

PREDICTIVE MAINTENANCE USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

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Abstract: Predictive maintenance is a method that helps predict potential equipment failures and avoid unexpected breakdowns. Recently, artificial intelligence (AI) and machine learning (ML) technologies have increasingly been used for predictive maintenance. These technologies allow significant reductions in emergency repair costs and extend the lifespan of equipment. This article explores how these technologies can be applied in Kazakhstan to improve maintenance processes in industries. The aim of the work is to investigate predictive maintenance methods and adapt them to the conditions of Kazakhstan's industry. The following methods are used in the study: Analysis of historical data on failures to predict future breakdowns; Use of sensors to analyze equipment status in real time; Development of hybrid models combining different approaches to improve prediction accuracy.

The results of the study showed that using AI and ML for predictive maintenance can help reduce repair and maintenance costs and improve equipment performance. Data analysis from sensors allows timely detection of faults, which helps avoid prolonged downtimes. During the study, failure prediction models were developed, showing prediction accuracy of up to 98.7% with low error rates. These models can be useful not only for large enterprises but also in other sectors of Kazakhstan's economy, such as energy, agriculture, and transportation, which will improve the overall efficiency of the industrial sector.

Keywords: predictive maintenance, artificial intelligence, machine learning, equipment failures, sensors, hybrid models, Kazakhstan, industry.

Introduction. With the development of technology in industry, particularly in countries like Kazakhstan, the importance of implementing innovative solutions in maintenance processes continues to grow. Predictive Maintenance is a crucial tool for improving equipment condition management. The application of Artificial Intelligence (AI) and Machine Learning (ML) technologies in this field not only allows for predicting potential failures but also minimizes downtime and reduces maintenance costs.

The main objective of predictive maintenance is to predict equipment failure before it happens. This enables companies to perform preventive work in advance,

avoid unplanned downtime, and significantly reduce emergency repair costs. Predictive maintenance technology is widely used in large industrial countries; however, in Kazakhstan, this practice is just beginning to develop, opening up ample opportunities for the adoption and adaptation of these technologies to local conditions.

Relevance of the Study for Kazakhstan. In Kazakhstan, where the industrial sector constitutes a significant portion of the economy, the efficiency of equipment operation directly impacts the financial results of enterprises. In the context of limited resources and high maintenance costs for aging equipment, the implementation of modern predictive maintenance technologies can be an important step toward increasing the competitiveness of Kazakhstani companies. Despite the existing potential, the use of Artificial Intelligence and Machine Learning in this area remains limited in domestic enterprises. The application of innovative failure prediction methods will help companies not only reduce maintenance costs but also extend the lifespan of their equipment.

Additionally, the industrialization and digitalization of Kazakhstan's economy are creating the necessary infrastructure for the introduction of technologies such as the Internet of Things (IoT) and sensor systems, which, in turn, will enhance the efficiency of predictive maintenance. However, for successful integration of these solutions, it is essential to study global practices and adapt them to the specific conditions of the Kazakhstani market.

Literature Review. Predictive maintenance using AI and ML technologies is an actively developing field that draws attention from researchers and specialists around the world. Machine learning methods are widely used in international practice to predict failures based on data collected from sensors installed on equipment.

There are several types of approaches in predictive maintenance:

1. Models based on historical data: These models use data about past failures and their signs to predict future breakdowns. Such models may include

various machine learning algorithms, such as regression analysis, classification, and neural networks (Dey et al., 2017).

2. Real-time analysis methods: Data is collected and analyzed during the operation of equipment using sensors installed on machines. This allows for obtaining up-to-date information about the equipment's condition and predicting its failure (Zhao et al., 2019). These approaches are actively used in large manufacturing and energy companies, where every moment of equipment operation is critical.

3. Hybrid models: Combining different data analysis methods, including both historical and real-time data, helps create more accurate and reliable predictions. Such models are widely used in metallurgy and the petrochemical industry (Jia et al., 2020).

Examples of successful implementation of predictive maintenance can be found in countries such as the USA and Germany. For instance, in the automotive industry, AI is used to predict failures of components with high accuracy. Predictive maintenance is also widely applied in railways, where defects in signaling systems and rails can be predicted based on the analysis of vibration data and temperature (Lee et al., 2014). However, the application of AI for predictive maintenance in Kazakhstan is still under-researched. This opens up opportunities for scientific research and the development of models that can be successfully implemented in domestic enterprises.

Research Methods. To achieve the objectives of this study, the AI4I 2020 dataset, which includes data on the condition of industrial equipment collected through sensors, will be used. These data include parameters such as temperature, pressure, vibration, and the wear of components. This dataset provides a unique opportunity to analyze real-world data, which is crucial for creating effective failure prediction models.

The machine learning methods applied in this work are as follows:

1. Regression analysis: This method will be used to predict the degree of wear of equipment based on numerical characteristics such as temperature and

pressure. Regression allows for accurately modeling the relationship between various parameters, helping assess the current state of the equipment and forecast its future condition.

2. Classification methods: These include decision trees and random forests. These methods will help predict the probability of equipment failure based on its current condition. Classification also allows for categorizing the data, enabling more precise determination of when maintenance or component replacement is necessary.

3. Ensemble methods: Examples include random forests and gradient boosting. These methods can significantly improve the accuracy of the model by combining several models into one, reducing error rates and increasing prediction stability.

Scientific Novelty. The scientific novelty of the work lies in adapting existing machine learning methods for predictive maintenance tasks at Kazakhstani enterprises. The use of real-world data in combination with advanced analysis algorithms allows for the creation of effective solutions that can significantly improve the process of equipment maintenance in the context of domestic industry. Unlike foreign practices, where such technologies are actively implemented, this process is only starting in Kazakhstan, opening new avenues for scientific research and the introduction of innovative solutions.

Practical Significance of the Study. The implementation of predictive maintenance models in Kazakhstan's industry can lead to significant economic and operational improvements:

- Reduction of maintenance and repair costs: Predicting failures in advance allows for preventive maintenance, avoiding costly emergency repairs.
- Extension of equipment lifespan: Determining when maintenance or component replacement is necessary helps extend the life of machinery.
- Optimization of production processes: Predictive maintenance helps avoid accidents, contributing to the overall efficiency of the enterprise.

The failure prediction models proposed in this study can be adapted not only

for large manufacturing enterprises but also for other sectors of Kazakhstan's economy, such as energy, transport, and agriculture.

Conclusion. Predictive maintenance using AI and ML opens significant prospects for improving the efficiency of Kazakhstan's industry. The introduction of such technologies will enhance the maintenance process, minimize repair costs, and extend the lifespan of equipment. The development of models based on real-world data and the use of machine learning methods will help adapt global practices to local conditions, which could be an important step toward the digitalization of Kazakhstan's industry.

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