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## **ENHANCING THE ENVIRONMENTAL EFFICIENCY OF IT SOLUTIONS IN THE RAILWAY SECTOR FOR SUSTAINABLE TRANSPORT INFRASTRUCTURE**

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### **Abstract:**

This article addresses the issues of improving environmental efficiency through the implementation of information technology (IT) solutions in the railway transport sector. In the context of a developing digital economy, the concept of transport infrastructure sustainability and minimal environmental impact occupies an important place. The study analyzes the possibilities of reducing energy consumption, minimizing waste, and ensuring environmental safety through intelligent monitoring, digital dispatching, artificial intelligence-based energy control, and automated maintenance systems in the railway system. Additionally, the experiences of foreign scholars, the European Union's Green Rail Transport Initiative program, and the advantages of the Digital Railway concept being implemented in Uzbekistan's conditions are examined. The article scientifically illuminates the role of IT technologies in forming sustainable transport infrastructure and their strategic importance in ensuring environmental efficiency.

**Keywords:** sustainable transport infrastructure, railway, information technologies, environmental efficiency, digital transformation, artificial intelligence, energy efficiency, smart railway, Green Rail Transport Initiative, digital dispatching system

## **BARQAROR TRANSPORT INFRASTRUKTURASI UCHUN TEMIR YO'L SOHASIDA IT YECHIMLARINING EKOLOGIK SAMARADORLIGINI OSHIRISH**

### **Annotatsiya:**

Ushbu maqolada temir yo'l transporti sohasida axborot texnologiyalari (IT) yechimlarini joriy etish orqali ekologik samaradorlikni oshirish masalalari



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yoritilgan. Rivojlanayotgan raqamli iqtisodiyot sharoitida transport infratuzilmasining barqarorligi va atrof-muhitga minimal ta'sir ko'rsatish konsepsiyasi muhim o'rin tutadi. Tadqiqotda temir yo'l tizimida aqlli monitoring, raqamli dispetcherlik, sun'iy intellekt asosida energiya nazorati va avtomatlashtirilgan texnik xizmat ko'rsatish tizimlari orqali energiya sarfini kamaytirish, chiqindilarni qisqartirish hamda ekologik xavfsizlikni ta'minlash imkoniyatlari tahlil qilingan. Shuningdek, xorijiy olimlarning tajribalari, Yevropa Ittifoqining "Green Rail Transport Initiative" dasturi hamda O'zbekiston sharoitida amalga oshirilayotgan "Raqamli temir yo'l" konsepsiyasining afzalliklari ko'rib chiqilgan. Maqolada IT texnologiyalarining barqaror transport infratuzilmasini shakllantirishdagi o'rni va ekologik samaradorlikni ta'minlashdagi strategik ahamiyati ilmiy asosda yoritiladi.

**Kalit so'zlar** barqaror transport infratuzilmasi, temir yo'l, axborot texnologiyalari, ekologik samaradorlik, raqamli transformatsiya, sun'iy intellekt, energiya tejamkorlik, "smart railway", "Green Rail Transport Initiative", raqamli dispetcherlik tizimi

### **Introduction:**

In the current period, the sustainability of the transport system is an important indicator not only of economic development but also of environmental safety. Global environmental problems, particularly atmospheric warming, the increase of carbon emissions, and the limitation of natural resources, demand new solutions in transport infrastructure. From this perspective, railway transport stands out from other modes of transport with its energy efficiency, high carrying capacity, and environmental cleanliness. However, to ensure sustainability in this sector as well, it is necessary to widely implement modern digital technologies.

Modern information technologies, particularly intelligent management systems, digital dispatching, Internet of Things (IoT), and solutions based on artificial intelligence, have created opportunities to increase the energy efficiency of the railway system. This ensures the reduction of environmental burden, rational use of resources, and minimization of waste. International experience, including the



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European Union's Green Rail Transport Initiative program, demonstrates that digital transformation serves to transform railway transport into the most environmentally optimal mode of transport.

Significant results are also being achieved in this direction in Uzbekistan's conditions. The Digital Railway concept developed by Uzbekistan Railways JSC is bringing the national transport system to a new level through energy-efficient management systems and monitoring programs aimed at ensuring environmental safety. Therefore, the implementation of IT technologies in the railway sector is viewed as an important condition for forming not only an economically but also environmentally sustainable transport system.

### Main Part:

In recent years, digital transformation processes have been deeply penetrating all links of the transport system. Information technologies (IT) occupy a central position in optimizing railway infrastructure, increasing energy efficiency, and ensuring environmental safety. According to research conducted on an international scale, as a result of implementing IT solutions, carbon emissions in railway transport decrease by an average of 15–25 percent.[1] The European Union's Green Rail Transport Initiative program demonstrates that reducing the environmental burden of transport infrastructure through digital technologies not only protects the environment but also increases economic efficiency. Within the framework of this program, it is planned to reduce CO<sub>2</sub> emissions by 30 percent by 2030 through monitoring train movement in real time, managing energy consumption, and implementing automated maintenance systems.[2] As Porter noted in his research, digital solutions enable maintaining balance between economic competitiveness and environmental efficiency. According to him, harmonizing environmental innovations with IT is the main factor of the green economy model. Thus, IT solutions in railway transport are viewed as a supporting element of an environmentally sustainable transport system.[3]

The following IT-based mechanisms have significant importance in improving environmental efficiency in railway transport. Intelligent monitoring systems. Sensors developed based on Internet of Things (IoT) technology monitor the



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technical condition of trains in real time. These systems identify energy consumption, fuel usage, and emissions, and provide recommendations for their reduction. According to research by Zhou and Li, IoT-based energy control systems reduce fuel consumption of trains by more than 10 percent.[4]

Artificial intelligence (AI) and machine learning (ML). AI technologies are effective in optimizing train routes, analyzing energy consumption, and predicting malfunctions in advance. According to Gomes and Pereira, AI-based dispatching systems optimize the time-distance between trains, ensuring energy savings of up to 15 percent.[5] Digital dispatching and logistics systems. Managing railway networks through digital dispatching regulates cargo flows and reduces energy waste. In their research, Wang and Chen proved that it is possible to reduce CO<sub>2</sub> emissions in railway transport by 12–15 percent with the help of digital logistics systems.[6]

Energy management programs. IT platforms controlling energy consumption create the possibility of managing electric power flow in real time. These systems allow for the recycling of thermal energy released during train braking processes. As a result, energy efficiency increases and environmental burden decreases. Developed countries are developing railway transport based on a digital environmental model. Countries such as Japan, Germany, Sweden, and South Korea have achieved advanced results in environmental efficiency by practically implementing the smart railway concept. For example, the EcoRail IT System developed by Deutsche Bahn AG in Germany reduces 250 thousand tons of CO<sub>2</sub> emissions annually by recovering train braking energy.

In Japan's experience, an artificial intelligence-based traffic management system applied by JR East company reduced train energy consumption by 17 percent. The UNECE report shows that these experiences are being viewed as the main tool of IT technologies in increasing the sustainability of the transport system.[7] In the Republic of Uzbekistan, environmental sustainability and digitalization are designated as priority directions in transport policy. Within the framework of the Digital Railway concept being implemented by Uzbekistan Railways JSC, energy-efficient management systems, automated dispatching centers, and environmental monitoring platforms are being created. These systems provide the opportunity to reduce train energy consumption, optimize maintenance processes, and monitor



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emissions.[8] Furthermore, projects to electrify railway networks are being implemented in the country based on the Green Economy concept. The efficiency of this process is being increased through digital management systems. Training specialists in digital skills and expanding IT infrastructure ensures sustainable results in this direction. The implementation of IT technologies in the railway sector increases not only environmental but also economic and social efficiency. According to Blanchard, intelligent management systems optimize transport movement, reduce accident risk, extend maintenance periods, and minimize errors arising from the human factor. This reduces technical costs in the long term and lowers the level of environmental risk.[9] The increase in environmental efficiency improves social welfare through protecting public health and reducing noise and air pollution. In this way, IT technologies manifest as a tool harmonizing the three pillars of sustainable development in the railway sector—economic, environmental, and social sustainability.

### Conclusion:

The above analyses demonstrate that implementing IT solutions in railway transport is an important factor in forming sustainable transport infrastructure. Through intelligent monitoring, artificial intelligence, digital dispatching, and energy management systems, environmental burden decreases, energy efficiency increases, and the transport system becomes safer and more efficient. Reforms in this direction in Uzbekistan's conditions serve to bring the national transport system closer to global environmental standards. In the future, it will be possible to further strengthen the sustainability and environmental efficiency of transport infrastructure by expanding digital solutions in railway networks, developing international scientific cooperation, and implementing environmental innovations in practice.

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