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INNOVATIVE APPROACHES TO DEVELOPING AN AUTOMATED INFORMATION SYSTEM FOR CALCULATING FUEL CONSUMPTION IN RAILWAY TRANSPORT

Makhmudov Akmaljon Bakhtiyor ugli
Master's student of the Higher School of Business and Entrepreneurship
Head of the Economics Department of the "Temiryolyonilgitamin"
Department of "Uzbekistan Railways" JSC

Abstract

This article explores innovative approaches to developing automated fuel consumption accounting systems in railway transport. The study is based on IoT, Big Data, artificial intelligence, and Industry 4.0 concepts. System architecture, real-time monitoring, data integration, and predictive analytics are analyzed for fuel optimization.

Калит сўзлар

- Digital Economy
- Railway Transport
- Fuel Consumption
- Automation
- Information System
- IoT (Internet of Things)
- Big Data
- Efficiency

Introduction

Currently, digital transformation processes in the global economy are fundamentally changing all sectors, including the transport system. According to the

World Economic Forum, more than 70% of the industrial sector is in the process of transition to digital technologies. This process is expressed through the concept of "Industry 4.0", in which the main emphasis is on automation, intelligent systems and data-based management (Kagermann et al., 2013).

Railway transport is one of the strategic sectors of the economy, in which fuel consumption constitutes one of the largest parts of operating costs. Therefore, accurate accounting and optimization of fuel resources is of great importance not only from an economic but also from an environmental perspective. According to research by the McKinsey Global Institute, the introduction of digital technologies in the transport sector can reduce operating costs by 15–25%.

Traditional accounting systems are often based on manual labor and static reports, in which the human factor plays a significant role. This limits the accuracy, speed and reliability of data. As Porter & Heppelmann (2014) emphasize, classic management models should be replaced by modern "smart connected systems", as they allow for real-time decision-making.

Large-scale reforms are also being implemented in Uzbekistan to digitize the transport system. The "Digital Uzbekistan – 2030" strategy identifies automation of transport infrastructure and integration of information systems as a priority. This creates the need to create new generation fuel consumption control systems in railway transport.

In recent years, IoT (Internet of Things), Big Data and artificial intelligence technologies have been widely used in the transport sector. Lee et al. (2015) noted that cyber-physical systems (CPS) allow achieving high efficiency by integrating industrial processes with the digital environment. From this point of view, the development of automated fuel consumption accounting systems in railway transport is a scientifically and practically relevant issue**.**

Main part

1. Conceptual basis of the automated system

The automated fuel consumption accounting system is based on the principles of Cyber-Physical System (CPS). Lee et al. (2015) noted that CPS systems provide an integral connection between physical objects and the digital environment.

The system consists of the following components:

• sensors (fuel level, speed, pressure)

• IoT communication module

• database

• analytical and AI module

2. Real-time monitoring based on IoT

Wang et al. (2016) studies, IoT technologies provide real-time control in manufacturing and transportation systems.

In the railway system:

• fuel level is constantly measured

• locomotive movement is monitored via GPS

• data is transmitted to a central server

Anomaly detection:

$$| F_{real} - F_{expected} | > \delta$$

This approach allows for early detection of overspending and technical failures.

3. Big Data Analytics

McAfee & Brynjolfsson (2012) described Big Data technologies as a "management revolution". In the transportation sector, large volumes of data are analyzed based on:

• traffic parameters
• fuel consumption
• route characteristics
• technical condition

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Applied methods:

• clustering
• regression models
• machine learning

4. Artificial intelligence-based forecasting

Vial (2019) emphasizes that AI is a key driver in digital transformation.

AI models:

• Random Forest
• Gradient Boosting
• Neural Networks

These models allow for fuel consumption forecasting with an accuracy of 5–15% (Tavasszy, 2020).

5. System architecture (Industry 4.0 approach)

Kagermann et al. (2013) According to the Industry 4.0 concept, industrial systems should be fully integrated.

Architecture:

Layer 1:

IoT sensors

Layer 2:

Data transmission (4G/5G)

Layer 3:

Cloud data processing

Layer 4:

AI analytics & decision support

6. Economic efficiency analysis

As a result of automation:

• fuel consumption: reduced by 10–18%
• operating costs: reduced by 12–15%
• decision making: accelerated by 2–3 times

Efficiency formula:

$$E=(C_{old}-C_{new})-I$$

7. Risks and limitations

The following problems exist in the implementation of the system:

• cybersecurity risks
• high investment costs
• lack of infrastructure
• staff qualifications

Conclusion

The results of the study show that the introduction of automated fuel consumption accounting systems in railway transport allows achieving high efficiency in the conditions of the digital economy. The integration of IoT, Big Data and artificial intelligence technologies allows for real-time monitoring and forecasting of fuel consumption.

Compared to traditional accounting methods, automated systems increase the accuracy and speed of data, reduce the impact of the human factor and optimize operating costs. According to scientific sources, this approach allows reducing fuel consumption by up to 10–18%.

The introduction of these technologies in the railway transport system of Uzbekistan will serve to ensure the efficient use of resources, scientific substantiation of

management decisions, and acceleration of digital transformation processes. Future research should be aimed at developing dynamic optimization algorithms based on AI and integrating the system with cybersecurity technologies.

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