Artificial Intelligence Based Predictive Maintenance for Two-Wheeler Automobiles

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Publication Date: 2025/04/03

Abstract: A wide variety of applications have been made possible by recent advancements in maintenance modeling that have been driven by data-based methodologies like machine learning (ML). Minimizing maintenance costs while guaranteeing functional safety over a product's lifetime has emerged as a formidable obstacle for the automobile industry. In order to do this, predictive maintenance (PdM) is an essential strategy. The vast amounts of operational data produced by current cars make ML a prime contender for PdM. Despite the abundance of literature on both PdM and ML in automotive systems, no comprehensive study has yet been published on ML-based PdM. There is a growing demand for this kind of study due to the rising quantity of articles in this sector. As a result, we evaluate the articles from both an application and ML standpoint after surveying and classifying them. After that, we will go over some open difficulties and potential areas for further study. We draw the following conclusions: (a) more research would be conducted with publicly available data; (b) most papers use supervised methods, which need labelled data; (c) combining data from multiple sources can improve accuracy; and (d) deep learning methods will continue to grow in popularity, but only if large amounts of labelled data are made available and efficient methods developed.

Keywords: *Predictive Maintenance (PdM), Machine Learning (ML) Artificial Intelligence (AI),Automotive Systems, Data-Driven Maintenance, Supervised Learning, Deep Learning.*

How to Cite: Vedita Vitthal Jepulkar; Dr. Narendra Chaudhari; Dr. Sushma Telrande (2025) Artificial Intelligence Based Predictive Maintenance for Two-Wheeler Automobiles. *International Journal of Innovative Science and Research Technology*, 10(3), 1905-1910. https://doi.org/10.38124/ijisrt/25mar1358

I. INTRODUCTION

The automobile industry is only one of several that has been profoundly affected by the fast development of artificial intelligence (AI). The use of AI in Predictive Maintenance is a game-changer in the automotive industry. It helps identify problems early on, which means less downtime and more efficiency for drivers. Unanticipated breakdowns, higher repair costs, and safety issues are common outcomes of reactive maintenance and periodic service, the two mainstays of traditional maintenance systems[1][2]. Conversely, AI-based predictive maintenance keeps an eye on a vehicle's vitals in real time and may foresee when they could fail by using ML, DL, and Internet of Things (IoT) sensors. Motorbikes, scooters, and other two-wheeled vehicles are common modes of mobility in both urban and rural regions. Nevertheless, their performance and safety are compromised by wear and tear caused by regular use and exposure to different road conditions. By evaluating sensor data, rider behavior, engine performance, and environmental conditions to anticipate component failures, AI-driven predictive maintenance has the potential to completely transform two-wheeler service. Reduced breakdowns, optimized maintenance schedules, and longer vehicle lifespans are all benefits of this method.Machine learning models, data collecting via the Internet of Things (IoT), cloud computing, and edge analytics are some of the important technologies covered in this article as it investigates the use of AI-based predictive maintenance for two-wheelers.

The paper goes on to discuss the pros, cons, and potential future applications of AI in two-wheeler vehicles, with the goal of improving their dependability, efficiency, and reducing associated costs.

Predictive quality, including safety analytics, warranty analytics, and plant facilities monitoring, as well as predictive maintenance (PdM), are all examples of manufacturing and mobility solutions that are increasingly relying on data-driven methodologies like machine learning (ML) [1, 2]. Methods for analyzing, forecasting, or predicting issues caused by performance deficiencies that may have negative impacts on safety are being developed. These approaches are referred to by various names, including E-maintenance, Prognostics and Health Management (PHM), Maintenance 4.0, and Smart Maintenance. In this context, ML-based techniques have become more important due to the data flood and the rise of the industrial internet of things. These approaches have elevated conventional maintenance modeling methods to new heights.

As the car evolves into a more intricate system, machine learning (ML) has been instrumental in transforming the automobile industry, which is a leading example of how ML has transformed an industrial sector [3][4][5]. In light of recent advancements in autonomous driving and changes to the drive-train, there is a growing need for practical, cost-effective solutions to guarantee the functional safety and durability of cars throughout their lifespan. Research is increasingly focused on ML-based PdM of safety- and cost-relevant components as a potential solution to the high system complexity and data-richness of cars[6].

There is a lack of a current study on the expanding subject of ML-based predictive maintenance (PdM) for automotive systems, even though several review publications have addressed both predictive maintenance (PdM) and machine learning (ML) respectively. But the need of such a study is being further driven home by the growing body of literature in this area. We mostly provide two things: We start by collecting and organizing articles on ML-based PdM for automotive systems. We next analyze these papers from several angles, including use cases and machine learning. Secondly, we want to spark new research ideas by identifying outstanding difficulties and discussing potential research pathways that may advance the subject. Predictive maintenance of automotive systems is our major emphasis in that setting, since it pertains to maintenance that occurs during usage rather than during production[7].

With this work, we want to provide a general introduction to ML-enabled PdM for use in automobiles. Along with academics and students, there are three groups of people who are interested in machine learning:(1) maintenance specialists who have traditionally used classical methods and are curious about the benefits of data-driven approaches;(2) ML professionals who are interested in important use cases, like the ones that maintenance offers to the automotive industry; and(3) automotive engineers who are interested in using machine learning to improve the safety and reliability of automotive systems[8][9].

The main contributions of this paper are:

First, we provide an overview of the areas of machine learning that are crucial to predictive maintenance. With the hope of fostering productive partnerships, this will open up the realm of ML-based PdM research to specialists in maintenance and machine learning.

From both a use case and a machine learning standpoint, we thoroughly review and classify articles pertaining to ML-based PdM for automotive systems.

Our main contribution is a list of unanswered questions and potential future study avenues in the subject. Readers may find this useful for recognizing unanswered research problems.

The automobile sector as a whole stands to gain a great deal from predictive maintenance. Manufacturers, fleet operators, and vehicle owners all benefit from this preventative method since it finds problems before they cause costly downtime. Maximizing the lifetime of vehicle components is achieved by predictive maintenance, which provides real-time alerts and early warnings.

Predictive maintenance is useful for car dealerships because it improves customer satisfaction by lowering the likelihood of breakdowns and facilitating proactive engagement with vehicle owners.

While lowering the number of product recalls and warranty claims, predictive maintenance may increase income for original equipment manufacturers (OEMs) from aftermarket sales and original replacement parts.

Reduced maintenance expenses, increased fleet availability and efficiency, enhanced vehicle security, fewer warranty claims, improved vehicle lifetime, and remote fleet monitoring are all general advantages. Everything from the engine to the gearbox to the exhaust to the vehicle's structural integrity may be fine-tuned for peak performance. Industrial equipment health may be monitored in real-time via predictive maintenance, which allows for the prediction of possible problems. In order to streamline their operations and improve the customer experience, some car manufacturers have previously used predictive maintenance technologies. Listed below are a few instances of such solutions:

Original Equipment Manufacturers (OEMs) and dealers may save money and time using Intuceo's predictive maintenance solutions, which use data from in-vehicle sensors and machine learning algorithms.

Using sensors and the Industrial Internet of Things (IoT), digital twin technology allows for in-depth equipment health monitoring in factories. It precisely captures the features, condition, and health of a physical object and generates a digital copy of it. It is worth mentioning that the digital twin adapts to the real vehicle's age and environmental conditions, allowing for constant tracking and applicability all the way through its lifespan[11].

An optimization method created by Infosys called the Vehicle Maintenance Workbench (VMW) combines artificial intelligence and machine learning to forecast when fleet cars would break down and when to schedule maintenance checks.

Minimizing downtime, maximizing fleet efficiency, and optimizing maintenance costs are all made possible by this platform.A solution driven by artificial intelligence has been created by Namyang R&D Center. It uses automobile acoustics to identify damaged components. The technology is able to identify patterns and deduce the source of strange noises with an accuracy of around 88% by training machine learning models using data from both working and broken engines. Early warnings of possible vehicle faults are provided by Questar's Vehicle Health Management (VHM) Platform, which employs artificial intelligence and data collected from inside the vehicle. By optimizing pollution filtering, this technology helps fleet operators decrease expenses associated with replacement parts, fuel consumption, and accidents, all while improving environmental sustainability.With the help of predictive maintenance and Over-the-Air (OTA) updates, vehicle owners may save time and money by avoiding the need for frequent trips to the service station. The onboard machine learning system is able to anticipate malfunctions and provide drivers with timely precautionary advice based on data collected from sensors that indicate possible faults. This preventative method guarantees peak performance from the car and helps avoid costly repairs[12].

II. LITERATURE REVIEW

Author(s) & Year	Title/Focus	Technology Used	Key Findings	Contributions
Raghuvira Pratap et al. (2024)	Predictive maintenance for two-wheeler vehicles using XGBoost	XGBoost	Predicts vehicle condition using parameters like temperature, torque, and tool wear.	Enhances accuracy in predictive maintenance by leveraging XGBoost’s ability to handle complex relationships.
Viyyapu Lokeshwari Vinya et al. (2024)	Cloud-based predictive vehicle health monitoring	IoT, LSTM (Long Short-Term Memory)	Uses real-time sensor data to predict maintenance needs and avoid downtime.	Proposes a scalable, cloud-based architecture integrating IoT sensors for predictive maintenance.
N. G. Kuftinova et al. (2024)	Transport system optimization and predictive maintenance	Machine Learning (ML), K-Means Clustering, GPUs, Cloud Computing	Applies clustering and optimization techniques for traffic and transport maintenance.	Improves real-time data processing, traffic flow prediction, and transport system stability.
Debie Shajie A et al. (2023)	Preventive maintenance using audio-based classification	CNN, AlexNet, VGG16	Uses engine audio data to classify defects with 75% accuracy.	Introduces audio-based fault detection for vehicle maintenance using deep learning.
E. Mohanraj et al. (2024)	Digital twin integration with predictive maintenance	Digital Twin, ML Algorithms	Explores real-time monitoring of vehicle components using digital twins.	Demonstrates the effectiveness of digital twins in predictive analytics for maintenance.
Shubham et al. (2024)	Automobile damage classification	Deep Learning, Image Processing	Achieves 93.66% accuracy in damage classification across various vehicle parts.	Helps accelerate insurance claims, fleet management, and maintenance using deep learning models.

III. METHODOLOGY

The first stage of predictive maintenance is gathering data from the vehicle's many sensors. A wide variety of sensors are possible, such as accelerometers, global positioning systems, temperature, oil pressure, and many more. The information gathered may take several forms, including readings from sensors, event logs, or time series data[13][14].

➢ *Preparing Data:*

Preprocessing is necessary before analysis since the acquired data often includes noise, outliers, and missing values. Data cleaning, data transformation, and feature engineering are some of the pre-processing procedures used to get the data ready for analysis.

➢ *Analyzing Data:*

Machine learning techniques like neural networks, decision trees, random forests, and regression are used to examine the data after pre-processing. Predicting when maintenance is needed, finding possible problems, and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1358

determining the remaining usable life of components may all be done using the analysis. Accuracy, precision, recall, and F1-score are some of the measures used to assess the performance of predictive models built using machine learning algorithms. The assessment is useful for finding out how well the models work and where they might be improved[15].

It is possible to include the assessed predictive models into the vehicle maintenance system after their evaluation. As part of the implementation, the models may be integrated with the current maintenance software, maintenance operations can be scheduled according to the predictions, and the predictive models' performance can be monitored. Models require ongoing refinement to adjust to new circumstances, and predictive maintenance is an iterative process that necessitates this. The models' performance will be tracked, the maintenance team's comments will be gathered, and the models will be updated according to new data. Gathering data from sensors, preprocessing it, analyzing it using machine learning algorithms, evaluating the models, implementing them, and continuously improving them are the steps involved in the methodology for predictive maintenance in automobiles using IoT and machine learning. The success of the approach relies on the quality of data obtained. prediction model accuracy and model-integration-with-maintenance-system capability[16][17].

Naive Bayes Classifier The Bayes Theorem allows us to use the information we currently know to calculate the likelihood of a proposition. Using it, you can accomplish both one-and multiple-class categorization. It is easy to comprehend and can be trained with a tiny dataset. Its strong scalability means that it expands linearly with the addition more predictor characteristics and data points. It is unaffected by nitpicky details and works with both continuous and discrete data. Its strengths are in natural language processing (NLP), yet it has found usage in many other areas as well, such as facial recognition and recommendation systems. It is useful for making predictions and building hypotheses based on existing facts[18].

Decision Tree Classifier With human oversight, this machine learning technique continually sorts data into subsets defined by a single parameter. The development cost is low, and it efficiently sorts unidentified data. They are so good at classifying data that they can do it even when no characteristics are known. Combinations of numerical and category properties are no problem for them to handle. Decisions are made at the terminal nodes and leaf nodes in a tree-like architecture, which visually represents the tree and its decision-making process. This is so simple that a beginner could get it immediately.

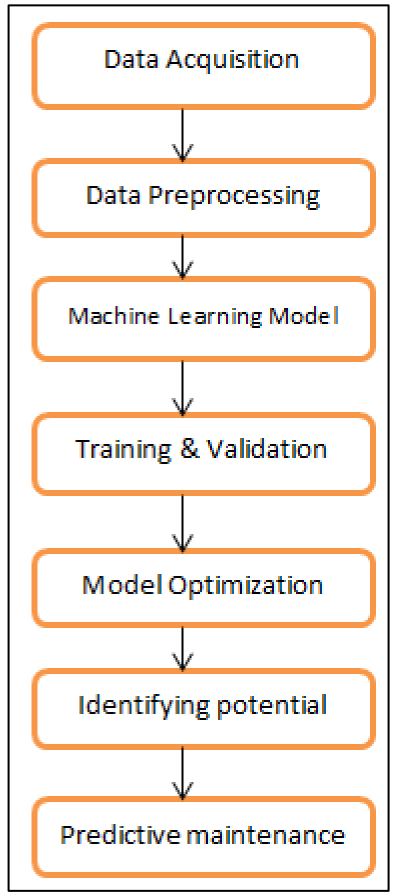

Fig 1 Block Diagram

It is essential that predictive maintenance systems deal with the complexities, peculiarities, and issues of industrial data. Some of the features of a PdM system include the following: the ability to quickly diagnose and detect failures; the ability to distinguish between different types of failures; resilience; the ability to identify novel faults; the ability to estimate classification errors; adaptability; the facility for providing explanations; minimal modeling requirements; real-time computation and storage handling; and ability to identify multiple faults. Two major problems with their activities and data variability are the ones that industrial use cases face. It happens even in assets with similar characteristics due to tolerances in mechanics, modifications to mounts, variances in EOC, and other factors. These characteristics make it difficult for machines and assets to reuse the PdM model. Additional relevant issues include doing appropriate pre-processing, designing characteristics to generate a dataset that represents the situation, and collecting high-quality data. Despite the high accuracy scores achieved by this maintenance index calculator system employing ML algorithms, more data collection and input should lead to even better results. Because this paper's approach relies on data analysis to provide outcomes, data gathering is a must. For example, you may collect data from the official websites of several carmakers like Hyundai, Ford, Toyota, and others using web scraping, a method that can extract many pieces of information from a website. In order to feed this algorithm more accurate structured data, it may be changed from unstructured data. One such way to get data is to form partnerships with automakers and gain official, approved records. Predictions made by Deep Learning algorithms tend to be spot on. In deep learning, a branch of machine learning, algorithms based on neural networks mimic how the human brain processes information. As an additional popular method, the Artificial Neural Network (ANN) may make predictions. Full-connected multi-layer neural networks are known as ANNs. The biases and teachable weights of CNN neurons allow the network to learn and improve[19]. Better predictions are another area where CNNs might be useful. Making a machine learning web app in Python and a Java app for Android so users can enter their vehicle model and manufacturer to get the best results is one possibility. It is expected that the program would provide accurate predictions for the maintenance index and the probability of component replacement based on the input. The predictions need to be shown on the screen. The interface ought to be easy to understand and utilize for first-time visitors.

IV. CONCLUSION

Reliability and efficiency of two-wheeler vehicles may be significantly improved with the use of predictive maintenance powered by artificial intelligence (AI). This system uses deep learning methods and machine learning algorithms like XGBoost and LSTM to accurately forecast when a car will fail and how bad it will be. By including IoT sensors, vital metrics like vibration, oil pressure, and engine temperature can be tracked in real-time, allowing for prompt maintenance interventions.In the end, the suggested AI-driven predictive maintenance system improves user safety, saves money, and prolongs the lifetime of the vehicle by reducing unexpected failures and optimizing maintenance schedules. In addition, fleet management and remote diagnostics are also made easier with cloud-based systems. The use of artificial intelligence (AI) in car repair is a giant leap toward smart and environmentally friendly vehicle systems, even if there are obstacles including data preparation and computing resource requirements. Predictive maintenance tactics will become even more effective and extensively used in the two-wheeler industry as a whole as a result of future developments in artificial intelligence, digital twin technology, and edge computing.

REFERENCES

[1]. R. P. A, S. Panda and S. S. G, "Predictive Maintenance for Two-Wheeler Vehicles Using XGBoost," *2024 10th International Conference on Advanced Computing and Communication Systems (ICACCS)*, Coimbatore, India, 2024, pp. 746-751, doi: 10.1109/ICACCS60874.2024.10717187.

[2]. V. L. Vinya, K. K. Manivannan, S. K. Manivannan, C. Sathiyamoorthy, M. Jagadeeswaran and B. Meenakshi, "Cloud-Enabled Predictive Vehicle Health Monitoring and Maintenance with LSTM Networks for Time-Series Analysis," *2024 First International Conference on Innovations in Communications, Electrical and Computer Engineering (ICICEC)*, Davangere, India, 2024, pp. 1-6, doi: 10.1109/ICICEC62498.2024.10808613.

[3]. N. G. Kuftinova, A. V. Ostroukh, O. I. Maksimychev, C. B. Pronin and I. A. Ostroukh, "Efficient Machine Learning Methods for Real-Time Transport System Optimization and Predictive Maintenance," 2024 Intelligent Technologies and Electronic Devices in Vehicle and Road Transport Complex (TIRVED), Moscow, Russian Federation, 2024, pp. 1-6, doi: 10.1109/TIRVED63561.2024.10769807.

[4]. E. Mohanraj, E. N, S. S and S. S, "Digital Twins for Automotive Predictive Maintenance," 2024 International Conference on Inventive Computation Technologies (ICICT), Lalitpur, Nepal, 2024, pp. 1579-1584, doi: 10.1109/ICICT60155.2024.10544392.

[5]. Shubham and D. Banerjee, "Robust Car Damage Identification Through CNN and SVM Techniques," 2024 4th International Conference on Technological Advancements in Computational Sciences (ICTACS), Tashkent, Uzbekistan, 2024, pp. 101-107, doi: 10.1109/ICTACS62700.2024.10841110.

[6]. "Predictive maintenance enabled by machine learning: Use cases and challenges in the automotive industry," by Andreas Theissler et al. Reliability engineering & system safety, 215 (2021): 107864.

[7]. Danilecki, Krzysztof, et al. "Modeling inventory and environmental impacts of car maintenance and repair: A case study of the Ford Focus passenger car." Journal of Cleaner Production 315 (2021): 128085.

[8]. Yang, Jianxin, Meng, Fanran, Zhang, Zhan, Sun, Xin, and Luo, Xiaoli. (2020). Life cycle assessment of lithium nickel cobalt manganese oxide (NCM) batteries for electric passenger vehicles. Journal of Cleaner Production. 273. 123006. 10.1016/j.jclepro.2020.123006.

[9]. Al-Muhtaseb Motaz, Mayyas Ahmad, "Reliability Analysis of Car Maintenance Scheduling and Performance," Jordan Journal of Mechanical and Industrial Engineering (JJMIE), vol. 4, no. 3, pp. 388–393, 2010

[10]. B. Pattanaik and S. Chandrasekaran, "Recovery and reliability prediction in fault tolerant automotive embedded system," 2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM), 2012, pp. 257-262, doi: 10.1109/ICETEEEM.2012.6494477.

[11]. Dolas, Dhananjay R., and Sudhir Deshmukh. "Reliability Analysis of the Cooling System of a Diesel Engine." 3.2 (2015): 57-62.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1358

[12]. Arena F, Collotta M, Luca L, Ruggieri M, Termine FG. Predictive Maintenance in the Automotive Sector: A Literature Review. Mathematical and Computational Applications. 2022; 27(1):2. https://doi.org/10.3390/mca27010002
[13]. Dragana Velimirović, Čedomir Duboka, Predrag Damnjanović. Automotive maintenance quality of service influencing factors, October 2016, Tehnicki Vjesnik Vol. 23(No.5):Article No. TV-20140402074657, DOI:10.17559/TV-20140402074657
[14]. Ioan Virca, Dorel Badea. Study on the Predictive Maintenance of Vehicles and its Management Using the Specific “Keep the Machine Running” Application.
[15]. Fabio Arena , Mario Collotta , Liliana Luca , Marianna Ruggieri and Francesco Gaetano Termine. Predictive Maintenance in the Automotive Sector: A Literature Review, 1 Introduction, 1.2 Predictive maintenance
[16]. Mahmuda Akhtar, Sara Moridpour, "A Review of Traffic Congestion Prediction Using Artificial Intelligence," Journal of Advanced Transportation, vol. 2021, Article ID 8878011, 18 pages, 2021. https://doi.org/10.1155/2021/8878011
[17]. Rüßmann, M.; Lorenz, M.; Gerbert, P.; Waldner, M.; Justus, J.; Engel, P.; Harnisch, M. Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries; Boston Consulting Group: Boston, MA, USA, 2015; Volume 9, pp. 54–89.
[18]. Lee J, Bagheri B, Kao HA. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. Manuf Lett 2015;3:18–23.doi:10.1016/j.mfglet.2014.12.001
[19]. Wuest T, Weimer D, Irgens C, Thoben K-D. Machine learning inmanufacturing: advantages, challenges,and applications. Prod ManufRes 2016;4:23–45. doi:10.1080/21693277.2016.1192517.