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Digital Control System for Electric Transport

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Abstract: The purpose of this research is to analyze digital technologies for managing electric transport, with a focus on their efficiency, safety, and integration into urban infrastructure, and to develop a digital control system for electric transport. The authors propose a concept of a digital management system characterized by the creation of a corporate digital control environment based on Internet of Things (IoT) technologies, artificial intelligence (AI), big data analytics, and intelligent control systems, coordinated by the Situation and Information Center of the Ministry of Transport of the Russian Federation. The methodological framework includes systems, comparative, and structural-functional analysis, as well as modeling. Key directions and challenges of digitalization in the Russian transport sector have been identified, including technological dependence on imports, regional disparities, and low digital literacy. The study presents a model of a digital control system for electric transport, incorporating real-time monitoring, predictive maintenance, adaptive traffic management, and cybersecurity. Special attention is given to the principles of Industry 5.0, particularly sustainability and human-centricity. The study concludes that a comprehensive approach integrating technological, organizational, and educational measures is required for the effective implementation of digital management systems in electric transport across Russia.

1 INTRODUCTION

Currently, the global community is witnessing a steady transition towards environmentally friendly electric transport. This trend is driven by increasing urbanization, the necessity of reducing carbon emissions, and the adoption of modern environmental standards. According to the International Energy Agency (IEA), the global electric vehicle (EV) fleet may exceed 125 million units by 2030. To support this development, the Government of the Russian Federation is implementing state programs aimed at achieving the national goal of creating a safe and comfortable living environment by 2030. One such initiative is the Moscow City Program “Development of the Transport System” (Government of Moscow, 2024), which promotes the expansion and integration of electric buses into the urban surface transport network, the development of charging infrastructure, and the modernization of metro rolling stock. As of January 1, 2024, the Moscow region recorded 8.6 million vehicles. That 1.5 times is more than in 2010. However, the number of trips per vehicle decreased by 38%, indicating a growing preference for public transportation, even among private vehicle owners. Managing such a large vehicle fleet without digital platforms would be inefficient and unsafe, especially considering the need for technical monitoring, charging schedule planning, and movement safety assurance (Pokrovskaya, Fedorenko, 2020).

Digitalization of the transport sector is recognized as a strategic priority in Russian state policy. Within the framework of the national program "Digital Economy of the Russian Federation," a key direction is the development of intelligent transport systems and the digital transformation of urban mobility (Government of the Russian Federation, 2024). The Ministry of Transport is currently implementing the “Digital Management of the Transport System of the

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Russian Federation" project, which utilizes IoT, databases, artificial intelligence, and GPS technologies to enhance the efficiency and sustainability of the infrastructure (Ministry of Transport of the Russian Federation, 2024). Figure 1 illustrates the classification of key digital technologies applied in electric transport control.

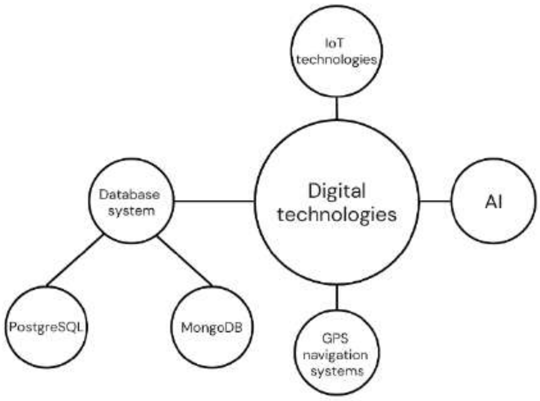

Figure 1: Classification of digital technologies in electric transport control.

The control of electric transport imposes specific requirements on digital solutions that differ significantly from those used in conventional automotive transport. The need to monitor energy supply, analyze real-time telemetry data, and maintain service cycles necessitates both the adaptation of existing tools and the development of specialized platforms (Zvezdina, Shokova, Marchenko, 2023).

In Russian practice, such solutions are being implemented in several key areas. For example, the company Cognitive Pilot develops advanced driver-assistance systems (ADAS) based on computer vision and machine learning technologies (Cognitive Pilot, 2024). The national ERA-GLONASS system enables the collection of telemetry data, integration with emergency services, and the creation of a centralized transport event database. The Mosgortrans charging infrastructure management system utilizes intelligent algorithms to optimize charging schedules, reduce stress on the power grid, and ensure uninterrupted control of electric buses under conditions of dense urban traffic.

The problems of digitalization of electric transport control have been dealt with by such Russian authors as O.D. Pokrovskaya, R.V. Fedorenko, E.R. Khramtsova, M.Yu. Zvezdina, Yu.A. Shokova, Yu.A. Marchenko, N.F. Soldatova, S.B. Ilyashenko, and N.V. Rebrikova (Pokrovskaya et al., 2020; Zvezdina et al., 2023; Soldatova et al., 2020).

In connection with the analysis, we can say that the digitalization process has already been launched throughout Russia. This process also applies to the transport field. In connection with the analysis, we can say that the digitalization process has already been launched throughout Russia, including in the transport field. The control of electric transport requires specialized digital platforms that address energy supply, telemetry, and maintenance needs. Integration of AI, IoT, and big data technologies improves control efficiency, safety, and sustainability. However, challenges remain, such as cybersecurity risks, lack of solution typology, limited empirical data, dependence on imports, regional digital inequality, and low digital literacy.

The study includes the following sections: introduction, materials and methods, results, discussion, conclusion and list of references.

2 MATERIALS AND METHODS

The scientific novelty of this research lies in the development of a digital control system for electric transport, which differs from existing frameworks through the formation of a corporate digital control environment. This environment is based on technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, and intelligent control systems, all coordinated by the Situation and Information Center of the Ministry of Transport of the Russian Federation (Federal State Budgetary Institution "Situation and Information Center of the Ministry of Transport of the Russian Federation" (FSBI "SIC of the Ministry of Transport of Russia")). An additional aspect of novelty is the alignment of the proposed system with the principles of Industry 5.0, particularly its emphasis on sustainability, technological sovereignty, and the human factor in the digitalization of transport systems.

Primary data sources included official government documents (strategies, programs, digitalization roadmaps), practical case studies of digital platform implementations in Moscow, and scholarly publications from both domestic and international journals.

The main objective of the study is to develop a system for electric transport control that includes the establishment of a digital control environment.

To achieve this goal, the following tasks were completed:

- level of digital technology integration in global and Russian transport sectors was analyzed;

- legal and regulatory framework for digitalization in the transport sector of the Russian Federation was reviewed;
- main challenges hindering the digitalization of electric transport in Russia were identified;
- model for a digital control system for electric transport was developed.

Object of study is the electric transport.

Subject of study is the digital control system for electric transport.

The scientific novelty consists in designing a digital control system for electric transport that creates a logistics-oriented corporate digital control environment. This environment is enabled by such technologies as IoT, AI, big data, and intelligent control systems, with control coordination provided by the Ministry of Transport’s Situation and Information Center. A further innovation is the integration of Industry 5.0 principles, focusing on sustainable development, technological independence, and human-centricity in the digital transformation of transport.

The methodological apparatus includes dialectical scientific inquiry and domain-specific research methods such as analysis, synthesis, comparison, logical and system-structural analysis, formalization, legal document analysis, and modeling.

A comparative analysis was also conducted to identify the strengths and limitations of current implementations. Furthermore, institutional and technological issues, such as dependence on imported technologies, lack of system integration, and digital illiteracy, were identified based on policy documents and empirical observations.

3 RESULTS

Despite the significant progress in implementing digital technologies for electric transport control, new challenges, such as those related to sanctions, require the mobilization of resources for import substitution and the development of advanced domestic technologies. These efforts aim to enhance user comfort while minimizing the human factor in control decision-making.

Table 1 presents the distinctive features and areas of application for key digital technologies in the control of electric transport:

Table 1: Key digital technologies in electric transport control: features and application areas.

Technology	Key feature	Application area
IoT Technologies	Real-time battery charge monitoring	Monitoring battery levels of electric buses for route planning, charging, and preventing vehicle downtime
	Technical condition monitoring of units and components	Monitoring brakes, motors, and batteries using sensors to prevent failures and schedule maintenance
	Environmental analysis via surveillance cameras	In-cabin monitoring for safety, anomaly detection, and passenger service improvement
	Contactless payment	Speeding up boarding, improving convenience and payment security (e.g., Face Pay in the metro)
	Real-time traffic light control	Optimizing electric bus flow, reducing delays and idle time at intersections
	Coordination of charging station controls	Managing charging infrastructure to reduce charging time and balance station loads
Databases	Volume and scalability of data	Fleet management, analysis of large-scale vehicle movement and technical data
	Real-time data processing	Monitoring battery status, charging stations, and transport flows in real time
	Integration with other systems	Interconnection with GIS, charging infrastructure,

		billing and accounting systems
	Analytics and forecasting	Predictive maintenance, route and energy consumption optimization
	Safety data processing and failure prevention	Accident monitoring, fault detection, and system reliability assurance
Artificial Intelligence	Automated decision-making and forecasting.	Route planning and traffic safety
	Big data processing and analysis	Traffic modeling, congestion forecasting, situational analysis

To address the aforementioned challenges, the government is prioritizing support for initiatives that accelerate the goals of digital transformation. One such initiative is the project “Digital Control of the Transport System of the Russian Federation”, which aims to create a unified national transport control center coordinated through the Situation and Information Center. The key objective is to improve the efficiency and safety of the national transport system through the integration of modern digital technologies. Table 2 outlines the main areas and functions of this national project.

Despite notable progress in the digitalization of electric transport control in the Russian Federation, a number of systemic challenges continue to hinder the full realization of digital transformation. Chief among these is the high degree of dependence on foreign technologies. Most of the solutions currently used in measurement systems, artificial intelligence, and IoT platforms rely on imported components, which poses critical risks under the conditions of external economic pressure and restrictions.

Table 2. Key directions and functions of the “Digital control of the transport system of the Russian Federation” project.

Key direction	Function
Creation of the Situation and Information Center of the Ministry of Transport	Real-time monitoring and control of transport flows to ensure prompt responses to changes in the transport environment
Online monitoring of transport vehicles, including unmanned systems	Tracking both conventional and unmanned transport to improve safety and optimize logistics
Online monitoring of transport infrastructure facilities	Observation and data analysis systems for roads, bridges, terminals, etc., enabling timely maintenance and repairs
Integration with the national data management system	Unifying transport data with other governmental systems to enhance inter-agency coordination and service quality

Based on the analysis of the current state of digitalization in the transport sector, the identified challenges, and the demands of urban mobility development, as well as the core directions of the national project “Digital Control of the Transport System of the Russian Federation”, a model for a digital control system for electric transport has been developed. This model is aimed at the integration of advanced digital technologies, the promotion of sustainable development, and the enhancement of service quality in urban mobility. Figure 2 illustrates the structure of the proposed system.

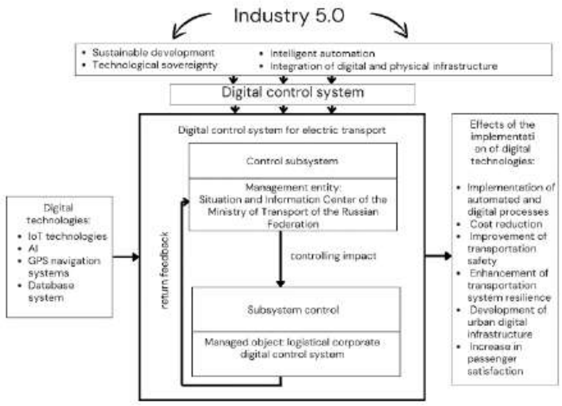

Figure 2: Model of the digital control system for electric transport.

The model presented in Figure 2 is designed in accordance with the principles of Industry 5.0. At its core is a digital control system that ensures seamless interaction between the control subsystem and the controlled transport assets. Industry 5.0 emphasizes the synergy between technology and human values, prioritizing sustainable development, intelligent automation, technological sovereignty, and the integration of physical and digital infrastructures.

In the context of electric transport control, this implies the creation of systems focused not only on control efficiency, but also on user convenience, safety, and environmental responsibility. Coordination is carried out by the Situation and Information Center of the Ministry of Transport of the Russian Federation.

The system actively utilizes cutting-edge digital technologies, including IoT solutions, artificial intelligence, GPS navigation systems, and structured databases. The implementation of these technologies aims to automate control processes, enhance safety, increase the resilience of the transport system, support the development of urban digital infrastructure, and improve overall passenger satisfaction.

Furthermore, the model incorporates feedback mechanisms between control entities and supervisory bodies to ensure high adaptability and responsiveness across the entire transport network.

4 DISCUSSION

Despite the significant achievements in the digitalization of electric transport control in the Russian Federation, several systemic challenges persist, hindering the full realization of digital transformation goals. Foremost among these is the continued dependence on foreign technologies. A substantial portion of the solutions employed in measurement systems, artificial intelligence, and IoT platforms rely on imported components, creating critical vulnerabilities under external economic pressures and geopolitical restrictions (Sidorov, 2022).

Another major issue is the insufficient integration of digital systems with existing urban infrastructure. Although steps are being taken toward building a unified digital ecosystem, practical implementation is hampered by data synchronization difficulties between transport operators and other municipal services.

Moreover, digitalization is more prevalent in major metropolitan areas, whereas the level of automation and adoption of digital solutions in regional cities remains relatively low (Rudenko, Zinoviev, 2021). This imbalance in coverage impedes the formation of a coherent, nationwide transport environment (Soldatova, Rebrikova, 2021).

A significant obstacle also lies in the shortage of qualified personnel in the fields of information technology, transport systems, and big data analytics. Training programs are currently fragmented and fail to meet the industry's comprehensive needs. In addition, public awareness regarding available digital services remains low. Applications, online payments, and route monitoring systems are still underutilized or unavailable to many citizens.

These challenges define a set of critical requirements for the design and implementation of digital control systems for electric transport in Russian cities:

- ensuring stable passenger flow through adaptive route regulation in response to real-time demand and peak load periods;
- improving passenger comfort and awareness via online displays, mobile applications with real-time schedules, load levels, and onboard conditions;
- forecasting system loads using external factor analysis (weather conditions, time of day, public events), enabling proactive fleet adjustments;
- rapid emergency response through automatic incident detection and integration with emergency services;
- continuous real-time monitoring of the technical condition of rolling stock, charging stations, and infrastructure facilities;
- integration with urban digital systems such as geographic information services (GIS), utilities, and public safety platforms;
- achieving import independence and robust cybersecurity through the deployment of domestically developed technologies;
- scalable system architecture capable of adaptation to both large cities and small or medium-sized municipalities.

Based on these criteria, the following strategic priorities for the development of digital electric transport control systems in Russia can be outlined:

1. Import substitution and advancement of domestic technologies. Efforts must focus on supporting initiatives that foster the creation of national platforms in the domains of AI, IoT, and sensor technologies, ensuring technological sovereignty for the transport sector. In parallel, new solutions should be developed to minimize the human factor in control decision-making.

2. Integration with urban infrastructure and formation of a digital ecosystem. It is essential to enhance coordination among transport, energy, utility, and information systems within cities to establish a unified digital environment. Particular attention should be given to regions with low levels of digitalization.

3. Development of human capital. Training programs for professionals in related fields, such as IT, transport planning, data analysis, must be prioritized at both university and industry levels.

4. Increasing public digital literacy. Expanding public information campaigns and improving user interfaces of digital services will increase passenger engagement and the overall effectiveness of digital solutions.

5. Implementation of key directions under the “Digital Control of the Transport System of the

Russian Federation" project. The creation of the Ministry of Transport's Situation and Information Center plays a central role, ensuring real-time monitoring and responsive control of transport flows. The project also entails the deployment of online monitoring systems for rolling stock (including autonomous vehicles) and infrastructure, as well as integration with the national data management system.

6. Enhancement of applied digital solutions. IoT technologies for battery monitoring, technical diagnostics, and passenger behavior tracking, as well as contactless payment, smart traffic light automation, and charging station coordination, should be developed in parallel with analytics, database management, and machine learning algorithms. This will enhance control controllability while optimizing costs and energy consumption.

These strategic priorities form the foundation for a sustainable and human-centered digital transformation of electric transport. Their consistent implementation will ensure the creation of an integrated, secure, and adaptable control system aligned with the technological and social imperatives of Industry 5.0.

5 CONCLUSIONS

The transition to a sustainable and efficient model of electric transport control within the framework of Industry 5.0 requires not only technological innovation, but also institutional transformation, human capital development, and a fundamental rethinking of the human role in digital environments. The principles of Industry 5.0, such as human-centricity, sustainability, technological sovereignty, and adaptive design, must serve as the foundation for the development of digital transport systems.

Digital control of electric transport is no longer merely a tool for improving efficiency; it is becoming the core infrastructure for building inclusive, environmentally responsible, and technologically independent urban mobility. The deployment of intelligent monitoring systems, predictive maintenance, adaptive traffic control, energy-efficient algorithms, and IoT- and AI-based solutions must be accompanied by the formation of a digital ecosystem designed for comfort, safety, and the real needs of citizens.

The experience of major cities such as Moscow and St. Petersburg confirms the effectiveness of integrated digital platforms. However, to scale the successes nationwide, current challenges must be addressed, namely, dependence on imported technologies, fragmented system integration, workforce shortages, and low levels of digital literacy.

In the long term, the digital control system for electric transport must be regarded as a cross-cutting socio-technological platform embedded within the broader urban environment. Only the synergy of technological, organizational, educational, and human-centered approaches will enable the full realization of Industry 5.0 principles and the construction of a resilient, adaptive, and user-oriented transport system for the future.

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