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*Tsyhankov S.***TRENDS AND DIRECTIONS IN THE DEVELOPMENT OF DIGITAL TECHNOLOGIES
IN THE TRANSPORT MARKET USING ARTIFICIAL INTELLIGENCE****Ukrainian State University of Science and Technology, Dnipro, Ukraine**

The article explores the directions of development of digital technologies of the transport market using artificial intelligence in the context of the emergence of a digital economy. It is substantiated that the integration of intelligent transport systems, digital platforms, big data and the Internet of Things forms a transition from static transport management to dynamic, data-driven models that increase the efficiency of the organization of transport processes, the transparency of logistics and the quality of management decisions. The key effects of the use of AI in transport are identified, in particular, demand forecasting, optimization of routes and resources, increasing safety and supporting sustainable development by reducing congestion and unproductive costs. Special attention is paid to the problems and limitations of the implementation of intelligent solutions, including insufficient development of digital infrastructure, data fragmentation, high investment costs, regulatory uncertainty and cybersecurity risks. It is concluded that the further development of the digital transport market requires a comprehensive approach to the formation of integrated digital ecosystems, improving the regulatory environment and developing human resources, which creates the prerequisites for increasing the competitiveness of the transport industry. The effectiveness of the digital transformation of transport largely depends on the coordinated implementation of interconnected technologies and the formation of a single information space for transport market participants. The model can be used as an analytical basis for systematizing the directions of digital development and substantiating management decisions regarding the implementation of intelligent technologies in the transport industry.

Keywords: digitalization of transport, transport market, artificial intelligence; intelligent transport systems, big data, digital platforms, Mobility as a Service, cybersecurity.

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Problem statement

The digital transformation of the transport market requires the implementation of artificial intelligence and modern digital technologies to enhance the efficiency, safety, and transparency of transportation. At the same time, their practical application is constrained by insufficient development of digital infrastructure, high costs, regulatory uncertainty, and

cybersecurity risks, which necessitates identifying priority directions and conditions for the effective implementation of AI in the transport sector.

Analysis of recent research and publications

Contemporary studies emphasize that the digitalization of the transport market is an irreversible trend, with key development directions including ITS, digital platforms, Big Data, IoT, and mobility service

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Tsyhankov S.

models. Researchers highlight that artificial intelligence enhances these processes through forecasting, route optimization, improved safety, and support for sustainable development; however, implementation is hindered by infrastructural, financial, regulatory, and cybersecurity barriers. Therefore, both domestic and foreign scientific works were analyzed, in particular those by O. V. Zaleskyi [13], S. S. Tsyhankov [11,12], O. V. Tarasenko [5], V. O. Zadoja [1,2], O. M. Lozhachevska [6], I. B. Turkin [7], S. I. Hrytsenko [8], A. Yu. Kovalov [10], and N. V. Suduk [9].

Purpose and objectives of the article

The purpose of the article is to determine the main directions of development of digital technologies in the transport market using artificial intelligence and to assess their impact on the efficiency and safety of transportation.

Main material of the study

In the modern conditions of the digital transformation of the economy, enterprises are forced to constantly adapt to new approaches and management technologies.

The active implementation of digital solutions significantly changes traditional models of organization, particularly in the transport sector, which is characterized by high dynamism, complexity of logistics processes, and integration with global markets. Innovative management models formed under digitalization are based on the use of such modern technologies as artificial intelligence, Big Data, the Internet of Things (IoT), blockchain, cloud computing, and mobile applications [13].

The application of these technologies is aimed at increasing the efficiency, flexibility, and adaptability of enterprises, as well as improving existing and forming new business processes in conditions of rapid environmental changes. Digital management provides оперативний access to relevant information, improves internal and external communication, facilitates automation of routine operations, and increases the transparency of management processes. As a result, this allows transport enterprises to make managerial decisions more quickly, reduce costs, improve service quality, and effectively respond to market challenges [10].

The transport market is a complex socio-economic system that ensures the mobility of freight and passenger flows and creates the preconditions for the sustainable development of national and global economies. Within the framework of the digital economy formation, there is a significant transformation of its functioning mechanisms due to the implementation of digital platforms, automated management systems, and intelligent analytical tools.

These changes contribute to improving the efficiency of transport processes and the quality of managerial decisions [5].

It should be emphasized that the formation of the digital economy is based on the development of an information environment characterized by timeliness, reliability, and accessibility of data. Under digitalization, communication and transactional processes move into the online space, ensuring continuous interaction between market participants and consumers. The central element of this model is the customer, whose needs, expectations, and digital behavior shape demand and determine the directions of business process transformation. At the same time, the mechanisms of influence on consumers are changing: the choice of goods and services is increasingly based on digital information channels, online reputation, recommendation services, and internet advertising. Accordingly, the role of direct “seller–customer” contact decreases, while the importance of digital platforms and analytical tools increases, enabling the identification of consumer preferences and improving the validity of managerial decisions [1].

Under these conditions, the digitalization of the transport market involves the comprehensive integration of information and communication technologies at all stages of transport activity – from strategic planning and organization of transportation to operational control and analysis of system performance. The active use of digital technologies creates opportunities for innovative development of the sector, contributes to improving transportation safety, resource efficiency, and environmental sustainability of transport infrastructure. In modern conditions, the transport market is increasingly forming as a dynamic intelligent ecosystem, the development of which is driven by the implementation of IoT, artificial intelligence, and platform solutions. This ensures efficient processing of large volumes of data, increases the effectiveness of transportation, enhances transparency of logistics processes, automates operations, and contributes to the creation of personalized transport services.

The transformation of the transport market under digitalization leads to the gradual replacement of traditional transportation models with digital platforms that provide real-time management of logistics processes, route optimization, reduction of operational risks, and enhanced control over the movement of goods and passengers based on data, automated systems, and artificial intelligence algorithms [6]. Thus, digital transformation changes not only the nature of the transport market but also approaches to its

functioning and management, making digital technologies a key factor in improving the efficiency of transport systems.

A key role in improving the efficiency of transport systems is played by intelligent transport systems (ITS), which are based on sensor technologies, video surveillance, and data analytics. The use of such systems ensures optimization of traffic flows, reduction of congestion, and increased capacity of transport infrastructure through adaptive real-time traffic management [2]. In addition, ITS create conditions for prioritizing public transport and emergency services, thereby increasing the overall efficiency of urban transport systems. Another important tool of transport digitalization is the use of Big Data and predictive analytics: the analysis of large volumes of information on traffic flows, weather conditions, seasonal demand fluctuations, and user behavior allows forecasting demand for transport services and adjusting transportation volumes according to real conditions, while predictive maintenance approaches enable early detection of potential failures, minimizing downtime and repair costs.

At the same time, the Internet of Things (IoT) and telematics systems provide continuous communication between elements of the transport network – vehicles, infrastructure facilities, and logistics

centers. This enables continuous monitoring of transportation parameters, including cargo location, transportation conditions, and resource consumption levels. The use of telematics contributes to route optimization, improved driving discipline, and reduced fuel consumption, which has positive economic and environmental effects.

Further development of digital technologies in the transport sector is associated with the spread of digital platforms and the concept of Mobility as a Service (MaaS), which integrate different modes of transport into a single information environment. Such solutions enable the creation of multimodal routes, simplify access to transport services, and improve user convenience, contributing to increased demand and more efficient use of transport infrastructure. Along with this, a separate direction of transport digitalization is the development of autonomous vehicles and unmanned aerial systems, which are gradually changing approaches to transportation and logistics organization. The use of autonomous solutions allows increasing the intensity of vehicle utilization, reducing dependence on the human factor, and optimizing delivery processes, particularly at the "last mile" stage [7].

To summarize the main directions of transport digitalization, it is advisable to systematize their technological basis and expected effects (Table).

Table

Identification of key digital technologies and the effects of their use

Development direction	Technological basis	Functional effect	Economic and social outcome
Intelligent Transport Systems (ITS)	Sensors, Big Data, AI	Real-time traffic management	Reduction of congestion, increased capacity
Digital transport platforms	Cloud technologies, optimization algorithms	Coordination of carriers and customers	Reduction of transaction costs, market transparency
IoT and telematics	Sensors, GPS, online monitoring	Monitoring of vehicle and cargo conditions	Minimization of downtime, cost reduction
Predictive analytics	Machine learning	Demand and technical condition forecasting	Resource optimization, reduction of accidents
Autonomous transport	AI, computer vision	Automation of transportation	Increased safety, reduced human factor

Source: developed by the author

The proposed model of the effects of digitalization of the transport market (Fig.) reflects the impact of digitalization through the integration of key digital

technologies, which collectively form the results of digital transformation, and their interaction ensures a positive impact on the transport market.

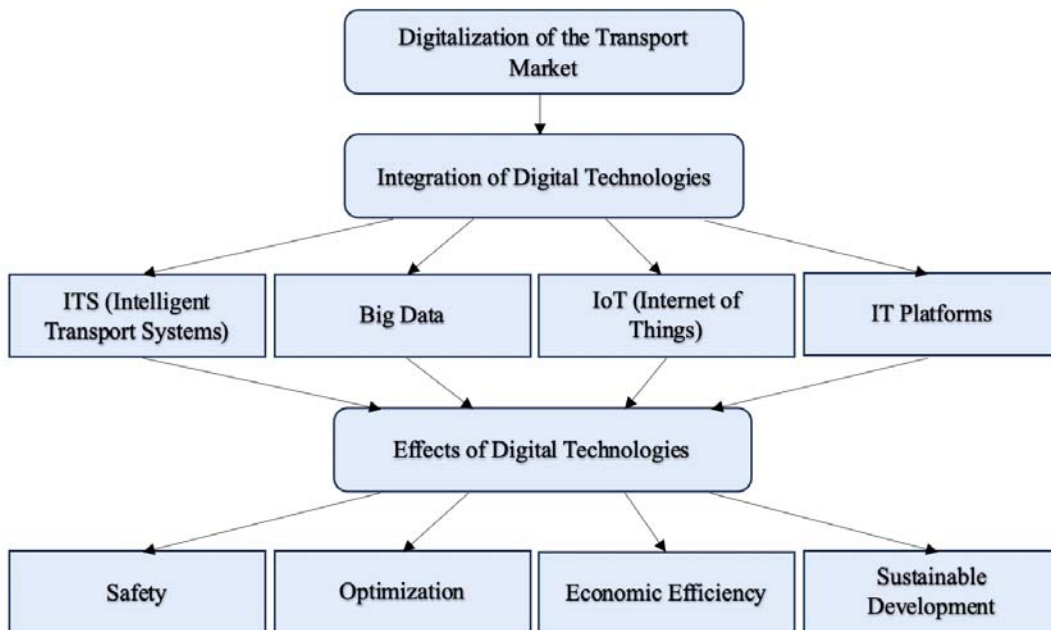


Fig. Model of the Effect of Digitalization of the Transport Market

Source: developed by the author

The effects reflected in the proposed model of transport market digitalization have a comprehensive impact on the functioning of the transport system, its performance, and competitiveness.

Safety is one of the key outcomes of implementing digital technologies and artificial intelligence in the transport sector. The use of intelligent transport systems, video analytics, sensor networks, and machine learning algorithms enables continuous monitoring of traffic flows, identification of potentially dangerous situations, and forecasting of risks before they occur. This contributes to reducing road accidents, increasing the reliability of transportation, and enhancing the protection of passengers and cargo. Automation of traffic management processes and the reduction of the human factor significantly improve the stability of transport system operations. At the same time, an important aspect is ensuring cybersecurity, as the integration of digital platforms, telematics systems, and IoT solutions increases the risks of cyberattacks and unauthorized access to data. Therefore, the implementation of modern information security tools, cybersecurity systems, and access management is a necessary condition for the safe functioning of a digitalized transport infrastructure.

Optimization of transport and logistics processes is achieved through the use of big data, analytical platforms, and the Internet of Things, which ensure real-time data collection and processing. This enables efficient route planning, avoidance of infrastructure overload, reduction of delivery time, and mitigation of congestion. Optimization also includes traffic flow management, synchronization of different modes of transport, and more rational allocation of resources, which increases the overall productivity of the transport system.

Economic efficiency is reflected in reduced costs for operating vehicles, maintaining infrastructure, and organizing transportation processes. Through automation, the implementation of digital platforms, and analytical tools, enterprises can minimize unproductive costs, reduce downtime, and improve resource utilization efficiency. In addition, digitalization enhances market transparency, reduces transaction costs, and improves interaction among participants in the transport process. As a result, this ensures increased competitiveness of transport enterprises and their investment attractiveness [3].

Sustainable development is an important consequence of the implementation of digital technologies in the transport sector. Route optimization

and congestion reduction contribute to lowering emissions and improving energy efficiency of transportation. The use of intelligent management systems allows for more rational resource use, reduces environmental impact, and supports environmentally oriented solutions. Furthermore, digitalization creates conditions for the development of new mobility models, including shared mobility services and the Mobility as a Service (MaaS) concept, contributing to a more balanced and sustainable transport system.

In summary, digital technologies and artificial intelligence significantly transform traditional models of transport system operation, enabling the transition from static management to dynamic, data-driven approaches. This creates the foundation for improving efficiency, safety, and sustainability of the transport market.

Further digitalization of the transport market is developing towards the intellectualization of management, automation of processes, and the formation of integrated digital ecosystems. A key driver of these changes is the implementation of artificial intelligence, which enables the transition from traditional management models to dynamic, adaptive, and data-driven solutions. In this context, intelligent transport systems combine sensor networks, data collection and analysis systems, and AI algorithms to improve traffic management efficiency, while digital platforms integrate participants in logistics processes into a unified information environment. Platform-based solutions optimize interaction between carriers, customers, and service users, increase operational transparency, and reduce transaction costs, while real-time logistics management promotes more efficient use of transport resources and improves service quality. A distinctive feature of the current stage is the focus on processing large volumes of data from infrastructure, vehicles, and user devices, which enhances the complexity of transport network management and helps reduce the environmental impact of transport [11].

Artificial intelligence also serves as a key tool for optimizing transport processes, as it enables the analysis of complex multi-factor systems and decision-making based on predictive models. Machine learning algorithms are used to optimize routes, reduce travel time, and improve infrastructure utilization efficiency, taking into account changes in demand and external conditions. An important direction is improving safety: intelligent algorithms allow for the detection of potentially dangerous situations, forecasting accident risks, and ensuring timely responses, thereby reducing the number of road accidents and increasing network reliability [8]. The use of AI is also significant from the perspective of sustainable development: traffic

optimization, congestion reduction, and rational route planning help reduce emissions and improve energy efficiency of transportation, while the integration of environmental indicators into decision-making processes meets modern requirements for transport sector development. In summary, the combination of intelligent transport systems, digital platforms, and AI algorithms for optimization, safety enhancement, and sustainability forms the basis for increasing the competitiveness of the transport market and its adaptation to the challenges of the digital economy [12].

At the same time, the active implementation of artificial intelligence and digital technologies in the transport sector is accompanied by a set of challenges and limitations that require separate analysis from the perspectives of economic feasibility, legal regulation, and human resource support. One of the key barriers is the insufficient level of digital and ICT infrastructure required for the full functioning of intelligent transport systems, as well as the fragmentation of information solutions and the lack of unified data exchange standards [4]. Additionally, high investment costs for infrastructure modernization, equipment procurement, software development, and cybersecurity remain a restraining factor, especially for small and medium-sized enterprises, raising issues of return on investment in digital projects [8]. Important limitations also include regulatory and ethical aspects of AI application (regulation of autonomous transport, personal data processing, liability for algorithmic decisions), as well as cybersecurity concerns, since increasing digitalization raises the vulnerability of transport infrastructure to cyberattacks and unauthorized data access [9]. A significant factor is also the shortage of qualified specialists and insufficient digital competencies of personnel, which may reduce the effectiveness of integrating intelligent solutions into practical operations.

Despite these barriers, the prospects for the development of the digital transport market are associated with the formation of integrated digital ecosystems that combine intelligent transport systems, digital platforms, and IoT technologies. Such integration ensures real-time traffic management, increases transparency of transportation, and creates conditions for real-time logistics, while also strengthening the environmental component through improved energy efficiency and reduced negative environmental impact.

Thus, digital technologies and artificial intelligence significantly transform traditional models of transport system functioning and ensure the transition to dynamic, data-driven management, creating the prerequisites for improving efficiency,

safety, and sustainable development of the transport market.

Conclusions

As a result of the study, the main directions of development of digital technologies in the transport market using artificial intelligence were analyzed. It was established that the digital transformation of the transport sector is one of the key factors in improving the efficiency of transport systems in the context of the digital economy. The integration of information and communication technologies, big data, the Internet of Things, and artificial intelligence algorithms contributes to the optimization of transport flows, improvement of transportation safety, and enhancement of logistics management processes.

The study determined that the use of intelligent transport systems, digital platforms, and AI-based analytical tools enables more efficient management of transport infrastructure, reduces transportation costs, and improves the quality of transport services. At the same time, it was found that the implementation of such technologies is accompanied by several problems and limitations, including insufficient digital infrastructure development, significant financial costs, regulatory barriers, as well as cybersecurity risks and a shortage of highly qualified specialists.

The practical significance of the obtained results lies in the possibility of using the proposed approaches to transport market digitalization to improve the efficiency of transport system management, optimize logistics processes, and develop intelligent transport services. The proposed directions for the development of digital technologies can be used by transport enterprises, public authorities, and other stakeholders in the transport sector when developing strategies for transport digital transformation.

The scientific significance of the study lies in the systematization of theoretical approaches to the development of digital technologies in the transport market and the identification of key directions for the use of artificial intelligence in the transport sector. The obtained results expand the scientific understanding of transport digitalization processes and can serve as a basis for further research in the field of intelligent transport systems.

Prospects for further research are related to a more detailed study of the economic efficiency of implementing artificial intelligence technologies in the transport sector, analysis of the impact of digital platforms on the development of the transport market, as well as the exploration of possibilities for integrating intelligent transport systems with the concepts of “smart city” and sustainable transport infrastructure development.

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НАПРЯМИ РОЗВИТКУ ЦИФРОВИХ ТЕХНОЛОГІЙ ТРАНСПОРТНОГО РИНКУ З ВИКОРИСТАННЯМ ШТУЧНОГО ІНТЕЛЕКТУ

Циганков С. С.

У статті досліджено напрямки розвитку цифрових технологій транспортного ринку з використанням штучного інтелекту в умовах становлення цифрової економіки. Обґрунтовано, що інтеграція інтелектуальних транспортних систем, цифрових платформ, великих даних та інтернету речей формує перехід від статичного управління перевезеннями до динамічних, даних-орієнтованих моделей, що підвищують ефективність організації транспортних процесів, прозорість логістики та якість управлінських рішень. Визначено ключові ефекти застосування ШІ у транспорті, зокрема прогнозування попиту, оптимізацію маршрутів і ресурсів, підвищення безпеки та надійності сталого розвитку через зменшення заторів і непродуктивних витрат. Окрему увагу приділено проблемам і обмеженням впровадження інтелектуальних рішень, серед яких недостатній розвиток цифрової інфраструктури, фрагментованість даних, високі інвестиційні витрати, нормативно-правова невизначеність і ризики кібербезпеки. Зроблено висновок, що подальший розвиток цифрового транспортного ринку потребує комплексного підходу до формування інтегрованих цифрових екосистем, удосконалення регуляторного середовища та розвитку кадрового потенціалу, що створює передумови для підвищення конкурентоспроможності транспортної галузі. Результативність цифрової трансформації транспорту значною мірою залежить від узгодженого впровадження взаємопов'язаних технологій та формування єдиного інформаційного простору для учасників транспортного ринку. Модель може бути використана як аналітична основа для систематизації напрямів цифрового розвитку та обґрунтування управлінських рішень щодо впровадження інтелектуальних технологій у транспортній галузі.

Ключові слова: цифровізація транспорту, транспортний ринок, штучний інтелект; інтелектуальні транспортні системи, великі дані, цифрові платформи, Mobility as a Service, кібербезпека.

TRENDS AND DIRECTIONS IN THE DEVELOPMENT OF DIGITAL TECHNOLOGIES IN THE TRANSPORT MARKET USING ARTIFICIAL INTELLIGENCE

Tsyhankov S.*

Ukrainian State University of Science and Technology,
Dnipro, Ukraine

*e-mail: tsigankov.2000@gmail.com

Tsyhankov S. ORCID: <https://orcid.org/0000-0002-4268-9016>

The article explores the directions of development of digital technologies of the transport market using artificial intelligence in the context of the emergence of a digital economy. It is substantiated that the integration of intelligent transport systems, digital platforms, big data and the Internet of Things forms a transition from static transport management to dynamic, data-driven models that increase the efficiency of the organization of transport processes, the transparency of logistics and the quality of management decisions. The key effects of the use of AI in transport are identified, in particular, demand forecasting, optimization of routes and resources, increasing safety and supporting sustainable development by reducing

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