

# AI-Enabled Predictive Tire Safety Systems for Motorcycles: A Review

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**Abstract:** Motorcycle safety is highly dependent on tire condition, yet tire-related failures continue to account for a significant proportion of road accidents. Traditional tire inspection methods are manual, infrequent, and prone to error, leaving riders vulnerable to issues such as worn tread, overheating, blowouts, and misalignment. Recent advances in Artificial Intelligence (AI), Machine Learning (ML), and sensor technologies have enabled predictive approaches to tire safety. This paper reviews four critical aspects of tire monitoring in motorcycles—tire tread depth prediction, tire temperature monitoring, blowout risk assessment, and wheel alignment deviation detection—and highlights the role of AI-driven systems in transforming motorcycle safety from reactive maintenance to predictive prevention.

**Keywords:** Tire, Temperature, AI, ML, Safety, Motorcycle

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## I. INTRODUCTION

Motorcycles are one of the most widely used modes of transportation, especially in developing regions where affordability, fuel efficiency, and manoeuvrability make them highly practical. However, they are also among the most vulnerable vehicles on the road, with tire-related failures ranking as a major cause of accidents. Since tires are the only point of contact between a motorcycle and the road, their condition directly affects stability, braking, handling, and overall safety. Small defects or wear issues can escalate rapidly, leading to severe consequences for riders.

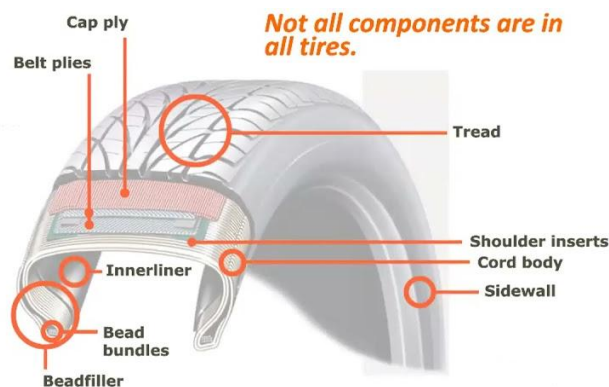


Fig 1: Tire Component

The primary tire-related concerns for motorcycles include tread wear, abnormal heating, sudden blowouts, and wheel misalignment. Worn tread reduces traction, particularly in wet conditions, while overheating accelerates tire degradation and increases the risk of sudden failure. Blowouts represent the most hazardous condition, occurring without warning and leaving the rider little time to respond. Wheel misalignment, though less immediately visible, contributes to uneven wear, reduced handling, and loss of fuel efficiency. Traditionally, these problems are detected through manual inspection or workshop diagnostics, both of which are time-consuming, error-prone, and infrequent.

While passenger cars have gradually adopted monitoring solutions such as Tire Pressure Monitoring Systems (TPMS), similar systems are less common in motorcycles. Moreover, TPMS and related technologies remain largely reactive, alerting the rider only after a dangerous condition has already developed. To truly enhance safety, the need of the hour is a predictive approach—one that can anticipate tire health issues before they compromise rider safety.

Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), and sensor technology have opened new possibilities for predictive tire monitoring. AI models can analyse complex sensor data, identify hidden patterns, and forecast potential risks. For instance, image-based deep learning models can predict tire tread depth with far greater accuracy than manual gauges. Similarly, thermal behaviour can be modelled using time-series analysis to predict overheating before it becomes critical. By fusing multiple inputs—such as pressure, temperature, tread depth, and vibration—AI systems can assess blowout risk in real time. Likewise, accelerometer and gyroscope data processed through machine learning algorithms can detect wheel alignment deviations, enabling timely corrective action.

The adoption of AI-driven systems offers significant advantages: continuous monitoring, predictive alerts, and rider convenience. Unlike manual inspection, these systems work autonomously, providing real-time insights without requiring additional effort. The emergence of low-cost IoT devices, miniaturized sensors, and embedded AI platforms further strengthens the feasibility of deploying such solutions in motorcycles, even in resource-constrained markets.

This review paper consolidates current developments in AI-based tire safety systems, focusing on four key areas: tire tread depth prediction, tire temperature monitoring, blowout risk assessment, and wheel alignment deviation detection. While research in each area has made promising progress, most approaches remain isolated, and an integrated predictive safety framework is yet to be realized. By bringing together findings across these domains, this paper aims to highlight opportunities for comprehensive and intelligent tire monitoring solutions that can transform motorcycle safety.

## II. TIRE TREAD DEPTH PREDICTION

Tire tread depth is one of the most critical indicators of motorcycle tire health, directly influencing grip, stability, and braking efficiency. As tread depth decreases, the ability of the tire to displace water diminishes, increasing the risk of hydroplaning and skidding, particularly under wet or slippery conditions. Traditional methods of tread depth inspection rely on manual tools such as gauges or visual observation. These methods, however, are error-prone, infrequent, and subjective, often failing to provide timely alerts for replacement.

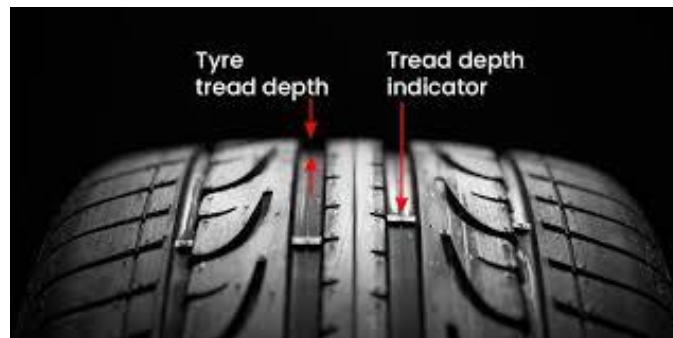


Fig:2 Tire Depth

Artificial Intelligence offers a transformative approach by enabling automated and predictive tread depth monitoring. Image-based systems using cameras or laser scanners capture tread surface data, which can then be analysed using computer vision and deep learning models such as Convolutional Neural Networks (CNNs). These algorithms can detect wear patterns, classify severity levels, and predict remaining tire life based on historical datasets. Additionally, regression-based ML models can estimate the rate of tread wear under varying riding conditions, enabling predictive maintenance schedules rather than reactive interventions.

The integration of AI in tread depth analysis provides significant benefits, including high measurement accuracy, early detection of abnormal wear, and the ability to forecast replacement needs. Such systems could be deployed through smartphone-based applications or embedded motorcycle sensors, making them scalable and accessible.

Method	Technology Used	Advantages	Limitations
Manual Gauge/Visual	Ruler, rider observation	Low cost, simple	Inaccurate, subjective, infrequent
Laser Scanning	Optical sensors	High accuracy, objective	Costly, requires calibration
AI-based Computer Vision	CNNs, deep learning, datasets	Automated, predictive, scalable	Needs large dataset for training

Table 1. AI vs. Traditional Approaches in Tread Depth Prediction

### III. TIRE TEMPERATURE MONITORING

Tire temperature is another critical factor affecting motorcycle safety and performance. Excessive heating can weaken the rubber compound, alter pressure stability, and accelerate tread wear. Overheating also significantly increases the likelihood of sudden blowouts. Traditional systems, such as Tire Pressure Monitoring Systems (TPMS), provide limited reactive alerts when pressure deviations occur, but they do not actively monitor or predict thermal behaviour.

AI-enabled tire temperature monitoring overcomes these limitations by combining thermal sensors, infrared imaging, and predictive analytics. Machine learning models, including regression analysis and time-series forecasting techniques (ARIMA, LSTMs), can predict abnormal heating trends under various riding conditions, such as high speed, overloading, or extreme ambient temperatures. These models analyze real-time data streams to forecast temperature rise before it reaches unsafe thresholds, providing early intervention opportunities.

The advantages of AI-based temperature monitoring include continuous thermal surveillance, predictive alerts, and integration with other tire health indicators (e.g., tread depth, pressure). Additionally, thermal patterns can reveal hidden mechanical issues such as brake drag or improper inflation, making it a multi-purpose diagnostic tool.

Method	Technology Used	Advantages	Limitations
TPMS (Reactive)	Pressure sensors	Simple, already available in cars	Not predictive, limited to pressure
Thermal Sensors	Embedded heat sensors	Direct measurement, real-time monitoring	Sensor durability in harsh conditions
AI-Based Prediction	ML (regression, LSTM models)	Predictive, multi-variable analysis	Requires data integration and training

Table 2. Approaches to Tire Temperature Monitoring

### IV. INTEGRATED RISK ASSESSMENT OF BLOWOUTS AND WHEEL ALIGNMENT

Tire blowouts and wheel misalignment are among the most critical hazards affecting motorcycle safety. Blowouts often occur due to a combination of factors such as overheating, underinflation, structural fatigue, or hidden tread damage, and they usually strike without warning. Wheel misalignment, on the other hand, develops more gradually but leads to uneven tire wear, compromised handling, and reduced fuel efficiency. Both issues place riders at significant risk if not detected early.

AI-enabled predictive systems provide a holistic approach by monitoring multiple data streams simultaneously. For blowout risk, data from tire pressure sensors, thermal probes, vibration monitors, and tread depth estimators can be fused and analysed with machine learning algorithms to detect hidden precursors of failure. Similarly, wheel alignment can be evaluated using gyroscope and accelerometer data, where AI models classify misalignment severity and differentiate between front and rear wheel deviations.

By merging these monitoring systems into a unified predictive framework, motorcycles gain real-time insights into two of the most dangerous tire-related problems. This integration not only improves early warning accuracy but also reduces maintenance costs and enhances rider safety by ensuring timely interventions before conditions escalate into accidents.

### V. LITERATURE REVIEW

The advancement of intelligent tire monitoring systems has been a growing focus in recent years, with research addressing tread depth estimation, temperature prediction, blowout prevention, wheel alignment, and predictive maintenance.

Rahman et al. [1] introduced an **automated tire tread depth estimation method using image processing**, demonstrating how computer vision can replace manual inspection by improving measurement accuracy and reducing human error. Complementing this, Shukla and Jain [2] provided a **comprehensive review of AI-driven predictive maintenance** for vehicle tires, outlining how machine learning (ML) and artificial intelligence (AI) can be integrated to forecast tire wear, optimize replacement schedules, and improve road safety.

In the domain of tire condition monitoring, Zhang et al. [3] proposed a **real-time tire temperature prediction model** using machine learning, emphasizing its role in preventing overheating-related hazards. Similarly, Kumar and Singh [4] focused on **sensor data fusion and deep learning** to predict tire blowouts, offering insights into how multi-sensor integration enhances early fault detection.

For two-wheeler dynamics, Lee et al. [5] investigated **wheel alignment fault detection in motorcycles** through vibration analysis and ML techniques, showing the significance of structural alignment in ensuring stability and safety. Foundational knowledge is further reinforced by Rajamani [6], who presented a comprehensive treatment of **vehicle dynamics and control principles**, including tire-road interactions and alignment fundamentals.

Extending the predictive maintenance perspective, Tiwari et al. [7] reviewed the applications of **AI in predictive vehicle maintenance**, underlining its relevance in tire health monitoring and lifecycle management.

Gohar et al. [8] advanced this field by developing **data-driven prognostic models** for predicting tire health and remaining useful life, demonstrating practical applications of ML for proactive maintenance.

Recent research has also highlighted **real-time blowout detection**. Li et al. [9] explored **sensor fusion methods for blowout detection and prevention**, enhancing system reliability by minimizing false alarms. Moreover, Mohan and Baskar [10] proposed an **IoT-enabled monitoring and predictive analytics framework** for two-wheelers, highlighting the potential of connected systems to provide real-time safety alerts and maintenance predictions.

Collectively, these studies underscore a shift from manual and reactive tire inspections toward **AI/ML-based, sensor-driven, and IoT-enabled predictive systems**. While early works focused on isolated parameters such as tread depth or temperature, recent research emphasizes **integrated approaches** combining data fusion, predictive analytics, and intelligent monitoring for comprehensive tire health management and improved vehicle safety.

## VI. DISCUSSION

The adoption of AI-enabled predictive tire safety systems in motorcycles signifies a paradigm shift from reactive fault detection to proactive accident prevention. Existing studies have demonstrated the feasibility of using image processing, vibration analysis, and thermal modelling for tire health monitoring. However, most implementations remain fragmented, focusing on a single aspect such as tread wear or temperature. A truly effective system requires an integrated multi-sensor and multi-model framework capable of simultaneously analyzing pressure, vibration, temperature, and alignment data.

In this context, IoT-enabled platforms offer a promising avenue. Low-cost wireless sensors embedded in tires or wheel assemblies can continuously transmit data to onboard processing units or cloud-based analytics systems. Edge-AI chips further enhance feasibility by allowing real-time computation on the motorcycle itself, minimizing latency and reducing dependence on external connectivity. Such integration ensures instant risk detection and alerts via dashboards, mobile apps, or even smart helmets.

Cost, however, remains a significant barrier, particularly in developing countries where motorcycles dominate road transport. For widespread adoption, systems must be lightweight, affordable, and energy-efficient, without significantly increasing the motorcycle's price. Collaborations between academia, industry, and policymakers will be critical in achieving this balance. Regulatory frameworks can accelerate adoption—similar to how Anti-lock Braking Systems (ABS) were mandated for motorcycles in several countries. Making AI-enabled tire monitoring mandatory could similarly reduce accident rates.

Finally, user acceptance must not be overlooked. Riders are less likely to adopt complex diagnostic systems unless they are intuitive and seamlessly integrated into the riding experience. Therefore, future research should prioritize user-centric design, ensuring that predictive alerts are timely, clear, and actionable.

## VII. CONCLUSION

AI-enabled predictive tire monitoring systems represent a transformative advancement in motorcycle safety. By shifting from periodic manual inspection to continuous, intelligent, and predictive monitoring, these systems address critical risks such as tread wear, overheating, blowouts, and wheel misalignment. The convergence of AI, IoT, and embedded sensor technologies makes it possible to develop affordable, real-time solutions suitable for motorcycles across both advanced and resource-constrained markets.

Future work should emphasize integration into unified platforms, combining multiple indicators into a holistic health score for motorcycle tires. Additionally, collaboration with policymakers and industry stakeholders could drive the adoption of safety regulations mandating tire health monitoring, much like ABS and emission standards. The development of smart helmets, mobile dashboards, and IoT-enabled rider assistance systems further enhances opportunities for real-world deployment.

In conclusion, predictive tire safety systems have the potential not only to reduce accident risks but also to extend tire life, lower maintenance costs, and improve fuel efficiency. As research advances toward scalable deployment, AI-driven solutions are poised to become an integral part of the future motorcycle safety ecosystem.

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