

Рисунок 3 – Текущий уровень и целевые показатели доли переработки полимерных отходов

Композиты из отходов – это стратегическое направление формирования циркулярной экономики, соединяющее экологическую необходимость с промышленным развитием.

СПИСОК ЛИТЕРАТУРЫ

1 Доклад «Состояние и перспективы развития рынка вторичных полимеров в России». – М. : Российский союз химиков, 2024.

Получено 20.05.2026

ISSN 2227-1155. Сборник студенческих научных работ.
Вып. 31. Гомель, 2026

UDC 629.4.083:004

A. V. FALEJCHIK (UD-11), V. D. PROKHORENKO (UA-11)
Supervisor – senior lecturer E. Y. MAKUTONINA

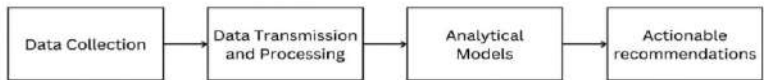
PREDICTIVE ANALYTICS (PREDICTIVE MAINTENANCE) OF LOCOMOTIVES = ОСОБЕННОСТИ ПРИМЕНЕНИЯ ПРЕДИКТИВНОЙ АНАЛИТИКИ (ПРОГНОЗНОГО ОБСЛУЖИВАНИЯ) В СИСТЕМЕ ЭКСПЛУАТАЦИИ И РЕМОНТА ЛОКОМОТИВНОГО ПАРКА

The rail industry, the backbone of global logistics and transportation, operates a vast network of infrastructure and rolling stock, with locomotives serving as the primary driving force. Traditionally, locomotive maintenance has relied on routine unscheduled repairs, major overhauls for scheduled restorations, or scheduled preventative maintenance (scheduled maintenance regardless of condition). While these methods serve their purpose, they are often ineffective, as roads can still cause unexpected downtime, disrupting schedules and incurring significant costs. Predictive analytics, also known as predictive maintenance,

represents a paradigm shift in rail transport management, using data and advanced algorithms to predict equipment failures before they occur. In this paper, we will examine the concepts of predictive analytics as they apply to locomotive maintenance, its implementation, benefits, challenges, and future prospects for the rail industry.

What is a predictive analytics? Predictive analytics involves the use of data, statistical algorithms, and machine learning methods to predict the likelihood of future outcomes based on historical and current data. Unlike routine and capital maintenance, which wait for a component to fail, or preventative maintenance, which follows a fixed schedule, predictive maintenance focuses on the actual condition of the asset. For locomotives, this means continuous monitoring of various parameters to detect subtle breakdowns or damage that indicate imminent failure, allowing maintenance to be carried out exactly when needed, rather than too early or too late.

The use of predictive analytics on locomotives depends on reliable data collection and sophisticated analytical capabilities. Here are the main areas of this system's work:



Data collection involves equipping modern locomotives with numerous sensors that collect vast amounts of data in real time. These sensors monitor: engine parameters (temperature, oil pressure, fuel consumption, exhaust gas analysis); traction systems (engine temperature, current, voltage, vibration); brake systems (air pressure, brake pad wear, duty cycles); wheel sets and bogies (vibration, acoustic data to identify defects (e.g., wheel scuffs, bearing problems)); auxiliary systems: HVAC systems, lighting, door mechanisms); operational data (location, speed, load, route terrain, weather conditions); maintenance records (past failures, repairs, component life) and etc. After data collection, data is transferred and processed when collected data is transmitted wirelessly (e.g., via cellular or satellite networks) to a central cloud system. Here, the raw data is processed, cleaned, and linked to other relevant datasets. The next stage is analytical models: machine learning algorithms are applied to the processed data. This may include: Anomaly Detection (identifying unusual failures that deviate from normal operating conditions); Regression Models (predicting continuous values, such as the remaining service life of components); Classification Models (categorizing the type of future damage); Pattern Recognition (identifying relationships between various sensor readings and historical defect events); Deep Learning (for complex systems, neural networks can analyze complex relationships in high-dimensional data) and etc. The whole process ends with actionable recommendations: analytical models generate insights, identifying potential problems, predicting failure probabilities, and recommending specific maintenance actions. These insights are then presented to maintenance teams through user-friendly dashboards and alerts, enabling

them to proactively plan repairs.

Implementing predictive analytics for locomotive maintenance offers numerous benefits:

Reduction of unplanned downtime is achieved thanks to anticipating failures, maintenance can be scheduled during scheduled maintenance intervals or off-peak periods, significantly minimizing unexpected disruptions and delays. Thanks to predictive analytics, maintenance costs are optimized, because repairs are performed only when needed, reducing unnecessary component replacements, labor costs associated with scheduled but unnecessary maintenance, and emergency repair costs. This also optimizes spare parts inventory, enabling just-in-time procurement. With fewer breakdowns, operational efficiency is increased and locomotives spend more time in service, resulting in higher fleet utilization and improved schedule adherence. One of the most important benefits is increased safety: detecting potential component failures before they become critical significantly reduces the risk of accidents and operational incidents, improving safety for staff, passengers, and freight. Proactive maintenance prevents minor issues from developing into major damage, thereby extending the lifespan of expensive locomotive components and the entire train which increases the service life of locomotives. Also the advantage remains the improvement decision making: data-driven insights give maintenance managers and operators a clearer picture of rolling stock condition, enabling more informed strategic decisions regarding fleet management and capital expenditures.



A prime example of companies successfully implementing predictive analytics in locomotive maintenance is Wabtec Corporation, one of the largest providers of rail technology and solutions globally (including the acquisition of GE Transportation). Their approach demonstrates how digital transformation can dramatically improve the operational efficiency and reliability of rail transport.

Wabtec uses a vast network of sensors installed on locomotives to collect re-

al-time data on the operation of engines, traction systems, brakes, wheelsets, and many other critical components. This wealth of data, including temperature, pressure, vibration, current, and voltage, is transmitted to advanced cloud platforms. Here, sophisticated machine learning and artificial intelligence algorithms analyze these data streams, identifying even the smallest anomalies and faults. For example, their Locomotive Performance Management solutions can predict potential component failures weeks or even months before they occur. These predictive models allow railway operators to shift from major or scheduled maintenance to more proactive, condition-based maintenance, thereby significantly reducing unplanned downtime, optimizing maintenance schedules, and significantly improving the safety and availability of their entire locomotive fleet.

Another good example of predictive analytics is Deloitte Insights. While manufacturing companies like Wabtec focus on developing and implementing specific technology solutions, Deloitte, through its Deloitte Insights analytics platform, plays a key role in shaping the strategic vision and providing industry-specific metrics for predictive analytics. Deloitte Insights offers in-depth analysis of the trends, opportunities, and challenges facing rail operators as they transition to smarter maintenance.

In its reports and articles, Deloitte Insights frequently highlights how predictive analytics based on big data and machine learning is becoming a critical factor in enhancing the competitiveness and sustainability of rail companies. They highlight not only direct cost savings from reduced unplanned downtime and optimized locomotive maintenance schedules, but also broader strategic benefits such as improved safety, extended asset life, and increased customer satisfaction thanks to more reliable schedules. Deloitte's publications help rail leaders understand how to integrate predictive analytics into their overall digital transformation strategy, overcome barriers related to legacy infrastructure and data management, and build operating models capable of fully realizing the potential of predictive maintenance. Deloitte Insights thus serves as a valuable resource for understanding business cases, implementation approaches, and future directions for predictive analytics in the rail sector.

Railway Technology is a leading international online resource providing up-to-date information on events, technologies, and trends in the global rail industry. The publication plays a key role in highlighting the practical application and development of predictive analytics in rail transport, making this complex topic accessible to a wide audience of specialists.

Railway Technology features numerous articles, interviews, and case studies on how rail companies and suppliers are implementing predictive maintenance solutions for locomotives. The publication focuses on real-world examples: from installing new sensors on rolling stock to implementing comprehensive data analytics platforms. Publications often feature case studies of specific companies already using predictive models to monitor the condition of their locomotives, predict failures, and optimize maintenance processes. Railway Technology

demonstrates how these technologies help reduce operating costs, improve train reliability, reduce downtime, and ultimately improve the overall efficiency and safety of rail operations, making cutting-edge developments understandable and accessible to all industry participants.

Despite significant benefits, implementing predictive analytics for locomotives has a number of challenges. These include high initial investments in innovative technologies and analytics platforms, the complexity of interfacing new systems with legacy infrastructure, ensuring data quality and security, and the need for specialized skills (data analysts, machine learning engineers).

However, the future of predictive analytics in rail transport looks promising, with several emerging trends: Edge Computing (processing data closer to the source (on the locomotive itself) to reduce latency and bandwidth requirements); Digital Twins (creating virtual copies of physical locomotives that simulate their behavior and predict performance under different conditions); Artificial Intelligence Integration (moving beyond prediction to more autonomous decision-making and prescriptive actions); Holistic Network Optimization (integrating locomotive health data with overall rail network management for comprehensive operational optimization); Sustainability (optimizing fuel consumption and reducing emissions through improved operational insights) and etc.

To conclude it should be mentioned that predictive analytics is transforming locomotive maintenance from a pressing necessity into a strategic advantage. By harnessing the power of data and advanced algorithms, rail operators can transition to a more proactive, efficient, and reliable operating model. While challenges remain, the undeniable benefits in terms of cost savings, improved safety, and improved operational performance make predictive analytics an indispensable tool for the modern rail industry, paving the way for a more sustainable and reliable future of transportation.

LIST OF REFERENCES

- 1 **Siegel, E.** Predictive Analytics: The Power to Predict Who Will Click, Buy, Lie, or Die / E. Siegel. – Hoboken : John Wiley & Sons, 2016. – 368 p.
- 2 **Mobley, R. K.** An Introduction to Predictive Maintenance / R. K. Mobley. – Amsterdam : Elsevier Science, 2002. – 448 p.
- 3 **Kuhn, M.** Applied Predictive Modeling / M. Kuhn, K. Johnson. – New York : Springer, 2013. – 600 p.
- 4 Predictive analytics: the future of railway transportation // Siemens Mobility. – URL: <https://www.siemens.com/global/ru/company/topic/mobility/predictive-maintenance.html> (access date: 29.04.2026).
- 5 Digital diagnostics and predictive maintenance of rolling stock // Russian Railways. – URL: <https://www.rzd.ru/ru/9796/page/103299?id=25577> (access date: 17.04.2026).

Получено 28.05.2026

ISSN 2227-1155. Сборник студенческих научных работ.
