APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN AUTOMATIC TRAIN CONTROL FOR RAILWAY TRANSPORT

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Abstract. *An integrated artificial intelligence (AI) platform is proposed for optimizing train operations in railway transport. The concept combines a unified data platform, machine learning (ML) and reinforcement learning (RL) prediction modules, real-time timetable rescheduling (MILP + RL), predictive maintenance, and cybersecurity standards. The goal is to reduce delays, improve capacity utilization, and enable proactive service management. Current literature shows that AI adoption in railways often remains at pilot stages due to fragmented data silos and limited integration across subsystems. This paper emphasizes the importance of data governance and standardization, while highlighting research gaps in predictive service integration, model robustness, and real-time decision support. Based on Uzbekistan's digitalization initiatives, a roadmap is proposed including evaluation metrics, risk assessment, and mitigation strategies.*

Keywords: *railway transport, train scheduling, rescheduling, integrated AI, machine learning, reinforcement learning, predictive maintenance, digital twin, data governance, cybersecurity*

Introduction

Railway transport is a vital component of modern mobility, enabling the safe and cost-effective movement of large volumes of passengers and freight over long distances. Efficient train operation management is essential for the stability of the transport system. In recent years, digitalization has accelerated across railway networks, driven by advances in information technologies, big data, and AI. These developments create new opportunities for optimizing train scheduling, reducing delays, and improving infrastructure utilization.

Key challenges in railway operations include timetable disruptions, infrastructure congestion, technical failures, human errors, and insufficient real-time data. Addressing these issues requires integrated AI solutions that combine predictive analytics, optimization algorithms, and real-time decision support. This paper proposes such a system, designed to unify train operations, maintenance, and safety management within a single platform.

Literature Review

Previous studies have explored AI applications in railway transport from different perspectives. Tang et al. (2022) reviewed AI applications in railways, noting strong progress in maintenance and inspection but limited adoption in operational decision-making. Davari et al. (2021) surveyed predictive maintenance approaches, emphasizing ML and DL methods for vibration and time-series data analysis. Bešinović et al. (2022) introduced a taxonomy of AI applications in railway transport, covering autonomous driving, maintenance, and traffic management, while raising concerns about ethics and explainability.

Zhu et al. (2024) examined machine learning in urban rail transit systems, highlighting applications in passenger flow prediction, delay forecasting, and cybersecurity perception. Qin et al. (2023) investigated federated learning for fault diagnosis in high-speed train bogies, demonstrating distributed intelligence but acknowledging scalability and privacy challenges. Pappaterra et al. (2021) reviewed public datasets for railway AI, finding that most are proprietary and fragmented, limiting benchmarking.

Despite these advances, most systems remain siloed, with train scheduling, maintenance, and safety managed separately. Integration across subsystems is rare, reducing overall efficiency. Research gaps include the lack of standardized datasets, limited interoperability, cybersecurity vulnerabilities, and insufficient focus on human-centered AI.

Conclusion

This study proposes an integrated AI system for optimizing train operations in railway transport. The model combines unified data management, ML/RL prediction modules, real-time timetable rescheduling, predictive maintenance, and cybersecurity standards. The expected benefits include efficient train scheduling, real-time decision support, improved infrastructure utilization, and enhanced safety. Future work should focus on implementing such systems in real railway infrastructures, evaluating economic efficiency, and addressing challenges of data governance, interoperability, and cybersecurity.

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