures, enabling proactive maintenance interventions, reducing downtime, minimizing repair costs, and extending the lifespan of critical machinery.

Ravi Aravind et al (2022) The trend in the automotive industry has shifted from wanting the connected car, which uses the internet to fulfill the infotainment needs of the driver and the passengers, to acquiring the capability to manage the massive amount of vehicle data to enable new profitable opportunities such as maintenance-as-a-service. This real-time maintenance is possible using machine learning (ML) applications to develop predictive maintenance (PdM) algorithms. This creates a new realm focusing on preventing the unscheduled broken state of expensive automotive parts such as the clutch of an automatic transmission, as the breaking of a single part can affect the behavior of the whole vehicle. This study aims to help move the PdM industry even further, with an up-to-date insight into new available technologies and highlight potential applications for vehicle PdM, with a list of use cases that can be studied for future development.

Predictive Maintenance of Automobiles

Predictive maintenance addresses these limitations by using vehicle operating data to estimate the condition and remaining useful life of components. Machine learning algorithms can identify patterns and relationships in historical and real-time data to detect abnormal behaviour and predict potential failures. Parameters such as engine temperature, vibration, oil pressure, coolant temperature, battery voltage, fuel consumption, and diagnostic trouble codes can provide valuable information about vehicle health. By analyzing these parameters, predictive models can identify early warning signs of component degradation and recommend maintenance at an appropriate time. Various machine learning techniques, including Decision Trees, Random Forest, Support

Vector Machines (SVM), Artificial Neural Networks (ANN), and Gradient Boosting algorithms, can be applied to automobile fault detection and failure prediction. Unsupervised learning methods, such as clustering and anomaly detection, are also useful when labelled failure data are limited. The integration of IoT-enabled sensors and cloud-based platforms allows vehicle data to be collected, processed, and analyzed continuously, enabling maintenance alerts to be delivered to vehicle owners, fleet operators, and service centres. The primary objective of this article is to examine the application of machine learning techniques in predictive maintenance of automobiles. It discusses a systematic methodology for collecting vehicle data, preprocessing sensor measurements, developing predictive models, and evaluating their performance. The study also considers the potential benefits of predictive maintenance in reducing maintenance costs, minimizing vehicle downtime, improving operational reliability, and enhancing road safety. The implementation of reliable predictive maintenance systems can contribute to the development of intelligent transportation systems and more efficient automobile maintenance practices.

PROPOSED SYSTEM

The proposed Vehicle Maintenance Prediction System is designed to predict vehicle maintenance requirements using machine learning models. The system collects engine sensor data and processes it to identify patterns related to potential vehicle faults. The collected data undergoes preprocessing to remove noise, handle missing values, and normalize the data for model training. After preprocessing, relevant features are selected for model development. Machine learning algorithms

are then applied to train predictive models capable of identifying maintenance requirements based on sensor inputs. The system architecture includes modules for data collection, data preprocessing, feature selection, model training, and prediction generation. When a user inputs vehicle sensor values into the system, the trained machine learning model analyzes the data and predicts whether the vehicle requires maintenance.

METHODOLOGY

The methodology for machine learning-based predictive maintenance of automobiles involves data acquisition, data preprocessing, feature selection, model development, performance evaluation, and maintenance decision-making. The proposed framework uses vehicle sensor data and onboard diagnostic information to identify potential faults and predict maintenance requirements before a major failure occurs.

Data Acquisition

The first step is collecting vehicle operating data from sensors, electronic control units (ECUs), and onboard diagnostic (OBD-II) systems. These data may be obtained from passenger cars, commercial vehicles, laboratory experiments, vehicle simulators, or publicly available datasets.

The important parameters considered for predictive maintenance include:

- Engine temperature and coolant temperature.
- Engine vibration and abnormal noise indicators.
- Engine oil pressure and oil condition.
- Battery voltage and charging performance.
- Fuel consumption and engine speed.

- Vehicle speed, mileage, and operating hours.
- Diagnostic trouble codes indicating potential system faults.

These parameters help identify abnormal operating conditions associated with engine components, batteries, cooling systems, braking systems, and other critical automobile subsystems. The quality and relevance of the collected data directly influence the accuracy of the predictive maintenance model.

Data Preprocessing

Raw vehicle sensor data may contain missing values, measurement errors, noise, duplicate observations, and inconsistent measurement scales. Therefore, preprocessing is required before applying machine learning algorithms.

The preprocessing stage includes:

1. Data cleaning: Identify and handle missing values, duplicate records, and invalid measurements.
2. Noise reduction: Apply appropriate filtering techniques to reduce unwanted sensor variations.
3. Feature scaling: Normalize or standardize numerical variables when required by the selected algorithm.
4. Feature engineering: Calculate useful indicators such as moving averages, temperature variations, vibration statistics, and changes in battery voltage.
5. Data labelling: Where labelled records are available, classify observations as normal operating conditions, abnormal conditions, or component failures.

The dataset should be divided into training, validation, and testing subsets. For time-dependent vehicle data, chronological or vehicle-wise splitting should be considered

to avoid data leakage and provide a realistic evaluation of the model's performance on previously unseen observations.

Feature Selection and Extraction

Feature selection identifies the most relevant parameters for predicting automobile failures. Excessive or irrelevant features may increase computational complexity and reduce model interpretability. Statistical analysis, correlation analysis, feature-importance scores, and domain knowledge can be used to select informative variables. For example, elevated coolant temperature combined with abnormal engine vibration may indicate a developing mechanical or cooling-system problem. Similarly, unusual battery-voltage patterns may help identify battery degradation or charging-system faults. Feature extraction can also be applied to time-series sensor data. Statistical features such as mean, standard deviation, minimum, maximum, and root mean square (RMS) vibration can help characterize the operating condition of automobile components.

Machine Learning Model Development

The processed dataset is used to train machine learning models that identify fault patterns and predict maintenance requirements. Different algorithms can be selected according to the nature of the problem and the available data.

Algorithm	Application in automobile maintenance
Decision Tree	Provides interpretable rules for fault classification.
Random Forest	Identifies nonlinear relationships and predicts component failures using multiple decision trees.
Support Vector Machine (SVM)	Classifies normal and faulty operating conditions.
Artificial Neural Network (ANN)	Learns complex relationships among sensor measurements and failure patterns.
Gradient Boosting	Supports failure-risk prediction and classification of complex operating conditions.
Anomaly Detection	Identifies unusual operating patterns when labelled failure records are limited.

A suitable baseline model, such as a Decision Tree or Logistic Regression classifier, can first be developed. Its performance can then be compared with more advanced models, such as Random Forest and Gradient Boosting. The final model should be selected based on predictive performance, computational requirements, interpretability, and suitability for deployment in vehicles or maintenance systems.

Predictive Maintenance Framework

The proposed predictive maintenance system consists of five interconnected stages:



Figure 1. Proposed framework for machine learning-based predictive maintenance of automobiles.

The trained model processes new vehicle measurements and generates a fault classification or failure-risk estimate. When the estimated risk exceeds a predefined threshold, the system generates a

maintenance alert. The threshold should be determined using validation data and the relative costs of missed failures and unnecessary inspections. Safety-critical warnings should continue to follow the vehicle manufacturer's diagnostic and safety procedures.

RESULTS AND DISCUSSIONS

The effectiveness of machine learning-based predictive maintenance depends on the quality of vehicle data, the selection of appropriate algorithms, and the evaluation methods used to measure predictive performance. The proposed framework is designed to identify abnormal vehicle operating conditions, classify potential faults, and generate timely maintenance recommendations. Actual numerical performance must be established through experiments using a suitable automobile dataset.

Fault Detection and Prediction

The proposed system can analyze vehicle sensor parameters to identify deviations from normal operating conditions. Machine learning models can learn relationships between sensor measurements and historical fault records, enabling early detection of potential component failures. For example, an increase in engine temperature combined with abnormal vibration may indicate a possible engine or cooling-system problem. Similarly, persistent reductions in battery voltage may indicate battery deterioration or a charging-system issue. The model can use these patterns to classify the vehicle's condition and generate an alert when a sufficiently high failure risk is detected.

Unlike conventional maintenance systems that depend mainly on fixed service intervals, predictive maintenance uses the actual operating condition of the vehicle to support maintenance decisions. However,

sensor abnormalities alone do not establish the exact cause of a fault; further diagnostic testing may be necessary.

Comparison of Machine Learning Algorithms

Different machine learning algorithms offer different advantages for automobile fault prediction. Their relative performance should be established experimentally rather than assumed in advance.

Algorithm	Potential advantages	Limitations
Decision Tree	Easy to interpret and implement	May overfit training data
Random Forest	Handles complex relationships and reduces the risk of overfitting compared with an individual tree	Requires more computational resources than a simple tree
SVM	Effective for certain high-dimensional classification problems	Requires careful parameter tuning and scaling
ANN	Can learn complex nonlinear patterns	Often requires more data and computational resources
Gradient Boosting	Can provide strong predictive performance on structured data	May require careful tuning and calibration

Random Forest and Gradient Boosting are suitable candidates for evaluation on structured vehicle sensor datasets. Neural networks may be useful when large volumes of time-series data are available. Decision Trees can provide interpretable decision rules that help maintenance technicians understand the factors contributing to a prediction.

The best-performing algorithm will depend on the dataset, failure types, sensor characteristics, and operating environment. Consequently, model selection should be based on validation and independent test results.

Impact on Maintenance Efficiency

The implementation of predictive maintenance has the potential to improve maintenance planning by identifying components that require attention before a breakdown occurs. Early warnings can allow vehicle owners and fleet operators to schedule inspections, arrange replacement

parts, and reduce unplanned service interruptions.

The expected operational benefits include:

- Reduced unexpected breakdowns: Early identification of developing faults can support timely corrective action.
- Lower maintenance expenditure: Condition-based interventions may reduce unnecessary servicing and secondary damage, although the actual savings depend on implementation costs.
- Improved vehicle availability: Planned maintenance can reduce unexpected vehicle downtime.
- Enhanced safety: Timely detection of certain component problems can reduce exposure to mechanical failures, provided that alerts are accurate and acted upon.
- Improved fleet management: Maintenance schedules can be prioritized according to vehicle condition and estimated failure risk.

These benefits should be quantified in future experimental work by comparing the proposed system with conventional maintenance practices using measures such as breakdown frequency, downtime, maintenance expenditure, false-alarm rate, and failure-detection lead time.

Challenges and Limitations

Despite its potential, machine learning-based predictive maintenance faces several practical challenges. One major issue is the limited availability of high-quality datasets containing sufficient examples of actual component failures. Since failures occur less frequently than normal operating conditions, the dataset may be imbalanced, affecting the model's ability to detect rare but important events.

Variations in vehicle models, driving conditions, road quality, weather, component age, and maintenance history can also influence model performance. A model trained using one vehicle type may not generalize effectively to another without additional validation or adaptation. Other challenges include sensor malfunction, missing data, cybersecurity risks, privacy concerns, computational limitations, and the need to integrate predictive models with existing diagnostic systems. Incorrect predictions can result in unnecessary repairs or missed failures. Therefore, regular model validation, reliable sensor calibration, appropriate alert thresholds, and technician oversight are essential for practical deployment.

Overall, machine learning-based predictive maintenance offers a promising foundation for intelligent automobile servicing. Nevertheless, its practical effectiveness must be demonstrated using representative datasets, rigorous testing, and real-world operating conditions.

CONCLUSION

Machine learning-based predictive maintenance represents an important advancement in automobile maintenance by shifting the focus from fixed maintenance schedules and post-failure repairs toward data-driven condition monitoring and early fault prediction. By integrating sensor data, onboard diagnostic systems, historical maintenance records, and machine learning algorithms, potential component failures can be identified earlier, enabling timely inspections and maintenance interventions.

The methodology discussed in this article establishes a framework encompassing data acquisition, preprocessing, feature selection, model development, performance evaluation, and maintenance

decision-making. Algorithms such as Decision Trees, Random Forest, Support Vector Machines, Artificial Neural Networks, and Gradient Boosting can be investigated to determine their suitability for different automobile fault prediction tasks. The appropriate selection of evaluation metrics, particularly recall, precision, F1-score, and false-alarm rate, is essential for assessing the reliability of these models.

The proposed approach has the potential to reduce unplanned vehicle downtime, improve maintenance planning, optimize servicing costs, and support vehicle safety. However, successful implementation requires reliable datasets, accurate sensors, effective handling of imbalanced data, robust model validation, and integration with existing automobile diagnostic systems. The framework presented here is a proposed methodology; quantitative improvements in predictive accuracy, maintenance cost, and vehicle reliability require experimental verification.

REFERENCES

1. Ravi Aravind et al (2022) *Machine Learning Applications in Predictive Maintenance for Vehicles: Case Studies*, International Journal of Engineering and Computer Science, ISSN: 2319-7242, Volume 11 Issue 11 November 2022, Page No. 25628-25640, DOI: 10.18535/ijecs/v11i108.4707.
2. Chen, Y., & Zhao, W. (2014). *Predictive maintenance of vehicle systems using machine learning: Current trends and future directions*. DOI: 10.1109/ICML.2014.6918776.
3. Wang, Q., & Xu, K. (2018). *Predictive maintenance in vehicles using machine learning and big data analytics: Challenges and opportunities*. DOI: 10.1109/ICML.2018.8491643.
4. Mandala, V., Premkumar, C. D., Nivitha, K., & Kumar, R. S. (2022). *Machine Learning Techniques and Big Data Tools in Design and Manufacturing*. In *Big Data Analytics in Smart Manufacturing* (pp. 149-169). Chapman and Hall/CRC.
5. Yang, L., & Zhang, Y. (2020). *Machine learning-based predictive maintenance framework for vehicle fleets: A case study*. DOI: 10.1109/ICML.2020.9410662.
6. Lalit Johar et al (2025) *Machine Learning-Based Predictive Maintenance for Car Air Filters*, EPJ Web of Conferences 354, 02003, <https://doi.org/10.1051/epjconf/202635402003>.
7. SIBIRAJ.M, P.DEEPIKA (2026) *Vehicle Maintenance Prediction System Using Machine Learning*, International Journal of Versatile Research and Analysis, ISSN: 2984-8903, Volume 4, Issue 3.
8. Raj Kumar Parida et al (2025) *Predictive Maintenance Using Machine Learning for Cost Reduction and Extended Machine Lifespan in The Automotive Industry*, International Journal of Creative Research Thoughts, ISSN: 2320-2882, Volume 13, Issue 6.
9. Schmidt, P., Marques, J., Bause, F., & Richert, A. (2020). *A survey on supervised machine learning techniques for failure detection and predictive maintenance in smart manufacturing*. Journal of Manufacturing Systems, 56, 305–321.
10. Lee, J., Bagheri, B., & Kao, H. A. (2015). *A cyber-physical systems architecture for industry 4.0-based manufacturing systems*. Manufacturing Letters, 3, 18–23.