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DIGITIZATION OF INDUSTRIAL PRODUCTION AND TRADE: TECHNOLOGIES, BENEFITS AND WAYS OF IMPLEMENTATION

Summary

The study analyzed the nature of the impact of digitalization on the development of manufacturing enterprises and trade through the study of their genesis and current state. Using the example of mechanical engineering and metallurgy of Ukraine and the world, the key directions of digitization in production and trade are analyzed. The impact of digitalization on ensuring the stability of Ukrainian enterprises during wartime is analyzed. Digital technologies and systems, platforms and services of production and trade are characterized. The advantages and disadvantages of the digital transformation of the sphere of production and trade were noted. Arguments have been made that digital technologies reduce trade costs. This means that digitization can help speed up international trade. Ways to promote the digitalization of the industrial complex and trade based on the improvement of management mechanisms and system coordination between key stakeholders: state institutions, scientific institutions and business are proposed.

Introduction

Digital and technological transformations as a process of widespread application of digital information technologies and new materials in the industrial complex are primarily aimed at spreading new ways of organizing production, materials processing technologies and business process

management. In modern conditions, time requires a significant increase in speed and a reduction in labor costs for the development of technologies for the manufacture of various parts and the installation of assemblies, units and mechanical equipment of machines. There is also the task of significantly increasing the accuracy and reducing the spread of deviations from the normalized indicators of the geometric parameters of the parts. Today, the "digitalization" of production processes accelerates the implementation of such tasks. The digitalization of production is inseparably connected to the digitalization of trade. Digital transformation involves changes in production processes, the development of new technologies and business models that affect the quality of products and, consequently, the growth of their competitiveness. Digital technologies thus facilitate market access and promote trade efficiency. All of this played a positive role in the context of the global turmoil of the COWID pandemic. Digitalization plays a particularly important role in wartime to support the industrial development of Ukraine and to ensure the sustainability of the foreign economic activity of Ukrainian producers. Currently, in Ukraine, national strategic documents do not cover most of these areas, and there is no targeted funding from the central and executive authorities for fundamental and applied research in these areas. All this requires improvement of management mechanisms and system coordination between key stakeholders: state institutions, scientific institutions and business.

Chapter 1. Directions of digitalization of industrial production

The industry has undergone significant transformations over the past few decades. On the one hand, production has become more fragmented, and its separate stages are dispersed in many countries, on the other hand, the rapid growth of innovation initiates the introduction of technologies and equipment on the latest technological basis. Today, to be more competitive in the context of globalization and increasingly strict environmental regulations [1], leading manufacturers of industrial products are switching to digital technologies. The use of digital technologies enables manufacturers to implement new processes along the entire value chain, from production and sales to service provision. That is why global industry leaders are actively digitizing core functions within their own internal vertical value chains, integrating them with horizontal supply chain partners, expanding their product offerings with digital capabilities, and implementing innovative services based on digital data. Such a trend indicates that digitalization is not just a transition from "analog" to digital data and documents, but a network of business processes between the creation of effective interfaces, integrated data exchange and management [2].

The World Intellectual Property Organization (WIPO) has published the Global Innovation Index 2023 [3], which this year has the slogan "Innovation in Uncertainty". This is the 16th edition of the Index, which ranks 132 world

economies and identifies the 100 best scientific and technological innovation clusters. This rating shows that, despite the war, Ukraine rose two places in the Global Innovation Index this year and occupies the 55th place (Table 1).

Table 1

Changes in the position of Ukraine in the ranking of the global innovation index for 2011–2023 (country-place in the ranking))

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1	CHE-1
SWE-2	SWE-2	SWE-2	GBR-2	GBR-2	SWE-2	SWE-2	NLD-2	SWE-2	SWE-2	SWE-2	USA-2	SWE-2
SGP-3	SGP-3	GBR-3	SWE-3	MAR-3	GBR-3	NLD-3	SWE-3	USA-3	USA-3	USA-3	SWE-2	USA-3
ZAF-59	MKD-62	TUN-70	BHR-62	SRB-63	MNG-55	QAT-49	GRC-42	RUS-46	THA-44	ROU-48	MDA-56	MKD-54
UKR-60	**UKR-63**	**UKR-71**	**UKR-63**	**UKR-64**	**UKR-56**	**UKR-50**	**UKR-43**	**UKR-47**	**UKR-45**	**UKR-49**	**UKR-57**	**UKR-55**
GUY-61	IND-64	MNG-72	JOR-64	SYC-65	BHR-57	THA-51	THA-44	GEO-48	ROU-46	MNE-50	MEK-58	PHL-56
DZA-125	SDN-141	YEM-142	SDN-143	SDN-141	YEM-128	YEM-127	YEM-126	YEM-129	YEM-131	AGO-132	GIN-132	AGO-132

Source: compiled by the authors [3]

In front of Ukraine is North Macedonia, behind is the Philippines. Also, this year, Ukraine for the first time entered the TOP-3 most innovative economies in the group of countries with below-average incomes. The degree of development of Ukrainian education, information and communication technologies, and the intellectual level of human capital received the highest ratings. The lowest are the state of the institutional field, trust in business, the state of infrastructure (which is not surprising in the conditions of a full-scale war).

It is worth noting that the problem of digitalization of business processes as the basis of the effectiveness of industrial enterprises is widely considered by leading global companies and research and analytical centers, since the quality of digital transformation not only of individual enterprises, but also of the entire industry depends on the level of its resolution. At the same time, attention is focused both on increasing the efficiency of the enterprises, and on ensuring the sustainable development of the industry in the context of increasing its environmentalization, resource efficiency and social security of employees. Also, the analysis of the effectiveness of activities and ensuring sustainable development based on the use of the concept "Industry 4.0" is constantly conducted and enlightened by managers of world leaders in the metallurgical industry, such as "Posco", "NSSMC", "BAOSTEEL", whose experience should also be researched and studied by domestic entrepreneurs as this is an important

element that will encourage investment and help transform domestic enterprises into equal participants in the competitive environment.

Besides the development and implementation of digital technologies in the real sector of the economy is occurring much more slowly than in other spheres of activity. This is due, first of all, to the need for large investments and a significant period of time for improvement, and even more so, the implementation of fundamentally new inventions to improve the production process, which is technologically quite stable [4, p. 90]. Along with this, innovations are still introduced in industrial production. In particular, the use of innovative technologies is a necessary point in the modernization of existing and construction of new production facilities [5]. The combination of innovative technologies and modern equipment makes it possible to increase product quality, energy efficiency of production, environmental safety and reduce financial costs in the future.

Among the main areas of industrial development based on digitization processes, there are [4, p. 90]:

– *Internet of Things (IoT)* – allows to operate industrial operations and processes effectively in real time and simultaneously connect all its parts over a large area, remotely control the operation of any device and equipment connected to a single system [6]. Reducing the price of sensors and many other field devices allows you to significantly increase the intelligence of physical objects into which they are integrated. Typical use cases are better equipment monitoring, including predictive analytics, tracking of machines, mobile personnel, optimization and better production management, etc. IoT is of particular importance in the extraction of primary resources, for example in the mining industry, the main facilities of which are located, as a rule, at a fairly large distance from the actual processing enterprises. An obstacle may be the lack of a stable Internet connection in many parts of the planet, however, the latest developments in the field of satellite communication in the near future may allow providing Internet coverage on 80% of the planet's territory;

– *smart devices* (sensors, counters) – control and optimize the operation of the equipment, allowing to accurately and quickly determine the amount of raw materials consumed in one or another industrial equipment, the deviations from the cost standards, the reasons for them, the level of consumption of energy resources, etc. Sensors collect a huge array of information, which is then interpreted by artificial intelligence, optimizing the production line and creating a synergistic effect. In particular, manufacturers of metal products are installing smart meters and other sensors to reduce CO2 emissions and reduce energy costs. Typically, businesses generate much of their own electricity using gas from their furnaces and rolling processes. However, most manufacturers use a large amount of electricity from external networks, constantly trying to reduce it. Also, thanks to the installed sensors, manufacturers are able to measure the

energy intensity of different grades of steel with high accuracy, which further contributes to the adoption of effective management decisions in order to reduce their cost, etc.;

– *predictive analytics (service)* based on data processing. Predictive maintenance is a such type of machine and equipment maintenance that replaces traditional methods of planned and preventive work. Stopping production (certain machines or lines) can cost an enterprise from several thousand to 2.5 million dollars. USA per day. Today, however, smart machines themselves can provide data on why and when a particular part or assembly might fail. And in this way, prevent malfunctions. Applying predicative analytics with new data processing methods and models can save up to 40% on maintenance and reduce unplanned downtime by up to 50% [7]:

– *added and virtual reality*. To master new machines, put them into operation, and then in service, operators and operating personnel previously used instructions in "pdf" or in printed format. However, when it comes to quickly finding the necessary information, as a rule, such things do not work – it takes too long! And when the image of the necessary node or part is presented in a visual form in 3D and also with all the accompanying information in real time about the state of the mechanism. This is how virtual and augmented reality technologies work. One of the first known augmented and virtual reality projects was launched in 1992 by the Boeing company. Due to the visualized representation of the wire harness for laying around the perimeter of the aircraft body and the presentation of the assembly diagrams of these wire harnesses, it was possible to speed up the installation and reduce the probability of errors during work. In general, virtual reality systems reproduce computer models of individual machine-building units, parts, buildings, structures, equipment and machinery in a three-dimensional image, with the possibility of their visualization, viewing, assembly and disassembly. Currently, augmented and virtual reality technologies are used in mechanical engineering to reduce the design time of products, and therefore, at the moment, it is necessary to use the advanced experience of virtual reality IT technologies to work with its virtual and digital prototype. When analyzing a project at the sketching stage, virtual reality technologies allow you to check the layout, evaluate ergonomics, detect collisions, change the appearance of the object, and also make changes to the project. Such technologies help to form and prepare visualized presentations of information materials. This approach of using virtual reality devices is possible for the simulation of assembly operations, analysis and the possibility of optimizing product manufacturing processes. As an example of the use of augmented and virtual reality technologies in the field of mechanical engineering, such companies as "Ford" can be cited, which uses virtual reality projects at the stage of designing cars. This allows you to work faster and more efficiently on the appearance of the car, as well as to work out the lines and

finishing elements in more detail. Working in this studio, Ford designers were able to design the layout of the dashboard, seats and control mechanisms in the new Ford Fiesta model. In addition, the "Ford" company is currently carefully studying the potential of a number of solutions in the field of virtual and augmented reality technologies for superimposing digital holograms on objects of the real world, which in the next decade will allow people to evaluate the characteristics of individual products that are interesting to them, for example, cars [8]. Also, the use of these technologies significantly reduces the costs of personnel training and equipment maintenance, as well as reduces the time for unplanned devices;

– *intelligent modeling and visualization of processes*, occurring inside the equipment on the basis of data obtained with the help of modern sensors, the application of the concept of digital twins (Digital twin – a virtual copy of every physical object, device, machine, production or industrial process that can be seen on any computer, which allows for a deeper understanding of individual processes without interfering with the product itself). They become especially important when analyzing processes in "closed" units – blast furnaces and steel furnaces, which must alternately be constantly loaded with layers of coke and agglomerate, ensuring a uniformly efficient gas flow. Until recently, topographic and temperature disturbances were difficult to identify. However, the Austrian plant Voestalpine, based on 3D radar, has developed a comprehensive model of the resource loading process, which includes real-time measurements of the temperature of the blast furnace, which has led to an increase in iron output and a reduction in harmful emissions [9]. In the field of mechanical engineering, virtualization and simulation technologies are increasingly used in the process of developing new products. This makes it possible to greatly reduce the cost and speed up the pace of development. Therefore, digital simulation – in all its varieties – becomes a mandatory part of the PDP (Product Development Process). Simulation and digitalization capture the entire life cycle – for example, from the design of a mechanical product, to the programming of the machines on which it is produced, and to the introduction into production. An even more advanced level are digital twin models that virtualize the behavior of a real object at all phases of its life cycle;

– *robotics* – robots can be used when there is a shortage of labor and in dangerous areas of production. In the metallurgical industry, the level of robotization is inferior to other industries, such as the automobile industry, but robots are used in the selection of liquid steel, control of its level and temperature measurement in smelting units, in slag loading, application and removal of refractory coatings. Unmanned aerial vehicle technologies are used to inspect hard-to-reach areas of the plant, as well as geodesy and mine planning. In general, it is planned that in the future all cranes and other equipment will be unmanned and controlled by artificial intelligence;

– *production management systems* (MES – Manufacturing Execution System) – it is a specialized system designed to solve tasks of synchronization, coordination, analysis and optimization of production. The abbreviation MES is sometimes deciphered as manufacturing enterprise solutions; this term is used in relation to all automated systems oriented to the task of production management. But sometimes the term MES denotes a set of functions of an automated system used for operational management of production only at the workshop level [10]. It is worth noting that MES is not a new thing in industry. At the same time, today we are talking about the fourth generation of MES (Manufacturing Execution System) – software for managing production processes in real time. From stand-alone local solutions to integrated and modular solutions, platform-based solutions that allow for easy integration of third-party solutions and applications are now in demand.;

– *cloud platforms and services*. Digitization is impossible today without IT infrastructure – networks and data centers. Maintaining your own, modern data center is a very expensive pleasure for most enterprises. Therefore, many manufacturers are switching to cloud services and platforms today. It is important for industrialists to know that the trend in Industry 4.0 is the use of ready-made platforms-as-a-services (PaaS) [7]. Almost every manufacturer of CAE/CAD/PLC/SCADA and even field devices offers integration into them today. Platforms such as Mindsphere (Siemens), Predix (GE), Ability (ABB), Ecostruxure (Schneider Electric) and many others are increasingly used, including in the engineering industry;

– *technologies based on powder metallurgy* – belong to additive technologies, the main difference of which is the addition of what is necessary, and not the removal of excess. They are one of the most advanced technologies for the production of finished metal products (currently, for the production of powders, it is necessary to melt the metal in any case), which make it possible to meet the individual needs of customers by printing unique products directly at the place where they will be used, and are distinguished by a shorter chain value creation. Metallurgical additive technologies (Direct Metal Fabrication) are considered as one of the strategic ones for development, primarily in the aerospace and defense industries. It is expected that the greatest effect can be obtained in the space industry (nozzles, parts and assemblies of liquid rocket engines); aircraft construction (complex profile parts of gas turbine engines, compressors); power engineering (shaped products from high-alloy steels); medicine, especially in surgery and dentistry (creating prostheses and implants); in the manufacture of tools for processing plastic products and parts obtained by injection molding; in the automobile and transport industry (combustion engine parts, structural parts); production of consumer goods [4, p. 92]. At the same time, today this technology is much more expensive than the traditional production of metal products due to the high cost of powders and

3D printers themselves, and has limitations regarding the materials used due to strict requirements for the surface and particle structure of the powders used, fluctuations in the quality of finished products, limitations on the size of printed parts. However, according to analysts' forecasts, in 2030–2035, the volume of the three-dimensional printing market in metallurgy may reach 10 billion USD as a result of the rapid development of technologies and deeper inclusion of the industry in the development and implementation of "smart technologies";

– *development of new products and materials, when the consumer is offered not even a product, but a complex solution* – a combination of new materials (alloys) with unique properties, technical engineering solutions for the use of new alloys in specific products. The development and introduction of metallurgical nanotechnologies, which are gaining special importance in medicine, electronics, and the chemical industry, is taking place at a rapid pace.

The implementation of digital technologies in production directly affects the organizational and economic sphere of enterprise activity, which makes it possible to improve other spheres, in particular marketing and logistics, namely to choose the best option in terms of price and method of transportation and reduce the area of warehouses, shorten delivery time, differentiate suppliers, etc.

In addition, digital technologies contribute to the improvement of the occupational health and safety system at enterprises, make work safer and eliminate the subjective factor in compliance with safety requirements. Everything makes it possible to eliminate the "human factor" of errors and switch to a paperless organization of control. Among the many advantages of digitalization in the field of occupational health and safety, the following main ones can be distinguished:

– *growing use of digital technologies* provided an opportunity to monitor workers in real time to reduce exposure to hazardous factors as a result, regulatory solutions were developed to limit the degree of danger from mechanisms. Based on the received signals, they warn and minimize these threats. In many enterprises where such technologies have already been implemented, modern occupational health and safety systems are successfully operating. For example, these are systems for virtual passing of tests on knowledge of occupational health and safety rules by employees using virtual reality (creating with the help of technical and software a virtual world that is transmitted to a person using the senses: touch, hearing and sight [12]. To create a convincing image, computer synthesis takes place in real time. With the help of special devices (glasses and joysticks), a person can get into the conditions of a production workshop and test his skills in virtual locations of production, where there is a threat of violation of safety rules. For example, workshops for moving cranes and large-sized equipment. It is with the help of virtual reality technologies that an employee can undergo testing to identify dangerous

situations on the territory of the production site. Practice shows that employees remember information better when they immerse themselves in real conditions than when they are simply told about occupational health and safety rules. It is also important for those who undergo the first briefing upon starting work, because it will be easier for the employee to navigate the workshop if he has already visited it virtually. A successful case is the implementation of the MODUS digital transformation program by DTEK in Ukraine. One of the most significant achievements of the MODUS program was the creation of a communication infrastructure at a depth of 500 m in the Yuvileyna mine (DTEK Pavlogradvugillia). The unprecedented for Ukraine example of "Wi-Fi in the mine" made it possible to increase the safety of miners and optimize the cycle of resource extraction. The communication system made it possible to receive data from various safety sensors in real time and notify miners about changes in air and gas parameters, monitor the work process with the help of video cameras, announce and carry out evacuation if necessary, and the mining dispatcher will be able to remotely help the worker in the event of an accident by sending a message on a smart pager lamp, is a miner's individual safety system [13].

Another system that contributes to reducing the risks of accidents at work is *behavioral audit system* – monitoring the actions of workers and warning the worker by the responsible person in case of violation of safe performance rules of work. This modern tool of communication between the worker and his management conveys to the worker the information that each of his violations can lead to an accident, which reduces such violations, which are recorded in real time and registered in a common data system using a mobile application. Moreover, not only the time and specifics of a specific employee's violation are recorded, but also his reaction and suggestions for improving the situation. The system receives objective data on the reasons for violating safety rules and, at the same time, opportunities to further avoid dangerous situations.

Digital motivation for labor protection and industrial safety can improve the process of reception and transfer of shifts by workers and promptly eliminate violations detected during transfer of shifts. When transferring a shift, it is important to analyze the state of the workplace: the presence of personal protective equipment, the appropriate condition of the equipment, the presence of extra items at the workplace. Indicators of the state of the workplace are entered into the system, the person responsible for the violation and the deadline for eliminating the identified deficiencies are set, which allows for an objective analysis of the situation at the workplace and increases the motivation of employees to comply with the established safety rules. At the same time, the emergency management module is promising – a special intelligent digital system that automates the process of investigating accidents and injuries at work and allows determining their causes. The basis of the system is artificial

intelligence, which uses a database of accidents that have already occurred in production for 10 years. With the help of the analysis, the system indicates to the commission about cases, possible direct and indirect causes of the case. When entering information into this system, corresponding reports and administrative documentation are automatically generated. This allows you to automatically set deadlines and monitor the progress of corrective measures (briefing, conducting training events, reviewing job instructions, implementing safe movement routes, training with the brigade, etc.) based on the results of the accident investigation.

If there is dangerous equipment at the enterprise that requires constant condition monitoring, a digital system for monitoring inspections of dangerous equipment is used. The main purpose of which is to eliminate the risk of arbitrary reduction or rerouting of preventive equipment inspection. The time is recorded with the help of an electronic tag reader installed at critical inspection points, the passage of which is recorded in the system. Data indicating the reasons for deviations and comments of the responsible person are entered on the central server. Important at the same time is the introduction of analyzers and sensors that will be able to transmit data and the time of detection of violations of regulated indicators with the help of Internet communication.

In general, the digitalization of business processes in production contributes to the improvement of the main efficiency indicators at industrial enterprises and creates additional opportunities for entering the European and world markets, in particular:

− *changes in the corporate management and organizational structure of companies with the removal and aggregation of some functions (finance, IT sector, repair work, personnel management, procurement, sales, etc.) in separate subdivisions*. Due to the digitalization, there is a clear distribution of responsibility areas along the management vertical, which eliminates duplication and the presence of "gray areas". A necessary condition is the recognition of future changes and a serious attitude towards them already on the part of the owners and management of metallurgical enterprises, as well as representatives of state authorities;

− *acceleration of horizontal and vertical integration of value chains* due to increased direct cooperation between all counterparties, minimizing the influence of intermediaries;

− *product life cycle management* – a long-known category of software products. And this is especially relevant for machine builders when it comes to innovation and constant changes. Various programs have long been used by designers and constructors. Digitization has brought further development of all processes in this direction, and most importantly, throughout the entire life cycle. The main trends in this field concern, first of all, the transfer of the

product life cycle management process to the cloud environment, which turns product data into valuable assets, collaboration platforms, micro-services, as well as blockchain integration;

− *vertical and horizontal integration of machines* using OPC UA. Vertical and horizontal integration of machines is a "feature" of Industry 4.0. Their implementation takes place through method No. 1 of interoperability – both vertically and horizontally (the entire value creation chain) of the enterprise – through the standard of OPC UA;

− *cyber security*. Greater openness of systems leads to greater vulnerability. Indeed, the Internet of Things is sometimes called the Internet of Threats. Cyber-attacks on Oblenergo, hacking of control algorithms in Siemens controllers at the Iranian nuclear power plant, and other (including other non-public) attacks are evidence of the vulnerability of digital technology users. Despite this, the world continues to move to cloud technologies and the industrial Internet of Things, where the issue of cyber security is one of the main. The IEC 62443 standard is mandatory for industrialists to follow this path and build their systems and products safely. For machine builders, the MEK 62451 (OPC UA) standard is also important, which allows you to "mount" the OPC server in the machine in a safe way;

− *new business models.* The transition to service models is a typical characteristic of Industry 4.0. Paradigm and approaches Everything-as-a-Service (XaaS) applied to everything around – SaaS (Software-as-a-Service) models, products and platforms (PaaS) have been in use for a long time. Now it's the turn of machine. Accordingly, an objective question arises – is it not possible to completely give your machine for use as a service, ensuring the final result of its work? Similar approaches are available today thanks to the full digitization of the machine. After all, the main problem of operation is machine maintenance. Thanks to predicative service, exclusively with a whole set of 4.0 technologies (digital twins, cyber security, cloud computing – analytics, etc.) all this becomes real.

It is worth noting that digitization in industry will have both positive effects and negative consequences. The positive effects include: increasing the efficiency and competitiveness of the industry due to the improvement of product quality, reducing costs (especially due to the reduction of energy and resource intensity), increasing the environmental friendliness of production (as a result of improving the quality of raw materials, finished products and development according to the concept of circular economy), reduction of injuries (due to wide use in dangerous areas of machine work); reduction of errors caused by the human factor as a result of increasing the volume and list of data processing operations performed with the help of artificial intelligence; radical reorientation to customer requests, pushing away from the order portfolio when setting up production; a higher degree of synchronization with

other types of activities and society due to the deepening of the participation of all counterparties in the process of creation, consumption and disposal of metal products (often in real time).

The negative consequences include: the possibility of losing large amounts of data due to an increase in cyber threats, possible errors by workers responsible for software development and initial collection of accurate data and entering information into the system, possible concentration of control levers in a small number of companies responsible for development and maintenance digital technologies; insufficient flexibility of response in the event of emergency and force majeure circumstances as a result of the fact that the automated control systems used, even if they are capable of self-learning, cannot adequately and creatively respond to absolutely all challenges; revolutionary changes in the number, structure and necessary training of the workforce, leading to a significant release of qualified workers in the metallurgical industry.

In general, in summary, we can conclude that digitalization enables industrial companies to collect and analyze data from a wider range of partners, suppliers, employees, end users in ways, and to influence production processes faster and more flexibly in order to produce quality products at lower costs.

Chapter 2. Transformation of international trade under the influence of digitalization

International trade, as one of the dynamic spheres of economic activity, is undergoing fundamentally new changes due to the spread of digital technologies and the emergence of innovations that contribute to inclusiveness and the growth of its efficiency [14].

Digitization of international trade has a dual nature of manifestation. On the one hand, this is the process of introducing digital technologies in trade relations at each of the stages (preparation, completion, support, execution of trade agreements), and, on the other hand, it is the diversification of foreign trade by involving in the circulation of new digital products and services that become objects of purchase and sale when using digital channels.

Transformational processes of international trade due to digitalization are on the agenda of leading international organizations and governments of most countries of the world. Publications of the World Trade Organization substantiate that for small and medium-sized firms from least developed countries, digital trade presents more opportunities than challenges [15]. Research by the UN European Economic Commission showed that digitalization of cross-border trade can increase the turnover of small and medium-sized enterprises in developing countries by 4.5% and create favorable conditions for their entry into international markets. In addition, it has been established that digitalization contributes to sustainable, inclusive and

sustainable trade. However, it is worth noting that developing countries need help from partners and international agencies to implement new technologies and tools to benefit from digital trade practices [16].

The Digital Riser report of the European Center for Digital Competitiveness from Europe Business School analyzed indicators of digital development for 140 countries, the results of which are summarized in a global ranking that compares and analyzes changes in the digital competitiveness of countries around the world [17]. Canada and Georgia are among the most active countries in terms of the speed of digital transformation in the world thanks to the policies they have implemented. Ukraine in the group of compared countries of the "Eurasia" block took the penultimate place, losing 66 points according to the "Thinking" indicator, which characterizes such indicators as digital skills among the active population; attitude to entrepreneurial risk; workforce qualification; mobile broadband access to the Internet (Figure 1).

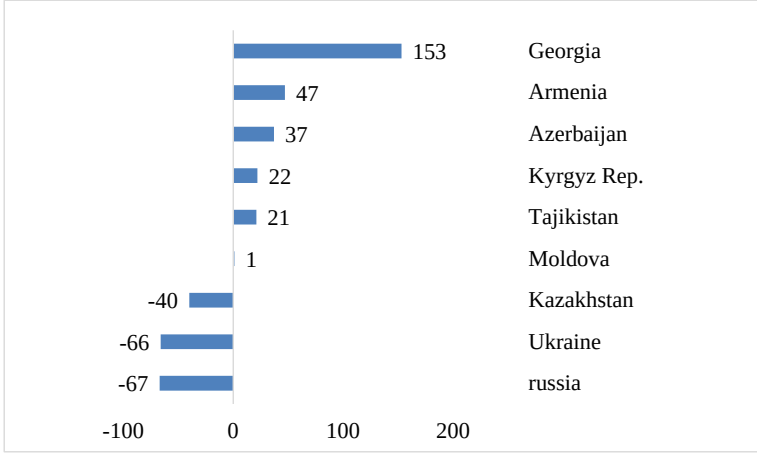

Figure 1. Ukraine's place in the group of compared countries of the "Eurasia"

Source: compiled by the authors [17]

There are also positive results: Ukraine gained 14 points in the rating for the "Ecosystem" block, which characterizes the availability of venture capital; spending time and money on starting a business; ease of hiring foreign labor. The ranking also shows growing digital competitiveness among the two global digital superpowers: China and the US.

According to the UNCTAD "Digital Economy Report 2021", the world leaders in digital trade are the USA, Japan, China, Germany, South Korea,

Great Britain, France, Canada, India and Italy [18]. Although the pace of digital transformation varies in different countries, the general trends show that digitalization has no geographical boundaries (Table 2).

Table 2

Digital trade leaders by country for 2021

Developed countries	Countries with transition economies	Latin America	Asian countries	African countries
Australia Canada EU-27 member states Iceland Israel Japan Liechtenstein New Zealand Norway Switzerland United Kingdom USA	Albania Georgia Kazakhstan Montenegro Moldova Russian Federation Macedonia Ukraine	Argentina Brazil Chile Colombia Costa Rica Ecuador Guatemala Honduras Mexico Nicaragua Panama Paraguay Peru Uruguay	Bahrain Brunei Darussalam China Indonesia Kuwait Malaysia Mongolia Philippines Qatar Republic of Korea Saudi Arabia Singapore Thailand Turkey UAE Hong Kong, China Taiwan	Benin Burkina Faso Cameroon Kenya Cote d'Ivoire

Source: compiled by the authors [18]

The digitalization of international trade has a significant impact on the implementation of the 2030 Agenda for Sustainable Development, creating great opportunities as well as challenges for developing countries. Countries have become more dependent on global supply chains that are managed by digital platforms and receive additional benefits from the implementation of digital technologies at each link of trade relations (Table 3).

The key factors accelerating the digital transformation in trade are the growing role of the consumer, the development of technological innovations, as well as the strengthening of partnership relations, which ensure the activation of innovation processes. In the conditions of information openness, there is a reduction in cost and acceleration of integration – horizontal and vertical. Its strategic role is how companies use digital technologies to improve the quality of goods and services, introduce new services, increase competitiveness, and simplify logistics channels (Table 3).

Table 3

Opportunities provided by digital transformation in international trade

Advantages	Characteristic
Increasing the profitability of trade operations	Reduction of transaction costs due to the absence of the need for financial investments in physical objects; reduction of intermediary operations; increasing return on investment (ROI), return on value (ROV) and expanding investment opportunities for all stakeholders.
Automation of data collection and reduction of documents	Ensuring effective control over all links of the value chain; transition to paperless document circulation
Data collection and statistical process control	Management of global specifications; simplifying bureaucratic procedures and reducing the cost of compliance with regulatory requirements
Simplifying access to markets	Facilitating access of economic agents to resources, information, knowledge, market information and large markets; reducing the costs of starting a new business
Optimization of logistics channels	Eliminating intermediary links, reducing the complexity and length of global value chains

Source: compiled by the authors [17]

The next factor is the exponential growth of innovation in terms of speed, volume and impact. This will provide a significant improvement in efficiency, productivity and cost reduction. In addition, there is a change in the role of the consumer, who becomes dependent on trends popularized through information and communication tools. An example is the formation of a healthy lifestyle culture, which necessitates the transition to the use of ecologically clean food products, stimulating the sale of food products with added useful qualities (superfoods, etc.). The formation of demand for new products is the key to success in competition, when new products appear faster than the consumer demand for them is formed.

The main digital technologies that are transforming international trade include:

1. *Blockchain* as a supply chain optimization solution with capabilities such as high cost, real-time tracking, efficiency and reliability. In international trade, blockchain is used to facilitate the issuance of letters of credit by banks using distributed ledger technology as a data exchange system for many functions such as real-time tracking, digital bills of lading. This can significantly increase trade in countries that often have high trade costs due to their lack of access to the sea. Big data increases the efficiency of production and exports, helping enterprises to effectively plan production, accurately estimate demand and optimize logistics. Likewise, IoT devices detect anomalies in real-time and transmit cross-border electronic information digitally, making trade data

collection more secure, efficient, fast and affordable. Blockchain has practical applications for simplifying the lengthy process of obtaining a letter of credit, a payment mechanism used in international trade. For example, Deloitte helped an Indian private bank to change the design of a letter of credit by developing a blockchain solution (based on the Ethereum platform). The solution reduced the release time from 20–30 days to hours, which had a significant impact on increasing the efficiency of trading operations.

2. *Artificial intelligence and machine learning* can be used to optimize the routes of merchant ships, control the movement of ships and trucks in ports, and translate electronic transaction searches from one language to another. Artificial intelligence is used not only to increase efficiency and improve consumer services, but also to make global trade sustainable. For example, in 2016 Google launched Global Fishing Watch, a real-time tool that uses machine learning to combat illegal fishing by providing a global view of commercial fishing based on vessel movements and satellite data. It can be used by governments and other organizations to identify suspicious behavior and develop sustainable policies. Artificial intelligence can be used to shape global value chains, facilitate e-commerce, simplify translation services and improve trade negotiations. Similarly, robotics and machine learning can work together to help pack, ship and track goods.

3. *Trading services through digital platforms* seamlessly connect customers with service providers in a way that was not possible before when such professional services were mostly delivered in person. Trading services online is getting easier – digital platforms like Upwork allow users to find service providers from around the world. In addition, mobile money accounts have been a major driver of financial inclusion, especially in developing economies. A seamless flow of cross-border e-commerce payments can increase the volume of trade between countries. The rise of global bank account ownership to 71% in developing countries has accelerated the use of mobile payment applications. In addition, applications such as AliPay, PayPal and Venmo have simplified international trade transactions and provided business opportunities for small and medium-sized enterprises.

4. *3D printing* contributes to the dematerialization of international trade, because it provides opportunities for the development of customized production, reduces the need for imports and requires less labor intensive. At the same time, 3D printing technologies require material resources that are available through international trade. These are polymers (plastics) and metals, as well as a number of other materials used in various 3D printing techniques. The impact of 3D printing on global trade is significant, especially as faster and cheaper 3D printing methods become available. For example, in the field of medical technology, the wider use of 3D printing technology increased exports of hearing aids by 58%.

The use of digital technologies expands opportunities for the development of international trade and contributes to the growth of the productivity of its participants. Digitalization reduces costs for startups and small and medium-sized enterprises, allowing them to use software products and related services for sale, avoiding additional costs for intermediary services, in particular for finding highly qualified specialists, unique equipment, instead allowing them to purchase the necessary services from suppliers located in any – anywhere in the world using digital platforms.

In Ukraine, the basic conditions for digital transformation have already been created, in particular those related to the sphere of trade. This is the creation of institutional and legal prerequisites, in particular, the activation of the activities of the Ministry of Digital Transformation, the state institution "Office for the Development of Entrepreneurship and Export", the Export Credit Agency, the Council of Exporters and Investors under the Ministry of Foreign Affairs of Ukraine, the Chamber of Commerce and Industry of Ukraine, regional trade and industry chambers that work in the field of supporting the national producer in promotion to foreign markets. At the same time, digitalization has influenced the improvement of interaction between all parties involved in this process. In addition, support for export-oriented areas of economic activity is also announced in key strategic documents. In the Plan of measures for the post-war recovery and development of Ukraine with a list of proposals for priority reforms and strategic initiatives of the National Council for the Recovery of Ukraine from the Consequences of the War in accordance with Presidential Decree No. 266/2022 of April 21, 2022, it proposes measures for the development of electronic public services, that will contribute to the restoration of the digital economy of Ukraine and its integration into the global digital space. At the same time, the lack of substantiation of strategic initiatives to facilitate the adaptation of Ukrainian business to technological digital challenges increases the gap between Ukraine and the developed countries of the world. To implement the tasks set in the Recovery Plan in this direction, it is important to synchronize materials in accordance with the European strategic course. In particular, according to the EU sectoral initiative Digitizing European Industry under the Digital Single Market package, ensure that businesses of all sizes, locations and sectors can take full advantage of digital innovation. For this, it is important to develop and adopt National strategic documents according to European principles; implementation of digital tools in the work of the State Customs Service; development of digital paperless document circulation and electronic procurement.

The introduction of digital tools makes it possible to accelerate Ukraine’s integration into the global trade space and facilitate access to markets, which involves both the harmonization of legislation and the approximation of trade practices to European standards.

Conclusions

Digital opportunities depend on the technological readiness of the country to implement these innovations in its industrial base. Those enterprises that have been unable to digitize their production processes lose their competitiveness and find themselves on the sidelines of added value creation economic flows. Unpreparedness and reluctance of responsible persons to make correct management decisions may lead to the disappearance of entire industries in the future.

Digital and technological transformations as a process of wide application in the industrial complex of digital information technologies and new materials are primarily aimed at spreading new ways of organizing production, technologies for processing materials and managing business processes. Currently, in Ukraine, state programs do not cover most of these areas, there is a lack of targeted funding from the central and executive authorities and fundamental and applied research in these areas. All this requires the improvement of management mechanisms and system coordination between key stakeholders: state institutions, scientific institutions and business, which involves:

− stimulation of industrial production through various forms of support (informational, institutional, financial – preferential lending to small and medium-sized businesses, projects of non-state business alliances aimed at the development of high-tech activities, including import substitution);

− creation of a bank and development funds, which was not possible during practically the entire independence of the country. As foreign experience shows, without such institutions, it is practically impossible to effectively implement programs for the recovery and restructuring of the economy and industry. As one of the tools that were not used, it is advisable to activate the attraction of population savings as financial instruments within the country;

− improvement of the state order and procurement system through the formation of strategic procurement planning, in particular for defense needs, which will contribute to ensuring sustainable growth rates of industrial production and, in the long term, will contribute to positive structural transformations associated with an increase in the share of products of processing industries and the share of high-tech and scientific products and services in GDP;

− reduction of control and regulatory functions of the state, liberalization of investments taking into account information and economic security of the state. First of all, numerous legislative and regulatory acts regarding the stimulation of foreign investments, the creation of a system of state guarantees for foreign investors should be revised;

− supporting the economic stability of the regions by providing grants for the development of small and medium-sized businesses and the restoration of

the industrial complex (primarily the food industry, stimulation of the development of small farms, etc.);

− actualization, consolidation and coordination of current state and industry strategic documents in accordance with the European practice in accordance with the war situation, in particular the National Economic Strategy 2030, supplemented by the necessary plans and strategies for post-war recovery. Before the war, few of the adopted strategies in Ukraine were implemented in accordance with the stated plans, so it is important to institutionally overcome this deficiency and, minimizing internal procedures, proceed to the implementation of the adopted measures;

− promote the development of cooperation with leading European companies in the implementation of investment projects (construction of new factories) for the production of high-tech military equipment, agricultural machinery, vehicles, etc., as well as stimulate the conclusion of concession agreements and the creation of joint ventures with European transport companies to restore the logistical support of Ukrainian enterprises;

− stimulate export activity, agreement on the removal of trade restrictions between the EU and Ukraine, as well as expansion of opportunities for export to Poland and other EU countries by rail and road transport;

− the involvement of national manufacturers in global value-added chains, in particular in European strategic value-added chains, and the stimulation of foreign investment in the territory of Ukraine in the post-war period by encouraging the relocation to the territory of Ukraine of the capacities of foreign companies that have ceased their activities in the territory of the Russian Federation, in particular in the automotive industry, electronics, food industry, etc.

The key sphere of influence is the development of clusters and innovative infrastructure (technology parks, scientific centers, business incubators, scientific and technical enterprises) and their cooperation with international companies.

In the process of research, it was established that digitalization of the economy in general and industrial production in particular is one of the priority tasks facing the government, business and society of all countries of the world. The world’s leading industrial companies, under conditions of instability of the business environment, are carrying out a deep digital transformation of business models, based primarily on the concept of "Industry 4.0 / 5.0", which, according to the forecasts of leading analytical and international organizations, should become a driver of sustainable economic development.

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