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ORIGINAL PAPER
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STUDY OF THE CONTEMPORARY TRENDS IN THE DEVELOPMENT OF TRANSPORT SYSTEMS OF THE UKRAINIAN RAILWAYS

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ABSTRACT

Motives: The development of development of informatization and digitalization is critical not only for improving the efficiency of transport operations, but also for promoting economic growth because digital and information technologies are becoming a key tool for managing technological processes and creating added value.
Aim: The aim is to study was to assess contemporary trends in the development of transport systems which rely on information and communication technologies and drive innovative development strategies in the Ukrainian railways.
Results: The study demonstrated that railway transport operations in Ukraine should be rationalized by transitioning to a new innovative model which incorporates high-tech infrastructure facilities and specialized complexes based on advances in scientific knowledge, modern technology, and equipment.

Keywords: digital transformation, digital advantages, innovative development, railway transport management

INTRODUCTION

Global scientific and technological trends of recent decades have significantly strengthened the role of transport systems in the socio-economic development of states, based on which the focus on the effective functioning of transport systems becomes one of the determining factors in the development of the economy of countries (Jabłoński & Jabłoński, 2020; Hryhorak et al., 2021; Fomin et al., 2021).

At the same time, the current stage of development of the world economy is based on the paradigm of establishing the principles of a new technological system and significantly increasing the importance of information (Zhu et al., 2018). This is explained by the fact that knowledge and information are one of the key elements of the digital economy, which today is reflected in all areas of economic activity and in the social sphere.

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Digitization in the railway industry is a complex, multifaceted process that affects various aspects of business processes and determines trends of the scientific and technological development. Despite the fact that the development and implementation of digital technologies and solutions is not a core activity for the most railway companies, development of appropriate spheres directly related to digitalization is today the main scientific and technological priority of the entire industry.

Currently, international organizations and associations exert significant influence upon the scientific and technological development of the railway industry. These organizations actively publish reports and White Papers which outline priority trends for the development of the railway industry, strategies for scientific and technological development, and note both challenges and the most successful products and technologies. Such documents directly affect the development vector of the entire industry. Among such documents, the following could be distinguished:

1. The White Paper of the European Commission "On the way to a single European transport space: Towards a competitive and resource-saving transport system" (hereinafter referred to as the EU White Paper);
2. White Paper issued by the Association of American Railroads "Putting technology to work. How Freight Rail Delivers the 21st Century" (hereinafter referred to as the White Paper of AAZ);
3. The EU Shift2Rail Railway Transport Development Program (hereinafter referred to as the EU Program).

Let us consider briefly the key trends of the scientific and technological development of the railway industry in accordance with the above-mentioned documents.

In the context of the digitalization of the railway industry, the EU White Paper highlights the following trends:

– Application of the improved intelligent railway network management systems and passenger mobility information system;
– Creation of an intelligent system for selling tickets for combined types of transport (arrangement of multimodal transportation);
– Rationalization of the traffic schedule and transport flows by using the TEN-T system (trans-European transport network) in the infrastructure;
– Use of intelligent transport systems;
– Deployment of the Galileo European global navigation satellite system;
– Application of detection and tracking technologies;
– Development of personal data privacy protection technology;
– Development of security technologies.

Among the priority areas of digitization, the White Paper of AAZ singles out:

– Real-time monitoring of infrastructure facilities;
– Use of innovative monitoring technologies to improve quality of the equipment maintenance;
– Prevention of errors caused by the human factor;
– Introduction of the special software for monitoring, planning and accounting of fuel and energy consumption;
– Use of intelligent sensors in the framework of the maintenance and repair processes;
– Application of big data and artificial intelligence technologies;
– Automation of production processes.

Among the priority areas of digitization in the EU Program, the following are indicated:

– Automated control of train traffic;
– Technologies of virtual coupling of railway cars;
– Ensuring cyber security;
– Use of "smart" stations;
– Introduction of "smart" energy supplies;
– Increasing compatibility of various services;
– Introduction of technologies for tracking the movement of trains, passengers and cargo;
– Creation of "service assistants" for travel.

It is worth noting that the leading EU and US railway companies are also implementing actively their own digital development strategies while identifying various advanced digital developments as their own priorities of the scientific and technological

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development. However, the mentioned strategies largely overlap and correlate with the above-mentioned documents.

At the same time, at the current stage of the development of railway transport in Ukraine, little attention is paid to the formation of programs, concepts and strategies for the development of information and digital technologies in the arrangement of railway transport (Fesovets et al., 2019).

The only hint at the improvement of existing information technologies in the transport is reflected in the Concept of the Development of the Digital Economics and Society in Ukraine for 2018–2020 (Verkhovna Rada of Ukraine, 2018a) and in the National Transport Strategy of Ukraine for the period until 2030 (Verkhovna Rada of Ukraine, 2018b). Document (Verkhovna Rada of Ukraine, 2018a) characterizes the plan of digital transformation measures, including those for transport; however, specific measures are not specified which would take into account specifics of the railway industry functioning, and this requires further studies. According to (Verkhovna Rada of Ukraine, 2018b), in the context of innovative development of the transport industry and the involvement of global investment projects, namely, introduction of integrated information systems for passengers and cargo owners, it is provided:

1. Implementation of the latest technologies and information support of transportation, in particular by creating a single information system of technological interaction of various types of transport (railway, water, automobile, and aviation), cargo owners, forwarders, and state control bodies at transport and checkpoints;
2. Implementation of innovative solutions and best global practices, in particular joint customs and border control during customs and other control procedures in the case of transportation as well as integration of information exchange systems between border and customs services and carriers to speed up control procedures;
3. Simplification of formalities and improvement of cargo handling technologies in logistics terminals, airports and ports of Ukraine;
4. Stimulating the introduction of innovative technologies (smart infrastructure and smart mobility) and intelligent transport systems;
5. Widespread use of "cloud" data storage technologies, virtualization, data centres etc.;
6. Increasing the capacity of the road network through the introduction of intelligent transport systems;
7. Implementation of systems for automated control of the preservation of cargo during transportation by all types of transport;
8. Creation of conditions for the development of transport and logistics activities and competitive ZRL-5RL providers.

This concept corresponds to the modern directions of development of transport systems based on the analysis of global trends (Granström et al., 2022; Doubell et al., 2021; Strelko et al., 2019):

- Formation of new concepts and technologies for the movement of goods and passengers (high-speed rail, magnetic levitation transport, hyperloop etc.);
- "Uberization" of the passenger and cargo transport market (when, thanks to the use of IT platforms (mobile applications), direct interaction between consumers and service providers is carried out);
- Development of unmanned (autonomous) vehicles;
- Development of electric transport technologies;
- Development of intelligent transport technologies, in particular intelligent traffic and safety management systems;
- Development of multimodal integration of transportation by various types of transport in regional, interregional and international connections, creation of large multimodal centres (hubs).

Taking into account the fact that in Ukraine many planned reforms to rationalize the operation of railway transport have not been implemented, as well as against the background of the lack of innovative strategies for the development of Ukrainian railways at the state level, an urgent need to develop projects for the development of information and digital technologies, as advanced directions of innovative activity, with the purpose of increasing efficiency of railway transportation.

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It is worth noting that the development of informatization and digitalization is an integral component not only for improving efficiency of transport, but also for the development of the country's economy, since digital and information technologies are becoming a key tool for managing technological processes and creating added value (Abushaega et al., 2021; Severino et al., 2021; Kulbovskyi et al., 2021; Statyvka et al., 2021, Fishchuk et al., 2018).

That is, one of the main mechanisms of improvement and development of transport systems, including of Ukrainian railways, in the new technological and economic conditions, development of the information technology system as well as their digital transformation should take place, which should be recorded at the state level.

The purpose of the paper is to study today's trends in the development of the transport systems of the Ukrainian railways in the context of digitalization and based on the study of international experience in this sphere.

LITERATURE REVIEW

The issue of digitalization of railway transport is covered in scientific publications (Zorić et al., 2022; Peraković et al., 2022; Timchenko et al., 2020). In the papers, attention is focused on the activation of digital transformations in railway transport of EU countries, the state of ICT implementation in railway transport is revealed, and the main directions of implementation of digital transformations in the domestic railway industry at the technological and organizational levels are determined.

Papers (Sharma & Sharma, 2022; Ursarova et al., 2022; Bibik et al., 2020) proposed a solution to an important problem – formation of managerial influence for the management of technological processes of cargo delivery by rail transport at the modern level of requirements for the efficiency of transportation organization. Application of the proposed method allows solving the problems of operational control practice in the formation of means of operational management of technological processes of the railway dispatching division.

Taking into account the views of scientists regarding the features of ensuring sustainable development of railway transport and taking into account the global trends of digital transformation of the transport and logistics space (Beek et al., 2019) it has been proven that the use of digital tools in the activities of railway transport enterprises will contribute to the improvement of safety and unification of train traffic management standards, improvement of innovation processes and investment activities of railway transport enterprises, improving the processes of digital interaction between enterprises of the industry with clients and expanding the list of information services for consumers of transport services as well as improving the personnel management system in railway transport.

Research on the innovative development of the railway transport in Ukraine was carried out in the papers (Pidopryhora & Kovalova, 2021; Tokmakova et al., 2016; Sementsova & Krykhtina, 2018). In paper (Pidopryhora & Kovalova, 2021), the authors note that the transition to the innovative path of development of the railway transport requires a qualitative change in the approach to the methodology and practice of managing the development of the industry as well as appropriate changes in the system of measuring and regulating the innovative activity of the business entities. However, the mechanisms and formalization of actions to implement the transition to the innovative path of the development of the Ukrainian railways have not been characterized.

Paper (Tokmakova et al., 2016) is dedicated to the study of the strategic guidelines for the innovative development of the railway transport in Ukraine. The result of the research conducted was the determination of the implementation of high-speed traffic as the main strategic orientation of the innovative development of the railway transport of Ukraine and the necessary condition for entering the global transport and logistics system of passenger and goods traffic. But in the study conducted the ways of implementing the characterized key spheres of innovation and investment activities of the railway industry enterprises are not sufficiently specified.

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Work (Sementsova & Krykhtina, 2018) is dedicated to highlighting the main problems of investment and innovation development of the domestic railway industry and providing recommendations on the ways to solve them. As a result of the study conducted, the authors formalized a number of measures to overcome the problems of investment and innovation development of the railway industry; however, digital transformation is not included in the proposed system of measures.

The papers (Ovchynnikova & Toropova, 2019; Mnykh, 2020; Obruch, 2019) are devoted to the study of the need for digital transformation in the process of development of the railway transport in Ukraine.

In paper (Ovchynnikova & Toropova, 2019), the role of digitization in the process of ensuring the efficiency of operation and competitiveness of the Ukrainian railway transport enterprises was determined. The authors outline the following areas of activities of the railway transport enterprises as the priority ones: development of customer service based on the use of digital communication channels, strengthening of the partnership relations based on the digital platforms, creation of forecasts based on Big Data, and implementation of the personnel strategies. However, the proposed measures are the basis for the economic rationalization of the railway activities through the use of digital technologies.

The strategic context of the balanced development of the railway transport enterprises based upon the digitalization is studied in paper (Mnykh, 2020). In the course of the study the author summarized the foreign experience of digitalization in the railway industry and identified the features of the innovative development of railway enterprises in competitive market conditions. But the determination of the strategic context of managing the balanced development of the railway transport enterprises was based exclusively on the conditions of digitalization of the economics of Ukraine taking into account the study of future technological and market trends.

The study conducted in work (Obruch, 2019) is dedicated to revealing the role of the digital platforms in the development of services rendered by the railway transport enterprises as well as determination of their advantages, functions, principles and organizational conditions of development. The author notes that increasing competitiveness and ensuring balanced development of the railway transport enterprises requires a comprehensive improvement of the processes of implementing their services which can be realized thanks to the use of digital tools, among which the development of the digital platforms is of great significance. However, the study conducted is focused only on the introduction of the digital platforms, while the process of digital transformation includes a wider toolkit of possible mechanisms for rationalizing the activities of the Ukrainian railways.

Thus, the review of the literary sources showed that quite a lot of studies were devoted to the need for innovative development of railway transport, including those taking into account importance of the digital transformation. However, the characteristics of specific mechanisms for the implementation of the innovative strategy of the development of the Ukrainian railways in the context of digitalization have not been studied much, and based on this fact this work is a relevant study and is of great importance.

Considering the fact that digitalization is achieved by implementing a system of solutions (services, applications, etc.) based on the state-of-the-art information and communication technologies that use a digital asset (a system of knowledge on business and external environment in the digital format which is covered by the right of ownership and/or right of use), formalization of the innovative strategy for the development of the Ukrainian railways in the context of this study is based on the basic principles of informatization and digitalization in the railway transport.

Global scientific and technical progress forms a significant reserve for improving the efficiency and quality of the transport process, the leading elements of which are the development of information and digital technologies in the operation of the transport systems. Currently, there are no programs for the innovative development of the railway transport in Ukraine regarding the development of informatization and digitalization of railway transportation, and it is therefore the selected research topic is particularly relevant.

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METHODOLOGY

To achieve the goal, the following tasks shall be solved:

1. Determining the basic principles of informatization in the railway transport which form the basis i.e. the necessary (but not sufficient) condition for digitization;
2. Investigating digitalization and its toolkit in the context of the railway transport functioning;
3. Performing an analysis of appropriate European strategic documents concerning railway transport with the identification of the key trends in the digital development;
4. Formalizing the most effective digital technologies for their application in the Ukrainian railways with the determination of the effects of their use.

When solving the mentioned tasks we used such methods of system analysis as abstraction and concretization, analysis and synthesis, induction and deduction, and formalization and specification.

RESULTS

Determination of the basic fundamentals of informatization in the railway transport

The analysis of the priority spheres of the scientific and technical development of the railway industry in the USA and the EU showed that the formation of the concept of informatization should be the initial stage in the rationalization of the activities of the Ukrainian railways which would take into account formation as well as introduction in the today's conditions of complex information technologies in the functioning of the industry, creation of a single information transmission network, significant increase of the capacity of the communication networks, introduction of the state-of-the-art software tools, and creating a modern system of collecting and processing primary information on the entire railway network.

The need to form the concept of informatization in the railway transport in Ukraine is determined by the fact that due to the development of the information system efficiency of the functioning of the industry increases, since the entire transport process, including organizational and technological as well as management and decision-making procedures is provided with proper information support. Based on this, we will consider the key principles in the implementation of the concept of informatization of railway transport:

1. Transformation from autonomous management systems of individual railway transport enterprises to complex information systems implementing massive management functions;
2. Transformation to integrated automated and automatic control systems;
3. Transformation to automated information and management systems;
4. Formation of a complex of interdependent centralized objects of databases and knowledge bases as well as the ones distributed according to levels and management;
5. Application of electronic document management in the new information technologies;
6. Provision of information interaction with all participants of the transportation process (formation of interaction of various types of transport), state permitting and control bodies based on electronic information exchange together with the application of international standards;
7. Focus of data infrastructure development on open systems interaction architecture, application of modern architectures such as, for example, client-server etc.

The need for continuous development of railway transport management information support is justified by the fact that in the conditions of restructuring the management system, changing functions and forms of ownership, increasing independence of enterprises, increasing and developing economic ties on a new economic basis without building a system of agreed models of basic and technological processes and defining basic information needs for their implementation is impossible. Based on this, it is advisable to consider the development of the informatization of Ukrainian railways as a system of coordinated functional models of information technology com-

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plexes that ensure the maximum implementation of one of the functions of railway transport management (Fig. 1).

On the basis of the proposed concept, it is possible to focus attention on the main business processes in the activity of railway transport with the distribution according to the existing levels of the management hierarchy of the functions performed at each level.

From a technical point of view, high requirements for the efficiency of management of the transportation process create the need for a higher level of informatization. This is explained by the fact that information

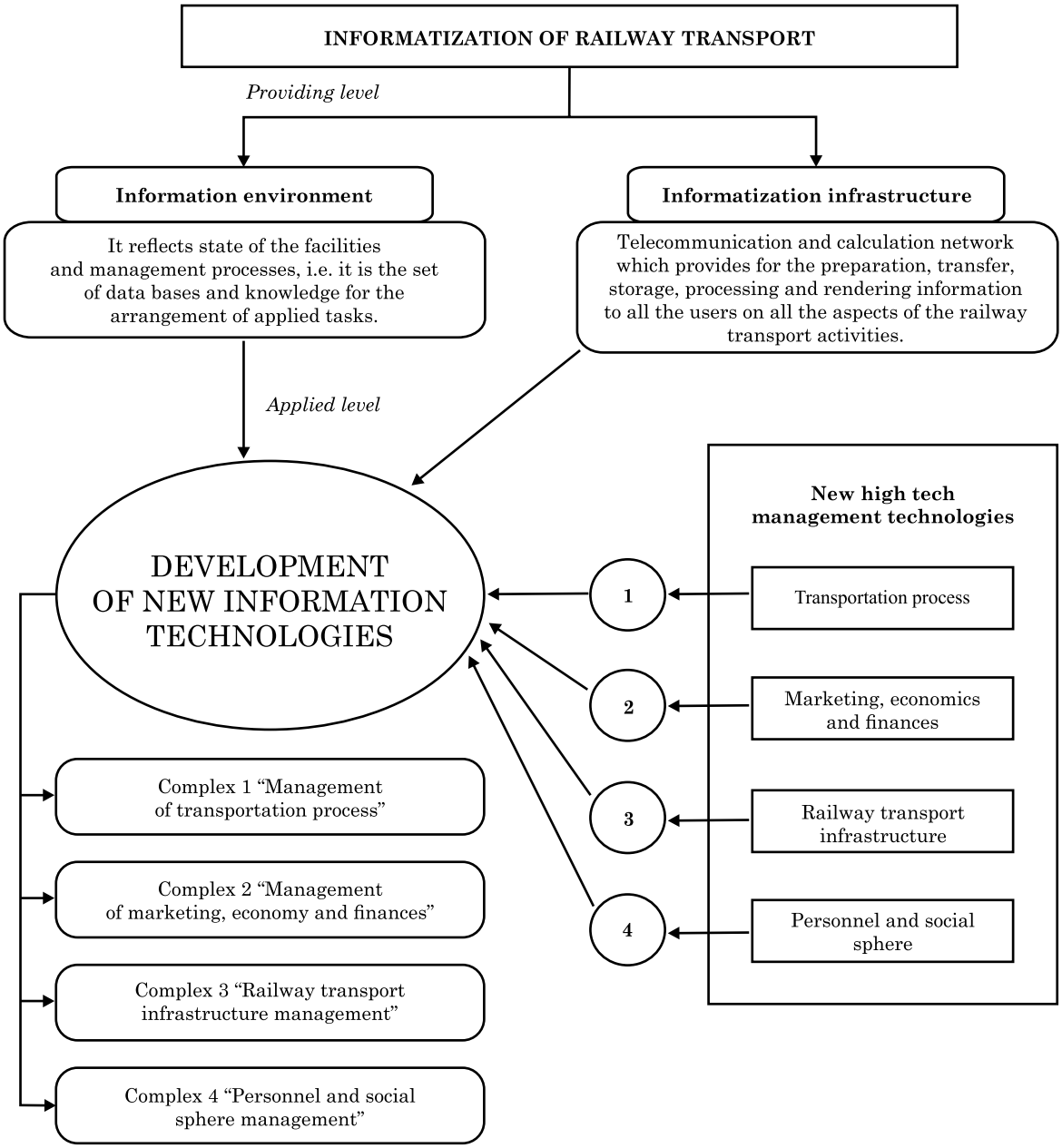

Fig. 1. Informatization of railway transport of Ukraine
Source: own elaboration.

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technology today is not just a means of supporting management, but one of the most important elements of the transport infrastructure, which from the category of auxiliary means has become the main technology and significantly affects the improvement of the transportation management process.

The prospects of informatization according to the concept (Fig. 1) are implemented in the form of a two-level structure:

1. Providing level – contains the information environment and forms the basis for information technologies;
2. Applied level – connects new methods, management mechanisms, information environment and informatization infrastructure.

According to the concept, a complex of information technologies is proposed, which are based on the following principles:

– Wide user access to the database and technical means;
– Use of modern methods and means of receiving and transmitting information at high speed and minimal distortion (program control and highly reliable communication channels);
– Highly effective means of automatic recording of information about rolling stock, automatic management of dynamic arrays of locomotives, wagons, and containers;
– Electronic document management of the transportation process according to simplified schemes of information circulation;
– Development of decision-making tools based on knowledge bases including situation modelling systems, option evaluations, and expert systems;
– Formation of elements and systems of artificial intelligence for decision-making in situations that are difficult to formalize;
– Development of user interaction languages with the information service system.

Digitalization and its toolkit in the context of railway transport functioning

The next stage of the development of railway transport in Ukraine should be transition to digital transformation which will be carried out on the basis of information technologies.

It is worth noting that there are significant differences between informatization and digitalization, in particular:

Informatization is a certain set of toolkits which includes technological provision and software as well as data transmission systems that allow certain types of reporting and information exchange;

Digitalization represents another level of development: after entering the necessary data into the digital system, thanks to digitalization, tasks set by the user are solved, information is analyzed, and a forecast is provided.

Therefore, the informatization system is organically included in the digitalization system, which necessitates the step-by-step rationalization of railway transport.

The digital transformation of the transport system involves a large-scale change in technological and organizational processes through their digitization, which is aimed at increasing the productivity of traffic organization and increasing efficiency of managing the entire transportation process while ensuring its absolute safety. The model of digital transformation also takes into account adaptive capabilities that allow quick and flexible response to changes in the market situation and ensure a high speed of decision-making based upon a balanced assessment of possible risks, which is achieved through the use of various digitalization tools and mechanisms.

Key elements of digital transformation that can be used in all types of business activities, including on railway transport, are shown in Figure 2.

By analogy with the consideration of the structure of railway transport informatization, it is advisable to form a system of agreed functional models of digitization complexes with proposed mechanisms for implementing digital transformation.

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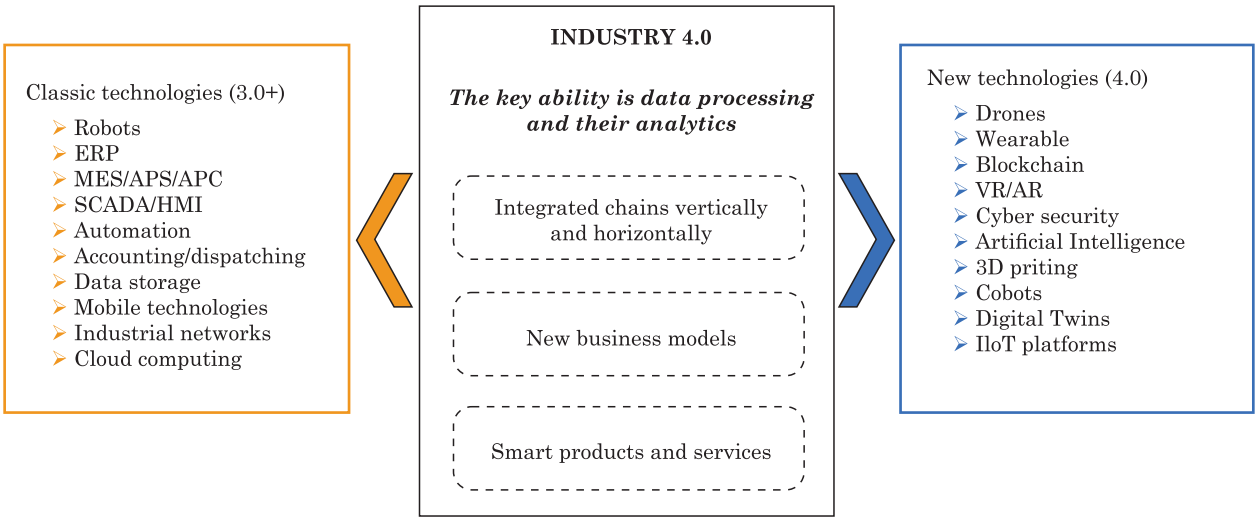

Fig. 2. Toolkits of digital transformation in all types of business activities
Source: own elaboration.

The structure of the digitalization of railway transport is expediently formed on the basis of the research carried out by The Mobility Innovation Lab (MIL) on the digital transformation of railways:
– Complex 1 "Digitization of management of operational work";
– Complex 2 "Digitization of asset maintenance";
– Complex 3 "Digitization of infrastructure maintenance";
– Complex 4 "Digitization of control and signalling systems";
– Complex 5 "Digitization of customer service".

As a result of the intensive development of information and communication technologies, the implementation of the digital transformation of railway transport should be carried out with the help of modern digitalization tools which will provide data analytics and an opportunity to comprehensively solve the issues of effective development of the digital system in the arrangement of railway transportation. Taking into account the key elements of digital transformation (Fig. 2), we will formulate a priority digitalization toolkit for Ukrainian railways:
– Cloud technologies;
– Distributed ledger technology;
– Big Data technology;
– Internet of Things concept;
– Augmented Reality technologies;
– Artificial Intelligence technologies;
– Additive technologies (Additive Manufacturing; Additive Fabrication).

We will provide a more detailed description of the proposed digital transformation toolkits.

Cloud technologies provide the possibility of providing the user with convenient and prompt access to a whole complex of computer resources and capacities via the Internet, including various servers, storage systems, services and applications the use of which involves the possibility of relieving them from the load without the involvement of the provider and significant operational costs. Thus, cloud technologies allow the transfer of data processing and storage functions from personal computers to Internet servers, which allows for instant remote access of any level from any part of the world and from any device to information resources, radically changing existing business models and increasing the effectiveness and efficiency of business operations.

Distributed ledger technologies allow for the organization, storage and exchange of data share by all participants of a trusted environment, each of which has a complete copy of the data ledger and access to the entire transaction history. At the same time, the reliability and security of information

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is ensured by cryptographic protection using special keys and an electronic signature, which allows monitoring the actions of all participants. Distributed ledger technologies provide synchronization of data ledger copies based on the agreement (consensus) of the participants to add new information, as well as reliable data protection against possible changes, partial or complete deletion.

One of the most common distributed ledger technologies is the blockchain technology, which is a sequential chain of data blocks that contain information built according to certain rules, when each new block is introduced into a chain of chronologically and cryptographically interconnected blocks. Thus, blockchain technology provides reliable storage of the entire data chain in the absence of centralized control.

Big data technology, the emergence of which is connected with the need to ensure the processing, analysis and storage of large volumes of constantly growing and updated data, the size of which exceeds the capabilities of traditional databases and analytical tools and systems. Currently, the main value of data is determined by the possibility of their participation in increasing competitiveness and efficiency of activities, creating new products, ensuring the validity and quality of management decisions made both on the basis of identified cause-and-effect relationships and on the basis of established correlation dependencies.

The concept of the "Internet of Things" provides for ensuring the interaction of physical and virtual objects and systems between themselves and the external environment based on built-in information and communication technologies and standards using communication channels. The development of cloud technologies and Big Data technologies, widespread computerization, and even a reduction in the cost of computing power and data transmission play a decisive role in the emergence of this concept. The Internet of Things, actually representing a set of interconnected devices, items, detectors and sensors, allows collecting various information about the connected control object and transmitting it for further processing and storage via the Internet.

Augmented reality technologies open up new opportunities for perceiving the surrounding world, enrich it and make it more valuable and informative. This technology allows you to supplement the real world with virtual elements distributed in space, in real time by overlaying special content (text, graphics, and audio sequence).

Artificial intelligence technologies are based on the use of various algorithms that provide simulation of human thinking processes to support decision-making. Artificial intelligence, being a cognitive tool, allows, based on the analysis of the capabilities of the human mind and modelling of the internal structure of the system, to make decisions depending on the problem and context in real time, which allows automating a significant part of production processes and ensuring the digitalization of economic and social processes.

Additive technologies make it possible to create objects by layer-by-layer addition (build-up) of material based on the data of their digital model with the help of computer three-dimensional technologies. Thus, additive technologies, or the so-called 3D printing, is based on the construction of an object by sequential application of layers that form its contours and appearance, which is an alternative to traditional methods of production and modernization of objects.

The considered mechanisms of digital transformation of railway transport allow not only changing individual business processes, but also to ensure the restructuring of the entire industry in general and set the trajectory of its future development. At the same time, the greatest effect will be achieved due to the synergy of technologies, that is, the possibility of their application in aggregate.

It should also be noted that on the basis of the development of the digitalization of railway transport of Ukraine, the realization of the transit potential of the country, the increase of revenues from the export-import of transport services, the provision of new opportunities for the development of the transport industry and the economy as a whole due to the integration of the national transport system into the international digital transport space are expected in the future on the conditions of equality, mutually beneficial cooperation and equitable accelerated development.

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Analysis of the European strategic documents concerning railway transport with the identification of the key digital development trends

In order to confirm the relevance and necessity of developing the proposed innovative model of the development of Ukrainian railways, it is advisable to analyze the European experience of the development of digitalization in railway transport in more detail.

In 2014, the European Union (hereinafter referred to as the EU) created the public-private joint venture of Shift2Rail (Association of Industrial Automation of Ukraine, 2022) to provide a platform for the coordination and development of research and innovation activities that will be integrated into advanced rail solutions. Although Shift2Rail does not define digitization as an objective per se, it carries out activities related to it in some of its five Innovation Programs (IPs). For example, the first program (IP1) is designed to strengthen the digitalization of train subsystems and equipment (traction, brakes and doors). IP2 aims to support the European Railway Traffic Management System (ERTMS) as a solution for signalling and control systems worldwide. IP4 introduces innovations in digital services for passengers (ticketing, trip tracking etc.), while IP5 focuses on new digital features that improve the punctuality of rail freight.

In June 2018, the European Commission (hereinafter referred to as the EC) adopted a proposal for the approval of the "Digital Europe" Program for 2021 to 2027, which is currently being discussed by the EU co-legislators in the context of long-term financial support. "2021–2027 Digital Europe Program" (Ciechanowska, 2020) is a funding instrument that will focus on strengthening the EU's potential in key sectors: high-performance computing, artificial intelligence, cyber security and digital skills. This program includes a transport component, which is included in the goal of the program with the aim of comprehensive development of digital capabilities in the country's economy and society.

As to more technical aspects, to improve the interoperability of digital technologies and foster innovation, the EC published the "ICT" Standardization Priorities for the Digital Single Market in April 2016. "ICT" standards ensure the interaction of digital technologies and are the basis of an effective single digital market, an important participant of which is railway transport. It assumes that digital technology is already a key element of rail transport and that the latter can bring benefits from the proposed ICT standardization. In the same month, to strengthen the industrial and innovation aspects of the Digital Market Strategy, the EC adopted the Regulation of "Digitizing European Industry – Making the most of the Digital Single Market" (Document 52016DC0180, 2016), the main objective of which was to ensure that industry in all sectors and territories are fully aimed at digital innovation. In this regulation, the transport sector is mentioned very briefly, limited to automated driving. Nevertheless, the EC identified five priority areas for standardization of all the industries – 5G provision, cloud computing, Internet of Things, data technology and cyber security.

Thus, the EU has been actively developing digital technologies for many years, including on the rail transport. In addition to the legal framework discussed above, it is worth paying attention to the strategic directions of the development of digitalization in the EU railway transport. Representing railways, The Community of European Railway and Infrastructure Companies (CER), The International Rail Transport Committee (CIT), European Rail Infrastructure Managers (EIM), and The International Union of Railways (UIC) companies jointly developed and presented the "Road Map for of Digital Railways" (A Roadmap for Digital Railways, 2020).

The roadmap presented digitization as a top priority for the development of the railway industry and a key to railway competitiveness. The main part of the document describes the modern mechanisms of digital transformation of railways, which the representatives recommend for implementation in order to rationalize the operation of EU railway

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transport. The proposed digitization toolkits includes (A Roadmap for Digital Railways, 2020):

1. Digitization of customer service:
   a. Adif Mobile is an application that shows real-time traffic information, train arrival and departure schedules, platform information, station and shopping area information and maps, and offers the option to subscribe to train and trip alerts;
   b. ÖBB multi-media portal platform is a partnership with a wireless connectivity and ICT solutions provider to provide an advanced multimedia portal platform for passengers, providing ÖBB customers with direct access to timely travel information and services, on-demand multimedia content and entertainment provided through the on-board train platform;
   c. Interoperable product service interface of the Association of German Transport Companies (VDV): almost every public transport organization (POO) in Germany which sets schedules and tariffs and concludes contracts for public transport has its own mobile application; since each application requires a separate registration, VDV eTicket Service has developed on behalf of several POOs an interoperable product service interface to make the mobile ticket convenient for customers;
   d. The Xrail project is a project that unites 6 railway partners (CFL cargo, DB Schenker Rail, Green Cargo, Rail Cargo Group, SBB Cargo and B Logistics) who aim to significantly increase the competitiveness of railcar shipments in Europe due to enhanced information before, during and after transportation as well as services for providing international transportation schedules, delay notifications and next-day arrival notifications.
2. Digitization of operational work (priority: Internet of Things & artificial intelligence):
   a. NMBS/SNCB's Optical character recognition (OCR) – digital technology that automates the previously manual input of railcar identification numbers through trackside cameras that check the composition of trains; this information can be used for various purposes: information for the passenger, maintenance point, traffic control, train staff; it detects vandalism; regular inspections can help determine where and when railcars were damaged;
   b. CFL Traceability of goods – tracking software capable of locating cargo using GPS, it also allows tracking the CO2 impact of transport services;
   c. DB's DIANA predictive maintenance platform – sensor technologies collect data in real time, which is then transmitted and distributed on the diagnostic and analysis platform (DIANA); the process includes measurement, collection, analysis and finally provision of structured data (DIANA is a user interface that enables a variety of applications, especially for predictive maintenance);
   d. SBB Adaptive steering (ADS) is a real-time management of railway services (mobile application for drivers) to avoid unscheduled stops; the dispatch software calculates the optimal speed for each individual train based on forecasts across the entire rail traffic network, thus creating a "green wave" for rail traffic (over 5,000 parameters are analyzed every three seconds and train traffic forecasts are calculated, then the recommended optimal speed is sent to the driver).
3. Digitization for the purpose of increasing the competitiveness of railways:
   a. RailTopoModel – a standard for all data exchanges in the sphere of railway infrastructure; the first release (RailTopoModel Version 1, April 2016) is the basis of a universal language designed to support digital continuity in railways throughout the lifecycle and operation of the rail network;
   b. Building Information Modelling – information modelling of objects, that is, the process of generating, creating and managing physical, environmental, commercial data throughout

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the life of the project using technologies based on models related to the project information database;
c. Swedish Trafiklab – ASTOC/SJ is a place where developers can share data and APIs (application programming interfaces) for public transport in Sweden and easily get the information they need to develop accurate services;
d. ATOC's open data – ATOC – opens information data for public access for use by developers and third parties, including information channels with national passenger information systems, in creating their own programs;
e. Open data platforms are open data platforms where there is an opportunity to cooperate with startups in order to solve current problems of the railway industry.

Therefore, the analyzed experience of the digital transformation of railway transport in Europe shows that the use of digital technologies is one of the main priorities for the development of the railway sector and its future. This is confirmed by the fact that for a long time the European railway industry has been offering its customers highly efficient and attractive transport services using modern technologies of digital transformation.

Formalization of the most efficient digital technologies for their application on the Ukrainian railways

On the basis of the study conducted, it is possible to formalize some possible solutions for the implementation of an innovative strategy for the development of Ukrainian railways in the context of digitalization, taking into consideration their current state.

Development of the existing and the implementation of the proposed digitalization options in the Ukrainian railway transport will ensure an increase in the efficiency of the activities, in particular:

1. In the field of passenger and suburban transportation:
   a. Improving the quality and velocity of passenger service;
   b. Increasing the innovative and investment attractiveness of the Ukrainian railways, creating new jobs;
2. In the field of freight transportation:
   a. Competitiveness of railway transportation, attraction of investments, private rolling stock, private traction, and rapid renewal of the freight wagon fleet;
   b. Improved system compatibility is to allow customers to travel using a wide range of different and connected regimes at a single integrated price;
   c. To arrange a multimodal logistics system with automation of contracting, payments, movement of accompanying documentation, insurance, etc.;
3. In the field of the infrastructure and rolling stock management:
   a. Reducing the rate of aging of the technical items, increasing the safety of train traffic;
   b. Rationalization (lowering) of operational costs;
   c. Restoration of the domestic locomotive industry and making it competitive in the future;
   d. Transition to repairs in accordance with the condition, reduction of costs for diagnostics and repairs, and rationalization of the depot network;
4. In the field of production:
   a. Preparation of the "base": availability of digital data in automatic mode for their further processing;
   b. Reduction of the costs for the production of individual spare parts; shortening the release dates of new products;
5. In the field of signalling and interoperability:
   a. Involvement of a larger number of providers will improve the quality and speed of the Internet, and as a result it will increase the comfort of the trip, the attractiveness of services due to additional services that could be provided with the aid of the Internet, in particular, Smart Mobility;
   b. Increasing comfort, attracting passengers, and increasing revenues due to connection to Smart Mobility.

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CONCLUSIONS

Currently, special attention is paid to the issues of informatization and digital transformation of various sectors of the economy and spheres of activity, and the development of transport systems in this context is becoming one of the priority directions of the country's strategic development.

The research conducted showed that within the framework of rationalizing the work of railway transport of Ukraine, it is necessary to foresee a transition to a new innovative model of functioning, the foundation of which will be high-tech infrastructure objects and specialized complexes that take into account scientific knowledge and achievements of advanced technology and equipment. For this purpose:

1. The basics of informatization and digitalization of railway transport are characterized as essential prerequisites for the modern technological, economic and managerial development of the industry, increasing the efficiency and safety of the transportation process as well as high-quality transport service for users of railway transport;
2. Structures, actual principles and mechanisms of implementation of the proposed new innovative model of railway transport development were formulated;
3. An analysis of the effectiveness of the development of digital technologies was carried out on the example of EU countries whose experience shows the priority of introducing digitalization into the strategic development of railways.
4. Possible solutions for the implementation of an innovative strategy for the development of the Ukrainian railways in the context of digitalization were formalized taking into account their current state, and effects of their implementation were determined.

It should also be noted that the development of projects for the innovative development of railway transport in the context of the introduction of modern information and digital technologies has high investment attractiveness, both for the transport system itself and for the country. This is confirmed by the fact that:

1. Railway informatization is not only an objective need for the organization of railway transport, but it can also increase labour productivity, expand transport markets, improve the quality of services for passengers and shippers, as well as promote reforms and innovations in the railway industry;
2. Due to the implementation of large-scale national projects of digital transformations – from priority sectors of the economy to such areas of life as medicine, education, transport, ecology, tourism etc., Ukraine will be able to reach a GDP value of $1 trillion as early as by 2030, i.e. 8 times more.

At the same time, implementation of the transition to an innovative model of development depends on the joint participation and interaction of the state, industry enterprises, innovative companies being developers of new technologies and equipment, expert institutes, including international ones, and the scientific and educational community.

Thus, one of the most acute problems of the Ukrainian railway transport is the low intensity of introduction of innovative technologies and systems, which negatively affects efficiency of functioning, image, economic indicators, and competitiveness. The study conducted in this work can become a universal tool for strategic planning of the innovative development of the Ukrainian railways in the context of informatization and digitization of their activities, and it will allow optimizing activities of the Ukrainian railways making them client-oriented, rationalizing management and control of working capacity, and integrating them into the European and Eurasian transport network.

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