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Collective monograph
Колективна монографія

DIGITAL TRANSFORMATIONS AS THE FOUNDATION OF UKRAINE'S SOCIO-ECONOMIC SECURITY IN THE POSTWAR PERIOD: CONCEPTS, TOOLS AND PROSPECTS

ЦИФРОВІ ТРАНСФОРМАЦІЇ ЯК ФУНДАМЕНТ СОЦІАЛЬНО-ЕКОНОМІЧНОЇ БЕЗПЕКИ УКРАЇНИ У ПІСЛЯВОЄННИЙ ПЕРІОД: КОНЦЕПЦІЇ, ІНСТРУМЕНТИ, ПЕРСПЕКТИВИ

2025

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
ZAPORIZHZHIA NATIONAL UNIVERSITY

Запорізький
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The monograph is based on the results of research within the framework of the project of basic scientific research, applied scientific research, scientific and technical (experimental) developments on the topic № 1/24 "European digitalization practices as a tool for ensuring socio-economic security in war and post-war period" (state registration number 0124U000600) (01.01.2024–31.12.2026).

The collective monograph is intended for scholars, teachers, students of higher education institutions, graduate students, doctoral students, practitioners, representatives of state authorities and local self-government, business, university administrative staff, representatives of civil society, the public and all interested persons.

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ЗАПОРІЗЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ

Запорізький
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Колективна монографія присвячена визначенню ролі цифрової трансформації у забезпеченні соціально-економічної безпеки України; дослідженню світового досвіду цифрової трансформації економіки, впливу цифровізації на соціально-економічну безпеку України; формуванню теоретичних, методичних і практичних основ забезпечення соціально-економічної безпеки шляхом цифрової трансформації економіки.

Монографія виконана за результатами досліджень у рамках проєкту фундаментальних наукових досліджень, прикладних наукових досліджень, науково-технічних (експериментальних) розробок за темою № 1/24 «Європейські практики діджиталізації як інструмент забезпечення соціально-економічної безпеки в умовах війни та повоєнний період» (державний реєстраційний номер 0124U000600) (01.01.2024–31.12.2026).

Колективна монографія розрахована на науковців, викладачів, здобувачів закладів вищої освіти, аспірантів, докторантів, фахівців-практиків, представників державних органів влади та місцевого самоврядування, бізнесу, адміністративного персоналу університетів, представників громадянського суспільства, громадськості та всіх зацікавлених осіб.

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CONTENT

PREFACE

In today's environment, it is extremely important for Ukraine to build an efficient and innovative economy that can quickly adapt to the challenges and threats of the market environment and ensure a high level of social and economic security. Digital transformation is an important tool for modernization, as it will ensure transparency of government processes, efficient use of resources and development of new forms of economic activity. It should be noted that the transition to the digital economy, the introduction of intelligent technologies, automation, e-government, and cybersecurity are important tasks at the level of the national economy. Accordingly, digitalization also contributes to the establishment of stable ties between regions, integration into the global market, and social justice. The introduction of digital technologies at enterprises allows forecasting crisis situations, monitoring security, and helps attract investment, create high-tech jobs, and increase business competitiveness. Thus, determining the prospects for digital transformation plays an important role in shaping the modern strategy of Ukraine's socio-economic development, determines the directions of sustainable development, increasing innovation and security in the long term. Scientists have covered a wide range of issues in terms of studying the trends of digital transformation and determining its impact on the socio-economic security of Ukraine.

The collective monograph is devoted to defining the role of digital transformation in ensuring the socio-economic security of Ukraine; studying the world experience of digital transformation of the economy, the impact of digitalization on the socio-economic security of Ukraine; forming the theoretical, methodological and practical foundations for ensuring socio-economic security through digital transformation of the economy.

The first section examines the theoretical foundations for implementing the European experience of digitalization of Ukraine's economy. A thorough analysis of the world experience

in terms of digitalization of enterprise logistics is carried out. The EU practices in the direction of digital transformation of inventory accounting are considered. The influence of global challenges on the transformation of business processes is determined. Recommendations for the digitalization of the Ukrainian economy in the context of European integration are provided.

The second section is devoted to the issue of the impact of digitalization on the socio-economic security of Ukraine. According to the results of the study, the role of digitalization for the sustainable development of the agrarian economy in the context of modern challenges is determined. The modern marketing strategies of enterprises are studied and the peculiarities of the transformation of the marketing communication strategy are determined. The relationship between the digitalization of the economy and the national security of Ukraine is revealed. Recommendations for ensuring national security through the introduction of digital technologies are formed.

The third section deals with the peculiarities of ensuring socio-economic security through digital transformation of the economy. The directions of ensuring the national security of Ukraine through the introduction of anti-crisis management mechanisms are identified. The role of modern technologies in identifying threats to national security is also revealed. The digital challenges of enterprise staffing are analyzed and the prospects for the use of digital technologies in the service sector are determined. Based on the results of the study, recommendations for the use of digital technologies for monitoring and managing logistics chains are formulated.

The collective monograph offers theoretical and methodological generalizations, conclusions, and practical recommendations that will be useful for researchers, teachers, students of higher education institutions, postgraduates, doctoral students, practitioners, representatives of state authorities and local governments, business, university administrative staff, representatives of civil society, the public, and all interested parties.

The collective monograph is based on the results of research within the framework of the project of basic scientific research, applied scientific research, scientific and technical (experimental) developments on the topic № 1/24 “European digitalization practices as a tool for ensuring socio-economic security in war and post-war period” (state registration number 0124U000600) (01.01.2024–31.12.2026).

ПЕРЕДМОВА

В умовах сьогодення надзвичайно важливим для України є побудова ефективної та інноваційної економіки, яка здатна швидко адаптуватися до викликів, загроз ринкового середовища і забезпечувати високий рівень соціально-економічної безпеки. Саме цифрова трансформація є вагомим інструментом модернізації, адже дозволить забезпечити прозорість державних процесів, ефективне використання ресурсів і розвиток нових форм економічної діяльності. Слід відзначити, що перехід до цифрової економіки, впровадження інтелектуальних технологій, здійснення автоматизації, запровадження електронного урядування та підвищення рівня кібербезпеки є важливими завданнями на рівні національної економіки. Відповідно цифровізація також сприяє налагодженню стабільних зв'язків між регіонами, інтеграції до глобального ринку та забезпеченню соціальної справедливості. Впровадження цифрових технологій на підприємствах дозволяє прогнозувати кризові ситуації, здійснювати моніторинг безпеки, а також сприяє залученню інвестицій, створенню високотехнологічних робочих місць, підвищенню конкурентоспроможності бізнесу. Отже, визначення перспектив цифрової трансформації відіграє важливе значення у формуванні сучасної стратегії соціально-економічного розвитку України, визначає напрямки сталого розвитку, підвищення інноваційності та безпеки в довгостроковій перспективі. Науковцями розкрито широке коло питань в аспекті дослідження тенденцій цифрової трансформації та визначення її впливу на соціально-економічну безпеку України.

Колективна монографія присвячена визначенню ролі цифрової трансформації у забезпеченні соціально-економічної безпеки України; дослідженню світового досвіду цифрової трансформації економіки, впливу цифровізації на соціально-економічну безпеку України; формуванню теоретичних, методичних і практичних основ забезпечення соціально-економічної безпеки шляхом цифрової трансформації економіки.

У першому розділі досліджено теоретичні засади впровадження європейського досвіду цифровізації економіки України. Проведено ґрунтовний аналіз світового досвіду в аспекті здійснення цифровізації логістики підприємств. Розглянуто практики ЄС в напрямку здійснення цифрової трансформації обліку виробничих запасів. Визначено вплив глобальних викликів на трансформацію бізнес-процесів. Наведено рекомендації щодо здійснення цифровізації української економіки в контексті євроінтеграції.

Другий розділ присвячений розкриттю питання впливу цифровізації на соціально-економічну безпеку України. За результатами дослідження визначено роль цифровізації для сталого розвитку аграрної економіки в умовах сучасних викликів. Досліджено сучасні маркетингові стратегії підприємств та визначено особливості трансформації маркетингової комунікаційної стратегії. Розкрито взаємозв'язок між цифровізацією економіки та національною безпекою України. Сформовано рекомендації до забезпечення національної безпеки через запровадження цифрових технологій.

У третьому розділі розкрито питання особливостей забезпечення соціально-економічної безпеки шляхом цифрової трансформації економіки. Визначено напрямки забезпечення національної безпеки України через впровадження механізмів антикризового управління. Також розкрито роль сучасних технологій у виявленні загроз національній безпеці. Проаналізовано цифрові виклики кадрового забезпечення підприємства та визначено перспективи використання цифрових технологій у сфері обслуговування. За результатами дослідження сформовано рекомендації щодо використання цифрових технологій моніторингу та управління логістичними ланцюгами.

В колективній монографії запропоновано теоретико-методичні узагальнення, висновки та практичні рекомендації, які стануть у нагоді для науковців, викладачів, здобувачів закладів вищої освіти, аспірантів, докторантів, фахівців-практиків, представників державних органів влади та місцевого самоврядування, бізнесу, адміністративного персоналу університетів, представників громадянського суспільства, громадськості та всіх зацікавлених осіб.

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SECTION 1
Global experience of digital transformation of the economy

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1.1. DIGITALIZATION OF ENTERPRISE LOGISTICS: GLOBAL EXPERIENCE

Introduction. In today's globalized world, logistics has become one of the key functional areas of any manufacturing enterprise, especially in high-tech industries such as engineering. The speed, accuracy, and efficiency of logistics processes directly affect not only the financial results of an enterprise, but also its competitiveness in international markets. Given the dynamic development of technology, accelerating changes in consumer demands, more

complex supply chains, and increased requirements for environmental sustainability, logistics can no longer operate according to traditional models. That is why the digitalization of logistics is coming to the fore, driving a new industrial revolution.

Digital logistics is not just the automation of individual processes, but a profound transformation of the entire logistics system using digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, cloud computing, digital twins, blockchain, supply chain management (SCM) systems, and robotic systems. In the context of global crises, supply chain disruptions, pandemic and military challenges, digitalization makes it possible to adapt the logistics system to an unstable environment, ensure its flexibility, transparency and sustainability [1].

The automotive industry, as one of the most logistically complex industries, has long been a leader in implementing digital innovations in logistics. According to international research, the world's leading automakers are actively investing billions of dollars in the digital transformation of their supply chains. Tesla, Mercedes-Benz, and Toyota demonstrate successful examples of deep integration of digital technologies at all stages of the logistics process, from supply planning to distribution of finished products. At the same time, Ukrainian manufacturers are only at the beginning of this journey, and their experience is valuable for understanding the real possibilities of adapting global practices in difficult economic and infrastructure conditions.

A study of global experience in the digitalization of logistics on the example of machine-building enterprises allows not only to identify current technological trends but also to assess the real effects, challenges, risks, and potential for scaling such solutions in the national context. This issue is particularly important in Ukraine, which, despite the war, is making efforts to preserve and develop its production potential, including in the machine-building and logistics sectors.

An analysis of global cases of digital transformation of logistics will help identify strategic areas of development for Ukrainian enterprises, formulate recommendations for the introduction of innovative logistics solutions, increase the efficiency of logistics

operations, attract investment, and create a digital infrastructure at the national level. Thus, the issue of digitalization of logistics at the current stage of economic development is not only relevant but also strategically important in the context of global integration and competitiveness of national business.

Presentation of the main results of the study. Digital logistics is a modern paradigm of organizing and managing logistics processes based on the widespread use of information and communication technologies to achieve greater efficiency, accuracy, transparency and adaptability in supply chain management. It covers all stages of the supply chain: procurement, storage, transportation, order processing, inventory management, distribution, and reverse logistics. Unlike traditional logistics, which relies on isolated automated systems, digital logistics is based on an integrated approach that ensures continuous real-time data exchange between all process participants.

In the scientific literature, digital logistics is often seen as a logical extension of the Industry 4.0 concept, which involves a profound transformation of production and logistics processes under the influence of digital technologies. It is not only the modernization of individual functions, but a fundamental change in the way decisions are made, interactions between departments, data exchange, and strategic planning. Digital logistics allows us to move from reactive to proactive management, where decisions are made based on foresight and scenario modeling, not just on actual data about past events [2].

One of the basic technologies of digital logistics is the Internet of Things (IoT), which allows for the integration of physical objects (vehicles, equipment, containers, warehouses, cargo) into a single network with the ability to exchange data. Sensors, chips, trackers, and AI devices record parameters in real time, such as location, temperature, load level, vibration, and equipment condition. This helps reduce the risk of damage, prevent downtime, and improve delivery accuracy.

Artificial intelligence (AI) processes large volumes of logistics data and automatically detects patterns, which allows optimizing transportation routes, forecasting demand, managing inventory, identifying risks, and responding to changes in real time.

Blockchain technology in logistics is a tool for ensuring transparency and trust between supply chain participants. It allows creating unchanging digital records of every transaction – from production to delivery to the end user. This is especially true for international transportation, where it is important to have proof of origin, compliance with transportation conditions, and the absence of falsifications.

Another important aspect of logistics digitalization is robotization. It includes the introduction of autonomous mobile robots in warehouses, robotic systems for sorting and packaging, automatic forklifts, unmanned vehicles, and delivery drones. In the large logistics centers of leading companies such as Amazon, Tesla, or Toyota, robotics allows for logistics operations with minimal human involvement, reducing the risk of errors, shortening order processing times, and improving workplace safety.

The expected effects of the digitalization of logistics are multifaceted. First and foremost, it is an increase in transparency due to the ability to obtain up-to-date information about each stage of the logistics process. Each participant – from the supplier to the customer – has access to relevant data, which minimizes delays, misunderstandings, or fraud. The second key benefit is increased efficiency: digital technologies can cut costs, reduce errors, lower inventory levels, and improve resource utilization. Finally, the system's adaptability to environmental changes is another critical effect. In a digital format, the logistics system can instantly respond to changes in demand, weather conditions, supply disruptions, or even geopolitical risks by changing routes, reorienting suppliers, or activating alternative logistics scenarios [3].

Thus, the digitalization of logistics is not just the introduction of new technologies, but a systemic change in the entire logistics paradigm. It is a way to create more flexible, sustainable and customer-oriented supply chains that can operate effectively in a world of constant change and high competition.

The digitalization of logistics is one of the key factors for increasing competitiveness in a globalized economy. Countries around the world demonstrate different levels of digital development

in this area, which depends on many factors, including economic potential, political situation, and government support. The most prominent leaders in digitalization are the United States, Europe and Asia, while Ukraine is still at the stage of implementing digital solutions [4].

European countries are actively working to create a unified digital transport ecosystem, including initiatives to standardize data exchange, such as eFTI (electronic Freight Transport Information), and support environmentally sustainable development through intelligent transport systems (ITS). In Western European countries, such as Germany, the Netherlands, and Belgium, digital solutions are integrated into supply chains through automated sorting centers, IoT, and cloud platforms. The Netherlands, for example, is a leader in implementing digital integration solutions in logistics, such as the automation of port processes in Rotterdam.

One of the main features of the European approach is the focus on reducing the environmental footprint through the use of digital technologies to optimize routes and reduce resource consumption. Support from government programs such as Horizon Europe ensures a high level of investment in innovation.

The United States remains a leader in the introduction of the latest technologies in logistics, particularly in areas such as Big Data, artificial intelligence, autonomous trucks and drones. Companies such as Amazon and FedEx are actively using these technologies to automate warehouses and optimize delivery routes. Amazon uses more than 500,000 robots in its warehouses to speed up processes and uses algorithms to predict demand.

In addition, the United States is actively testing autonomous transportation technologies to reduce costs and improve road safety. The country's legal framework is flexible and supports an innovative approach that allows testing new models, particularly in the transportation sector, without significant regulatory restrictions.

Asia, particularly China, Japan, and South Korea, is experiencing rapid development of digital technologies in logistics. China is actively investing in automated logistics hubs, self-driving trucks, and drones.

China is also actively using artificial intelligence and 5G to improve communication and transportation management.

Japan is focusing on integrating digital technologies into manufacturing logistics, using advanced solutions to optimize inventory and delivery, while South Korea is actively testing autonomous trucks and AI innovative solutions for process automation.

In Ukraine, the digitalization of logistics is still in its infancy. Leading companies such as Nova Poshta and Ukrposhta are introducing automated sorting centers, CRM systems, and mobile applications for parcel tracking. In particular, Nova Poshta has opened an automated terminal in Lviv that can handle up to 20,000 parcels per hour [5].

Despite the difficult political and economic situation, the country continues to develop digital solutions in logistics, which allows it to improve delivery efficiency even in times of war. However, the main challenges remain the lack of stable infrastructure, lack of investment, and human resources.

According to Table 1, the United States is a leader due to its large-scale investments in the latest technologies, such as AI, Big Data, autonomous trucks and robots, which allows to significantly improve the efficiency of logistics processes.

Europe demonstrates a high level of integration and standardization within a single transport system, in particular through initiatives that support sustainable development.

Asia stands out among other regions due to its rapid adoption of new technologies, particularly in China, where significant investments are made in advanced infrastructure and process automation. Despite existing challenges, Ukraine is actively developing digital technologies in the logistics sector, especially at the level of individual companies, which is a positive sign for the further advancement of this field.

Digitalization is a crucial factor in the development of modern machine-building enterprises, helping to optimize production processes, reduce costs, and increase efficiency. Contemporary companies are actively implementing technologies such as the Internet of Things (IoT), artificial intelligence, blockchain, robotics, and other advanced IT solutions to enhance their logistics operations.

Table 1

The state of logistics digitalization in the world

Parameter / Region	Europe	USA	Asia	Ukraine
Level of Digitalization	High	Very High	Very High	Medium
Key Technologies	IoT, AI, eFTI, ERP, Blockchain	AI, Big Data, Drones, Robots	IoT, 5G, Blockchain, Robots	ERP, WMS, Mobile Applications
Government Policy	Coordination, Regulation	Flexibility, Incentives	Active Government Support	Limited, No Systematic Approach
Infrastructure	Developed	Highly Developed	High-Tech	Partially Damaged by War
Investment	High (e.g., Horizon Europe)	Very High (e.g., IIJA)	High (Public + Private)	Limited
Strengths	Standardization, Sustainability	Innovation, Scalability	Scale, Flexibility	Adaptability, Flexibility
Key Challenges	System Fragmentation	Cybersecurity, Workforce	Uneven Implementation	War, Finances, Workforce

Source: compiled on the basis of [6; 7]

Digitalization in the machine-building industry is especially relevant due to the increasing demands for delivery speed, supply chain transparency, and the reduction of the carbon footprint. Enterprises that adopt modern digital technologies can significantly enhance their competitiveness and adapt to rapidly changing market conditions. It is important to note that large companies such as Tesla, Mercedes, and Toyota are investing heavily in digital solutions, which allows them to maintain their market leadership. At the same time, Ukrainian manufacturers like KRAZ have great potential for modernization and the adoption of digital technologies, which would improve their operational efficiency and enable integration into global supply chains.

The data presented in Table 2 highlights the disparity in the level of digitalization between leading global car manufacturers and the

Ukrainian enterprise KRAZ. Tesla, Mercedes, and Toyota factories are at the forefront of technological advancement, actively integrating cutting-edge technologies into their production processes and logistics operations. Tesla has invested over $8.5 billion in the development of digital technologies, enabling a high level of automation across all stages of production. This includes robotics, the use of IoT, artificial intelligence (AI), and blockchain technologies for supply chain management. Mercedes-Benz and Toyota also show significant investments in "Industry 4.0" and green logistics, with Mercedes-Benz allocating €3.3 billion to the development of robotics and automation.

Meanwhile, the KRAZ plant, one of Ukraine's leading heavy machinery manufacturers, is currently at a less advanced stage of digitalization. Investments in modernization at the enterprise amount to only about $5 million, mainly from state orders and international military contracts. This is significantly less than what global leaders invest, which limits the company's ability to implement the latest solutions, such as robotics and full automation.

The main challenge for KRAZ is the lack of sufficient funding for large-scale adoption of advanced technologies. As a result, the company only utilizes selected automation elements, such as basic ERP systems for supply chain monitoring and warehouse automation. However, there is considerable potential for modernization, particularly through the integration of IoT, AI, and robotics, which would allow the enterprise to increase efficiency and reduce production costs.

Digitalization is also a key factor in improving product quality and optimizing logistics processes, particularly for the KRAZ plant, which could benefit from implementing more efficient solutions for supply chain management and real-time production monitoring.

The digitalization of logistics in Ukraine is a crucial area for economic development, especially amid current challenges such as globalization, war, and the need to modernize infrastructure. In recent years, there has been significant progress in utilizing digital technologies to optimize transportation and cargo delivery processes.

However, serious problems remain, particularly outdated infrastructure and instability due to external threats.

Table 2

Digital solutions at machine-building enterprises

Parameter	Tesla	Mercedes-Benz	Toyota	KRAZ
Level of Digitalization	High	High	Medium	Low
Investment in Digital Technologies (10 years)	$8.5billion(R&D, automation)	€3.3 billion in automation and Industry 4.0	$2.5 billion for plant digitalization	$5 million in automation (current level)
Key Technologies	IoT, AI, Blockchain, Robotics, TMS, WMS	IoT, AI, Robotics, ERP, Green Logistics	IoT, AI, Robotics, Lean Production	ERP, Partial Robotics, Warehouse Automation
Digital Strategies	Full integration of digital solutions into production	Industry 4.0, Green Logistics, IT System Integration	Lean Production, Supply Chain Digitalization	Process Automation, Monitoring
Level of Robotics	High (fully automated lines)	High (robots on assembly lines)	Medium (robots on assembly lines)	Partial Robotics (warehouse and packaging)
IT Solutions in Logistics	TMS, WMS, Blockchain for supply chain management	ERP, WMS, TMS, Warehouse Automation	AI, IoT, Automated Transport Systems	ERP system for supply chain monitoring
Key Challenges	Data Security, Integration of New Suppliers	Robot Downtime Risks, Integration Complexity	Uncertainty about Future Technologies	Limited Funding, Weak Infrastructure
Future Plans	Expand Automation, Implement New AI Solutions	Deepen Automation and AI Integration	Develop IoT and AI for Supply Chain Optimization	Expand Warehouse Automation, Implement New IT Solutions

Source: compiled on the basis of [8; 9; 10; 11]

One of the main weaknesses of Ukrainian logistics is underdeveloped infrastructure, especially outdated roads, railway tracks, and ports. Nonetheless, investments in infrastructure modernization, including national and international transport routes, are gradually improving the situation. In recent years, over UAH 3 billion has been allocated for infrastructure enhancement. However, the war has once again put many of these projects on hold.

On the other hand, there is significant potential for the development of digital technologies such as IoT, artificial intelligence (AI), and Big Data for monitoring and managing logistics flows. Ukrainian companies are actively adopting advanced IT solutions to optimize cargo transportation and improve warehouse management. Notably, "Nova Poshta" demonstrates substantial progress in this area by actively implementing warehouse automation and intelligent cargo management systems.

The state plays an important role in supporting digitalization by creating national platforms for transport and logistics flow monitoring, as well as providing incentives for businesses. However, a key issue is the lack of a clear national strategy for implementing cutting-edge technologies in logistics. The private sector is rapidly advancing in this direction, particularly companies like Nova Poshta, which already utilize digital solutions to enhance delivery processes.

As shown in Table 3, investment support from both the state and the business sector is crucial for digitalization. While the private sector is actively investing in new technologies, state support remains insufficient, which limits the potential for rapid development. The issue of cybersecurity, which is critical for implementing digital solutions, also remains unresolved and could hinder the large-scale transition to digital technologies. Given the significant impact of the war on infrastructure, the government needs to strengthen its role in infrastructure recovery and support for digital innovations. In the coming years, we can expect the growth of startups and the startup ecosystem in the logistics sector, which will further motivate investment and collaboration with international partners.

Table 3

State and prospects of logistics digitalization in Ukraine

Aspect	Today	Prospects for the Next 5–10 years
Logistics Infrastructure	Developed transport network (roads, railways, ports), but requires modernization	Infrastructure modernization (road repairs, railway upgrades, port development)
Digital Technologies	Implementation of IT platforms for cargo monitoring, partial use of IoT and Big Data in supply chain management	Development of "smart" logistics platforms, automated warehouses, delivery drones
Investment	Private and public investments, including infrastructure modernization (over UAH 3 billion in 2020)	Increased investment in digital technologies, growth of logistics startups
Data Security	Cybersecurity and data protection issues due to lack of effective security measures	Development of national cybersecurity infrastructure, improved data protection
Impact of War	Disruption of supply chains, blocked ports, infrastructure destruction, partial use of digital solutions	Infrastructure recovery, implementation of new technologies to stabilize logistics
Customs Infrastructure	Gradual automation of customs processes, but significant improvement still needed	Full automation of customs operations, use of electronic documents and blockchain
Transportation and Flows	Partial automation of transport, especially in large warehouses and enterprises	Widespread adoption of autonomous vehicles and electric trucks
Role of the State	Support through infrastructure and digital economy development programs, creation of national monitoring platforms	Enhanced state role in coordinating digital initiatives, creating incentives for investors
Startups and Innovation	Early AI startups and innovation projects in the sector, but limited overall impact	Development of innovative logistics startups, implementation of robotics and drones

Source: compiled on the basis of [12; 13]

Digitalization of logistics in Ukraine holds significant development potential, but it requires large-scale investments in infrastructure, the improvement of digital solutions, and an adequate level of cybersecurity. The role of the state in this process is critically important, as it must create favorable conditions for the development of digital startups and innovative projects. Ukraine also needs to actively work on restoring and modernizing its infrastructure, which is essential for sustainable economic development during wartime and post-war recovery [14].

Conclusions. The digitalization of logistics is a strategic direction for the development of the global economy, and its importance amid globalization and technological transformation cannot be overstated. Studying current trends and global best practices in this field highlights the necessity of implementing digital technologies in logistics for both large international corporations and small and medium-sized enterprises in Ukraine.

Digitalization efforts in Europe, the USA, Japan, and China demonstrate the effectiveness of technologies such as IoT, artificial intelligence, blockchain, and automated supply chain management systems. These technologies help reduce costs, increase transparency, and improve logistics efficiency. In Ukraine, despite challenges with outdated infrastructure and political instability, there is observable progress in implementing digital technologies in logistics – although this process still requires substantial investment and strong governmental support.

Digitalization is particularly vital for Ukrainian businesses, which face numerous challenges due to the war and infrastructure recovery needs. At the same time, it opens new opportunities for modernizing logistics processes and adapting to new realities, especially in a context of instability and limited resources.

To successfully digitalize logistics in Ukraine, it is necessary not only to improve infrastructure but also to promote educational programs for training highly skilled personnel, invest in startups, and actively cooperate with international partners to implement cutting-edge solutions. Governmental support must become a key factor in the logistics transformation process, providing a sound legal framework for the development of digital technologies.

Ukraine's logistics sector has a real chance to become globally competitive if digitalization is accelerated through a comprehensive approach involving infrastructure development, education, investment, and international partnerships. This will allow Ukraine to effectively integrate into the global economic space, ensuring stability and innovative growth in logistics operations.

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1.2. INTERNATIONAL BUSINESS MANAGEMENT IN THE CONTEXT OF THE DIGITAL ECONOMY: THE EUROPEAN DIMENSION

Introduction. The modern digital economy is significantly transforming international business, changing management models, organizational structures, and companies' competitive strategies. In the digital era, traditional business methods are giving way to advanced technologies such as artificial intelligence, big data, blockchain, and cloud computing. Amid globalization and digitalization, companies are

compelled to adapt their management processes to remain competitive in international markets.

The European Union is one of the global leaders in implementing digital technologies in international business, establishing effective regulatory mechanisms and supporting innovative development. The digital transformation policy, particularly the EU initiatives to create a Single Digital Market, contributes to improving business conditions, optimizing logistics, financial operations, and supply chain management.

Studying the European experience helps identify best practices in digital management and their adaptation to the conditions of other countries. Beyond technological changes, digitalization poses new challenges for international business management, including cybersecurity issues, personal data protection, regulation of digital platforms, and automation of business processes.

Therefore, researching the specifics of digital management in international business within the European context is important for understanding current trends, developing effective management strategies, and enhancing the competitiveness of companies in the global economy.

Presentation of the Main Research Findings. The essence of the digital economy consists in the application of digital technologies for the creation, processing, storage, and transmission of information, fundamentally transforming traditional business models and economic relations. It is grounded in internet technologies, big data, artificial intelligence (AI), cloud computing, and blockchain, which collectively provide enhanced speed, flexibility, and accessibility of economic processes.

Data serves as the cornerstone of the digital economy, representing a novel form of valuable resource analogous to oil or capital within the traditional economic framework. A defining characteristic of the digital economy is the transition from physical assets to digital platforms and services, thereby reshaping approaches to the production, distribution, and consumption of goods and services.

Furthermore, the digital economy facilitates the globalization of business by enabling enterprises to access international markets without necessitating a physical presence. Digitalization also

fosters the automation of business processes, the emergence of new employment modalities such as freelancing and remote work, and induces structural changes within labor markets.

Nonetheless, the digital economy introduces significant challenges, including issues of data security, digital divides among countries and economic sectors, and the imperative to adapt legal and regulatory frameworks. The deployment of digital technologies mandates robust cybersecurity measures, a requirement of particular importance for the financial sector and international business operations.

Simultaneously, digitalization presents novel opportunities for economic growth, productivity enhancement, and the establishment of competitive advantages within the global economic environment.

These conceptual frameworks delineate contemporary approaches to business management in the digital milieu and constitute the foundation for corporate competitiveness at the international level (see Table 1).

Table 1

Key Concepts of Digital Management

Concept	Essence	Main Tools and Approaches
1	2	3
Digital Transformation	Comprehensive transition of a company to digital technologies aimed at enhancing business process efficiency	Big Data, AI, cloud technologies, automation, IoT
Agile Management	Flexible management approach that enables rapid adaptation to market changes	Scrum, Kanban, Lean, DevOps
Platform Economy	Utilization of digital platforms to facilitate interactions between consumers and providers of goods or services	Marketplaces (Amazon, Alibaba), fintech platforms, crowdsourcing
Virtual Teams Management	Managing distributed teams working remotely through digital technologies	Zoom, Microsoft Teams, Slack, Trello

Continuation of Table 1

1	2	3
Business Process Automation (BPA)	Application of digital technologies to minimize manual labor and improve process efficiency	RPA (Robotic Process Automation), ERP systems, CRM systems
Digital Marketing	Promotion of brands, goods, and services via digital channels	SEO, content marketing, social media, targeted advertising
Cybersecurity Management	Ensuring protection of company information resources from cyber threats	Data encryption, multi-factor authentication, antivirus software

Source: compiled based on [2–6]

The European Union's digital economy policy is aimed at developing digital technologies, strengthening the competitiveness of European companies, and creating a secure digital environment. One of the key initiatives is the Digital Europe Programme, which supports the development of supercomputers, artificial intelligence, cybersecurity, and digital skills.

Moreover, the EU actively works on establishing the Digital Single Market (DSM), which seeks to eliminate barriers between member states by simplifying e-commerce, ensuring the free flow of data, and protecting user rights in the digital environment.

European initiatives and programs support digital business by investing in new technologies and facilitating their adoption in entrepreneurial activities. For instance, the Horizon Europe Programme finances innovative projects, particularly in the fields of digitalization and artificial intelligence. Additionally, the Digital Innovation Hubs Programme assists small and medium-sized enterprises in adapting digital technologies to enhance productivity and competitiveness.

Regulation of the digital market within the EU also plays a crucial role in ensuring transparency and fair competition. The Digital

Services Act and the Digital Markets Act aim to oversee the activities of digital platforms and protect consumer rights. Furthermore, the General Data Protection Regulation (GDPR) establishes stringent requirements for the processing of personal data, ensuring security and trust in the digital space.

All these initiatives collectively shape the European digital ecosystem (see Table 2), which fosters the development of international business.

Table 2

EU Digital Economy Policy and Initiatives to Support Digital Business

Direction	Description	Key Programs and Regulations
Digital Europe	EU program focused on the development of digital technologies including supercomputers, AI, cybersecurity, and digital skills	Digital Europe Programme (DEP)
Digital Single Market (DSM)	Removal of barriers between member states to simplify e-commerce, enable free data flow, and protect user rights	Digital Single Market Strategy
Funding for Innovation in the Digital Economy	Support for research and development in digital technologies	Horizon Europe
Support for Digital Business Transformation	Assistance to small and medium-sized enterprises in implementing digital solutions	European Digital Innovation Hubs (EDIH)
Regulation of the Digital Market	Oversight of digital platform activities to ensure transparency, fair competition, and user protection	Digital Services Act (DSA), Digital Markets Act (DMA)
Personal Data Protection	Establishment of strict requirements for personal data processing and ensuring information security	General Data Protection Regulation (GDPR)

Source: compiled based on [11; 15]

These initiatives contribute to creating a favorable environment for the development of the digital economy in Europe and enhance the competitiveness of European companies in international business.

In light of the EU's digital economy policy, the use of Big Data, AI, IoT, and Blockchain represents a strategic direction for the development of European companies (see Table 3). The EU actively invests in these technologies through programs such as Digital Europe and Horizon Europe, fostering innovation, scientific research, and digital technology advancement.

The use of Big Data enables European companies to analyze vast amounts of information to create new business models and improve services. Artificial Intelligence (AI) is integrated into production processes, optimizes managerial decision-making, and supports intelligent systems for personalized marketing campaigns. The Internet of Things (IoT) helps European companies optimize supply chains and production by enhancing efficiency through real-time monitoring of assets and processes. Blockchain is utilized to ensure the security and transparency of financial transactions, which is a key priority for the EU in the context of developing the Digital Single Market. Business process automation and electronic document management are also important components of EU policy. Within the framework of the Digital Single Market (DSM) initiative, the EU works on integrating business processes into the digital environment, which involves simplifying cross-border operations and access to services.

ERP and CRM systems are actively employed by European companies to automate management, financial, and logistics processes. Robotic Process Automation (RPA) enables companies to reduce costs and increase data processing efficiency, particularly in sectors such as finance and insurance. Electronic document management is becoming a standard across all EU countries, ensuring greater efficiency in information exchange between public authorities, businesses, and citizens.

Virtual teams and remote personnel management have become an important part of the EU's digital transformation policy, especially following the COVID-19 pandemic. The EU actively supports

initiatives that enable companies to develop remote work processes through the Digital Europe Programme and digital skills development programs. The use of cloud platforms for collaboration allows European companies to work with teams across the continent, reducing office space costs and attracting talent from various countries.

At the same time, the EU imposes strict data protection requirements in the context of remote management, ensured through the General Data Protection Regulation (GDPR).

Table 3

EU Policy on Digital Technologies in Business

Technology / Approach	Description	European Initiatives and Programs
Big Data	Utilization of large data sets for forecasting and improving business models	Horizon Europe, Digital Europe Programme
AI (Artificial Intelligence)	Integration of AI for automating business processes, personalizing marketing, and management decisions	AI for Europe, Digital Europe Programme
IoT (Internet of Things)	Connecting devices to the Internet for monitoring and optimizing business processes	Digital Single Market, Horizon Europe
Blockchain	Use for secure and transparent transactions, including smart contracts	Digital Services Act, Blockchain Partnership
Business Process Automation (RPA)	Automation of routine tasks to enhance efficiency	Digital Europe Programme, Horizon Europe
Electronic Document Management	Transition to digital documents to simplify business operations and reduce costs	eIDAS (Electronic Identification and Trust Services)
Virtual Teams	Management of remote teams via digital platforms	Digital Skills and Jobs Coalition, Digital Europe Programme

Source: compiled based on [5]

These technologies and programs help the EU ensure the competitiveness of European companies in the global digital environment and promote the integration and development of the Digital Single Market within the European Union.The European Union actively implements digital technologies in the business environment, considering them a key factor for economic development (see Table 4). The main directions of digital policy include the development of artificial intelligence, cybersecurity, cloud computing, and digital finance. Under the Digital Europe Programme (2021–2027), an investment of €7.5 billion is allocated to digital innovations, which will contribute to enhancing the competitiveness of European companies. Special emphasis is placed on supporting small and medium-sized enterprises (SMEs) through European Digital Innovation Hubs (EDIHs), which provide companies access to advanced technologies and consulting services. Initiatives on digital education and the expansion of the 5G network to ensure high-speed internet connectivity are also being implemented. In 2023, the level of digitalization of companies in the EU reached 75 %, which is 10 % higher than in 2020.

At the same time, there are challenges, notably the varying levels of digital maturity among companies across different countries, which complicates unified digital transformation. For example, 85 % of companies in Denmark have a digital strategy, whereas in Bulgaria this figure is only 45 %. To bridge this gap, the EU has introduced the Digital Markets Act (DMA) and the Digital Services Act (DSA), which regulate digital competition and online security.

Table 4

Key indicators of business digital transformation in the EU

Indicator	2020	2023	Expected 2027
Business digitalization level (%)	65	75	85
Investments in Digital Europe (billion EUR)	–	7.5	9.2
Share of SMEs using cloud technologies (%)	40	55	70
5G coverage in urban areas (%)	30	68	90
Number of EDIHs	81	151	200+

Source: compiled based on [4; 5; 6]

The analysis of the table indicates a dynamic development of business digitalization within the EU. Specifically, the level of digitalization among enterprises increased from 65 % in 2020 to 75 % in 2023, with a forecasted rise to 85 % by 2027. This reflects the active adoption of digital technologies, which contributes to enhanced business efficiency and competitiveness in the global market. Investments in the Digital Europe programme have significantly increased, enabling wider access for companies to cloud technologies, artificial intelligence, and 5G networks. For example, the share of small and medium-sized enterprises (SMEs) using cloud computing rose from 40 % in 2020 to 55 % in 2023, with an expected increase to 70 % by 2027. Significant progress is also evident in the deployment of 5G networks: urban coverage expanded from merely 30 % in 2020 to 68 % in 2023 [5].

Despite positive trends, the digital divide among EU countries remains a challenge. The expansion of European Digital Innovation Hubs (EDIHs) from 81 in 2020 to 151 in 2023, and an expected 200+ by 2027, assists small enterprises in adapting to the digital economy. Thus, the EU continues its targeted policy aimed at removing technological barriers and ensuring the equitable implementation of digital technologies in business.

The level of business digitalization varies significantly across EU countries. The highest indicators are observed in Denmark, Finland, Sweden, the Netherlands, and Estonia (Table 5). These countries possess advanced 5G infrastructure and actively implement cloud technologies, artificial intelligence, and automated business processes. For example, 85 % of companies in Denmark use digital technologies for operational management, while in Estonia, 98 % of enterprises employ electronic document management.

Besides technological readiness, government support plays a crucial role. For instance, Finland has programs funding digital startups, while the Swedish government invests in training entrepreneurs in digital skills. In the Netherlands, 90 % of companies utilize Big Data analytics to enhance business efficiency. This demonstrates that digitalization depends not only on technology but also on the country’s development strategy.

Table 5

Comparative Indicators of Business Digitalization in Leading EU Countries

Country	Level of Business Digitalization (%)	Use of Cloud Technologies (%)	Use of Artificial Intelligence (%)
Bulgaria	45	32	20
Romania	48	35	22
Greece	42	30	18

Source: compiled based on [5–6]

This contrast with the leading countries (Denmark, Estonia, Netherlands, etc.) highlights the existence of a digital divide within the EU. The EU's efforts are focused on overcoming these inequalities through support for digital education, infrastructure development, and investment in innovation.

Table 6

Use of Digital Technologies by Businesses in Countries with Lower Indicators

Country	Business Digitalization Level (%)	Use of Cloud Technologies (%)	Use of Artificial Intelligence (%)
Greece	50	40	25
Romania	48	35	20
Bulgaria	45	30	18

Source: compiled based on [7–8]

Overall, successful EU countries demonstrate that digital transformation is a key factor for business competitiveness. Other states that are currently lagging in this process receive EU support to implement new technologies and digital strategies.

The digital transformation of business in the countries of the European Union varies in its level of development, depending on economic capabilities, government support, and infrastructure. Scandinavian countries, as well as the Netherlands and Estonia, are leaders thanks to a high level of company digitalization, active

use of artificial intelligence, and developed digital infrastructure. Meanwhile, countries in Southern and Eastern Europe, such as Bulgaria, Greece, and Romania, have low rates of digital technology adoption, creating a certain gap within the EU.

The main factors for successful digitalization include government incentives, investment in digital education, and access to modern technologies. For example, in Sweden, 87 % of companies use financial technologies for payment automation, while in the Netherlands, 90 % of enterprises have implemented big data for business process analytics (Table 7). These countries also have advanced 5G infrastructure that provides high-speed internet and stable connectivity for businesses.

In contrast, countries lagging behind in digital transformation exhibit insufficient integration of the latest technologies into business processes. For instance, in Bulgaria, only 30 % of enterprises use cloud computing, and in Greece, this figure reaches 40 % [8]. The lack of adequate digital infrastructure and a shortage of qualified personnel are the main barriers to business digitalization in these countries.

Table 7

Use of Digital Technologies in Business in EU Countries

Country	Use of Cloud Technologies (%)	Integration of Big Data (%)	Use of 5G (%)
Sweden	68	78	90
Netherlands	72	90	88
Finland	70	75	85
Estonia	78	70	80
Denmark	75	72	87

Source: compiled based on [7–8]

Table 7 shows the level of digital technology adoption in business across selected EU countries. Estonia leads in cloud technology adoption (78 %), while the Netherlands ranks highest in Big Data integration (90 %). Sweden has the highest use of 5G (90 %). Denmark and Finland also demonstrate high, albeit slightly lower,

levels of digitalization. Overall, all the analyzed countries actively use modern technologies, indicating a high level of digital transformation in business across the region.

Table 8

Use of Digital Solutions in Countries with Lower Indicators

Country	Use of Cloud Technologies (%)	Integration of Big Data (%)	Use of 5G (%)
Greece	40	35	50
Romania	35	30	45
Bulgaria	30	25	40

Source: compiled based on [9–10]

The overall level of digital business transformation in the EU increases each year, but the digital gap between leading countries and those lagging behind (Table 8) remains significant. The most successful states, such as Sweden, the Netherlands, and Estonia, have well-developed infrastructure, support for digital startups, and actively use cutting-edge technologies. Meanwhile, countries with lower performance need to increase investment in digital infrastructure and education in order to catch up with the leaders. The EU is already implementing special funding programs to reduce this gap, which will contribute to the overall digital integration of European business in the future.

The digital economy is significantly reshaping business practices, especially at the international level. In the European Union, digitalization has become a key factor in competitiveness and innovative development in international business. EU countries are implementing digital strategies to transform their business models, adapting them to emerging technologies such as artificial intelligence, blockchain, the Internet of Things, and big data.

One of the key aspects of effective international business management is the integration of digital technologies into business processes. In EU countries, platforms for e-commerce, online financial technologies, and cloud-based services are actively developing,

enabling businesses to operate in international markets with reduced costs and increased efficiency. Digital infrastructure – including high-speed internet, platforms for digital payments, and data automation and analytics technologies – plays a critical role in this transformation.

An important component is also risk management in international business in the context of the digital economy. This includes data protection, cybersecurity, and adaptation to rapidly changing global conditions. European companies operating in international markets often face the challenge of complying with digital regulations in different countries. The EU is actively working on unifying digital standards and norms to ensure fair business conditions at all levels.

Key trends in international business management in the digital economy are presented in Figure 1.

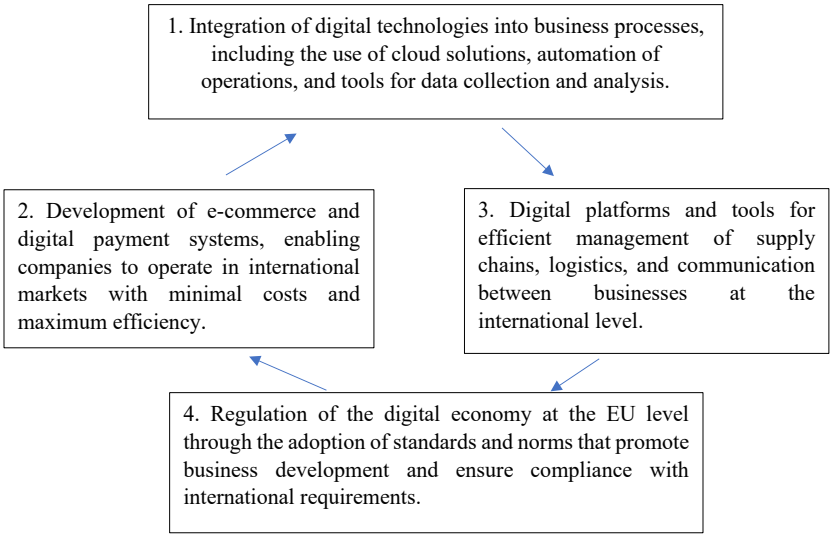

Fig. 1. International Business Management in the Digital Economy

Source: compiled based on [6]

International business management in the context of the digital economy within the European Union is undergoing significant

transformation. The use of advanced digital technologies, such as artificial intelligence and big data, enables European companies to expand their presence in global markets. However, along with new opportunities come new risks – including cyber threats and regulatory challenges – that require attention from both governments and businesses.

1. Integration of digital technologies into business processes. The integration of digital technologies into business processes is one of the key trends in the digital economy. This includes the use of cloud technologies, artificial intelligence (AI), big data analytics, and business process automation. In EU countries, companies are actively implementing these technologies to optimize operations and improve efficiency.

Cloud solutions allow enterprises to store and process data without the need for significant investment in physical infrastructure. AI is used for managerial decision-making, demand forecasting, supply chain optimization, and customer interaction. The use of big data analytics enables companies to better understand consumer behavior and adapt their strategies to evolving market conditions.

1. Development of E-commerce and Digital Payment Systems

E-commerce and digital payment systems have become the foundation for companies entering international markets. Thanks to the growth of e-commerce platforms (such as Amazon, eBay, Alibaba), businesses can sell their products globally without requiring a physical presence. This significantly reduces operational costs, particularly in logistics and marketing, making business more accessible for small and medium-sized enterprises.

2. Digital payment systems (such as PayPal, Stripe, Apple Pay) enable companies to efficiently process transactions worldwide, ensuring high payment speed and reduced transaction costs. These technologies allow businesses to enter new markets more rapidly, attract more customers, and operate with international buyers without the complications of currency restrictions.

3. Digital Platforms and Tools for Efficient Supply Chain, Logistics, and Communication Management

Digital platforms for managing supply chains, logistics, and communication have become critically important for businesses operating in international markets. This includes supply chain management platforms (such as SAP, Oracle), which allow companies to track product movement, monitor inventory, and forecast demand. These systems help businesses reduce storage costs, avoid overstocking or stockouts, and improve overall efficiency.

In logistics, digital tools assist in optimizing delivery routes, reducing delivery times, and lowering transportation expenses [11]. Additionally, digital platforms facilitate efficient communication among all stakeholders in international business operations, simplifying interactions with partners, suppliers, and customers.

4. Regulation of the Digital Economy at the EU Level Through the Adoption of Standards and Norms

The regulation of the digital economy at the EU level plays a crucial role in fostering business development and ensuring compliance with international requirements. By adopting unified digital standards and legal frameworks, the EU creates a consistent regulatory environment that supports fair competition, protects consumer rights, and enhances trust in digital services. These regulations help harmonize digital business practices across member states, allowing companies to operate more smoothly within the Single Market and beyond. This regulatory consistency is especially important for cross-border transactions, data protection (such as GDPR), and cybersecurity compliance.

The European Union is actively working on the harmonization of regulatory frameworks concerning the digital economy to ensure fair conditions for businesses. This includes the development of standards for data protection (such as the General Data Protection Regulation – GDPR), ensuring cybersecurity, and creating legal frameworks for the use of emerging technologies such as artificial intelligence, blockchain, and the Internet of Things. The EU is also actively adopting legislation to support innovation while protecting the rights of consumers and small businesses. This includes the development of instruments to ensure equal competition conditions and

to safeguard citizens' interests in the digital space [12]. Such initiatives help businesses operate under a unified set of rules across the entire EU, which is essential for international operations.

Overall, the digital economy creates new opportunities for international business by allowing companies to significantly reduce costs and increase the efficiency of their operations. EU countries, by implementing digital strategies, foster innovation and competitiveness, supporting businesses in adapting to new technologies. However, successful management of international business in the digital age requires consideration not only of technical capabilities but also of legal and ethical aspects that define the proper functioning of the market.

The European Union pays particular attention to the development and regulation of the digital economy through the adoption of legislative acts and the creation of common standards for all its member states. The regulatory system of the digital economy in the EU aims to ensure fair competition, consumer rights protection, and cybersecurity. One of the key regulatory instruments is the General Data Protection Regulation (GDPR), which establishes strict requirements for the processing of personal data within the EU and governs their transfer outside the Union. GDPR (Table 9) helps prevent the misuse of personal information, creating conditions for more transparent and ethically responsible business practices.

In particular, the EU is actively working on standards for the development of cloud technologies, blockchain, artificial intelligence, and other advanced technologies. Within the framework of the European Digital Strategy, plans are also being implemented to create common infrastructures for the digital economy, such as platforms for electronic payments, digital identities, and product certification. These initiatives promote innovation and reduce barriers for companies entering the EU's single digital market.

At the same time, European digital market policy is focused on protecting intellectual property rights and ensuring a level playing field for businesses through the standardization of rules and regulations across all member states. On the other hand, the EU is actively taking

measures to regulate cybersecurity, which is critical for ensuring the security of information technologies and protecting businesses from cyber threats. One such step is the adoption of the Directive on Network and Information Security (NIS2), which establishes requirements for protecting critical infrastructure from cyberattacks.

Regulation also includes standards to ensure transparency of algorithms used in artificial intelligence and machine learning, aiming to protect consumer rights and prevent discrimination in automated decision-making.

Table 9

Key regulatory initiatives of the EU in the digital economy

Initiative	Description	Year Implemented
GDPR	Regulation for the protection of personal data and privacy	2018
Digital Single Market	Creating conditions for free trade of digital products and services within the EU	2020
NIS2 Directive	Cybersecurity regulation to ensure protection of critical infrastructures	2022
European Data Act	Standards for data processing, ensuring data availability and security	2021
Artificial Intelligence Act	Regulation of AI use to ensure ethical application and transparency of algorithms	2022

Source: compiled based on [2–6]

The EU's regulatory initiatives in the digital economy are aimed at creating a secure, transparent, and competitive digital environment. The GDPR, introduced in 2018, became a key document for personal data protection. The "Digital Single Market" initiative (2020) simplified the trade of digital services within the EU. To enhance cybersecurity, the NIS2 Directive was adopted in 2022, while the European Data Act (2021) established standards for data processing. The latest significant step was the regulation of artificial intelligence

(the Artificial Intelligence Act, 2022), which ensures the ethical use of algorithms. These initiatives contribute to the development of the digital economy by maintaining a balance between innovation and security.

The regulation of the digital economy in the EU (Table 10) is comprehensive and aims to create a safe and transparent environment for technological development. The introduction of the GDPR is an example of how the EU strives to control the processing of personal data and protect user privacy. This is a crucial element, as the growing use of big data, artificial intelligence, and the Internet of Things poses risks to personal security and citizens' privacy. GDPR implementation places requirements on organizations across the EU and sets fundamental data processing standards that foster trust in digital platforms.

On the other hand, the creation of the Digital Single Market stimulates the growth of innovative companies, lowers barriers for businesses, and allows them to enter new markets within the EU. This provides companies with significant development opportunities without the need to adapt to different national legislations, thus facilitating international business. Furthermore, the NIS2 Directive and other cybersecurity initiatives promote the development of a secure digital environment, which is necessary to protect critical infrastructure and ensure safety amid increasing cybersecurity threats.

It is also important to note that the EU is actively working on the standardization and regulatory framework for emerging technologies such as artificial intelligence and blockchain. This enables the establishment of ethical norms for the use of these technologies, ensuring their transparency and accountability. Against the backdrop of the growing adoption of artificial intelligence and automated decision-making, the EU is developing regulations that help maintain fairness and equality in relationships between consumers and businesses. These initiatives allow the European Union to become a leader in digital economy regulation on the international stage, providing businesses and consumers with a high level of security, transparency, and fairness.

Table 10

Statistics on the digital economy and regulation in the EU

Initiative	Key Indicators and Statistics	Impact/Changes
GDPR	400,000 infringement complaints, fines over €1 billion	Increased trust in digital platforms, improved personal data protection
NIS2 Directive	150,000 cyberattacks in 2022, rising cybersecurity incidents	Enhanced critical infrastructure security, standardization of cybersecurity measures
European AI Act	50 % of enterprises use AI, growth plan to 25,000 companies by 2025	Regulation of ethical AI use, ensuring transparency and fairness of algorithms
Digital Single Market	14 % growth in internal trade of digital services in 2021	Legalization and support of free trade in digital goods and services within the EU

Source: compiled based on [13; 14]

GDPR and personal data processing**:** According to the European Commission, the number of organizations violating GDPR requirements continues to rise. In particular, during the period 2020–2021, fines totaling over €1 billion were imposed for data protection breaches. Since its implementation in 2018, more than 400,000 GDPR infringement complaints have been filed. These figures demonstrate how seriously the EU treats compliance with data protection standards across all member states.

1. Cybersecurity and the NIS2 Directive: According to the report by the European Union Agency for Cybersecurity (ENISA), EU countries recorded over 150,000 cyberattacks in 2022, most of which targeted critical infrastructures and digital platforms. The NIS2 Directive aims to reduce these numbers through standardized security requirements and the prevention of cyber threats for critical sectors. It is forecasted that by 2025, the majority of companies in the EU will be required to comply with cybersecurity standards under this directive.

2. Artificial Intelligence and European Regulations: The European Union is also actively working on regulating artificial intelligence. According to data from the European Commission, more than 50 % of European enterprises already use AI for process automation and data analysis. In 2022, the Artificial Intelligence Act was adopted to regulate the use of such technologies, aiming to prevent potential ethical issues and ensure algorithmic transparency. Over 25,000 companies in the EU plan to implement AI by 2025, which necessitates the establishment of clear ethical standards for its application.

Regulation of the EU digital economy through initiatives such as GDPR, the NIS2 Directive, and the European AI Act significantly contributes to the development of digital markets within the EU by reducing risks for companies and ensuring data and infrastructure security. The establishment of clear norms and standards, for example regarding artificial intelligence, allows the EU to maintain leadership in innovative technologies while ensuring fairness and transparency. Thus, regulation promotes not only the growth of the digital economy but also the creation of a safe and ethical environment for businesses and consumers across Europe.

The European Union is actively working on regulating the digital economy to ensure transparency, security, and ethical use of emerging technologies. One of the key initiatives (Table 11) is the General Data Protection Regulation (GDPR), adopted in 2018 with the aim of strengthening the protection of personal data of EU citizens. GDPR sets strict requirements for the collection, processing, and storage of personal data, forcing companies worldwide to adapt their processes to comply with these standards. Violations of these regulations result in significant fines, encouraging adherence to high security standards.

Another important EU initiative is the NIS2 Directive (Network and Information Systems Directive), which came into effect in 2022. It focuses on improving cybersecurity across the EU, especially for critical infrastructures and key sectors such as energy, healthcare, and finance. The NIS2 Directive obliges companies to implement mechanisms to protect their information systems from cyber threats and to report cybersecurity incidents. This contributes to raising the overall security level of the Single Digital Market [15].

Table 11

Key EU Initiatives in Regulating the Digital Economy

Initiative	Description	Impact on Business and Society
GDPR	General Data Protection Regulation in the EU. Ensures high transparency and security in personal data processing	Enhances data privacy protection, reduces risks of consumer rights violations
NIS2 Directive	Regulates the strengthening of cybersecurity for important and critical infrastructures in the EU	Strengthens cybersecurity across sectors, improves reliability of infrastructure and data
European Artificial Intelligence Act	Establishes legal frameworks for the use of artificial intelligence in the EU, ensuring safety, transparency, and ethical AI application	Introduces rules for responsible AI use, reduces risks of abuse and discrimination
Digital Services Directive	Regulates digital service platforms, ensuring fair business conditions in the digital environment	Promotes healthy competition and consumer protection in digital markets

Source: compiled based on [16–17]

The third key initiative is the European Artificial Intelligence Act, adopted in 2021, which establishes legal norms for the use of artificial intelligence in the EU. This act aims to create a safe and ethical environment for AI applications, ensuring transparency and trust in automated systems. At the same time, it introduces clear rules for the development and use of AI systems to prevent discrimination, manipulation, or other abuses, thereby maintaining a balance between innovation and consumer rights protection.

The digital economy of the EU is actively regulated through key initiatives such as GDPR, the NIS2 Directive, and the European Artificial Intelligence Act, which enhance the security, ethics, and transparency of the digital market. The adoption of these standards is an important step toward creating a sustainable and secure digital

environment that fosters trust between consumers and businesses. For businesses, this means the need to adapt to new regulatory requirements, which reduces the risks of violations, improves reputation, and opens opportunities to operate within the EU's single digital market.

The EU also implements specific projects that demonstrate the effectiveness of its digital economy policies (Table 12).

The eIDAS Initiative ensures secure electronic identification and electronic signatures across all EU countries. This significantly reduces bureaucratic barriers, cuts administrative costs, and improves the efficiency of business processes, especially in the financial sector.

Table 12

Successful EU Projects to Promote Initiatives in the Digital Economy

Project	Description	Impact on Business and Economy
eIDAS	Initiative to ensure secure electronic identification and signatures across the EU	Simplifies transactions and enhances business security, reduces administrative costs
Digital Single Market	Development of a single digital market to provide seamless access to digital goods and services within the EU	Expands markets for businesses, improves competition, and stimulates e-commerce growth
Horizon 2020	Program funding innovations in technology, science, and research	Supports startups, fosters development of innovative technologies, and increases investment in the digital economy

Source: compiled based on [18]

The Digital Single Market Project aims to establish a single digital market by removing cross-border restrictions on digital goods and services. This allows businesses to expand their activities throughout the EU, promoting growth in online trade and competition among small and medium-sized enterprises.

The Horizon 2020 Program funds innovative research in artificial intelligence, cybersecurity, and big data. It supports the development

of high-tech startups and the commercialization of innovations, strengthening the EU's position in the global digital economy.

The implementation of projects such as eIDAS, Digital Single Market, and Horizon 2020 demonstrates the effectiveness of the EU's policy in supporting the development of the digital economy. These initiatives contribute to simplifying business processes, improving access to new markets, and stimulating innovation. Thanks to such projects, the European Union is actively moving towards the creation of a unified digital space, which holds significant potential for further economic and technological development in the region.

Conclusions. The digitalization of the economy has fundamentally changed approaches to organizing and managing international business. The use of cutting-edge information technologies, such as big data, artificial intelligence, and automation, enables enterprises to improve the efficiency of managerial decisions, reduce costs, and increase competitiveness in global markets. The transformation of business processes through digital technologies opens new opportunities for company development in a rapidly changing international environment. European countries are actively adapting to these new realities by integrating digital innovations into international business strategies. European enterprises strive to ensure a high level of security and data protection, which is a crucial aspect in the context of international operations. The integration of digital technologies also allows businesses to operate more effectively within the European Union's single digital market, reducing barriers to international trade and promoting the development of European startups and innovative companies.

For the successful development of international business in the digital economy, it is important to ensure further integration of cutting-edge technologies into corporate strategies, develop employees' digital skills, and create infrastructure for secure data exchange. It is also recommended to strengthen cooperation between governments, businesses, and academic institutions to create a favorable environment for innovation and support digital startups. Additionally, raising consumer trust in digital platforms and maintaining transparency in data usage are vital.

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1.3. DIGITAL TRANSFORMATION OF INVENTORY ACCOUNTING: EUROPEAN PRACTICE AND UKRAINIAN REALITIES

Introduction. Digital transformation of inventory accounting is becoming an important stage in the development of modern enterprises, as it opens up new opportunities for optimizing material resource management, reducing costs and increasing the efficiency of production processes. In the context of rapid globalization and technological development, the use of innovative information systems in the field of inventory accounting allows for significantly simplifying

and automating data processing, which leads to more accurate control over resources and prompt response to changes in market conditions.

The relevance of the topic is due to several important factors.

Firstly, digitalization is a global trend that covers all sectors of the economy, including the inventory accounting sector. European countries are already actively implementing modern information technologies to automate this process, which allows them to achieve high results in resource management, ensure accurate accounting and reduce costs for storage and processing of inventories. This includes the use of solutions based on artificial intelligence, the Internet of Things (IoT), automated inventory management systems, and blockchain technologies to ensure transparency and traceability of inventory.

Secondly, for Ukraine, in the conditions of constant economic instability and the need to ensure effective management of limited resources, the digital transformation of inventory accounting is no less important. However, domestic practice has not yet reached the same level of integration of digital technologies into this process as in European countries. This creates certain difficulties and barriers for enterprises wishing to implement innovative technologies, and requires a deeper analysis of existing problems, opportunities and prospects for the development of this area.

Thus, the study of the digital transformation of inventory accounting in the context of European practice and Ukrainian realities is extremely relevant, since it allows not only to identify the main problems that hinder the effectiveness of this process in Ukraine, but also to formulate recommendations for the implementation of advanced European practices taking into account national characteristics and needs of enterprises. This will be an important step towards modernization and increasing the competitiveness of the Ukrainian economy in the global context.

Presentation of the main results of the study. During the study, it is important to pay attention to the research of domestic and foreign scientists studying this problem. Since digitalization is an important direction of development of modern business, numerous scientific works cover both theoretical and practical aspects of implementing

the latest technologies in the field of accounting and inventory management.

In order to better understand the current state of research, an analysis of the works of domestic and foreign scientists related to the digital transformation of inventory accounting was carried out. Table 1 below provides a comparative overview of the main studies in this area.

Table 1

Comparative analysis of scientific research in the field of digital transformation of inventory accounting

Authors	Researched questions
1	2
Andrusyak V. M., Khoroshilova I. O., Smirnova N. V. [4]	Studying the impact of digitalization on accounting and auditing in Ukraine, in particular: adaptation of enterprises to new technologies, changes in control processes, implementation of automated systems to increase the efficiency of auditing and accounting, analysis of the problems and benefits of digital transformations in accounting.
Svystun L. A., Nosenko D. O. [10]	Digitalization of inventory management processes at enterprises, including: automation of production inventory accounting, use of ERP systems for inventory management, improvement of real-time control and accounting processes, as well as the benefits of digital technologies in reducing storage and supply costs.
Shevchuk O., Muravsky V. [12]	Innovative technologies in accounting: implementation of the latest information systems for accounting automation, use of blockchain technologies for accounting transparency, implementation of machine learning systems to improve inventory forecasting processes, as well as integration of modern IT solutions into financial inventory control.
Semenova S. [11]	The role of digital technologies in accounting processes, features of the implementation of automated accounting systems in Europe, studying the experience of EU countries in automating financial forecasting, using analytical tools to optimize inventory management, and integrating Big Data technologies into accounting and control.

Continuation of Table 1

1	2
Kulyk V. A., Karpenko E. A. [7]	Process-oriented inventory management: research into the effectiveness of implementing automated accounting systems, integration of inventory management technologies with other enterprise functions (production, logistics, finance), the impact of automated systems on reducing costs and increasing accounting accuracy.
Desyatnik M. V., Korol S. Ya. [5]	Automation of accounting and inventory management in crisis situations, in particular in war conditions: the use of flexible and adaptive systems for inventory management, analysis of the problem of supply disruptions, implementation of reservation and distribution systems for goods, as well as the role of digital solutions in optimizing inventories in unstable conditions.
Aishwarya Lakshmi S., Keerthana R., Pradeep S., Dr. J. Krithika [1]	Digital transformation of supply chain management: research into the role of digital technologies (ERP, IoT, AI) in reducing inventory management costs, improving logistics and supply chain management, the role of data in optimizing costs and forecasting enterprise needs, and implementing the latest IT solutions in global supply chain management.
Bruhns H. R. [2]	The role of artificial intelligence in inventory management: research into implementing AI to forecast inventory needs, developing automated inventory systems, optimizing supply chains using AI, creating adaptive inventory systems that can anticipate market changes and quickly adapt processes.

Source: compiled based on [1; 2; 4; 5; 7; 10; 11; 12]

Analysis of scientific research indicates an active interest in the digitalization of inventory accounting both in Ukraine and abroad. Domestic researchers focus on the impact of digital technologies on accounting systems, analyzing the benefits and challenges of their implementation. Foreign works, in particular the experience of EU countries, provide valuable information on the use of ERP systems, big data analytics, artificial intelligence and blockchain in accounting processes. These studies emphasize the importance of integrating

modern technologies to improve the efficiency of inventory management and financial forecasting.

After considering scientific views and research, in particular on the implementation of digital technologies in inventory accounting, the importance of a detailed analysis of the problems faced by enterprises on the path of digital transformation in this area becomes obvious. Problems that arise during the transition to digital accounting systems require comprehensive research, as they directly affect the efficiency of inventory management and the financial results of enterprises.

Studying the problems of digital transformation of inventory accounting is an important stage in the process of modernization of accounting and management processes at enterprises, as it allows not only to identify existing barriers and challenges, but also to suggest ways to overcome them. Determining the main causes of these problems is critical for the successful implementation of new technologies and achieving maximum effect from their application in inventory accounting.

Considering the above, the study of the problems of digital transformation of inventory accounting is extremely relevant and requires in-depth analysis both for Ukrainian realities and for European experience, since it is these problems that can determine the further efficiency and sustainable development of production processes at enterprises (Table 2).

One of the main problems is the lack of full automation of inventory accounting processes, as well as the insufficient level of integration of accounting systems with other business functions (finance, production, logistics). Many enterprises use outdated or disparate software solutions, which complicates data exchange between different departments and, accordingly, reduces the efficiency of inventory management.

The increase in the volume of data generated by the digitalization of accounting creates new challenges for enterprises in processing and analyzing this data. Many companies face problems in correctly interpreting large volumes of information, which reduces the accuracy of forecasts and the efficiency of inventory management.

Table 2

Problems of digital transformation of production inventory accounting and their causes

Problems of digital transformation	Causes of occurrence
Insufficient level of automation and integration of systems	– high cost of implementing new technologies; – lack of qualified IT specialists; – uncertainty in choosing the optimal technological solutions.
Difficulty in processing and analyzing large amounts of data	– lack of powerful analytical tools for processing large amounts of data; – imperfection of existing forecasting algorithms; – lack of skills among employees to work with new tools.
Problems in data security and information protection	– imperfect information protection system in old IT systems; – lack of proper training of personnel on cybersecurity; – increased risk of cyberattacks due to insufficient use of modern protection tools.
Resistance to change from staff	– lack of motivation for change among employees; – insufficient qualification of personnel; – psychological unpreparedness for changes in work processes.
High costs of implementing new technologies	– high initial costs for software development and implementation; – additional investments for personnel training; – uncertainty in the return of investments at the first stages of transformation.

Source: compiled based on [3; 6]

Digital technologies create new threats to data security. Enterprises can be subject to hacker attacks, information leaks or data loss, which can lead to serious financial and reputational losses. Given the sensitivity of inventory accounting data, the issue of information protection is critically important [3].

An equally important problem is the resistance of personnel to the implementation of new digital technologies. Changes in accounting

processes require employees to acquire new knowledge and skills, as well as a willingness to adapt to new working conditions. This can cause stress and reduce efficiency during the transition to digitalization.

Digitalization requires significant financial investments in the development and implementation of new technologies, as well as in personnel training and system support. For small and medium-sized enterprises, this can be a serious financial According to the analysis of the problems of digital transformation of inventory accounting, it can be noted that the introduction of new technologies into this process faces several significant barriers. The main problem is the insufficient level of automation of accounting processes and low integration of systems between different business functions, which reduces the efficiency of inventory management.

The issue of processing and analyzing large volumes of data is also important, since many enterprises lack the necessary tools for their effective processing [6]. Particular attention should be paid to cybersecurity issues, since the increase in digital technologies increases the risks of data leaks and cyberattacks. In addition to technical aspects, an important problem is personnel resistance to change, which complicates the process of transition to new digital systems.

Finally, the high costs of implementing new technologies are another significant barrier for many enterprises, especially small and medium-sized ones. Thus, to effectively overcome these problems, it is necessary to develop strategies that include the comprehensive implementation of automated systems, employee training, and significant investments in cybersecurity and infrastructure. This will allow you to maximize the potential of digital technologies for effective inventory management.

Digital transformation is one of the main trends in the modern business environment, and its impact on accounting, in particular on inventory accounting, is extremely important. In European countries, modern technologies such as ERP systems, IoT, and AI have long been integrated into inventory management processes,

which allows you to significantly increase efficiency, reduce costs, and optimize supply chains. In Ukraine, although digitalization is developing, many enterprises still face problems integrating the latest technologies into their inventory management processes, in particular due to the high costs of implementing technologies, lack of qualified personnel, and lack of a sufficiently developed IT infrastructure. Below in Table. 3 presents a comparative analysis of European practice and Ukrainian realities in the digital transformation of inventory accounting [8].

Table 3

A comparative analysis of European practice and Ukrainian realities in the digital transformation of production inventory accounting

Parameter	European practice	Ukrainian practice
Inventory accounting automation	Using integrated ERP systems, IoT, AI for inventory management. Processes are automated, data is processed in real time.	Many enterprises use outdated software solutions, automation in the initial stages.
Integration with other functions	High integration with finance, production, logistics, which allows you to reduce costs and improve forecast accuracy.	Low integration between accounting systems and other business functions, which reduces the efficiency of inventory management.
Reducing costs and increasing efficiency	Using blockchain technologies, AI to optimize processes, reduce storage and transportation costs.	The use of technologies is only at some enterprises, but significant spread has not yet been observed.
Risks and barriers	High implementation costs, employee qualifications, cybersecurity. Investments in staff development and IT infrastructure.	High initial costs, lack of qualified IT specialists, staff resistance to change.

Source: compiled based on [8; 9]

As we can see, inventory automation in Europe is actively using integrated solutions, which allows to reduce costs and increase accounting accuracy. In Ukraine, this process is at an early stage, and many enterprises are still working with outdated software products.

The integration of inventory accounting with other business functions is an important component of success in Europe, where such integrated systems allow to reduce errors and improve enterprise management. In Ukraine, enterprises face problems of integration of various functions, which reduces the efficiency of management processes.

Technologies for reducing costs and increasing efficiency, in particular blockchain and artificial intelligence, are actively implemented in European countries and provide significant savings and transparency in supply chains. In Ukraine, these technologies have not yet been widely used, although interest in them is growing.

The risks and barriers to digital technology adoption are similar in both regions, but in Ukraine these problems are more pronounced due to the lack of qualified personnel and the high costs of initial technology implementation [9].

Thus, while Europe is already using digital technologies for inventory management at a fairly high level, Ukraine still needs to overcome a significant number of barriers to successful transformation in this area. Investing in IT infrastructure, developing personnel, and overcoming psychological resistance to change are important steps for Ukraine on the path to digitalizing inventory accounting.

As the analysis shows, the introduction of digital technologies in inventory accounting provides significant benefits, such as reducing costs, increasing accounting accuracy, optimizing logistics processes, and integrating with other business functions. However, the key factor determining the speed and scale of digital transformation is investment in technology and infrastructure.

Investing in digitalization of inventory accounting is a strategic decision with long-term consequences. It requires significant initial investments in software, hardware, personnel training and adaptation of business processes. At the same time, in European countries such investments have already proven their effectiveness, allowing businesses not only to reduce costs, but also to increase competitiveness.

In view of this, it is important to consider in more detail the investment aspect of digitalization – what investments are needed, what sources of financing can be attracted, how the effectiveness of such investments is assessed and what financial risks should be taken into account. Researching these issues will allow assessing the real capabilities of Ukrainian enterprises to implement modern technologies and develop optimal approaches to their financing.

Ukrainian companies are gradually implementing digital solutions for inventory accounting. For example, Kormotech, a leading manufacturer of animal feed, successfully implemented the INTUIFLOW system, which led to an increase in production and sales by 40 % while maintaining overall inventory levels and reducing finished goods inventories by 45 %.

Another example is YUKO, a lubricants manufacturer, which, after implementing INTUIFLOW in its distribution, achieved a halving of inventory and a 60 % increase in sales in the first four months.

Pharmaceutical company Farmak invested 9 million euros in implementing a new drug production site equipped with advanced digital solutions that ensure maximum sterility and increase labor productivity.

In Europe, the digitalization of inventory accounting is part of broader initiatives to implement Industry 4.0. A study of Portuguese companies showed that they face problems such as a lack of vertical and horizontal integration of information systems, poor data quality and insufficient use of MES (manufacturing execution systems).

At the same time, large European companies are actively investing in digital technologies for inventory management. For example, companies using the SAP S/4HANA system can automate warehouse and inventory management processes, which increases supply chain efficiency.

Investing in digitalization of inventory accounting is necessary to increase the efficiency and competitiveness of enterprises. Ukrainian companies that have implemented modern digital solutions have achieved significant improvements in inventory management

and sales growth. European experience emphasizes the importance of integrating information systems and using advanced technologies to optimize inventory management processes. However, for successful digitalization, it is necessary to take into account factors such as technical infrastructure, personnel training, and integration of new systems into existing business processes [6].

For the successful implementation of digital technologies, Ukrainian enterprises should take into account the experience of European companies that have already achieved a high level of automation. Important aspects of this process are process optimization, personnel training, cybersecurity, and strategic investments.

Below is Table 4, which contains the main practical recommendations for digitalization of inventory accounting in the context of Ukrainian realities and European experience.

Table 4

Practical recommendations for Ukraine on digitalization of inventory accounting

Destination	Ukraine	Europe	Recommendations for Ukraine
1	2	3	4
Accounting automation	Partial implementation of ERP systems, use of IT-Enterprise, MASTER, but many processes remain manual	Wide use of SAP, Oracle, Microsoft Dynamics, warehouse automation using WMS, RFID	Implementation of complex ERP systems, integration with warehouse and logistics modules
Staff training	Low level of digital literacy, lack of mandatory accounting automation programs	High level of specialist training, continuous professional development	Development of corporate training programs, implementation of online courses, cooperation with universities

Continuation of Table 4

1	2	3	4
Investments in digital transformation	Limited funding, dependence on government support programs	High level of investment in innovation, active support from the state and the EU	Introduction of tax breaks for businesses, creation of state grants for digitalization
Cybersecurity	High risks of cyberattacks, low level of data protection	Strict legal regulation, multi-level protection, certified security systems	Development of national cybersecurity standards, employee training, information security audit
Strategic planning	Lack of long-term digitalization strategies	Clear plans and roadmaps for implementing digital solutions	Development of state and corporate digital transformation strategies

Source: compiled based on [6]

The proposed recommendations are aimed at overcoming key barriers in the digitalization of inventory accounting of Ukrainian enterprises. Optimization of automation processes, staff training and investments in cybersecurity will contribute to increasing the efficiency of inventory management. The implementation of modern domestic software solutions will ensure that accounting processes comply with international standards and improve the competitiveness of Ukrainian companies.

Conclusions. Thus, based on the research conducted, we note that the digitalization of inventory accounting is an important stage in the development of modern accounting, which ensures increased efficiency of resource management, transparency and accuracy of accounting processes. Analysis of European experience shows that the successful implementation of digital technologies

in this area contributes to cost optimization, reducing fraud risks and improving managerial decision-making. At the same time, Ukraine faces a number of challenges, including regulatory and legal restrictions, insufficient technical support and low digital literacy of personnel. For further effective implementation of digital solutions in inventory accounting in Ukraine, it is necessary to improve the legislative framework, invest in modern technologies, and improve the qualifications of accounting personnel. Only a comprehensive approach to digital transformation will allow Ukrainian business to integrate into global economic processes and increase its competitiveness.

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1.4. DIGITALISATION OF THE UKRAINIAN ECONOMY IN THE CONTEXT OF EUROPEAN INTEGRATION

Introduction. In today's world, digitalisation is a defining trend in the development of national economies, transforming traditional business models and creating new opportunities for competitiveness. The relevance of the study is driven by the need for a deep understanding of the current state of digitalisation of the Ukrainian economy in the context of European integration processes. The purpose of this article is to analyse the current state of digitalisation of the Ukrainian economy in the context of its European integration aspirations based on international indices and compare it with the EU's digital transformation goals. The results of the study will help identify the strengths and weaknesses of digital transformation in Ukraine and formulate recommendations to accelerate its European integration in the digital sphere.

The main material of the research. The term "digital economy" was first used in the scientific discourse in 1995, which was directly related to the rapid development of economic relations based on digital information and communication technologies [1]. Over time, this

concept has gained considerable importance and has become firmly established in modern scientific usage.

To date, there is certain diversity in the scientific environment in the interpretation of the essence of the 'digital economy'. In particular, G. Karcheva defines the digital economy as an innovative and dynamic economic paradigm, the key characteristics of which are the active introduction of innovations and information and communication technologies in all types of economic activity and spheres of public life without exception [2]. This approach, in her opinion, contributes to the growth of efficiency and competitiveness of both individual enterprises and the national economy as a whole, as well as to improving the living standards of the population. On the other hand, S. Koliadenko interprets it as a system based on the creation of electronic goods and services by high-tech business units and their further distribution through e-commerce mechanisms [3]. In addition, the digital economy is seen as a complex set of relations arising in the processes of production, distribution, exchange and consumption based on online technologies and focused on meeting the needs for life's goods [4]. This leads to the formation of fundamentally new ways and methods of doing business and requires the development and implementation of effective state regulation tools.

Analysing the above definitions, it can be stated that a common element in different approaches to understanding the digital economy is the emphasis on the key role of information and communication technologies as the basis for new forms of economic interaction and value creation.

Based on this, we can identify a number of characteristic features of the digital economy, including the intensive use of digital technologies in all sectors of the economy, the growing importance of e-commerce and online, the production and consumption of digital content and services, the formation of new business models, databases, and the increasing level of automation and digitalisation of production processes.

In Ukraine, the first signs of a digital economy can be traced back to the early 2000s with the growth of Internet penetration and the development of the first forms of e-commerce. The gradual expansion of the use

of information technology in the banking sector, telecommunications, and other industries has been a sign of the preconditions for deeper digitalisation of the economy in the years to come.

The intensification of Ukraine's European integration course has given a significant impetus to the digitalisation process. The European Union defines far-reaching goals in the field of digital transformation for such key elements as skills, infrastructure, business, and government in the framework programme Digital Compass 2030: The European Way to the Digital Decade [5].

In the context of skills development, the strategic goal is to ensure that at least 80 % of all adults have basic digital skills and that the EU has 20 million employed ICT professionals with a greater gender balance in this area.

In terms of infrastructure, the key objective is to create a secure, productive and resilient digital infrastructure, including gigabit connectivity for all EU households, 5G coverage of all settlements, doubling the EU's share of global production of advanced and sustainable semiconductors, deploying 10,000 (ten thousand) climate-neutral, highly secure edge nodes and developing the first quantum accelerated computer.

In the area of business development, the priority remains to accelerate the digital transformation of businesses, with the aim of ensuring that 75 % of EU companies use cloud computing services, big data and artificial intelligence; more than 90 % of SMEs reach at least a basic level of digital intensity; and the number of EU "unicorns" is doubled.

As for the government, the ambitious goal is to digitise public services to ensure 100 % online delivery of key public services, 100 % citizen access to their electronic health records, and 80 % citizen use of a digital identification solution.

For Ukraine, alignment with the goals and principles of the "Digital Compass 2030…" – programme is extremely important for its European integration aspirations and the modernisation of its economy and society. An overview of Ukraine's participation in key European programmes aimed at supporting digital transformation is presented in Table 1.

Table 1

Ukraine's participation in European digitalisation programmes

Programme name	Source of funding	Main goals and directions
EU4Digital Programme	European Union	Supporting the development of the digital economy and society in the Eastern Partnership countries (including Ukraine). Improving online services, enhancing cybersecurity, developing digital infrastructure, facilitating digital trade and harmonising digital markets with the EU.
Digital Europe Programme	European Union	Providing access to funding for projects in the areas of high-performance computing (€2.2 billion), artificial intelligence, data and cloud services (€2.1 billion), digital skills (€580 million), and the use of digital technologies in the economy and society (€1.1 billion).
EGAP Programme (E-Governance for Government Accountability and Participation)	Eastern Europe Foundation Innovabridge Foundation in partnership with the Ministry of Digital Transformation	Promoting the digitalisation of regions and the development of e-government.

Source: [6; 7; 8]

Thus, Ukraine is using a variety of tools to stimulate the development of its digital economy and to bring it closer to EU standards in this important area.

In this context, an analysis of the current state of the digital economy in Ukraine is of particular relevance. A detailed understanding of the current situation is a prerequisite for developing effective strategies and policies aimed at accelerating the

country's digital transformation and its integration into the European digital space.

The Digital Economy and Society Index (DESI) is a valuable tool for assessing the progress of EU member states in the digital sphere, but Ukraine, not being a member of the EU, is not officially assessed by this methodology [9]. At the same time, to gain a broader understanding of the current state of digital transformation in Ukraine, it is advisable to turn to other international metrics. One such authoritative tool is the Global Innovation Index (GII). The GII assesses the innovation capabilities and outcomes of countries around the world using about 80 indicators grouped into blocks of innovation resources and outcomes.

In 2024, Ukraine was ranked 60th among 133 countries, showing a decline from 55th place in 2023 [10]. The dynamics of Ukraine's position in the Global Innovation Index (GII) in the period from 2020 to 2024 are set out in Table 2.

Table 2

Dynamics of Ukraine's position in the Global Innovation Index (GII)

Year	Place in the GII	Innovation costs	Innovation results
2020	45th	71th	37th
2021	49th	76th	37th
2022	57th	75th	48th
2023	55th	78th	42th
2024	60th	78th	54th

Source: [10]

Thus, there is a downward trend in Ukraine's overall ranking, from 45th in 2020 to 60th in 2024. The Innovation Expenditures indicator shows relative stability with a slight increase in 2023–2024, but remains at a rather low level. At the same time, Innovative Outputs fluctuated, but generally showed an increase until 2024. For a deeper understanding of the current situation, it is advisable to consider key indicators that characterise various aspects of Ukraine's digital economy: the state of the institutional and business environment, the

level of human capital and research, and the level of infrastructure development.

An assessment of the institutional and business environment based on the Global Innovation Index (GII) for 2024 is presented in Table 3.

Table 3

Assessment of the institutional and business environment based on the Global Innovation Index (GII) for 2024

№	Category	Indicator	Score / Value	Place
1	**Institutions**		**30.8**	**107**
1.1	**Institutional environment**		**28.8**	**117**
1.1.1		Operational stability for business	26.7	123
1.1.2		Government effectiveness	31.0	99
1.2	**Regulatory environment**		**25.3**	**106**
1.2.1		Quality of regulation	33.1	90
1.2.2		Rule of law	17.5	115
1.3	**Business environment**		**38.2**	**84**
1.3.1		Policy stability for doing business	46.0	72
1.3.2		Business policy and culture	30.3	54

Source: [10]

The data indicate that there are significant challenges in the institutional and regulatory environment that may hinder innovation. The business environment has some strength, but also requires further strengthening, especially in terms of support for entrepreneurship. These findings highlight the need for reforms aimed at improving stability, public administration, regulatory quality and the rule of law to create a more favourable climate for innovation and economic growth.

Another important aspect for analysing Ukraine's digital economy is the assessment of human capital. The assessment of human capital and research based on the Global Innovation Index (GII) for 2024 is presented in Table 4.

Table 4

Assessment of human capital and research based on the Global Innovation Index (GII) for 2024

№	Category	Indicator	Score / Value	Place
2	**Human capital and research**		34.3	54
2.1	**Education**		**58.9**	**43**
2.1.1		Expenditure on education, % of GDP	5.9	16
2.1.2		Public funding per pupil (secondary school), % of GDP/per capita	28.5	10
2.1.3		Expected duration of schooling, years	13.3	76
2.1.4		PISA results in reading, mathematics and science	439.5	43
2.1.5		Pupil-teacher ratio (secondary school)	8.3	18
2.2	**Higher Education**		**37.2**	**49**
2.2.1		Gross tertiary enrolment, %	70.7	44
2.2.2		Graduates in science and engineering, %	25.7	40
2.2.3		Inward mobility of higher education students, %	4.9	50
2.3	**Research and development (R&D)**		**7.0**	**69**
2.3.1		Researchers (FTE) per million population	580.8	66
2.3.2		Gross expenditure on R&D, % of GDP	0.3	70
2.3.3		Global corporate investors in R&D (top 3), US$ millions	0.0	41
2.3.4		QS University Rankings (top 3)*	16.9	56

Source: [10]

Overall, Ukraine has some strength in education, particularly in terms of public funding per pupil (secondary school), but the data suggests that the research and development sector needs to be significantly strengthened to stimulate innovation and the development of the digital economy.

This is critical for stimulating innovation, which, in turn, is a prerequisite for strengthening national socio-economic sustainability and ensuring the country's competitiveness in the context of global digitalisation of the economy. An analysis of the current state of innovation shows that Ukraine lags far behind in terms of the number of start-ups, which are key drivers of innovation. In particular, there are only 33 start-ups per million people in Ukraine, which is significantly lower compared to 500 in the European Union [11; 12].

Given the identified needs to stimulate innovation and the overall context of global digitalisation of the economy, the state of infrastructure development is an equally important aspect for a comprehensive analysis. The quality and accessibility of digital infrastructure, including broadband, mobile communications, and cybersecurity, is the fundamental basis for deploying digital services, supporting businesses, and ensuring effective interaction in the digital economy. An assessment of the level of infrastructure development in Ukraine based on the Global Innovation Index (GII) for 2024 is presented in Table 5.

In the area of information and communications technology (ICT), Ukraine scores relatively well (75.6, 56th place), particularly in terms of access to ICT. Online government services are rated quite high (79.5, 34th place), and e-participation is at an average level (59.3, 57th place). However, general infrastructure is rated much lower (13.8, 117th). Electricity production per capita is relatively high, but logistics efficiency and gross fixed capital formation are low.

Conclusions. Summarising the analysis based on the Global Innovation Index (GII) for 2024, the following conclusions can be drawn about the current state of Ukraine's digital economy. The country's overall position in the ranking demonstrates a negative trend, indicating the need to intensify efforts to stimulate innovative development.

Table 5

Assessment of the level of infrastructure development in Ukraine based on the Global Innovation Index (GII) for 2024

№	Category	Indicator	Score / Value	Place
3	**Infrastructure**		**35.5**	**82**
3.1	**Information and communication technologies (ICT)**		**75.6**	**56**
3.1.1		Access to ICT	87.9	74
3.1.2		Use of ICT	–	–
3.1.3		Online government services	79.5	34
3.1.4		E-participation	59.3	57
3.2	**General infrastructure**		**13.8**	**117**
3.2.1		Electricity generation, GWh/million population	3 605.8	60
3.2.2		Logistics efficiency	27.3	76
3.2.3		Gross fixed capital formation, % of GDP	14.1	125
3.3	**Environmental sustainability**		**17.3**	**81**
3.3.1		GDP per unit of energy consumption	5.5	115
3.3.2		Use of low-carbon energy, %	31.3	32
3.3.3		ISO 14001 environmental certificate/US$ billions of GDP at PPPU Low-carbon energy use, %	0.8	81

Source: [10]

An assessment of the institutional and regulatory environment has identified significant challenges that could hinder innovation and economic growth. The operational stability of businesses, government efficiency, and the rule of law need to be improved. At the same time,

the business environment has certain strengths, but requires further support, especially in terms of entrepreneurship development.

In terms of human capital and research, Ukraine performs relatively well in education, particularly in terms of funding and pupil-teacher ratios. However, the research and development sector is a weak link and needs to be significantly strengthened to ensure sustainable innovation development.

In terms of infrastructure, Ukraine has made some progress in information and communications technology and the development of online government services. However, the overall state of the infrastructure, especially in terms of logistics and investment, remains insufficient.

In general, to accelerate digital transformation and strengthen Ukraine's competitiveness, comprehensive reforms are needed to improve the institutional and regulatory environment, intensify research and development, develop human capital, and modernise infrastructure. Successful integration into the European digital space requires systematic efforts and a strategic approach to the development of the digital economy.

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1.5. IMPACT OF GLOBAL CHALLENGES, INCLUDING THE COVID-19 PANDEMIC, ON BUSINESS PROCESS TRANSFORMATION

Introduction. The modern economy is undergoing constant changes under the influence of globalization processes, technological progress and crisis phenomena, among which the COVID-19 pandemic has become one of the most powerful challenges of recent decades.

This period was a test for many businesses that were forced to adapt their business models, accelerate the adoption of digital technologies, and rethink approaches to business process management. Therefore, the issues of enterprise digitalization were studied by: Zub P., Kalach G. [1], Kononenko J. A., Karnaukhova G. V., Balyuk O. V. [2], Korobka S. V. [3], Lisova R. M. [4], Fedulova L. I. [5], Cherep A. V., Dashko I. M., Ohrenych Yu. O. [6], Cherep A., Cherep O., Ohrenych Yu., Kurchenko M. [7], Cherep O. H., Dashko I. M., Bekhter L. A., Pidlisnyi R. O. [8], Cherep O. H., Oleinikova L. H., Bekhter L. A., Veremieienko O. O. [9], Cherep A. V., Ohrenych Yu. O., Oleinikova L. H., Veremieienko O. O. [10]. But it is advisable to study the processes of digital transformation in the context of globalization.

Summary of the main results of the study. An example of an effective digital transformation is the activities of the Ukrainian logistics operator Nova Poshta LLC, which, even in the face of the pandemic, has demonstrated the ability to adapt flexibly and develop rapidly. Thanks to the introduction of digital services, automation of logistics operations, and effective monitoring of internal processes, the company has maintained its competitiveness and strengthened its market position [11].

In modern management, the term "business process" is considered to be a set of interrelated actions or tasks performed to create value for the end user. However, for a full understanding of this phenomenon, a general definition is not enough – it is important to analyze the deep essence of business processes as a key component of the enterprise's functioning.

The essence of a business process is that it is a structured, holistic and repeatable activity that has a clearly defined input (resources, information), a sequence of logically related actions and a result – a specific product or service that creates value for an internal or external customer. In this context, a business process is not an isolated function or task, but an end-to-end system that integrates various business units into a single coordinated model of action [12].

The key characteristics of business processes include:

– focus on results that satisfy customer requirements;
– sequence and logic of operations;

– repeatability – processes are carried out regularly and can be documented;

– formalization – processes can be described, modeled and optimized;

– cross-functionality – covering several structural units of the enterprise;

– potential for improvement through monitoring and digital technologies [13].

Thus, the essence of a business process is revealed in its ability to ensure consistency, efficiency and controllability of the enterprise's activities, orienting it towards achieving strategic and operational goals.

Business Process Management (BPM) involves a comprehensive methodology within which processes are not only identified, but also actively monitored, analyzed, optimized and automated [14].

In this context, monitoring of business processes is a critical element of the management system – it identifies deviations, risks, bottlenecks and provides management with objective data for decision-making. Monitoring allows you to assess the effectiveness of processes, timely identify imbalances between planned and actual indicators, and quickly respond to changes in the environment.

The main approaches to monitoring business processes include:

– operational monitoring focused on tracking current kpi in real time;

– tactical monitoring, which allows to analyze intermediate results and dynamics of changes;

– strategic monitoring, which ensures that business processes are in line with the company's long-term goals [15].

On the technological side, monitoring can be implemented through integration with ERP systems (e.g., SAP, Microsoft Dynamics), BPM systems, Business Intelligence (BI) tools, and digital dashboards that provide real-time visualization and analytics. Business process monitoring is especially relevant in the context of global challenges, such as the COVID-19 pandemic. During this period, companies faced the need to quickly adapt operational schemes, transfer some processes

to remote mode, and ensure the stability of supply and service chains. Only effective digital monitoring made it possible to maintain control, reduce risks and ensure business continuity [16].

Business management has always been a complex system that requires a precise balance between strategic vision and flexibility in decision-making. However, with the development of digital technologies, these approaches have undergone significant changes. Digitalization is no longer just a tool for automating routine operations. It has become an all-encompassing management paradigm that shapes new models of business organization, transforms the interaction between departments, and changes the very logic of enterprise management.

In the 21st century, digital technologies have become key to increasing the competitiveness of companies. Previously, innovation was perceived as an additional advantage, but today it is a matter of survival. This was especially evident during the COVID-19 pandemic, which exacerbated the need for rapid response, flexible planning, remote control, and rapid information exchange. Businesses that had the proper digital infrastructure were able to maintain their efficiency, while others found themselves facing the need to accelerate the implementation of digital solutions in a crisis mode [17].

Modern management in the digital era is increasingly based on the principles of transparency, integration, and analytics. Whereas earlier decision-making was based mainly on a manager's intuition or limited information, today the emphasis is shifting to objective data collected in real time. This is changing not only the tools used by the management apparatus, but also the very concept of management: linear vertical structures are gradually being replaced by flexible, decentralized models in which each unit can respond quickly to changes in the environment, having access to complete information.

An example of a successful implementation of digital management transformation is Zara, which actively implemented a fast fashion model based on digital demand analysis even before the pandemic. The system of collecting data from retail stores and online channels allowed the company to make management decisions based on real

consumer demand. This allows Zara to respond to changing trends in a matter of days, which is made possible by the digital integration of logistics, production, and marketing. Another striking example is Siemens, which has digitized its internal control system for production processes by integrating IoT solutions into production lines. This made it possible not only to monitor the condition of the equipment but also to automatically predict potential failures, planning maintenance before a breakdown occurs. Thus, enterprise management has become more predictable and adaptive, and decision-making has become fast and data-driven [18].

At the same time, digitalization is changing the requirements for management. A manager must be not only a strategist, but also an analyst who can work with large amounts of data, understands the principles of cybersecurity, knows how to coordinate digital teams, and is familiar with modern software. This requires new approaches to the formation of management teams and staff training.

However, despite its many benefits, digitalization of management remains a complex process, often accompanied by employee resistance, difficulties in integrating new systems, and the need for significant investment. Many companies trying to go digital face the problem of incompatibility between the old organizational culture and new technological approaches. Without an appropriate change in mindset, digitalization risks remaining just a technical modernization without any real management effect [19].

Thus, digitalization in management is not only about technology, but also about changing the principles, values, and logic of interaction within the enterprise. It requires a systematic approach, strategic vision and readiness for deep transformations. In a world where global challenges are becoming more and more frequent, digital thinking is becoming the basis for business sustainability and flexibility.

The COVID-19 pandemic has become not only a global health and social crisis, but also a powerful catalyst for economic transformation. Businesses around the world found themselves in a situation where their usual business models had lost their effectiveness, and classic management and operational processes needed to be immediately

restructured. This global challenge has dramatically accelerated the digitalization of business processes, forcing companies to change their internal structures, customer engagement strategies, supply chains, and approaches to human resources management. One of the key transformations was the shift to a remote work format, which required a review of internal management processes. Many companies that previously did not see the need for remote work had to adapt quickly. Twitter, for example, was one of the first to announce that it would allow its employees to work from home indefinitely, even after the pandemic ended. This meant not only technical restructuring – ensuring data security, organizing online communications – but also changing management approaches to control, performance evaluation, and maintaining corporate culture.

Another vector of change has been the rapid development of e-commerce. According to the UNCTAD, in 2020, the share of e-commerce in global retail turnover increased from 14 % to 17 % in just one year. This has forced thousands of companies to rethink logistics, warehouse management, customer service, and marketing. Businesses such as Amazon and Alibaba not only withstood the pandemic but also strengthened their positions thanks to pre-existing digital infrastructures. At the same time, less prepared companies were forced to urgently launch online stores, implement CRM systems and look for new distribution channels [20].

The pandemic has also brought the topic of flexible supply chains to the forefront. Due to restrictions on the movement of goods, border closures, and disruptions in logistics routes, companies such as Apple have reconsidered their dependence on suppliers in certain regions and started diversifying their chains. This has led to in-depth analysis and digital process modeling, which has allowed for better risk forecasting, inventory management, and increased resilience to external shocks.

The healthcare sector, in particular pharmaceutical companies, has demonstrated another facet of transformation – the integration of digital tools into R&D. For example, Pfizer and BioNTech developed a vaccine against COVID-19 using artificial intelligence to analyze genetic data and speed up clinical trials. This indicates

a shift from traditional to flexible digital models of innovation, where speed and accuracy are becoming critical competitive advantages.

In addition, the pandemic has caused a transformation of approaches to customer experience. Brands have started to actively use chatbots, automated support services, and customer query analytics to replace physical interaction with digital channels. For example, Starbucks introduced mobile applications for contactless ordering before the pandemic, but in 2020 the company significantly expanded this system, adapting its business processes to new realities. What was once an innovation has become a necessity. The psychological aspect of business transformation deserves special attention. The pandemic has exacerbated the issue of employee adaptation to new conditions, the growth of digital fatigue, and the need for mental support for staff. Many companies have begun to implement digital employee wellness platforms, offering consultations with psychologists, interactive trainings on maintaining productivity in isolation, creating virtual teams, and more. This once again proved that digital transformation is not only about technology, but also about people in the new digital ecosystem.

Conclusions. The study made it possible to draw a number of conclusions about the nature, transformation and current mechanisms for monitoring business processes in the context of digitalization, which has been especially intensified by global challenges, in particular the COVID-19 pandemic.

An in-depth theoretical analysis of the concepts of “business process” and “digitalization”, their interrelation and role in modern strategic management of an enterprise was carried out. It is found that business processes are the basis for the functioning of an organization, and their monitoring ensures control over efficiency, timely identification of problems and implementation of improvements. Digitalization, in turn, is not just a tool for automation, but a component of a deep transformation of management approaches, which allows for adaptability, transparency and flexibility of business. The COVID-19 pandemic has revealed vulnerabilities in traditional management systems and stimulated a global review of methods for

organizing business processes – with an emphasis on remote models, online infrastructure and real-time analytics.

As a result, the COVID-19 pandemic turned out to be a kind of "crash test" for all elements of business processes – from human resources management to logistics and innovation. Those companies that had already started digital transformation earlier gained an advantage, while others were forced to make changes in the conditions of the crisis. Global challenges have not just accelerated digitalization – they have fundamentally changed the idea of an effective business process. Today, companies can no longer afford to ignore the need for digital solutions – it has become the basis for long-term viability and adaptability in the new reality.

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SECTION 2
The impact of digitalization on socio-economic security of Ukraine

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2.1. ANALYSIS OF THE UKRAINIAN LABOR MARKET 2024: KEY INDICATORS, SENTIMENT, AND AI RECOMMENDATIONS

Introduction. The year 2024 marked another stage of challenges and transformations for the Ukrainian labor market. Martial law, economic uncertainty and social challenges have significantly affected employment dynamics, salary policy and expectations of both employers and employees. Despite the difficulties, Ukrainian business demonstrates resilience and readiness to adapt, as evidenced by positive changes in the indicators of recovery of enterprises, income dynamics, and labor market activity.

Summary of the main results of the study. In 2024, Ukrainian business demonstrated further recovery from previous shocks. According to the data, 86 % of companies reported a full recovery in their operations, which is 6 % higher than last year. Another 12 % of companies are operating in a partial mode, but intend to resume full operations in the future.

More than a quarter (28 %) of Ukrainian companies recorded positive revenue dynamics, which is 5 % more than in 2023. Stability of their revenues was reported by 22 % of organizations, which is also a slight increase compared to the previous year.

Among the companies that have faced a decrease in revenues this year, the largest share is accounted for by those whose losses amounted to up to 25 % (12 % of companies). This figure decreased by 3 % compared to 2023. Every tenth company experienced a reduction in revenue of 25–50 %, while last year there were 7 % more such companies. In general, every tenth organization lost more than 50 % of its revenue over the past year, but in 2023, 9 % of companies experienced such significant losses [7].

The vast majority of organizations (88 %) hired staff in 2024, with 59 % of companies recruiting for all areas of their operations. This situation is likely to continue next year: 92 % of companies announced their plans to hire staff in 2025.

The trend in salary payments in 2024 became more stable compared to the previous year. Only 2.6 % of the surveyed companies reported a reduction in compensation. The level of remuneration remained unchanged in 15.8 % of organizations. The companies that increased salaries this year state that the largest share of them was among those who increased payments by 11–20 %. Further salary increases in 2025 are planned by 74 % of organizations [1].

In 2024, Ukrainian businesses were more focused on maintaining what they had achieved than on actively scaling up and finding new markets. In general, the main priorities of companies this year are as follows: maintaining the existing staff in full (68.5 %), maintaining a competitive level of remuneration (65.5 %), and retaining current markets and customers (52 %). The search for new markets or customers was prioritized by 38.2 % of companies, and 14.2 % of organizations made efforts to open new business lines.

Relocation of business abroad or opening of new representative offices in other countries was carried out by 3 % and 5.8 % of companies, respectively.

Thus, the real situation has made adjustments to the plans of many companies, as at the end of last year the number of companies planning changes and growth was much higher. In particular, 53.7 % of companies sought to find new markets or attract new customers. Expansion of business through new lines of business or in other regions was planned by 15.1 % and 13.2 % of companies, respectively.

Despite the economic difficulties and instability, Ukrainian companies have outlined positive intentions for business development for the next year. Among the top five priority areas, the surveyed organizations named the following aspirations: to retain the current team in full (52 %), to find new markets/customers (47 %), to retain existing markets/customers (38 %), to increase employee salaries (34 %), to maintain the level of employee remuneration at the highest possible level (23 %) [3].

The share of employed professionals has increased. While last year 67 % of surveyed professionals reported being employed, in 2024 this figure rose to 81 %. However, the average job search time remained unchanged at 3–6 months. The most common problem faced by professionals when looking for a job is the inability to find an option with a decent level of remuneration, as stated by 45 % of respondents. One in five job seekers (21 %) noted a decrease in the number of vacancies in their specialty.

Compared to the previous year, the number of professionals who fear layoffs in their company over the next six months has increased. This was reported by every fifth specialist (22 %), while last year such fears were shared by 17 % of employees.

Salaries remain one of the key issues for employees. For the vast majority (40.8 %) of surveyed professionals, their salaries have not changed compared to 2023. Salaries were reduced for 12.3 % of employees. Among those who received a salary increase, the largest share was among those whose compensation increased by 11–20 % [7].

Thus, 70 % of job seekers are not ready to lower their salary expectations even in case of employment difficulties. Last year, 62 % of specialists stated this position.

Half of the surveyed professionals are currently actively looking for a job or plan to start looking for a job in the near future. The

average duration of a job search is 3–6 months. The main difficulties faced by Ukrainians in the employment process include the following problems when looking for a job:

– 45 % of respondents cannot find a job with an acceptable level of pay.

– 21 % noted a decrease in the number of available vacancies in their specialty.

– 20 % complain about the lack of responses from recruiters to their job applications.

– 17 % report a lack of feedback after interviews or interviews.

– 12 % have faced discrimination from potential employers based on age [1].

Every tenth respondent said that there are no vacancies in their current place of residence or country of origin that meet their professional interests.

Only 22 % of surveyed professionals did not experience any negative changes in the process of job search and subsequent employment.

Let us consider the main employment problems that have arisen since the beginning of the war in (Table 1).

Table 1

The main problems of employment in the conditions of war (multiple choice)

I can't find a job with a decent salary	45 %
I did not feel any negative changes	22 %
There was a decrease in the number of vacancies in my profession	21 %
Recruiters don't respond to job applications	20 %
Lack of feedback after the interview or interview	17 %
I can't find a job because of age discrimination (50+)	12 %
There is no work that interests me where I live now	11 %
Other	9 %
I am an IDP and I am reluctant to be hired	5 %
I don't know how and where to look for a job	4 %
I am abroad and cannot find a job that interests me	2 %
I am a veteran and they are reluctant to hire me	1 %

Source: based on [1]

Despite the difficult situation in the labor market caused by martial law, a significant part of the surveyed professionals (64 %) expressed overall satisfaction with their current job.

This indicator showed an increase compared to the previous year, when the level of satisfaction was 56 %. At the same time, one in five surveyed professionals expressed some degree of dissatisfaction with their current employment [4].

The value of comfort and safety in the workplace has increased among Ukrainian employees. This factor was ranked third in terms of importance among the motivators and retention factors this year, second only to the level of salary. In addition, employees began to pay more attention to good communication with management.

The top five reasons (other than salary) for keeping employees at their current job include:

– the ability to work remotely (45 %);
– favorable team atmosphere (35 %);
– comfortable and safe working conditions (33 %);
– good relations with the manager (33 %);
– flexible work schedule (32 %) [6].

There is an increase in the attention of Ukrainian employees to such aspects as the company's support of its employees during the war, the availability of interesting projects and tasks and the freedom to implement them, the company's socially responsible position, and shared values in the team.

The importance of these factors for employees is also confirmed by the list of the main demotivators that, in addition to dissatisfaction with the level of salary, can lead to dismissal from the current place of work:

– Lack of friendly atmosphere in the team (32 %).
– Lack of comfortable and safe working conditions (29 %).
– Lack of good relations with the manager (29 %).
– Lack of opportunities for career growth (28 %).
– Lack of opportunities to work remotely (28 %).

The salary situation is of paramount importance in our changing environment [6].

Salary remains a key criterion for employees when choosing an employer. Recognizing this, Ukrainian businesses

have made significant efforts to maintain competitive salaries. According to the surveys, 41 % of employees reported that their compensation level has not changed compared to 2023. The share of those whose incomes increased was 47 %, while 12 % of Ukrainians faced a pay cut.

Amid the difficult economic situation, businesses were cautious about raising wages. Only a limited number of employees experienced a significant increase in monetary compensation of 31 % or more – only 3 % of respondents reported such a significant increase in their income [1].

Despite the challenging economic environment, Ukrainian employees are largely unwilling to make concessions in their salary expectations, even in the event of employment difficulties.

This position was expressed by 70 % of respondents, which is 8 % more than in the previous year. Among those who are still ready to partially concede their salary demands, the largest share is accounted for by those who agree to a reduction of up to 5 % in order to get a job.

Let's look at the data of the survey "Are employees ready to reduce their salary demands and by how much if they face difficulties in finding a new job?" in Table 2.

Table 2

Readiness of employees to reduce their salary expectations

No, I am not ready to (a) lower the bar	70 %
Yes, I am ready to reduce my desired salary by no more than 5 %	15 %
Yes, I am willing to reduce my desired salary by 6–15 %	7 %
Yes, I am willing to reduce my desired salary by 16–25 %	4 %
I'll accept any one they offer	3 %
Yes, I am willing to reduce my desired salary by 26–35 %	1 %

Source: based on [1]

Due to the mismatch between their skills and knowledge and the requirements of employers, an increasing number of Ukrainians

are considering retraining. Compared to the previous year, the share of professionals who are willing to learn a new profession in order to increase their competitiveness in the labor market and increase their salaries has increased by 9 % (from 54 % in 2023 to 63 % in 2024). Currently, every tenth respondent (12 %) is already learning a new profession, and another 9 % of respondents plan to do so in the future [7].

Over the year, the number of those who are not ready to learn new knowledge and skills has decreased, citing significant experience in their current profession as a reason. While last year there were a quarter of such specialists (24 %), in 2024 only 19 % of Ukrainians declared their unwillingness to study and retrain. Table 3 presents data from the employee survey: "Are employees ready to re-profile and learn something new if there are difficulties in finding a job in your profession?".

Table 3

Data from the survey of employees on re-profiling

Yes, I want to get a new profession to be more in demand in the labor market and receive a higher salary	63 %
No, I am not ready to learn something new, I have been in this profession for many years	19 %
I am already learning a new profession	10 %
Yes, I want to get a new profession that I have been dreaming of for a long time	8 %

Source: based on [1]

Let's analyze the current state of the labor market using artificial intelligence, which is a topical issue today.

For the first time in the Labor Market Barometer survey, GRC. UA experts used artificial intelligence to analyze the responses of respondents in both key categories. The responses of employers and employees/candidates to open-ended questions were processed and analyzed using AI. The goal was to obtain visual images reflecting the perception of the current state of the labor market by both target audiences, as well as to compare their responses [1].

The result was a number of interesting images and associations. According to artificial intelligence, employers perceive the current labor market as a "burned-out forest", emphasizing the destruction of the labor market ecosystem and the need to restore it.

Other interesting associations of today's labor market formed by AI include the following components:

– "Tired Tiger" – symbolizes the exhaustion and fatigue of both key market participants: employers and employees/candidates.

– "Water flowing through fingers" – reflects the transience of opportunities or lost chances.

– "The Hunger Games" – based on fierce competition for available resources (personnel, jobs).

– "The Storm" – personifies the turbulence and chaos that prevail in the labor market.

– "Tightrope walker" – conveys a sense of instability and the need to constantly balance existing risks.

– "Squirrel in the wheel" – symbolizes the feeling of fruitless work and lack of progress [1].

In addition, AI suggested the image of "night before dawn", which hints at positive future changes, symbolizing a difficult period preceding a potential improvement in the situation.

Based on the analysis, artificial intelligence formulated recommendations for labor market participants.

Possible ways to solve existing problems on the part of employers:

1. Competitive remuneration: ensuring the level of wages that corresponds to current economic realities.

2. Softening the requirements for candidates: lowering the selection criteria for applicants without work experience or older people.

3. Transparency of communication: providing clear feedback after interviews.

4. Simplification of the hiring procedure: minimizing bureaucratic processes during the hiring process.

5. Inclusive work environment: adaptation of workplaces for veterans, people with disabilities and internally displaced persons [1].

Recommendations for job seekers:

1. Continuous learning and adaptation: use the available time to improve your skills and learn new ones.

2. Active position: focus not only on the level of salary, but also on companies with a healthy corporate culture.

3. Realistic assessment: compare your own skills and experience with the current requirements of the labor market.

Thus, according to AI analysis, the current labor market is in crisis, but retains the potential for recovery and growth. The key challenges are economic instability, discrimination, lack of transparency, and mismatches between employers' and candidates' expectations. To successfully adapt to new challenges, job seekers need to be flexible and willing to learn, and employers need to create attractive conditions that will motivate professionals to stay in the Ukrainian labor market.

Over the past three decades, the Ukrainian labor market has undergone significant transformations and faced a variety of political, economic, and social challenges. During this time, business has demonstrated the ability to respond quickly, adapt and develop several development scenarios. Thus, at the end of 2024, despite the difficult economic situation and the general situation in the country, most employers expressed their intention to strengthen and develop their companies in Ukraine. In 2025, businesses will focus on maintaining their existing teams of employees in full, retaining current markets and customers, actively seeking new ones, and maintaining wages at the highest possible level or, under favorable conditions, increasing them [5].

In addition, a significant number of companies plan to expand their activities both geographically and by developing new business areas next year.

According to the survey, the share of companies planning to relocate abroad is only 3 %. Another 3 % of companies announced their intention to open new offices in other countries.

Most companies demonstrate their intention to actively recruit new employees in the future. Half of the companies (53 %) plan to expand their staff in all areas of their operations. A quarter of employers

(26 %) will focus on hiring in certain specific areas. Every tenth company (13 %) will recruit staff to replace those who have left the company.

The vast majority of companies are optimistic about salaries in 2025. Two-thirds (75 %) of employers plan to increase wages to some extent. 17 % of companies intend to keep salaries at the current level [1; 2].

Almost half (49 %) predict an increase in salaries in their companies, with most of them planning an increase in the range of 11–20 %.

The majority of companies (66 %) plan to leave the bonus system unchanged in 2025. A quarter (28 %) of employers plan to increase the amount of additional payments. Among those who intend to increase bonuses and bonuses, a significant number plan to do so, up to 20 %.

Conclusion. In 2024, the Ukrainian labor market is in a state of complex but dynamic transformation. Despite external challenges, many companies demonstrate resilience, gradual growth, and optimistic plans for the future. The recovery in business activity, stabilization of wages, and positive hiring expectations demonstrate the desire of Ukrainian businesses to retain the domestic market and invest in human capital.

At the same time, structural problems are becoming more acute: an imbalance between the expectations of candidates and the requirements of employers, a limited number of decent jobs, discriminatory barriers, a lack of transparent communication. Employees increasingly value not only wages, but also security, a team atmosphere, flexibility and support in times of crisis. There is growing interest in retraining as a means of maintaining competitiveness in the labor market.

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2.2. DIGITALIZATION FOR THE SUSTAINABLE DEVELOPMENT OF UKRAINE'S AGRICULTURAL ECONOMY AMID CONTEMPORARY CHALLENGES

Introduction. The article explores the critical issue of the survival and development of Ukraine's agricultural sector in the context of a full-scale war, analyzing the impact of the conflict on agricultural exports and emphasizing the necessity of digitalizing the agricultural economy. The loss of arable land and resource shortages under wartime conditions create an urgent need for innovative approaches to agribusiness management. The authors argue that digital transformation is a key factor in ensuring the resilience and competitiveness of the agricultural sector under the new realities.

Digital farming, as a new concept, offers solutions for optimizing production processes, monitoring field conditions, and controlling seed quality.

The implementation of modern technologies such as drones, geographic information systems (GIS), and Big Data allows farmers to effectively adapt to the challenges of war. The article also discusses the role of digitalization at every stage of agricultural production – from research and development to distribution. The authors emphasize the importance of automating logistics processes, which helps reduce costs and increase efficiency. Furthermore, the training of specialists capable of working with digital technologies is considered a crucial factor in the successful transformation of the agricultural sector. The article highlights that the active implementation of digital solutions in agriculture not only supports the survival of enterprises during wartime but also opens new opportunities for entering international markets. Overall, the research findings confirm the importance of digitalization for the sustainable development of Ukraine's agricultural economy in the face of contemporary challenges.

The purpose of this study is to analyze the challenges facing agricultural exports during the war and to justify the need for digitalization of the economy to overcome these difficulties.

The study objectives include analyzing changes in the structure of sown areas, yields, production volumes, and exports of agricultural products; assessing the war's impact on logistics chains, access to resources, and agricultural product prices; identifying digital technologies that can be effectively applied in Ukrainian agriculture; identifying barriers to the digital transformation of the agricultural sector; developing a roadmap for implementing digital technologies; and evaluating the economic efficiency of digital solutions.

The materials used in this study include:

1) scholarly articles and research dedicated to the digitalization of agriculture, as well as studies conducted in Ukraine and other countries that have faced similar challenges;
2) statistical data;
3) market analysis;

4) examination of the experiences of countries that have successfully implemented digital technologies in agriculture.

The research employed the following scientific methods: system analysis to identify relationships between various elements of the agricultural production system and the role of digital technologies in optimizing them; comparative analysis to compare the state of Ukraine's agricultural sector before and during the war, as well as with other countries; modeling, which enables the creation of a predictive model to assess the impact of different digital technology development scenarios on the agricultural sector.

The scientific article proposes the creation of an integrated platform that would unite all participants in the agri-food chain – from producers to consumers. Such a platform would optimize logistics processes, ensure transparency of all operations, and strengthen trust in Ukrainian products on global markets. The platform would enable real-time tracking of goods, allowing for rapid responses to shifts in market conditions and minimizing risks.

A key aspect of digital transformation is the simplification and automation of customs procedures. Transitioning to electronic document management, implementing electronic certificates, and using modern information technologies would speed up customs clearance, reduce corruption risks, and lower exporters' costs. The development of e-commerce in the agricultural sector is also identified as a promising direction. Creating online platforms for selling agricultural products would help attract new clients globally, increase sales volumes, and diversify exports.

However, digital transformation involves not only technological solutions but also the establishment of a favorable legislative environment. The article highlights the need to develop and implement laws that will encourage investment in digital technologies within the agricultural sector, ensure intellectual property protection, and safeguard against cyberattacks. Cybersecurity is one of the most crucial aspects of digital transformation. Under wartime conditions, the risk of cyberattacks increases significantly, making it essential to take all necessary measures to protect digital systems and data.

Thus, the digital transformation of Ukraine's agricultural sector is a necessary step to ensure its resilience and competitiveness during wartime. The adoption of modern technologies will enable the optimization of production processes, enhance logistics efficiency, simplify customs procedures, and open up new markets for Ukrainian agricultural products.

A promising direction for future research is the optimization of the export potential of Ukraine's agro-industrial complex. Key priorities include improving the efficiency of logistics chains, implementing modern technologies for storage and processing of agricultural products, ensuring high quality and safety standards, and strengthening the global image of Ukrainian agri-food products. Achieving these goals will not only increase export volumes and raise foreign currency inflows to the state budget, but also contribute to job creation and overall economic growth. Reaching these objectives will require a synergy of efforts from government bodies, business entities, and international organizations.

During the war, the export of agricultural products faces significant challenges due to disrupted logistics chains, restricted access to ports, and transportation routes. These conditions threaten not only the country's food security but also its economic stability, which heavily depends on the agricultural sector. Therefore, there is an urgent need to adapt infrastructure and trade processes to the new realities, which requires the implementation of modern digital solutions. The digitalization of the economy could become a key instrument for improving agribusiness management and ensuring uninterrupted export flows. This issue also includes the need for rapid adaptation of the legal framework to support digital initiatives in the agricultural sector. Such an approach can strengthen the country's position on international markets even amidst armed conflict.

The digitalization of business processes continues to evolve rapidly, increasingly integrating into traditional business models. Researchers from various countries are exploring opportunities to transform enterprises through technologies that enable real-time analytics using smart devices and specialized software. This phenomenon spans across all sectors of the economy, including agriculture.

In their work, Ukrainian scholars such as M. V. Hazuda [1], M. V. Rudenko [2], N. M. Horobets [3], I. V. Voronenko [4], S. O. Kostenko [4], S. S. Kiporenko, and N. P. Yurchuk [5], among others, have focused on the applied aspects of digital development in the agricultural sector. International researchers, including M. Bacco, P. Barsocchi, A. Walter, A. Gotta, M. Ruggeri, E. Ferro, and R. Huber [6; 7], have also examined various approaches to implementing digital technologies in agricultural production. However, despite numerous studies, the process of digitalizing agricultural production under martial law remains insufficiently explored, which highlights the relevance of this research.

Future scientific studies are encouraged to focus on opportunities to increase the export volumes of agricultural products, reduce logistics and storage costs, enhance product quality and safety, increase market transparency and trust, boost the competitiveness of Ukraine's agricultural sector in global markets, create new jobs, and strengthen the country's economic stability. Achieving these outcomes will require joint efforts from the state, businesses, and international organizations.

The purpose of this article is to analyze the challenges faced by agricultural exports during wartime and to justify the necessity of economic digitalization as a means to overcome these difficulties. The research objectives include examining existing problems in logistics and trade, as well as identifying digital solutions that can optimize agricultural exports.

Presentation of the Main Research Findings. Despite certain steps toward digitalizing the agricultural sector, many aspects of this process remain underdeveloped. Particular attention must be given to the development of effective mechanisms for digital monitoring and management of agricultural supply chains in times of crisis. The issue of implementing integrated digital platforms for international trade that consider wartime conditions also remains unresolved. Furthermore, cybersecurity in the context of digitalization is insufficiently addressed, which poses risks during trade operations. In addition, the legal framework enabling the full deployment of digital solutions in the agricultural sector requires further research and development.

The international experience of European countries that have suffered significant wartime losses demonstrates that substantial changes in both the economy and society are possible with adequate external financial support. The long-standing successes of these countries show that economic transformation is achievable, though it requires adaptation to local conditions and available resources. While there are no universal solutions for overcoming economic crises, Europe's experience can offer valuable guidance for Ukraine.

Given that Ukraine is one of the world's leading exporters of agricultural products, its potential for economic recovery through the agricultural sector is considerable. For example, Ukraine is the global leader in sunflower oil and meal exports, accounting for half of the world's supply of this product. The country also ranks second in barley and rapeseed exports, and third in rye and sorghum exports. In total, Ukraine supplies about 10 % of the world's grain. Notably, the agricultural sector generates up to 40 % of the country's foreign currency earnings, contributing significantly to the stabilization of the national currency.

However, the war has severely damaged infrastructure, particularly the ports that are vital for exports. The restoration of port infrastructure and improved access to financial resources – especially credit – remain critical for stabilizing the banking system and the broader economy.

Before the full-scale war, agriculture was one of the key sectors of the Ukrainian economy, playing a significant role in international trade.

In the pre-war period, Ukraine supplied major markets with grain, oilseeds, and other agricultural products. Between 2013 and 2021, the share of agricultural exports increased significantly, particularly against the backdrop of declining metallurgical exports. In 2021, the agricultural sector accounted for 41 % of the country's total exports, exceeding USD 27 billion. The primary buyers of Ukrainian products included EU countries, China, India, Egypt, and Turkey – underscoring Ukraine's global importance as a food supplier.

Ukraine is one of the world's leading suppliers of agricultural products, playing a critical role in ensuring food security for many countries. The increase in the share of agricultural exports

to 41 % highlights the significant potential of agriculture within Ukraine's economy. The main buyers of Ukrainian products include the EU, China, and India, underscoring the global importance of Ukrainian agricultural goods. However, the war has posed serious challenges to the country's export capabilities, particularly due to destroyed infrastructure. Despite these difficulties, Ukraine's agricultural sector remains a crucial element of both national and international economic stability.

Table 1

Ukrainian Agricultural Exports in 2021

Product	Volume (million tons)	Value (billion USD)
Sunflower oil	5	6.4
Corn	23	5.9
Wheat	19	5.1
Rapeseed	2.7	1.7
Barley	5.8	1.3

Source: Compiled by the authors based on data from [1]

Ukrainian agriculture has become one of the main targets of Russian aggression, as it underpins economic stability and food security both domestically and globally. Before the war, Ukraine controlled over 32.7 million hectares of arable land, but due to the occupation of significant territories, this figure dropped to 26.5 million hectares. The loss of access to fertile land has severely limited the production of key agricultural commodities, directly affecting the country's export potential. In addition to land seizures, Russia has deliberately blocked Ukraine's Black Sea ports, through which most grain exports traditionally passed. These actions have global repercussions, as Ukrainian grain plays a vital role in feeding countries, particularly in Africa and the Middle East. Russia has also systematically looted agricultural equipment and harvests, deepening the food crisis. These destructive acts are part of a broader strategy aimed at economically weakening Ukraine and undermining its ability to finance the war and supply food to itself and the world.

The situation is further complicated by the fact that, until recently, Ukraine was one of the leading wheat exporters on the Euro-Asian continent. This was possible due to optimal climatic conditions, particularly soil moisture, which contributed to high yields of this crop (Figure 1). International food aid from organizations such as the World Food Programme (WFP) could potentially address food shortages. However, due to the war, these organizations now face difficulties, as Ukraine supplied around 50 % of the wheat used in such aid. Even before the war, rising agricultural prices limited international organizations' purchasing capacity. This highlights that Russia's full-scale invasion of Ukraine has effectively triggered a global food crisis.

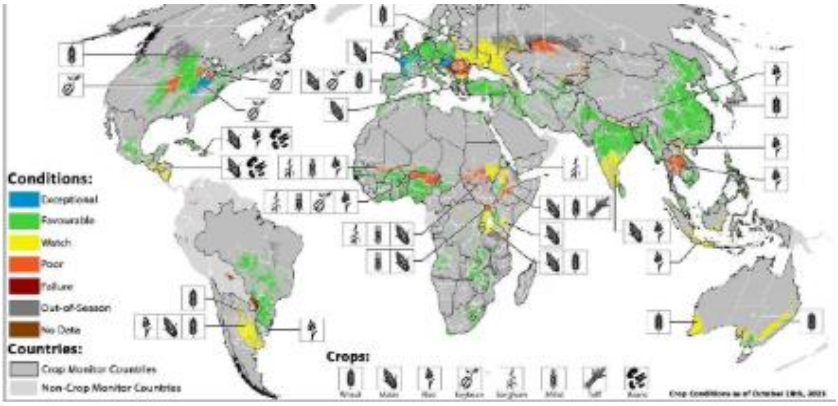

Fig. 1. Map of crop conditions summarizing information for all AMIS member countries across major production areas of wheat, maize, rice, and soybeans

Source: Compiled by the authors based on data from [7]

According to the latest report by the Kyiv School of Economics (KSE) on the Third Rapid Damage and Needs Assessment (RDNA3), as of December 2023, Ukraine's agriculture sector had suffered losses totaling USD 80 billion. This figure includes USD 10.3 billion in damage to or destruction of assets, with agricultural machinery accounting for 56.7 % of these losses. An estimated 181,000 units of equipment were damaged or destroyed, along with 2.8 million tons

of grain, 1.2 million tons of oilseeds, 124,000 tons of fertilizers, and 11.6 million liters of fuel.

Russian attacks also caused major destruction to storage facilities, resulting in the loss of approximately 20 % of Ukraine's storage capacity (excluding occupied territories). Although livestock and aquaculture account for a smaller share of Ukraine's agrarian sector, they also suffered damages of USD 254 million and USD 35 million, respectively. The total income losses in the agricultural sector are estimated at USD 69.8 billion.

In the first year of the war, production of grains and oilseeds fell by 30 %, and producer prices for corn and wheat dropped by 45 %, despite rising global food prices. Total losses due to reduced productivity are estimated at USD 34.3 billion, while losses from falling domestic prices – caused by Russia's export blockade – add another USD 24.1 billion.

Table 2

Key Agricultural Losses in Ukraine, 2023

Type of Loss	Estimated Loss (USD billion)
Asset damage	10.3
Share of losses due to machinery	56.7 % of total asset losses
Loss of grain and oilseeds	2.8 million tons of grain, 1.2 million tons of oilseeds
Reduced production	34.3
Losses due to price drops	24.1
Total income loss	69.8

Source: Compiled by the authors based on data from [3]

This situation represents one of the most severe crises in Ukraine's agricultural sector, requiring significant recovery efforts, as the losses have impacted not only the domestic market but also jeopardized global food security.

The destruction of the Kakhovka Dam by Russia on June 6, 2023, led to a large-scale disaster, flooding over 620 km² of territory. This caused massive humanitarian, environmental, and economic damage

to Ukraine, with the agricultural sector suffering the most. According to the joint Post-Disaster Needs Assessment (PDNA) report by the Government of Ukraine and the United Nations, damage to the agricultural sector reached USD 406.6 million, primarily due to the loss of irrigation systems.

Before its destruction, the Kakhovka Dam supplied water to one of the largest and most critical irrigation networks in Ukraine, covering up to 800,000 hectares of fertile land. Following the disaster, over 300,000 hectares were left without irrigation and are now dependent solely on rainfall, which could reduce crop yields by up to 70 %. This event delivered yet another heavy blow to Ukraine's agricultural sector, which was already suffering massive losses due to the war.

In 2023, Ukraine's agriculture faced serious challenges caused by Russian aggression, which resulted in extensive damage. Despite the hardships, recovery efforts and grain export operations continued. Important indicators of progress included data on grain, legume, and flour exports, reflecting a partial recovery in agricultural output. However, in 2024, the situation remained unstable due to ongoing issues such as damaged infrastructure, limited market access, and port blockades.

According to Ukraine's State Customs Service, grain and flour exports in 2024 increased compared to 2023. Nevertheless, despite the rise in volume, concerns remain regarding the quality and competitiveness of Ukrainian products. Wheat, barley, and corn remain the main export crops. Export volumes (Table 3) highlight the need for new strategies to adapt to wartime conditions. The following table presents a comparison of grain and flour exports from Ukraine in 2023 and 2024, reflecting changes in the country's agricultural sector.

Analysis of grain and flour exports from Ukraine in 2023 and 2024 reveals significant changes in the agricultural sector.

Comparative data indicate a substantial increase in export volumes in 2024, reflecting a partial recovery in agricultural production. In particular, wheat exports increased by 80 %, signaling a rebound in its production. However, despite positive trends, issues related to product quality and market access persist. A 145 % growth in barley exports indicates its competitiveness on the global market.

Table 3

Comparison of Grain and Flour Exports from Ukraine in 2023 and 2024

Category	2024/2025 MP		2023/2024 MP	
	Total	including: in October 2024	Total as of 16.10.23	including: as of 16.10.23
Total grains and legumes (kt)	12,483	2,035	7,690	937
– Wheat	7,081	983	3,927	593
– Barley	1,588	265	650	28
– Rye	10,6	3,1	0,8	0,0
– Corn	3,543	779	2,995	310
Wheat flour (kt)	20,1	2,7	38,0	3,4
Other flour (kt)	2,0	0,5	1,3	0,2
Total flour (grain equivalent)	22,1	3,2	39,3	4,8
Total exports (grain + flour)	12,512	2,039	7,742	942

Source: Compiled by the authors based on data from [5]

Conversely, the decline in flour exports suggests a need for adaptation to new conditions. The situation is further complicated by infrastructure damage and port blockades that hinder logistics. This underscores the urgency of developing new strategies to support exports. The volume of Ukrainian grain exports remains critical to global food security, especially as many countries face food shortages. In conclusion, 2024 should become a year of new opportunities for Ukraine's agricultural sector despite the challenges it brings.

Turning to digitalization processes in agriculture, the digital transformation of agricultural exports during wartime in Ukraine has become crucial for sustaining the sector.

Key strategic initiatives among major agro-companies include business process automation and implementation of electronic document flow – both of which enhance management efficiency and reduce costs. The introduction of Customer Relationship Management

(CRM) systems and market analysis tools helps producers better understand consumer needs. For example, the agroholding "KERNEL" launched a multifunctional platform called "Open Agribusiness", which facilitates communication among agricultural producers. This platform provides services such as a Forward Program to finance production modernization. Thanks to a GNSS correction service, farmers can operate automated machinery in the fields with high precision. The "Agrotechnologies" service offers insights into cutting-edge agricultural practices implemented by the company. These innovations foster partnerships and information exchange within the agri-business community, promoting growth in Ukraine's agricultural economy. Thus, digitalization becomes a key factor in the survival and recovery of the Ukrainian agricultural sector during wartime.

Due to the war, many Ukrainian farmers face severe challenges during the planting season, including the loss of farmland, landmines, and fuel shortages for machinery. This highlights the need for broad adoption of digital technologies in agribusiness. One innovative solution is the use of drones for pesticide application, which can help compensate for fuel shortages. The readiness of Ukrainian farmers for digitalization is a vital factor, as digital farming integrates financial and field data for effective farm management. It relies on precision and smart agriculture methods, along with web platforms and Big Data analysis. Digital farming can be implemented through smart devices connected to the Internet (Internet of Things, IoT) or through Software as a Service (SaaS) models within the AgTech sector. When equipment transmits data over a global network, it becomes part of the IoT ecosystem, enabling solutions across industries. IoT leverages intelligent devices and the Internet to automate processes, assisting in areas like traffic control, security, agriculture, energy efficiency, and healthcare. In recent years, many IoT projects have emerged, especially in the U.S., Europe, and the Asia-Pacific region (see Figure 2).

Thus, these projects demonstrate the vast potential of digitalization and automation across various sectors. As such, IoT can significantly enhance the efficiency and productivity of agriculture.

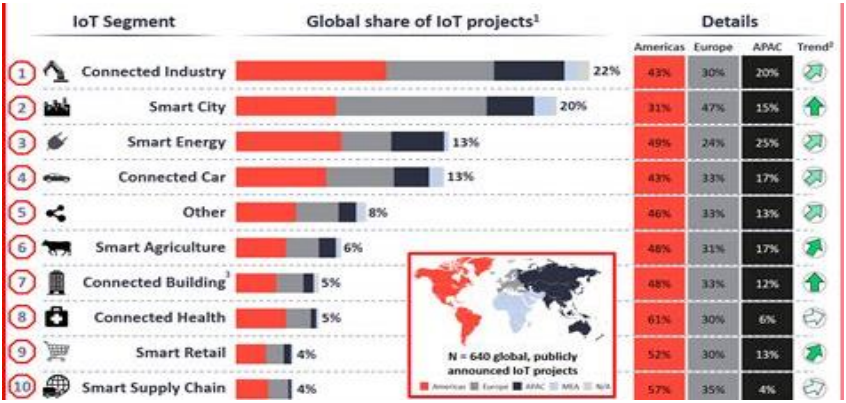

Fig. 2. Global Distribution of IoT Projects in the USA, Europe, and APAC Countries

Source: Compiled by the authors based on data from [8]

In agriculture, IoT enables the effective use of modern technologies such as sensors, drones, robots, and cameras to collect and store data, which is later subjected to advanced analytics. In addition to monitoring field conditions, IoT plays a crucial role in managing overall farm operations, allowing for the development of accurate financial forecasts. Thanks to advancements in satellite imagery, machine learning, and cloud technologies, predictive analytics software is becoming increasingly accessible and scalable. These tools allow agricultural producers not only to respond to current conditions but also to plan future production stages based on the insights gained.

The key stages of seed production and the opportunities enabled by digitalization are illustrated in Figure 3.

Thus, the integration of IoT into agriculture can significantly enhance the efficiency and profitability of agricultural production.

As illustrated in Figure 3, digital farming plays a crucial role in shaping the seed value chain. Implementing digitalization at all stages of seed companies' business processes – from research and development to final sales – is key to improving agricultural productivity. At the research stage, close monitoring and selection

of seed material allows for the digitalization of trial data from field stations. This enables researchers to thoroughly analyze the performance of various seed varieties.

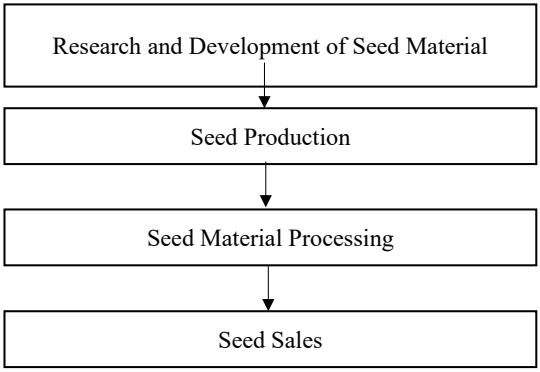

Fig. 3. Stages of Seed Production Activities in Digital Farming

Source: Compiled by the authors based on data from [1]

During the seed production stage, digital technologies support the selection of the best seed material based on previous findings, facilitating its expansion over larger agricultural areas. After harvesting, seed processing becomes critical for detecting poor quality or counterfeit seeds, requiring close monitoring of their origin. The use of QR codes on packaging allows consumers to trace the origin and quality of the seed material. In the sales stage, digitalization also considers climate conditions, enabling agri-companies to adapt their sales strategies effectively to weather fluctuations, while information platforms serve as vital tools for communication among farmers to share seeding optimization recommendations [2, pp. 82–83].

The digitalization of the agricultural sector necessitates the adoption of modern technologies such as satellite imagery, drones, and geoinformation services that enhance the monitoring of farmland. To achieve high performance, it's also important to improve management components, including the digitalization of decision-making metrics. The use of Big Data technologies and

economic-mathematical models ensures effective data analysis, supporting process optimization in the agri-sector. Furthermore, training managerial staff in IT competencies is essential for the successful application of digital tools.

Conclusions. Thus, digitalization of the economy in Ukraine has become critically important in wartime conditions, particularly in the agricultural sector. The loss of arable land and limitations in resources necessitate new approaches to agribusiness. Digital farming, as an innovative method of agricultural management, offers solutions for monitoring, controlling, and optimizing production processes. The use of technologies such as drones, geographic information systems, and Big Data enables farmers to adapt effectively to emerging challenges.

Agri-companies can leverage digitalization opportunities at all stages of the seed value chain – from research and development to sales. This includes productivity monitoring, seed selection, and quality control through digital tools such as QR codes. Digitalization also enhances logistics by automating warehousing and transportation processes, helping to reduce costs and improve efficiency.

Moreover, the implementation of information platforms ensures communication between farmers and facilitates the sharing of best practices to improve crop yields. An essential aspect is the training of specialists capable of working with digital technologies, which strengthens the competitiveness of agricultural enterprises. The systematic use of digital tools enables businesses to explore new markets, expand their customer base, and attract international investment for the recovery of the agricultural sector.

In conclusion, to ensure the sustainable development of agribusiness in Ukraine during the war, it is necessary to actively implement digital solutions. This will not only improve production efficiency but also help the country access new international markets, safeguard food security, and drive economic development. Research findings confirm that digitalization in the agri-sector is a key factor not only for survival but also for prosperity amid modern challenges.

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2.3. THE UKRAINIAN LABOR MARKET IN THE CONTEXT OF DIGITALIZATION AND MARTIAL LAW

Introduction. Ukraine's current labor market is undergoing a profound transformation caused by two parallel challenges: the digitalization of the economy and the impact of martial law. These factors lead to radical changes in the structure of labor supply and demand, forms of labor organization, and require adaptation by the state, business, and citizens.

In the context of the study of the modern labor market of Ukraine under the influence of digitalization and martial law, a number of Ukrainian scholars who analyze these problems can be mentioned: V. Hrynevych and O. Shubina study the transformation of the labor market under the influence of digitalization and martial law [3]; Libanova E. M. and Makarova O. V. analyze migration processes, labor loss and labor market adaptation during the war [4]; Kulikov O. Yu, Bondar T. P. consider the impact of technological changes on employment and the need for retraining [5]; Mishchenko V. I., Onyshchenko A. M. study remote employment, gig economy and regulatory changes under martial law [6]; Kinakh A. V., Savchuk V. S. analyze employment policy, support for IDPs and integration of digital technologies into government programs [7].

The work of these scholars covers key aspects of employment transformation, migration, technological change, and regulatory challenges.

Summary of the main results of the study. Ukraine's current labor market is undergoing profound structural changes caused by full-scale Russian aggression and global transformations in employment. The war has not only destabilized traditional employment models, but also accelerated the processes of digitalization, changes in the professional structure and migration of labor resources. Under these conditions, there is a need for a systematic analysis of the key factors shaping the new reality of the Ukrainian labor market.

This article examines the main determinants of its transformation, in particular, the impact of martial law on employment, the role of digital technologies in the adaptation of businesses and employees, and the effectiveness of government regulatory mechanisms. The findings allow us to assess the prospects for further development of the labor market in the face of current challenges.

Let's analyze the main factors of transformation of the Ukrainian labor market during the war:

1. Impact of martial law on the labor market:
– reduction of the number of jobs;
– increase in unemployment;
– mass migration and mobilization;

– destruction or evacuation of enterprises;
– change of business profile for military needs;
– state employment programs (e.g., "Army of Recovery") [2].

2. Digitalization as a key factor of adaptation:
– development of digital services (public services, education, medicine);
– growth of remote work and online learning;
– development of freelancing and IT-sphere [7].

3. Transformation of employment forms:
– development of the gig economy, freelancing, self-employment;
– reduction of traditional forms of labor due to migration and infrastructure destruction;
– demand for new professions (logisticians, UAV operators, cybersecurity specialists, crisis psychologists) [10].

4. Social challenges for the labor market:
– shortage of labor in the areas of active hostilities;
– return of refugees to work;
– insufficient level of digital literacy in certain groups of the population [11].

5. State initiatives to support the labor market:
– introduction of digital tools ("Diia", electronic certificates);
– retraining programs (IT areas, courses for the unemployed);
– support for small businesses and startups [1; 2; 3; 7].

These factors affect Ukraine's current labor market, creating new conditions for businesses, employees, and government policy.

Thus, Ukraine's current labor market is undergoing a profound transformation caused by two key factors: a full-scale war with Russia and the accelerated digitalization of the economy [1]. Martial law has also led to serious structural changes: job losses, mass migration, mobilization, and the reorientation of businesses to military needs. The government has responded to these challenges with employment and business support programs, but the shortage of personnel in some regions remains critical.

It is worth noting that digital technologies have become a key tool for the economy's survival, enabling remote work, online education,

and public services. The IT sector has demonstrated resilience and even growth, becoming one of the drivers of the economy, and new forms of employment (gig economy, freelance, self-employment) are gaining popularity, while traditional labor models are losing relevance. At the same time, there is a demand for new professions related to war and technology.

Social challenges, such as staff shortages, refugee returns, and low digital literacy, require comprehensive solutions from the government and businesses.

It should be noted that government policy is aimed at digitalizing services, supporting employment, and developing new skills among the population. However, long-term strategies are needed to stabilize the labor market, including investment in education, infrastructure, and support for small businesses.

Going forward, Ukraine's economic recovery will depend on its ability to adapt to new conditions, integrate digital technologies, and ensure social stability. The labor market will not return to its pre-war state, so the key challenge is to create a flexible, sustainable and innovative employment model.

Against the backdrop of these catastrophic changes, the Ukrainian labor market has demonstrated an impressive ability to adapt, forming new mechanisms of functioning. While at the beginning of the full-scale invasion we observed chaotic processes – mass layoffs, shutdowns of production facilities and forced migration of millions of citizens – a year and a half later, holistic transformation trends have emerged.

Thus, from the initial chaos and destruction, the Ukrainian labor market has moved on to form a new model that combines:

– flexible forms of employment;
– technological solutions;
– social adaptation;
– strategic planning.

This transformation was made possible by both the internal resilience of businesses and citizens and systemic support from the government. Overcoming the consequences of the war for the labor market is still ongoing, but today we can talk about the formation of a fundamentally new employment paradigm in Ukraine.

As of January 1, 2024, more than 30 % of the working-age population lost their jobs or were forced to change their place of residence. Many businesses have ceased or reduced their operations. According to the International Labor Organization, the number of jobs in Ukraine has decreased by more than 4.8 million compared to the pre-war period.

About 8 million Ukrainian citizens were forced to leave the country, seeking safety and employment abroad. Many of them joined foreign labor markets, which led to the loss of qualified personnel. At the same time, a large number of men were mobilized, which also created a staff shortage in certain industries.

The largest losses were in the industrial, construction, transportation, and tourism sectors. At the same time, there is a growing need for logistics, healthcare, IT, and social services. New professions related to humanitarian aid, reconstruction, cyber warfare, and information security are emerging. These data demonstrate the depth of the crisis caused by the war, as well as the key areas of labor market transformation. They are directly related to the factors discussed earlier (martial law, digitalization, new forms of employment) and reveal their specific consequences [13]:

1. Scale of impact: destruction of traditional employment:

– job losses and reduced business activity confirm the need for government support programs (such as the "Army of Recovery");

– figures show that it will take years to restore pre-war employment levels – even if the fighting stops.

2. Scale of impact: destruction of traditional employment:

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– figures show that it will take years to restore pre-war employment levels – even if the fighting stops.

3. Sectoral consequences: economic restructuring:

– the decline of some industries (industry, tourism) and the rise of others (IT, logistics, cybersecurity) show how the war accelerates the redistribution of labor;

– the emergence of new professions confirms the trend towards flexibility and lifelong learning.

4. Challenges for the labor market: systemic problems:

– shadow employment and social protection: The need to legalize work and expand social guarantees;

– psychological aspects: employee exhaustion requires the inclusion of psychological support in employment programs;

– gap between education and the market: the need to synchronize curricula with the needs of the economy (e.g., through public-private partnerships);

– digital divide: without developing infrastructure and skills in the regions, inclusive recovery is impossible;

– IT emigration: the loss of IT specialists is a direct signal to improve conditions.

We can see that this data not only illustrates the problems, but also shows the relationship between destruction, adaptation, and future reforms. For example:

– migration → staff shortage → emphasis on automation and remote work;

– growth of the IT sector → need to bridge the digital divide;

– new professions → require an updated education system.

Thus, overcoming the consequences of the war for the labor market is impossible without a comprehensive approach that combines economic stimulus, investment in infrastructure, social protection, and educational innovations. It is this comprehensiveness that will form the basis for sustainable recovery.

In parallel with the military challenges, Ukraine is facing digitalization processes that are changing the requirements for employee qualifications and creating new forms of employment. Studies by Sumy State University emphasize that digital transformations have a contradictory impact on the labor market, causing both the loss of traditional jobs and the emergence of new ones related to digital technologies. Digitalization is a global process that is rapidly changing the structure of employment, work formats, and professional requirements. In Ukraine, this process has intensified under the influence

of the COVID-19 pandemic, and in the context of martial law, it has become especially relevant as a means of supporting the economy, ensuring access to services and preserving jobs [9].

According to studies by Hrynevych V. V. and Shubina O. O. [3], digitalization has become a key factor in the adaptation of the Ukrainian labor market to wartime conditions, contributing to the:

1. Digital transformation in the economy is a driver of new opportunities:

– the emergence of new professions (cybersecurity, data analytics) compensates for the loss of jobs in traditional sectors;

– the transformation of "old" professions (e.g., teachers are switching to online education) confirms that digital skills are now a requirement for most specialties.

2. New forms of employment are a response to the challenges of war:

– remote work has allowed millions of people, including IDPs and residents of frontline areas, to maintain employment;

– freelance platforms have become a lifeline for those who have lost their jobs, providing access to international markets;

– this emphasizes the globalization of the Ukrainian workforce and the need to support such formats (for example, through taxation or training).

3. Automation and AI are a challenge and a prospect at the same time:

– the disappearance of routine professions (e.g., call center operators) forces a review of the vocational education system;

– the need for analysts and creatives emphasizes the importance of soft skills (critical thinking, project management);

– without mass retraining (as in the Diia.Digital Education program), these changes will lead to an increase in unemployment among low-skilled workers.

4. Digital education is the basis for future competitiveness:

– training in IT skills (even basic ones) helps older people avoid exclusion from the labor market;

– integration of digital tools into school and university education is key to training new personnel.

Let's analyze how this relates to other challenges:

– migration and staff shortages: Remote work allows attracting Ukrainians who have left;

– industry changes: The IT sector is growing, compensating for losses in industry;

– social problems: The digital divide between urban and rural areas could deepen inequality if left unaddressed.

Thus, digital transformations are not just a "trend" but a strategic way to restore the labor market. We can see that they:

– create new jobs;

– allow you to work in war conditions.Allow you to work in war conditions;

– require rapid training and support from the state.

Without digital adaptation, overcoming the consequences of the war will be impossible. Therefore, the priorities should be:

1. Mass digital education (including regions).
2. Incentives for the IT sector (tax benefits, protection from mobilization).
3. Infrastructure (fast internet, coworking spaces).

This will help turn threats into opportunities and create a sustainable model of the labor market of the future. Digitalization opens up new horizons for economic development, innovation, and increased competitiveness of employees. Improving digital skills, adapting to flexible forms of employment, and supporting digital entrepreneurship are key tasks for the state.

Digitalization is not only a challenge but also a powerful opportunity for labor market modernization. Its effective implementation requires the synergy of public policy, business, and civil society [4; 5].

To compare the labor market indicators of pre-war and wartime, see Table 1.

Table 1 shows that by 2022 (stable development):

– digitalization was gradually being introduced into business (e-commerce, online banking), but the scale was limited;

– remote work was only gaining momentum (the COVID-19 pandemic accelerated the process);

– the IT sector was growing, but was not the main driver of the economy;

– government digital services (Diia) had just started [6].

Table 1

Digitalization and the Ukrainian labor market: a comparative analysis (2020–2024)

Indicator	2020–2021 (pre-war period)	2022–2024 (martial law period)
Number of IT specialists	~285,000 (2021)	~320,000 (2023) (+12 %)
Remote work	~15 % of employees	~35–40 % (2023)
Freelancers	~500,000 (2021)	~1.5 million (2023)
Unemployment	~500,000 (2021)	18–25 % (2022–2023)
Job losses	–	4.8 million (according to ILO)
IT services export	$6.8 billion (2021)	$7.3 billion (2023)

Source: developed by the authors based on [6]

After 2022 (accelerated transformation):

– massive transition to online: banks, education, medical services have switched to remote formats;

– IT as an "anti-crisis shield": the sector showed growth (+7 % of exports in 2023), despite the war;

– freelancing explosion: the number of remote workers has increased 3 times due to migration and destruction of offices;

– state in digital: "Diya" and e-services have become critical to the functioning of the state [7].

Let's look at the problems that have arisen due to the war and digitalization:

1. Staff shortages in critical industries, namely:

– outflow of IT specialists abroad (up to 100 thousand in 2022–2023);

– mobilization of qualified specialists (engineers, doctors).

2. Digital divide:

– 30 % of the population (especially the elderly) lack basic digital skills;

– lack of Internet infrastructure in villages and frontline areas.

3. Shadow employment: up to 40 % of workers (especially in the service sector) work unofficially.

4. Imbalance between education and the labor market: some universities or some educational programs are based on "pre-war" programs.

5. Psychological challenges: burnout due to constant stress and instability.

Based on the problems that have emerged since the start of the full-scale invasion, the following recommendations for the state should be taken into account:

– create "digital war bonds" – tax breaks for IT companies that invest in training and infrastructure;

– scale up Diia.Digital Education to include mandatory courses for the unemployed;

– legalize freelancing – simplify taxation for the self-employed.

For business:

– develop hybrid models of work – a combination of offline and online formats;

– invest in retraining – corporate training centers (for example, together with UNIT.City).

For citizens:

– learn a minimum of digital skills – even for "non-digital" professions (e.g., Excel basics for accountants);

– use state support – grants for training (e.g., from the Ministry of Digital Transformation).

Thus, the war has accelerated digital transformation, but it has not become a panacea. Without systemic solutions (education, infrastructure, social protection), the risks will increase, including

– inequality between "digital" and "non-digital" citizens;

– loss of competitiveness due to the outflow of personnel.

Now is a critical moment for the formation of a sustainable labor market model, where digitalization complements (but does not replace) social guarantees. Ukraine's labor market is undergoing profound and ambiguous transformations in the context of digitalization and martial law. On the one hand, the war has had devastating effects on employment, social security, and migration dynamics. On the other

hand, digitalization is creating new employment opportunities and shaping a more flexible and adaptive labor market model. Successful overcoming of the consequences is possible only if the government, business, and educational institutions consolidate their efforts. Particular attention should be paid to the development of digital skills, support for the IT sector, and reintegration measures for internally displaced persons. In the future, this may contribute to a more innovative, mobile, and sustainable economy.

Conclusions. Ukraine's labor market has undergone profound transformations under the influence of digitalization and martial law. On the one hand, the war caused large-scale job losses, changes in the employment structure, and massive labor migration. On the other hand, digital technologies have become a powerful tool for adaptation: the role of remote work, online learning, and process automation in the private and public sectors has increased. Governments, businesses, and society are increasingly integrating IT solutions to support employment, retraining, and retention of human resources. This creates the basis for a new, flexible, and technology-oriented labor market that can withstand the challenges of instability.

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2.4. MARKETING STRATEGIES OF BUSINESS ASSOCIATIONS IN THE CONTEXT OF ECONOMIC DIGITALIZATION

Introduction. The modern conditions of societal development, in which the economy is being digitalized, are also accompanied by the transformation of joint economic structures – such as holdings, clusters, and corporations – rather than just individual enterprises. Marketing strategies thus require new adaptability and flexibility, focusing on customer experience data and new technologies. Digitalization has already become a prerequisite for the survival and effective functioning of joint business entities.

Holdings, clusters, corporations, and financial-industrial groups face the need to establish a unified digital system, harmonize integrated business processes, consolidate marketing approaches, and unify information systems.

Main findings. Modern marketing is moving away from traditional formats and gradually transitioning too digital. Traditional marketing focuses on all types of target audiences, including uninterested ones, while digital marketing prioritizes audiences genuinely interested in the business, its goods, and services. This is achieved through communication and promotion via social networks, online channels, and search engines [1].

Digital marketing in business allows for clear evaluation of what works and what doesn't, by measuring the success of campaigns. It optimizes campaigns for better results and enables direct communication with clients, allowing for feedback and improvement – essentially, digital direct marketing.

Modern direct marketing encompasses all marketing activities aimed at business or social enterprise development, based on identifying or even forming demand and satisfying it through direct communication, which enables a highly personalized approach to each segment of the target audience.

Paradoxically, digital transformation allows for such direct customer interactions not only through internal efforts but also via outsourcing [2].

In Ukraine, the main types of business associations include associations, corporations, consortia, concerns, holdings, conglomerates, financial-industrial groups, and franchises [3]. Companies merge to gain economic, organizational, and strategic benefits that are difficult or impossible to achieve independently. These benefits include:

– Reduced unit costs of production and distribution.
– Creation of a stronger market player.
– Centralized logistics and marketing for business associations.
– Access to international markets.
– Expansion of operations in the sector, etc. [4].

In recent years, especially since the start of the full-scale Russian-Ukrainian war, Ukrainian businesses have demonstrated high adaptability focused on development and recovery of the national economy. New management approaches are being implemented, particularly in customer relations and marketing management. With growing awareness of the

potential for individualized and personalized customer relations through modern technologies, marketing is becoming increasingly automated – either in-house or outsourced – to meet the demands of target market segments and ensure economic efficiency.

Modern AI programs are rapidly developing and, in marketing, can enhance customer experience, optimize marketers' time, segment and cluster audiences, and improve budget efficiency. Some AI technologies still require ethical guidelines and cautious use but should not be ignored – they're an objective reality. Skilled use of automation opens new horizons for business efficiency. Companies can choose between developing their own tools or outsourcing – each option must be assessed in terms of customer focus and cost-effectiveness.

Modern marketing strategies include: loyalty cards; guerrilla marketing; branding tools; discount coupons; and promotional gadgets (USBs, pens, keychains, etc.). For instance, "membership cards" for loyal customers can offer access to special discounts or unique offers. Guerrilla marketing – common for budget-conscious businesses – uses unconventional, affordable campaigns (e.g., outdoor installations, stickers, contextual ads). Branded apparel can also serve as promotional gifts for loyal customers or top employees. Targeted discount coupons or bundled products with promotional gadgets can encourage trials and reviews [2].

Retention strategies focus on maintaining existing customers and increasing their loyalty. These involve tools like email marketing, loyalty programs, personalized discounts, and special offers – aimed at repeat purchases. Repeat sales are highly profitable, generating more revenue from less investment and engaging a more loyal audience. However, relying solely on current clients is risky – their number may decline – so continuous outreach to new audiences is essential.

To objectively assess marketing effectiveness in business associations, it is necessary to analyze promotion channels, identify problems in customer interaction, assess customer feedback and brand perception, and evaluate associations and emotions triggered by the brand.

It is also advisable to monitor metrics like profitability ratios and comprehensive analytics. Evaluation should consider types of marketing effectiveness indicators, systematic assessment methods, synergies, the specifics of digital marketing performance, research to enhance decision-making, and marketing risks.

Understanding and analyzing competitors is key in forming and implementing marketing strategies for business associations. Without deep market insight, the strategy may fail. Benchmarking is a tool for comprehensive competitor analysis. To stay ahead, businesses must study others' experiences, avoid ineffective practices, and adopt efficient tools.

Benchmarking allows a comparative analysis to understand one's market position and evaluate average industry performance. These methods help assess effectiveness, market trends, advantages, and the influence of business associations on the market [4].

Digital transformations affect all areas of life. Marketing is no exception – it adopts digital solutions to foster interactivity, product awareness, and customer communication. While data volumes grow, so do threats. For example, at the end of 2024, Russian hackers attacked Ukrainian state registries, which remained non-operational for over a month, disrupting business processes. Such incidents underline the need for better cybersecurity.

Outsourced marketing services in Ukraine are provided by agencies like eSputnik, HIGHWAYTOTOP, Jumator, Mnews.agency, Netpeak, and others. Proper communication channel management significantly boosts conversions. Centralizing channel management and optimizing it with the right tools is essential.

For instance, eSputnik offers automation for personalized marketing messages without needing technical experts. Urgent news can be delivered via mobile marketing – push notifications, SMS, messengers. Scenario-based distribution prioritizes budget-friendly channels while ensuring effectiveness. Loyalty programs and CRM data enable personalized messaging. Online behavior helps tailor recommendations for physical stores. Each business must evaluate the pros and cons based on its own context.

Current marketing trends in Ukraine and globally are shaped by the challenges of the Russian-Ukrainian war and digital transformation. AI programs are powerful assistants capable of analyzing vast data and making accurate forecasts. However, even the most advanced technology cannot yet generate the emotional appeal of brands. Specialists must master all AI tools, ideally within a single platform, to save time and focus on strategic planning for business associations [5].

An example of a successful integrated business marketing strategy is the partnership between Carrefour and Google. Carrefour was the first French retailer to work with Google on a new grocery shopping interface, launched in 2019 via Google Assistant and Google Shopping.

Carrefour opened an innovation lab in Paris in partnership with Google Cloud, where Carrefour engineers collaborated with Google AI experts to develop new customer experiences. Google supported Carrefour's digital transformation by implementing G Suite and collaboration tools across the group.

Their partnership included: Carrefour's presence on Google Shopping and Assistant in France; the Carrefour-Google innovation lab; and accelerated digitalization of the Carrefour Group.

Through this partnership, Google contributed AI, cloud, and retail interface technologies, while Carrefour provided product and logistics expertise. Their joint goal: deliver innovative shopping experiences across stores, online platforms, smartphones, and voice assistants.

Table 1

Carrefour's Financial Indicators Before Partnership with Google (2017)

Indicator	Value
Net Sales	€78.9 million
EBITDA	€3.6 million
Net Profit	€531.0 million
Operating Profit	€700.0 million
EBITDA Margin	4.6 %
Operating Profit Margin	2.5 %

Source: [6]

Carrefour's Financial Indicators After Partnership with Google (2024).

Table 2

Carrefour's Financial Indicators After Partnership with Google (as of 2024)

Indicator	Change
Sales Growth	+9.9 % (like-for-like)
E-commerce GMV Growth	+18 %
Operating Profit Growth	+1.4 % (excluding FX)
Company Valuation	€9.22 billion
Increase in Ordinary Dividends	+6 %

Source: [7]

The partnership marked a stage in Carrefour's digital transformation, with 9.9 % sales growth, cost optimization, 18 % e-commerce growth, and the adoption of Big Data and AI technologies. Following the partnership, Carrefour automated logistics, expanded online sales, and integrated e-commerce (Table 3).

Table 3

Comparative Metrics Before and After Carrefour-Google Partnership

Metric	**2017**	**2024**
Total Sales (€ bn)	78.9	86.8
Operating Profit (€ bn)	0.7	1.2
Mobile App Downloads (m)	5.0	33.0

Source: [8]

AI reduced costs in demand forecasting and inventory management. Figure 1 illustrates profit growth.

Digitalization has already reshaped the marketing "rules of the game". Business process automation, data analytics, and communication channels are evolving rapidly. Digital transformation is key to forming effective marketing strategies for business

associations. CRM systems, Big Data analysis, and BI platforms enable deeper market interaction, improved marketing efficiency, and stronger competitive positioning.

Marketing strategies for business associations now include:

– Business Intelligence support for decisions.
– Big Data segmentation and personalization.
– Integrated CRM database management.

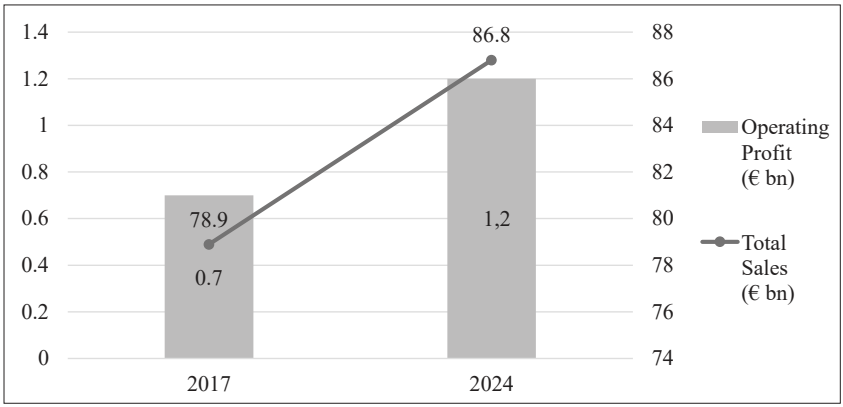

Fig. 1. Carrefour's Total Sales and Operating Profit Growth

Sources: [6–8]

These strategies ensure seamless multichannel customer interaction. By synchronizing real and digital marketing efforts and integrating CDP platforms, integrated businesses deliver unified customer experiences, build loyalty, and optimize communication across complex networks.

Merged companies can develop a unified communication platform to synchronize messaging across social networks, offline stores, and mobile apps while promoting Customer Data Platforms (CDPs).

Conclusion. In today's increasingly digital economy, mergers are no longer just about capital accumulation or market share – they're strategic responses to digital transformation, changing consumer behavior, and global competition.

Marketing strategies during mergers play a decisive role in successful integration, value creation, adaptation to digital channels, and enhanced market interaction. These strategies must be flexible, data-driven, customer-oriented, and technologically adaptive.

Thus, an effective marketing strategy in business consolidation not only ensures synergy of resources and competencies but also acts as a growth engine, fostering innovation and sustainable development in the digital era.

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2.5. TRANSFORMATION OF MARKETING COMMUNICATION STRATEGY

Introduction. In the modern business environment, marketing communications are undergoing constant changes due to digital transformation, the development of artificial intelligence and changing consumer behavior. Modern companies are forced to adapt their strategies, implementing new technologies and approaches for effective interaction with the audience. It has been proven that an effective marketing communication policy plays a key role in the development of companies, it provides the principle of information in marketing, audience engagement, motivates interaction with the brand and influences the speed of decision-making on the purchase of a product. Since the number of communication channels is constantly increasing, marketers are constantly searching for the most effective of them, and therefore in finding ways to transform the marketing communication strategy.

Presentation of the main research results. The current stages of transformation of marketing communication policy should be based on the following components: systematic communications management, a comprehensive approach to communication channels, targeting the target audience and forming hooks for attention management, forming a sales funnel, and retention marketing (Fig. 1).

Research proves that the list of marketing communications tools can be expanded now, and most likely it will expand in the future. Old

forms are developing, new ways of transmitting marketing messages appear, it has been proven that this process is dynamic and constantly improving. It is worth noting that all marketing communications tools are closely interconnected and have a common goal – to accelerate the promotion of goods in target markets, to encourage buyers to take active actions (purchase or make repeat purchases, distribute reviews and recommendations), to inform. However, they help to achieve a common goal in different ways and play a different role in the implementation of marketing tasks [1].

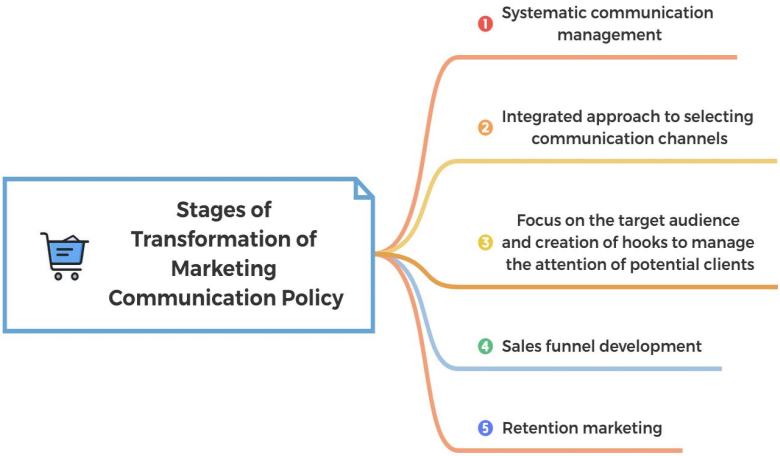

Fig. 1. Stages of transformation of marketing communication policy

Source: own development

To achieve the effect of implementing a communication policy, it is necessary to manage it and follow certain stages. The stages of managing a communication policy are presented in Fig. 2.

Analyzing Fig. 2, it should be noted that communication policy management today involves not only the choice of communication channels, but also compliance with the sequence of stages: determining communication goals; determining the target audience; developing an appeal; choosing communication channels, their optimal complex;

Fig. 2. Stages of managing marketing communication policy (off-, online)

Source: own development

determining the communications budget; assessing the effectiveness of communications and operational management, adjustments, if communication did not provide the expected result, in conditions of rapid changes in trends and consumer behavior, an important component of marketing communication policy management is the constant analysis and adaptation of strategies. The use of analytical tools, which helps to assess the effectiveness of advertising campaigns, identify the strengths and weaknesses of communication policy and make the necessary adjustments in a timely manne.

In a period of high competition and overly demanding attitude of customers to the offer of companies, there is a need for communication channels that allow companies not only to improve interaction with the target audience, introduce customizations, but also increase the level of trust and loyalty of customers. One of the main areas of improvement is the digitalization of marketing communications. Modern technologies open up new opportunities for a personalized approach to customers. The use of social networks, chatbots, email marketing and mobile applications allows companies to quickly and effectively convey information to consumers, adjusting the content to their needs and interests.

But practice shows that replacing one channel with another does not lead to the efficiency of marketing business processes, so marketing communication policy should be improved by integrating multi-channel communication and creating an omnichannel strategy.

Multi-channel marketing communication integration is a strategy that ensures the use of various channels of interaction with customers, such as: social networks, email, mobile applications, websites, physical stores, etc. The combination of online and offline communication channels allows you to create a holistic perception of the brand, which is positive for the modern customer.

The next stage of the transformation of marketing communication policy is focusing on the target audience and forming hooks to manage the attention of potential customers, taking into account that consumer behavior is becoming increasingly difficult to track, because sometimes the client ignores advertising, sometimes he is

able to make spontaneous decisions and buy little-known products from an advertisement, at a certain period the consumer forms a basket and carefully studies the properties of the product, pricing policy, functionality, etc., sometimes, on the contrary, he is bought by offers and headlines that form triggers or indicate benefits.

The target audience of a brand is potential customers who can become potential buyers of a product promoted through various communication channels. In order to define your target audience as accurately as possible, it should be divided into several segments based on general characteristics: gender, age, geographical, financial and professional characteristics, etc.

It has been proven that the target audience of a business cannot be absolutely all people who live, for example, in one region, city or country. Each individual product has its own unique characteristics, which determines the formation of an equally unique target audience. For the purpose of effective communication at the initial stages of its formation, a portrait of the target audience of the product (company) is determined [2].

Given the significant number of competitors in the Internet space and, as a result, a significant information load, a potential client evaluates Internet advertising instantly. Given these marketing research results, there is a need to form hooks to keep the client's attention and increase the rate of response to advertisements, which is measured by the click-through rate (CTR).

CTR (Click-Through Rate) reflects the percentage of users who clicked on a link after viewing an ad. One of the methods of increasing the response to an ad is through properly formed communication. In practical activities, there is a concept of a formula for successful advertising (Fig. 3).

Offer (target audience or problem) + Deadline + Call to action, (1)

where, Offer is a strong proposition, advantage, appeal to the target audience, or problem addressed by the advertised product.

Fig. 3. Formula for successful advertising

Source: own development

Deadline – a time limit (size, quantity) creates a feeling of a lost opportunity, of not receiving a benefit, and motivates an urgent decision to purchase a product or order a service;

Call to action – an incentive to action, a mandatory component of an advertising message that shows the client the way to make a purchase [3].

In building an effective communication policy, a properly formulated appeal encourages potential customers to make a decision to purchase a product. The process of making decisions by customers about purchasing a product is complex and multi-stage. It includes several key stages, at each of which companies can influence consumers, directing them to make a purchase (Fig. 4).

Thus, understanding the stages of customer decision-making allows companies to more effectively build their marketing strategies, increase consumer trust and increase sales. By influencing each stage of this process, a business can shape a positive customer experience and strengthen its competitive position in the market. A modern marketing tool – a sales funnel – can help build effective communication with a customer for the long term and motivate them to make a purchase.

The sales funnel is considered one of the effective business tools that demonstrates the features of the client's movement from the moment of interest in the product to its purchase. The model works regardless of the sales sphere – online (on the Internet) or offline.

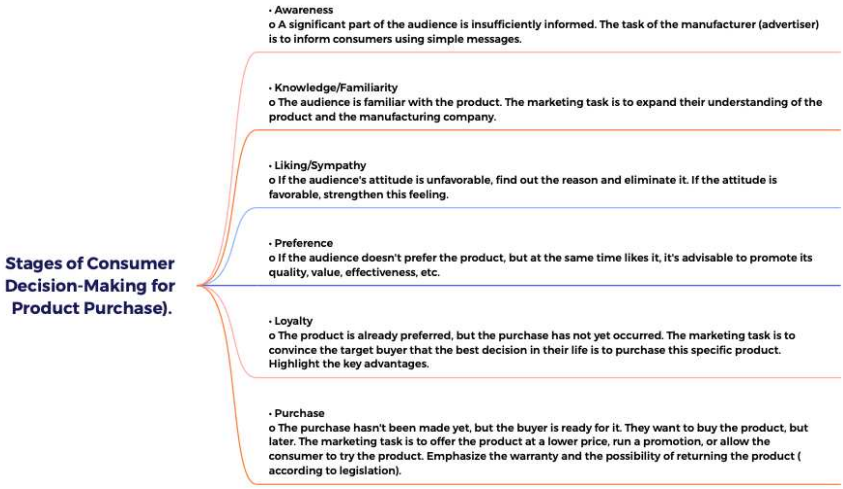

Fig. 4. Stages of a consumer's decision to purchase a product

The owner of the site (business) must clearly imagine and understand all the features of the consumer's path to purchasing the product.

The funnel begins to be built on the business premises when a potential customer enters the site (enters the store).

The essence of the sales funnel is to find out at what stage customers can leave the business area. The main goal of its construction is to return potential customers to the business area (for example, the website) and bring them to the final point, that is, to purchase a product or order a service (motivate to buy). The sales funnel will allow you to analyze the quality of marketing management, identify problems and eliminate them in a timely manner.

Using a sales funnel system, you can define separate phases for customer management and sales process automation.

The sales funnel shows the business owner at which stage the client most often leaves the business area (leaves the site). Thus, the entrepreneur is guided by the stages of the sales funnel and can offer potential clients who were interested in his business (products), but

for certain reasons did not reach the final point of sale, to conclude a cooperation agreement. The main point of building a sales funnel is the mandatory registration of potential clients when entering the business area (website). After registration, having email or mobile phone details, the business owner can make contacts with interested parties and, if they leave the site, will have the opportunity to inform and send them advantageous offers in order to return clients and bring them to the final point of the funnel. The sales funnel provides indicators (analytics), which are very important in online promotion for building an effective business and tracking certain business processes [1–3].

For a modern enterprise, a sales funnel may look like this (Fig. 5).

Fig. 5. Sales funnel

Source: created by the author

By controlling the stages at which a potential customer left the site (business territory) using the first stage of the funnel (registration), the business owner can reconcile all issues and resolve problems that were bothersome or unacceptable to the potential customer through direct sales.

At each stage of the funnel, the business owner's task is to motivate a potential customer to return or continue moving through the funnel to the final point, that is, to purchase a product or order a service. To do this, it is necessary to formulate offers in advance that will stimulate the consumer to buy the product, namely:

1. Login to the site (registration) – an offer to register in order to obtain contacts for further informing the client.
2. Site review – at this stage, you need to provide a user-friendly interface and simple functionality so that the client can easily service themselves on the site.
3. Interest in the product (search and study of the product) – if the client is interested in the product, but for some reason left the site, you can offer them discounts, point out the benefits, provide information about prices in other stores, compare the product's functions with similar ones, justify the profitability, warn about the limited stock, create an artificial shortage, etc.
4. Adding a product to the cart – if the customer added the product to the cart and left the funnel, it is advisable to offer a discount for a new (regular) customer, free shipping (or on favorable terms), service, the possibility of returning the product, a guarantee, or simply remind that adding the product to the cart does not guarantee its reservation and the product remains on free sale until the price is paid.
5. Sales – at this stage it is important to retain the client and motivate him for further cooperation, to build partnership relationships. Relationships, provide discounts on subsequent products, assign the status of a regular customer, offer gift certificates, bonuses, etc. [1–5].

In the presented figure, the funnel has a double arrow stage, which also means that the task of modern marketing communication policy should be based on the return of a client who has purchased the company's product at least once – which indicates that the product being promoted meets certain needs or solves the client's problems and he is likely to systematically buy it. It should be noted that the strategy of returning a client and "binding" him to the company is a cheaper business process than finding and winning the attention of a new client who is not familiar with the product, therefore it is necessary to form strategies for returning

regular customers and establishing long-term cooperation with them: form bonus systems, promotional codes for subsequent orders, certificates, cashback, etc. Such a strategy is called Retention marketing, relevant offers effectively form and launch through remarketing (retargeting), which is focused on an audience that has previously collaborated with the business page and is interested in its product.

Conclusions. Therefore, the proposed ways of transforming the marketing communication strategy have practical significance and can be implemented in the marketing policy of modern companies. InImproving marketing communication policy is an important step towards achieving success in marketing. Companies that actively implement digital technologies, experiment with a comprehensive approach to the formation of marketing communication policy are able to win over competitors and manage customer attention. In the conditions of rapid development of marketing tools, only constant improvement of communication strategy allows companies to remain relevant and attractive to their audience.

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2.6. INTERCONNECTION OF ECONOMIC DIGITALIZATION AND NATIONAL SECURITY OF UKRAINE

Introduction. In today's environment, where the external environment is changing and digitalization processes are intensifying,

information is a key resource, and digital technologies are improving all spheres of society. It should be noted that the digitalization of the economy is a key factor in the transformation of Ukraine's economic system in the face of hybrid threats and increased competition. At the same time, there is a need to protect information and strengthen cybersecurity. At the same time, national security encompasses economic, information, energy, and cybersecurity components, which are undoubtedly interconnected with digitalization processes.

Digitalization processes cover many areas where various digital technologies are used, such as the economy, social and military spheres, and many others. Digitalization helps to shape and strengthen the national security of the state. Theoretical and practical approaches to the essence of the concept of "digitalization" have been defined by the following scholars: Li X., Ratti C. [1], Li X., Zhang C., Li W., Ricard R., Meng Q., Zhang W. [2], Mitchell R. L. [3], Pope D. G., Sydnor J. R. [4], Regeda Y. O., Regeda V. O. [5], Shakir A., Staegemann D., Volk M., Jamous N., Turowski K. [6], Haustova V. E., Kriachko E. M., Bondarenko D. V. [7], Yang J. [8], Cherep A. V., Sarbey L. S. [9], Cherep A., Dashko I., Ohrenych Yu. [10], Cherep A., Cherep O., Ohrenych Yu. Kurchenko M. [11], Cherep O. H., Oleinikova L. H., Bekhter L. A., Veremieienko O. O. [12], Haustova M. G. [13], Melnichenko B., Figel N. [15]. Thus, digitalization affects the level of national security of countries, which confirms the relevance of the study.

Summary of the main results of the study. The rapid development of information and communication technologies opens up many opportunities to improve the efficiency of public administration, strengthen defense capabilities, stimulate economic growth, ensure environmental safety, and improve the quality of life in society. Despite the many positive aspects, there are several important drawbacks: the growing level of cyberattacks, disinformation companies, technological dependence, and digital inequality.

In this context, the study of the role of digitalization as a tool for shaping the national security of the state is extremely relevant. Understanding the potential of digital technologies, identifying the

risks associated with them, and developing effective strategies for their use are key tasks to ensure the sovereignty, stability and sustainable development of the state in the context of digital transformation.

It should be noted that the digitalization of Ukraine's economy and national security are closely interconnected: cybersecurity is a component of national security, as the growth of digital operations increases the number of cyberattacks and the need to protect the information system; digital data transparency ensures increased economic security through the introduction of an electronic administration system that allows for greater control over public finances, the use of big data analytics, which avoids economic costs; the introduction of digital technologies allows to ensure the continuity of business processes, the stability of public administration; digitalization has a positive impact on information security, as the introduction of digital mechanisms allows to verify data, inform the society; the development of artificial intelligence, the introduction of digital platforms, blockchain solutions are a prerequisite for ensuring digital security.

Thus, the role of digitalization is to deeply penetrate digital technologies into all spheres of society, the economy, and the state. This is not just digitization or automation of processes, but a rather qualitative transformation of the way we interact, do business, provide services, and make decisions using digital tools and data.

In general, digitalization involves the transformation of information and processes into digital ones, i.e. digitization of documents, transfer of communication to an online format, use of electronic signatures, etc. Digital technologies are introduced to optimize and create new processes, including the use of artificial intelligence, cloud technologies, the creation of new technologies and services based on digital capabilities, the development of fast mobile communications, the Internet, and data exchange platforms. Digitalization requires new skills, adaptability, and readiness to use digital tools from citizens and employees

At the same time, it is important to distinguish between the following concepts: digitization – converting information from a conventional form to a digital one, the first step towards digitalization; digitalization – using digitized information and digital technologies to improve existing processes and operations; digital transformation – a deeper and more

strategic change that involves fundamental rethinking of business models, creation of new values and change of organizational culture under the influence of digital technologies [14; 16].

In national security, digitalization is a powerful tool that covers all three levels: from digitization of intelligence data to the introduction of digital command and control systems and strategic digital transformation of the defense sector to counter modern threats.

It should be noted that "national security of Ukraine is the protection of state sovereignty, territorial integrity, democratic constitutional order and other national interests of Ukraine from real and potential threats" [17]. Let us analyze the existing approaches to understanding the essence of national security:

1. The realist approach assumes that the state is the main actor in international relations, and national security is the main goal of the state. The main emphasis is placed on the protection of sovereignty, territorial integrity and political independence [14; 16].

2. The liberal approach develops the understanding of national security not only in terms of military character, but also covers economic, environmental, social, and political aspects. At the same time, the emphasis is placed on the interconnection of the state, international institutions, democracy and human rights, which are factors of stability and security of the state [14; 16].

3. Human-centered approaches assume that human security is the main object. Also, threats are considered not only from the state, but also from structural inequality, poverty, discrimination and other social problems [14; 16].

4. The comprehensive approach emphasizes the importance of understanding the different aspects of national security and trying to integrate elements of different approaches. National security is a multifaceted concept that includes military, political, economic, social, informational, environmental aspects [14; 16].

Having considered the existing approaches to understanding the essence of national security, it is advisable to determine the relationship between digitalization and national security through a set of approaches:

1. Realistic approach: digitalization is seen as an important factor in building up the military and economic power of the state. The development of cyberwarfare and artificial intelligence systems for defense purposes, high-tech production based on digital technologies, contributes to strengthening military capabilities and economic competitiveness, which are key elements of national security in a realistic sense [14; 16].

2. Liberal approach: digitalization is a prerequisite for economic growth, introduction of innovations, innovative development, improvement of living standards, automation of business processes at enterprises, which are important prerequisites for national stability and security. Liberals see digital technologies as a tool for promoting democratic values, freedom of speech and access to information, which contributes to a more sustainable and secure society. The liberal approach emphasizes the importance of international cooperation in combating transnational cyber threats such as cybercrime and cyberterrorism, which requires joint efforts and the creation of international norms and institutions [14; 16].

3. Human-centered approach (critical approach): Critical theories can emphasize the risks of deepening social inequalities as a result of digital transformation. Unequal access to digital technologies and skills can create new forms of social vulnerability and marginalization, undermining the overall security of society. Critical approaches also draw attention to the potential of digital technologies to increase state control and surveillance of citizens, which can violate human rights and freedoms, which are important elements of security [14; 16].

4. Comprehensive approach: recognizes that digitalization affects national security simultaneously in many dimensions (military, economic, social, information). An effective national security policy in the digital era should take into account all these aspects and coordinate the efforts of various government agencies, business and civil society [14; 16].

Conclusions. It should be summarized that the digitalization of Ukraine's economy is a direction of ensuring efficiency, innovative development, increasing competitiveness, entering international markets, and a fundamental tool for strengthening national security. At the same

time, an important role is played by the effective integration of digital technologies into all spheres of state life, which will allow to identify and respond in a timely manner to threats and risks of the external environment, to ensure the country's economic growth in the face of constant challenges. Among the areas of improving national security through digitalization processes are the following: strengthening control over economic processes, increasing transparency of financial data through the introduction of artificial intelligence technologies, establishing data integration between government agencies, improving the system of digital monitoring of finances; development of the cybersecurity system by establishing cooperation with international partners, exchanging data on cyber threats, and training civil servants and business representatives on the main aspects of digital security; development of digital infrastructure by attracting investments in software development and cyber defense; improving information security by supporting information literacy of the population, countering disinformation; training of personnel in digital security. Thus, the integration of digitalization of the economy and national security will increase the competitiveness of the country's economy.

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2.7. THE IMPACT OF INDUSTRY 4.0 ON THE FINANCIAL SUSTAINABILITY OF MACHINE-BUILDING ENTERPRISES

Introduction. Industry 4.0, known as the fourth industrial revolution, is characterized by the introduction of modern digital technologies that integrate physical and virtual production systems. This concept involves the use of the Internet of Things (IoT), big data, artificial intelligence, and other innovations to create smart factories [11]. For machine-building enterprises, the implementation of Industry 4.0 principles is a key factor in achieving financial sustainability and sustainable development [8].

The introduction of Industry 4.0 technologies helps to optimize production processes, which leads to lower costs and increased efficiency. Automation and digitalization minimize the human factor, reducing the number of errors and equipment downtime. This, in turn, improves product quality and increases the company's competitiveness in the market.

In addition, the use of big data and analytics allows businesses to make informed financial decisions, forecast demand, and manage

resources more efficiently [56]. This ensures the stability of cash flows and increases the financial stability of the enterprise.

The purpose of the article is to analyze the role of Industry 4.0 in ensuring the financial sustainability and sustainable development of machine-building enterprises. The main focus is on the impact of digital technologies on the efficiency of production processes, increasing competitiveness and optimizing management decisions.

The topic of implementing Industry 4.0 and its impact on the financial sustainability and sustainable development of machine-building enterprises is the subject of research by many scholars, in particular:

– V. M. Osipov and O. S. Kovalevska: in their article "Strategy of the machine-building enterprise in the context of the declarative paradigm "Industry 4.0"" they investigated the conceptual foundations of the emergence and development of Industry 4.0, as well as determined the place of Ukraine in this process [7];

– L. Vdovenko: in the article "Instruments of State Financial Support for the Agricultural Sector under Martial Law" she considered financial mechanisms that can be used to support the financial stability of enterprises, including machine-building ones, in crisis situations;

– S. V. Hlibka: in the monograph "Industry 4.0 Concept: Problems of Implementation and Certain Legal Aspects of its Implementation in Ukraine", he studied the issues of formation of Industry 4.0 in Ukraine and certain legal aspects of its implementation, focusing on economic and legal factors that affect the development of economic activity in the digital economy [10];

– The Association of Industrial Automation Enterprises of Ukraine (AIAEU) has developed the "Strategy for the Development of Industry 4.0 in Ukraine", which focuses on the main priorities and initiatives in this area [1];

– I. Dashko, who actively studies digitalization in various aspects of the economy and governance, namely: in the article "Dynamics of Digital Public Services Development in the Context of Ukraine and EU Member States" together with L. Mykhailichenko. Mykhailichenko analyzes the development of digital public services in Ukraine and the

EU and examines Ukraine's place in the digital well-being ranking and proposes a strategy for the digital transformation of public services in Ukraine [6]; in the article "Digitalization of the Economy in the Context of the COVID-19 Pandemic as a Strategic Platform for the Development of the State's Economy" the impact of the pandemic on the world economy, the role of digital technologies during this period and the prospects for digital transformation in Ukraine are studied; in the work with E. Loseva: "Digitalization as a Modern Trend in the Development of Human Resources Management" examines the impact of digitalization on human resources management, analyzes current trends and challenges in this area [3]; the article "Advantages and Challenges of Digitalization of the Ukrainian Economy" explores the basic principles of digitalization of the Ukrainian economy and analyzes the advantages and challenges associated with this process [9].

These researchers and organizations have made a significant contribution to the study of the impact of Industry 4.0 on the financial sustainability and sustainable development of machine-building enterprises, analyzing both theoretical aspects and practical approaches to the introduction of the latest technologies into production processes.

The topic of Industry 4.0 implementation and its impact on the financial sustainability and sustainable development of machine-building enterprises is also the subject of research by many foreign scholars. They analyze how digitalization, automation and integration of modern technologies affect the efficiency, competitiveness and environmental responsibility of enterprises:

– K. Schwab is the author of the book "The Fourth Industrial Revolution", where he analyzes the impact of Industry 4.0 on various industries, including mechanical engineering, and discusses the challenges and opportunities it brings to business and society;

– G. Luks examines the impact of digital technologies on production processes and financial sustainability of enterprises, in particular in the machine-building industry;

– E. Schmidt examines the impact of artificial intelligence and big data on business processes and development strategies of enterprises, including machine-building companies;

– M. Porter analyzes how Industry 4.0 changes the competitive environment and affects the sustainability of enterprises;

– S. Essen studies the strategies for implementing Industry 4.0 in industrial enterprises and sustainable development.

These researchers and their work make a significant contribution to understanding how Industry 4.0 is transforming the machine building industry, affecting the financial sustainability and sustainable development of enterprises.

At the same time, new questions arise in relation to this research, which requires more detailed research to identify areas for improvement.

Summary of the main results of the study. Sustainable development involves a balance between the economic, environmental and social aspects of an enterprise, and Industry 4.0 contributes to this through:

– environmental responsibility: through precise monitoring and management of resources, businesses can reduce energy and material consumption, which reduces their environmental footprint [2];

– social aspect: automation of routine processes allows employees to focus on more creative and strategic tasks, increasing their job satisfaction and stimulating professional development [4];

– economic efficiency: increasing productivity and product quality opens up new markets and opportunities for growth, ensuring the long-term stability of the enterprise [1].

The study determined that Industry 4.0 is a key factor in ensuring the financial stability and sustainable development of machine-building enterprises. The main results of the study can be summarized as follows:

1. Digital technologies contribute to the financial sustainability of enterprises:

– automation and digitalization of production can optimize costs, increasing productivity by reducing downtime and product defects [8];

– the use of big data and artificial intelligence (AI) allows forecasting production needs and efficiently managing resources, which helps stabilize the financial flows of enterprises [5];

– the introduction of cyber-physical systems (CPS) and the Internet of Things (IoT) in mechanical engineering allows monitoring production processes in real time, which has a positive impact on their economic efficiency [2].

1. Industry 4.0 contributes to the sustainable development of machine-building enterprises:

– environmental sustainability: digitalization of production helps to reduce energy and raw material consumption, reducing CO_2 emissions and other environmental pollution [4];

– social aspect: automation of routine processes allows employees to engage in more creative and strategic tasks, which increases their job satisfaction and motivation for professional development;

– economic efficiency: digital tools allow machine-building enterprises to adapt to market changes faster, create innovative products and strengthen their competitive position [1].

1. The main challenges of implementing Industry 4.0 in mechanical engineering:

– high initial costs of digital transformation, which makes it less affordable for small and medium-sized businesses [8];

– insufficient level of digital infrastructure in Ukraine, which complicates the integration of Industry 4.0 into production processes [2];

– lack of qualified specialists capable of working with new technologies, which requires significant investment in staff training [4].

1. Strategies for overcoming challenges and recommendations:

– government support and stimulation of investments in the implementation of Industry 4.0 technologies through tax incentives, grant programs and international partnerships [1];

– development of digital infrastructure, in particular the introduction of high-speed Internet and 5G technologies in industry [2];

– educational initiatives and cooperation with universities to train specialists in the field of digital economy and production automation [4].

Challenges of implementing Industry 4.0 in Ukraine.

Despite the obvious advantages, Ukrainian machine-building enterprises face a number of challenges in implementing Industry 4.0:

– financial constraints: high initial investments in new technologies may be unaffordable for many enterprises [8];

– insufficient infrastructure: lack of the necessary digital infrastructure slows down the implementation process;

– lack of qualified personnel: the need for specialists capable of working with the latest technologies requires investment in training and retraining.

Let's analyze the data for 2022–2024, which illustrate the impact of Industry 4.0 on the financial sustainability of Ukrainian machine-building enterprises (Table 1).

Table 1

Statistical data for 2022–2024: Impact of Industry 4.0 on the financial sustainability of machine-building enterprises

№	Indicator	Years		
		2022	2023	2024
1	Production volume, thousand units.	10.0	11.2	12.0
2	Unit cost, UAH.	1000.0	920.0	850.0
3	Net profit, UAH million.	1.8	2.9	4.2
4	Profitability, %	12.0	16.0	19.4
5	Share of defects, %	8.0	4.0	2.0
6	Maintenance costs, UAH million.	2.5	2.2	2.0
7	Energy costs, UAH million.	1.5	1.3	1.1
8	Downtime, %	15.0	10.0	5.0

Source: developed by the author

Table 1 shows the key financial and production indicators of the machine-building enterprise for 2022–2024. These tables illustrate the dynamics of changes under the influence of the introduction of Industry 4.0 technologies, namely:

1. The volume of production (thousand units) increased from 10.0 thousand in 2022 to 12.0 thousand in 2024, which indicates an increase in production efficiency.

2. The unit cost (UAH) decreased from 1000 UAH to 850 UAH, which is the result of automation, resource control and loss reduction.

3. Net profit (UAH million). It shows an increase in profitability: from UAH 1.8 million in 2022 to UAH 4.2 million in 2024, which is more than a twofold increase.

4. Profitability (%). Increased from 12 % to 19.4 %, which demonstrates an improvement in the financial return on production activities.

5. Share of defects (%). Decreased by 4 times – from 8 % to 2 %, thanks to the implementation of real-time quality control systems.

6. Maintenance costs (UAH million). Decreased from UAH 2.5 million to UAH 2.0 million, which indicates a shift to IoT-based preventive maintenance.

7. Energy costs (UAH million). Reduced from UAH 1.5 million to UAH 1.1 million as a result of increased energy efficiency.

8. Downtime (%). Significant reduction from 15 % to 5 % due to digital monitoring of equipment condition.

Thus, Table 1 clearly demonstrates the positive impact of Industry 4.0 on the production productivity, profitability, and cost structure of enterprises. These dynamics indicate a strengthening of financial stability and an increase in the competitiveness of the machine-building business.

The implementation of the Industry 4.0 concept in Ukraine, especially in the machine building sector, is accompanied by a number of significant challenges that hinder the dynamics of digital transformation:

1. Insufficient digital infrastructure. Many companies face limited access to high-speed internet and modern IT solutions, which makes it difficult to integrate the latest technologies into production processes.

2. Lack of financial resources. Investments in the modernization of production and the introduction of Industry 4.0 technologies require significant funds, which are often unavailable to Ukrainian machine-building enterprises.

3. Insufficient staff qualifications. The lack of specialists with the necessary skills to work with the latest technologies is a significant obstacle to digital transformation.

4. Political and economic instability. An unstable situation in the country can scare away potential investors and slow down the modernization process.

5. Lack of a clear state strategy. Uncertainty in government policy to support Industry 4.0 leads to insufficient coordination of efforts between different sectors of the economy.

6. Cybersecurity issues. The growth of digitalization increases the risk of cyberattacks, which many businesses are not prepared for.

7. Resistance to change on the part of management. Unwillingness or fear of large-scale changes can slow down the process of implementing the latest technologies.

To overcome these challenges, a comprehensive strategy is needed, including infrastructure development, training, investment attraction, and active support from the state – a comprehensive strategy for implementing Industry 4.0 in Ukrainian machine building:

1. Institutional support and legislative framework:

– development and approval of the state program for digital transformation of industry;

– definition of clear standards, technical requirements and regulations for Industry 4.0;

– creation of a centralized body to coordinate digital initiatives.

2. Investments and financial support:

– introduction of preferential loans, grants and subsidies for modernizing enterprises;

– partnership with international institutions to obtain financing;

– encouraging venture capital to support startups in the field of mechanical engineering.

3. digital infrastructure:

– development of high-speed Internet and data centers;

– creation of regional hubs for digital transformation;

– integration of enterprise IT systems at the national level.

4. Training and professional development:

– introduction of educational programs in universities in the areas of IoT, Big Data, Smart Manufacturing;

– regular trainings for enterprise personnel;

– creation of certification programs according to Industry 4.0 standards.

5. Innovations and R&D:
– creation of digital modeling, testing and prototyping laboratories;
– stimulating cooperation between scientific institutions and enterprises;
– financing innovative projects in the field of artificial intelligence, robotics and automation.
6. Cybersecurity:
– development of a national strategy for industrial cybersecurity;
– introduction of mandatory audits of IT systems;
– training of cybersecurity specialists.
7. Monitoring and performance evaluation:
– introduction of KPI systems to assess the level of digitalization of enterprises;
– annual update of analytical reports on progress;
– formation of open registers on the state of implementation of Industry 4.0.

The application of this strategy will significantly increase the financial sustainability of machine-building enterprises through increased efficiency, competitiveness and adaptation to global trends.

Challenges of implementing Industry 4.0 in Europe:

1. Uneven level of digitalization among EU countries. The level of implementation of Industry 4.0 differs significantly between developed and less developed member states, which creates a gap in competitiveness.
2. Limited funding for digital transformation. Despite the availability of EU funds, some countries face problems in accessing investments in digital modernization.
3. Lack of skilled labor. Industry 4.0 requires specialists with knowledge in IT, data analytics, and artificial intelligence, which are in short supply in the labor market.
4. Cybersecurity and digital threats. Increasing automation and network connectivity increases the risk of cyber threats.
5. Resistance to change and lack of a culture of innovation. Some managers and staff resist digitalization out of fear of losing control or position.

6. Lack of a unified European coordination policy.

Each country has its own digitalization strategy, which complicates synergy at the EU level.

To overcome these challenges, we recommend a comprehensive strategy for overcoming the challenges of Industry 4.0 in Europe:

1. Unification of the EU digital policy:
– to create a pan-European digital platform;
– to develop common standards and criteria for digital transformation for all EU countries;
– to ensure coordinated action within the Digital Europe program.
2. Financial support for innovation:
– use of Horizon Europe and Digital Europe Program funds;
– expanding access to finance for SMEs (small and medium-sized enterprises);
– partnership with the private sector through public-private partnership schemes.
3. Human capital development:
– reform of the education system with an emphasis on STEM and digital skills;
– creation of the EU Skills Agenda platform for retraining workers;
– support for the mobility of students and professionals between EU countries.
4. Investments in infrastructure and digital technologies:
– construction of pan-European 5G networks and data centers;
– development of smart factory and the Internet of Things at enterprises;
– introduction of Industry 4.0 innovation centers in the regions.
5. Digital security:
– implementation of ENISA cybersecurity standards;
– raising awareness of cyber threats among businesses and citizens;
– formation of national incident response centers (CSIRT).
6. Support for innovation culture:
– encouraging enterprises to experiment through pilot project support programs;

– establishing communication between universities, startups and businesses;

– holding hackathons, competitions, business forums on digital solutions.

The impact of Industry 4.0 on the financial sustainability of machine-building enterprises (2022–2024).

The introduction of Industry 4.0 technologies significantly affects the financial sustainability of machine-building enterprises:

1. Increase in productivity and efficiency: the use of automation, robotics and IoT allows to optimize production processes, which leads to lower costs and higher profitability.

2. Reduced operating costs: intelligent monitoring and data analytics systems help identify inefficiencies and reduce unproductive costs.

3. Improved product quality: Industry 4.0 technologies provide more precise quality control, which reduces the number of defects and returns, positively affecting financial performance.

4. Production flexibility: the ability to quickly adapt to changes in demand provides companies with a competitive advantage and stable revenues.

5. Investment in technology: Although the introduction of new technologies requires significant initial investment, the long-term benefits in terms of increased efficiency and cost savings offset these costs.

6. Cybersecurity risks: Increased digitalization increases the risk of cyberattacks, which can lead to financial losses. Investments in cybersecurity are needed to protect data and systems.

7. The need for staff retraining: the introduction of new technologies requires new skills from employees. Investing in staff training and development is critical for a successful transformation.

In general, Industry 4.0 has the potential to significantly increase the financial sustainability of machine-building enterprises, provided that it is implemented strategically and managed.

Based on the above, let's consider the steps to implement Industry 4.0 to strengthen financial sustainability:

1. Audit of the enterprise's readiness for Industry 4.0:

– to analyze digital maturity;

– to assess the financial condition and potential for investment;

– to identify bottlenecks in production that can be automated.

2. Develop a digital strategy:

– define specific goals (e.g., reducing costs by 20 % in 2 years);

– create a digitalization roadmap with a phased implementation of IT solutions.

3. Investing in technology:

– install IoT sensors to monitor equipment;

– implement ERP/MES systems for real-time production control;

– apply AI/ML to predict failures and optimize inventory.

4. Financial optimization:

– reduce losses through automated quality control;

– use IoT data to reduce energy consumption;

– increase logistics efficiency through digital planning.

5. Personnel development:

– to train employees in robotics, data analytics, digital engineering;

– to launch a retraining program or cooperate with technical universities.

6. Cybersecurity:

– implement basic IT infrastructure protection;

– audit cybersecurity systems and update access policies.

7. Performance evaluation:

– implement KPIs: operating costs, downtime, profitability;

– audit the results achieved every 6 months.

Let's look at an example of expected results based on the recommended steps for implementing Industry 4.0 (Table 2).

Table 2

Example of expected results (2022–2024):

№	Indicator	Before implementation	After 2 years
1	Product profitability	8–12 %	18–22 %
2	Equipment downtime	15 %	5 %
3	Maintenance costs	–	−20 %
4	Volume of defects	8 %	2 %
5	Energy efficiency	–	+25 %

Source: developed by the author

Based on the results of Table 2, the following conclusions can be drawn:

1. Increase in product profitability: profitability increases from 8–12 % to 18–22 %, which indicates a significant improvement in financial results due to optimization of production processes and cost reduction.

2. Reduction of equipment downtime: a decrease from 15 % to 5 % means an increase in the efficiency of the use of enterprise assets through the introduction of digital monitoring and predictive maintenance.

3. Reduced maintenance costs: an expected 20 % reduction confirms the effectiveness of IoT-based systems and analytics that avoid unscheduled repairs.

4. Significant reduction in rejects: the reduction of rejects from 8 % to 2 % indicates an improvement in product quality due to automatic control and real-time data analytics.

5. Improved energy efficiency: a 25 % increase shows that Industry 4.0 implementation contributes to more efficient use of resources, reduced energy costs, and increased environmental sustainability.

In general, the results of Table 2 clearly demonstrate that Industry 4.0 has the potential to significantly improve the financial sustainability of an engineering enterprise, while ensuring increased profitability, reduced risks, and increased efficiency.

Conclusions. The study results confirmed that Industry 4.0 plays a key role in ensuring the financial sustainability and sustainable development of machine-building enterprises. Digital technologies can improve production efficiency, reduce costs and enhance the environmental responsibility of businesses. However, to fully implement Industry 4.0, a number of barriers need to be overcome, which is possible through strategic cooperation between the government, business, and research institutions.

Thus, Industry 4.0 is a key element for ensuring the financial sustainability and sustainable development of machine-building enterprises. The introduction of modern technologies can increase efficiency, reduce costs, and improve product quality. However, to realize this potential, it is necessary to overcome the existing challenges through joint efforts of the state, business, and educational institutions.

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2.8. DIGITALIZATION AS A TOOL FOR ENSURING NATIONAL SECURITY

Introduction. In today's world, national security increasingly depends not only on military strength or political stability, but also on the ability of the state to effectively use digital technologies. In the

21st century, new threats, including cybercrime, information warfare, and attacks on critical infrastructure, require new methods of defense from the state.

Domestic and foreign scholars have studied digitalization processes that cover all spheres of life – economy, education, healthcare, public administration and, most importantly, the security sector, namely: Korotun N. V. [1], Mitchell R. L. [2], Pope D. G., Sydnor J. R. [3], Regeda Y. O., Regeda V. O. [4], Shakir A., Staegemann D., Volk M., Jamous N., Turowski K. [5], Haustova V. E., Kriachko E. M., Bondarenko D. V. [6], Cherep A. V., Voronkova V. G., Cherep O. H. [7], Cherep A. V., Ohrenych Yu., Oleinikova L. H., Vasylenko D. O. [8], Cherep O. H., Oleinikova L. H., Bekhter L. A., Veremieienko O. O. [9], Yang J. [10].

Summary of the main results of the study. Digitalization is the process of large-scale implementation of digital technologies in all spheres of public and government life to increase the efficiency, transparency and accessibility of services, management and communications. It is not just the automation of existing processes, but a profound transformation of the way the state, citizens, and businesses interact.

As defined by the Ministry of Digital Transformation of Ukraine, digitalization involves the use of digital tools to create convenient electronic services, optimize processes, and ensure better interaction between the government and the public.

Digitalization covers the following key areas:

– implementation of e-government;
– development of digital infrastructure;
– use of big data and analytics;
– creating platforms for online interaction;
– development of digital skills among the population.

In the context of security, digitalization is becoming not only a management tool, but also a means of responding to new types of threats, in particular in cyberspace, the information field and critical infrastructure.

National security is a state of protection of vital interests of an individual, society and the state from internal and external

threats. It covers a wide range of areas that together ensure the state's resilience to the challenges of the modern world.

According to the Law of Ukraine "On National Security", the main components of national security include [11]:

– Political security – ensuring the stability of the political system, state sovereignty, independence and territorial integrity.

– Economic security – stable economic development, energy independence, financial stability and protection of critical infrastructure.

– Military security – the ability of the state to defend itself against armed aggression, support for the combat capability of the Armed Forces and other security agencies.

– Cybersecurity – protection of state information systems, communication networks and data from cyberattacks, malware and hacker threats.

– Information security – protection of society from information influence, propaganda, disinformation and preservation of information sovereignty.

– Environmental safety – preventing environmental disasters, monitoring the environment, and rational use of natural resources.

– Social and humanitarian security – ensuring the rights and freedoms of citizens, access to quality education, healthcare and social protection.

– Defense and industrial security – development of the national military-industrial complex and preservation of strategic potential.

In today's environment, digitalization is becoming an integral part of the national security system. It not only transforms traditional governance and communication mechanisms, but also creates new tools for detecting, preventing and neutralizing threats.

Digital technologies allow you to:

– Quickly process and analyze large amounts of information, which increases the effectiveness of decision-making in a crisis or threat.

– Ensure transparency of governance – e-governance reduces corruption, promotes government accountability and strengthens public trust.

– To increase the cyber resilience of the state – the creation of reliable cyber defense systems allows to prevent interference in the internal processes of the state, as well as to ensure the smooth operation of critical infrastructure.

– Develop a system of national monitoring and response – digital tools allow tracking potential threats in real time [12].

– Counteract information attacks – analytical platforms can detect the spread of fake information, and digital campaigns can inform the public and counteract disinformation [13].

It is especially important that digitalization helps to strengthen interagency cooperation: data exchange between law enforcement agencies, local governments, emergency services, and other institutions becomes fast and efficient [14].

Cybersecurity is a set of measures, strategies, technologies and institutional mechanisms aimed at protecting information systems, digital infrastructure, personal and state data from unauthorized access, attacks, destruction or manipulation. In the context of digitalization, cybersecurity is becoming a key element of national security [15].

The main areas of state cyber defense include:

– Protection of critical infrastructure. Critical infrastructure is the facilities on which the stability of the state depends (power plants, transportation, communications, financial institutions). Their cyber defense is of paramount importance.

– Developing early detection systems for cyber threats. This includes monitoring of the digital space, risk analysis, and the creation of a cyber response center that can quickly detect attacks and coordinate defensive actions.

– Ensure the security of state information resources. All government databases, registries, and portals (including Diia) must be securely protected. This is achieved through encryption, user authentication, backup and multi-level access control.

– Training and awareness raising in the field of cyber hygiene. The human factor is often the weakest link in a security system. That is why it is important to train both civil servants and citizens in the

basics of cybersecurity, such as using secure passwords, detecting phishing attacks, etc.

– International cooperation in the field of cybersecurity. Cyber threats are often transnational in nature. Participation in international initiatives, information exchange with partners, and integration into global cyber defense systems help strengthen national positions [16].

– Legal regulation and regulatory framework. Effective cybersecurity is impossible without modern legislation that regulates liability for cybercrime, sets security standards and incident response procedures.

In today's digital world, cyber threats have become a real challenge to the national security of any country. They are constantly evolving and include both technical attacks on infrastructure and information and psychological influence on society. For Ukraine, which is in the midst of a hybrid war, the issue of cyber defense is particularly relevant.

The most common types of cyber threats to the state are:

– Cyber attacks on critical infrastructure. These are attacks on energy, transportation, finance, and communications facilities. They can cause paralysis of important systems, for example, stopping power supply or banking operations.

– DDoS attacks (distributed denial of service attacks). The purpose of such attacks is to disable the websites of government agencies, e-government services or information resources.

– Malicious software (viruses, trojans, spyware). Used to steal confidential data, track user activity, lock down systems, or demand ransom (e.g., ransomware).

– Phishing attacks. Aimed at deceiving users to gain access to logins, passwords, or financial information. Often used against government officials and journalists.

– Hacking into government accounts or IT systems. Could lead to the leakage of classified information, manipulation of data, or undermine trust in the government.

– Cyberintelligence and espionage. Carried out by foreign intelligence services or hacker groups to obtain strategically important information about defense, politics, and the economy.

– Information and psychological operations (IPO). They are carried out through social networks, news platforms, bots to destabilize society, influence public opinion, create panic or distrust of the authorities.

– Data manipulation and fake information campaigns. This includes the dissemination of fakes, hacked documents, fake news, which can affect elections, the reputation of government agencies, the course of military or diplomatic operations [17; 18].

Cyber incidents that have occurred in Ukraine and abroad clearly demonstrate the growing level of threats to national security in the digital age. These incidents have a significant impact on government agencies, businesses, and society as a whole. Several vivid examples of such incidents illustrate the scale and diversity of cyber threats.

Examples of cyber incidents in Ukraine [18; 19]:

– Attack on the power grid (2015). One of the largest cyber attacks on critical infrastructure in Ukraine occurred in December 2015, when hackers attacked the energy system, causing massive power outages in Kyiv and other regions. The attack was carried out using malware that damaged the control systems of power plants. This was the first ever attack that led to real physical consequences – power outages.

– WannaCry (2017). Ukraine became one of the countries that was severely affected by the global cyberattack with the WannaCry ransomware. The attack affected tens of thousands of computers around the world, including government agencies and critical infrastructures in Ukraine, resulting in significant financial and organizational losses.

– Attack on the PrivatBank system (2016). In 2016, Ukraine's largest bank, PrivatBank, suffered a massive DDoS attack that disrupted its online services, including banking operations. This became a vivid example of how cyber threats can affect the financial stability of a country.

– Espionage attacks (2017). Numerous cases of cyber surveillance by foreign government agencies have been recorded in Ukraine. In particular, groups of hackers attacked government agencies to steal confidential data, including documentation on defense and military issues.

– Examples of cyber incidents in the world.

– Stuxnet attack (2010). One of the most famous cyber incidents in the world is the Stuxnet attack that hit nuclear facilities in Iran. The malicious program, created to sabotage Iran's nuclear program, damaged centrifuges used for uranium enrichment. This incident was the first time cyber weapons were used in the international arena.

– Attack on Sony Pictures (2014). In 2014, hackers from a group linked to North Korea carried out a cyberattack on Sony Pictures. They hacked into the company's servers and stole a large amount of confidential data, including emails and unreleased movies. This attack was considered an act of cyber terrorism.

– WannaCry attack on medical institutions (2017). The WannaCry ransomware attack, which spread to more than 150 countries, caused serious disruptions in the work of medical institutions, including in the UK. More than 70,000 NHS (National Health Service of Great Britain) computers were infected, leading to the cancellation of operations and interruptions in the provision of medical services.

– SolarWinds attack (2020). In 2020, one of the largest and most complex cyber incidents in history was detected – an attack on SolarWinds. Hackers, likely working on behalf of the state, hacked into SolarWinds software updates, which led to the compromise of many government and private organizations in the United States, including the Department of Defense, the State Department, and others.

Conclusions. Thus, digitalization acts as a multifunctional security tool that covers both the prevention of external threats and ensuring internal stability. Without proper digital development, it is impossible to imagine modern national security, especially in the context of hybrid warfare and dynamic technological changes.

Therefore, in the context of globalization and hybrid conflicts, digital tools are becoming an important element of national resilience. The development of e-governance, cyber defense systems, digital defense infrastructure and information security opens up new opportunities to strengthen the country's sovereignty.

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SECTION 3
Methodological framework for ensuring socio-economic security through digital transformation of the economy

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3.1. MODERN RESPONSE TECHNOLOGIES AND THREATS TO NATIONAL SECURITY

Introduction. Ensuring Ukraine's national security is a top priority for the state amidst a complex and dynamic geopolitical environment. The ongoing armed conflict, hybrid threats, and cyberattacks require constant search for and implementation of innovative approaches and tools to protect sovereignty, territorial integrity, and citizens. In this context, modern technologies play a key role, offering unprecedented opportunities to strengthen the country's defense capabilities, detect and neutralize threats at early stages, and respond effectively to crises.

This study provides a comprehensive analysis of the use of advanced technologies in the field of national security in Ukraine, examines the main threats facing the state, and assesses the potential of technologies in ensuring resilience and safety. Special attention is given to key technologies and recommendations for further strengthening Ukraine's national security through technological innovation.

Presentation of Key Research Findings. In the context of ongoing military actions, several modern technologies are actively employed in the service of Ukraine's national security. Artificial intelligence (AI) and machine learning are becoming increasingly important tools in this domain. These technologies offer considerable potential for analyzing large volumes of data to detect threats, automate decision-making processes, and support military operations [1]. Machine learning algorithms can be used to identify anomalies in network traffic – potential indicators of cyberattacks – or to analyze satellite imagery for signs of suspicious activity along borders.

The advancement of generative AI introduces new possibilities, including the creation of realistic training simulations for military personnel and the development of intelligent decision support systems [2]. However, it is important to note that adversaries may also leverage generative AI to produce more convincing disinformation campaigns and phishing attacks. On a global scale, there is increasing competition among states for leadership in AI development, emphasizing the strategic significance of this technology for national security [4].

Quantum technologies, particularly quantum computing, have the potential to revolutionize numerous fields, including national security. Quantum computers could significantly accelerate complex computations, useful for cryptography, material science, and big data analysis. At the same time, the development of quantum computing poses a threat to existing encryption systems, as these computers could theoretically break many current cryptographic algorithms. Advancing quantum technologies requires substantial investment in research and development, with major tech companies playing a key role due to their financial and scientific capabilities.

International cooperation in the field of quantum technologies is also crucial for ensuring national security, as no single country can independently cover the full scope of research in this area [4].

Biotechnologies have a broad range of applications relevant to national security, including the development of new medical treatments and vaccines, the creation of biosensors for threat detection, and the use of biological processes in industry and agriculture.

However, the advancement of biotechnology also carries risks, such as the potential creation of biological weapons and the threat of bioterrorism. Rapid progress in biotechnology – especially when combined with artificial intelligence – may lead to unforeseen consequences for national security. Increasing competition among major global powers in this field further highlights the strategic importance of biotechnology [2; 4].

Unmanned systems, particularly drones, have become indispensable tools for intelligence gathering, surveillance, strike operations, and logistical support in military contexts. Drones can be used for border monitoring, detection of illegal activity, counter-terrorism operations, and assessment of disaster consequences. At the same time, there is a growing threat of terrorist groups using drones to carry out attacks. This makes the development of counter-drone technologies–such as detection, interception, and neutralization systems–increasingly vital. The lack of a clear national strategy for drone use and regulation may pose a significant threat to national security [4].

Satellite technologies are critically important for communication, navigation, intelligence, and surveillance in support of national security. Satellites are used to collect intelligence, monitor borders, ensure communication between military units, and provide navigation services. A key aspect is ensuring the resilience of satellite systems against cyberattacks and physical threats, as their failure can have serious implications for national security. The growing number of small satellites is making space technology more accessible, but also complicates oversight of their potential military use. The private sector is playing an increasingly important role in satellite technology development, which may affect state control in this strategically vital area [4].

Cybersecurity technologies are a crucial element in protecting national interests in the digital space. A wide range of technologies and systems – including intrusion detection systems, firewalls, antivirus software, threat detection and response systems, as well as encryption and biometric authentication technologies – are used to defend against cyber threats. Artificial intelligence plays an increasingly important

role in enhancing cybersecurity by helping detect anomalies, predict attacks, and automate response processes.

Cyber threats are becoming more complex and diverse, including attacks on critical infrastructure, ransomware, and phishing campaigns. Effectively countering these threats requires close international cooperation and information sharing on cyber incidents [4; 5].

Artificial intelligence has proven highly effective in identifying potential national security threats by analyzing large volumes of data. Machine learning algorithms can detect anomalies in network traffic that may indicate a cyberattack, or recognize patterns in video and photo imagery to help identify suspicious individuals or objects. AI systems can analyze data from various sources, including social media and open-source platforms, to detect signs of planned terrorist activities or the spread of disinformation.

Satellite imagery and remote sensing data are also used to monitor borders, detect illegal activities such as arms or drug smuggling, and assess the impact of natural disasters and technological accidents. AI plays a key role in processing and analyzing this data, helping identify patterns and anomalies that may indicate potential threats. However, it should be noted that adversaries are also actively using AI to enhance their attack methods, which necessitates the ongoing development and adaptation of threat detection systems [1; 7].

Preventing national security threats is just as important as detecting and responding to them. In the field of cybersecurity, this is achieved through the implementation of comprehensive protection systems, including the use of firewalls, intrusion detection systems, data encryption technologies, and multi-level authentication, including biometric methods. At the borders, biometric technologies are employed to identify individuals and monitor their movement, helping to prevent the entry of persons who may pose a threat. Unmanned aerial vehicles are used to patrol borders and detect illegal crossings, smuggling, and other illicit activities. The effectiveness of these measures depends not only on the availability of modern technologies but also on their proper implementation, continuous monitoring and timely updating, as well as the training level of personnel responsible for their operation [8].

In the event of a national security threat, modern technologies provide tools for rapid and effective response. Unmanned systems can be quickly deployed to assess the situation, conduct search and rescue operations, deliver essential supplies to disaster zones, and ensure communication. In cyberspace, cyber intelligence and cyber defense tools are used to identify the sources of attacks, analyze their nature, and neutralize their harmful impact. Swift and coordinated response requires effective cooperation between various government agencies and services, as well as efficient real-time threat information sharing. The use of cyber weapons is a complex issue that requires careful consideration of all potential consequences and compliance with international law [9].

Ukraine continuously faces an increasing number and complexity of cyber threats, which pose a significant danger to national security. State-sponsored cyberattacks–often backed by hostile nations–target critical infrastructure, government institutions, and the private sector with the aims of espionage, sabotage, and destabilization. Cybercrime is also a major concern, involving ransomware attacks, theft of personal data, and financial fraud. These cyber threats can have far-reaching consequences, disrupting essential services, causing significant economic losses, and undermining public trust in state institutions.

As a country on the front line of cyber conflict, particularly in the context of Russian aggression, Ukraine must continuously improve its cybersecurity system and actively engage in international cooperation in this field [6].

Terrorism and extremism remain serious threats to national security in many countries, including Ukraine. International terrorist organizations, as well as domestic extremist groups, may use violence to pursue political, ideological, or religious goals. Terrorist groups actively leverage modern technologies to plan and execute attacks, including using unmanned aerial vehicles (UAVs) for reconnaissance and strikes, as well as encrypted communication channels to coordinate operations and spread propaganda.

Terrorism threats can be both external and internal, often rooted in deep social, economic, and political issues. An effective

counter-terrorism strategy requires a comprehensive approach that includes not only security and law enforcement measures, but also efforts to prevent radicalization, combat extremist ideologies, and address the underlying causes that contribute to the rise of terrorism [6].

Hybrid warfare is a complex phenomenon that combines military and non-military methods to achieve strategic objectives. It includes the use of information warfare, economic pressure, cyberattacks, support for proxy forces, and other unconventional means. Hybrid threats are aimed at undermining a state's internal stability, creating chaos and distrust in authorities, and influencing political processes in favor of the aggressor. Information operations, a key element of hybrid warfare, involve the dissemination of disinformation, propaganda, and manipulation of public opinion to weaken society and erode its will to resist. Countering hybrid warfare requires coordinated efforts from all branches of government, civil society, and international partners to strengthen the country's resilience across all domains [6].

Disinformation campaigns are powerful tools used to influence public opinion and destabilize societies. These campaigns involve spreading false or distorted information to mislead, incite panic, undermine trust in state institutions, and provoke social conflict. In the context of the Russian-Ukrainian conflict, disinformation is one of the aggressor's primary tools aimed at undermining Ukraine's sovereignty and territorial integrity. Social media, online platforms, and emerging technologies – such as artificial intelligence for creating deepfake videos and audio – are actively used to spread such content. Combatting disinformation requires a comprehensive approach that includes enhancing media literacy among the population, supporting independent media, employing technology to detect and debunk fake content, and fostering international cooperation in this field [2; 6].

Artificial intelligence (AI) is a powerful tool in the fight against cyber threats. AI-based systems can analyze vast volumes of network traffic and user behavior data to detect anomalies indicative of cyberattacks. Machine learning algorithms are used to identify malware, phishing emails, and other types of cyber threats. In the context of disinformation, AI can analyze large sets of textual and

visual data to detect fake news, bots, and coordinated disinformation campaigns on social media. AI systems can also automate incident response processes, allowing for rapid threat neutralization and mitigation of consequences. However, it is crucial to remember that malicious actors are also leveraging AI to enhance their attack strategies, making it essential to continually update and advance AI-based defense systems [5; 6].

Unmanned aerial vehicles (UAVs) have become essential tools in counterterrorism operations, enabling surveillance of suspicious individuals and objects, as well as carrying out precision strikes on terrorist targets. Drones are also used to detect and neutralize explosive devices, helping to preserve the lives of security personnel. In border protection, drones are employed to patrol vast areas, detect illegal crossings, and uncover smuggling operations. Satellite imagery and remote sensing data provide valuable information for monitoring borders, identifying military activity, and tracking the movements of terrorist groups. The use of UAVs and satellite technologies allows for real-time intelligence gathering, enhances situational awareness, and reduces risks to personnel during high-risk operations [7].

Cybersecurity technologies play a critical role in defending against hybrid attacks that combine cyber and physical methods of influence. Intrusion detection systems and traffic analysis tools help identify cyberattacks – which are often integral to hybrid operations – at early stages. Encryption technologies and secure communication channels are used to prevent the interception of sensitive information, which is vital in countering information operations, another key component of hybrid warfare. DDoS protection systems help maintain the continuous operation of critical online services and infrastructure, which may be targeted during hybrid conflict. Effective protection against hybrid attacks requires a comprehensive approach that integrates various cybersecurity technologies and fosters coordination among government agencies, the private sector, and international partners [7].

The use of modern technologies in the field of national security is inevitably associated with issues of privacy and personal data protection. Surveillance technologies such as facial recognition

systems, geolocation tracking, and communication analysis are capable of collecting vast amounts of information about citizens, which may lead to violations of their right to privacy. Striking a balance between the need to protect national security and the right to privacy is a complex task that requires clear legal regulation of the collection, storage, and use of personal data in this domain. The absence of adequate legal frameworks can result in abuse and the violation of fundamental human rights [10].

The use of technology in national security may also significantly impact civil liberties and human rights, including freedom of expression and the right to peaceful assembly. Facial recognition systems may be used to monitor participants in peaceful protests, which could have a chilling effect on public demonstrations. It is important to ensure that the application of such technologies does not lead to disproportionate restrictions on these freedoms. Special attention must be given to the bias of artificial intelligence algorithms, which can result in discrimination and unfair outcomes in law enforcement and other areas. To ensure compliance with ethical standards and human rights, it is necessary to develop appropriate ethical guidelines and principles for the use of technology in national security.

The deployment of technologies in the national security sector must also comply with international law, including the laws of war and human rights law. This is especially important in the context of using cyber weapons and autonomous systems, which may have serious consequences for civilian populations and international security. International law has yet to fully adapt to the rapid development of emerging technologies, leading to legal ambiguities and gaps. Therefore, there is a pressing need for international cooperation to establish new norms and principles to govern the use of technology in military and national security contexts, while ensuring respect for fundamental human rights and freedoms [10].

The use of autonomous systems, such as unmanned aerial vehicles and artificial intelligence systems, in the field of national security raises important questions about accountability for their actions. In cases of errors or unforeseen consequences, it can

be difficult to determine who is responsible for the damage caused [2]. The concept of a "human-in-the-loop", which ensures that human oversight is maintained in making critical decisions, is one approach to addressing this issue. Delegating decision-making entirely to autonomous systems may reduce accountability and complicate incident investigations. Therefore, it is essential to develop clear mechanisms of control and responsibility for the use of autonomous systems in national security, ensuring transparency and accountability in their operation [10].

Ukraine actively cooperates with the European Union and the North Atlantic Treaty Organization (NATO) in the field of cybersecurity. Numerous support programs are in place to strengthen Ukraine's cyber resilience, facilitate the sharing of threat intelligence, and conduct joint training exercises. Ukraine participates in collaborative projects to exchange cyber threat data and best practices in cyber defense. Joint exercises and training sessions are held regularly to improve readiness for responding to cyber incidents [10].

Ukraine receives significant financial and technical assistance in cybersecurity from the United States, the United Kingdom, Canada, and other countries. These programs aim to provide Ukraine with essential equipment, software, and expert support to strengthen its cyber defenses. International support plays a crucial role in bolstering Ukraine's cyber defense capabilities, especially amid ongoing aggression.

Ukraine also actively participates in international forums, conferences, and seminars on cybersecurity, where it exchanges knowledge and experience with foreign partners. Joint research projects in the field of cybersecurity and defense technologies are being conducted, enabling Ukraine to access cutting-edge knowledge and innovative developments. Developing international partnerships and engaging in joint initiatives is a key component of strengthening Ukraine's national security [10].

Ukraine cooperates with Western companies and partner countries in the development and implementation of advanced defense technologies, including the production of weapons and military equipment. Ukraine also participates in NATO programs aimed

at the joint development and deployment of cutting-edge military technologies. These joint projects contribute to the modernization of the Ukrainian army and defense industry according to modern standards, while also attracting foreign investment and technology to enhance national defense capabilities.

In the future, the role of artificial intelligence (AI) in the military sphere is expected to grow significantly. Autonomous systems, combat robots, and intelligent command-and-control systems could fundamentally change the nature of warfare [5]. AI may be used for battlefield decision-making, managing large military formations, analyzing intelligence data, and guiding precision weapons. However, the development of AI in military contexts also raises serious ethical and legal concerns, particularly regarding the creation and use of lethal autonomous weapons.

The advancement of quantum computing could introduce new and highly sophisticated cyber threats. Quantum computers have the theoretical ability to break many existing cryptographic algorithms, potentially compromising the security of confidential information, including state and military secrets. This has made the development and implementation of quantum-resistant cryptographic algorithms an increasingly urgent priority [1].

Future developments in biotechnology and its potential use for military purposes are also anticipated. This could include the creation of new types of biological weapons, methods for enhancing soldier performance, and other military applications. Controlling biotechnology development and preventing its use for military purposes has become a critical task for the international community. It is necessary to strengthen international regimes regulating biological weapons and ensure compliance with existing treaties and conventions in this field.

A significant increase in both the volume and quality of disinformation created using AI – particularly deepfake technologies – is expected. Detecting such disinformation will become increasingly difficult, as AI enables the creation of highly realistic fake videos, audio recordings, and texts that are hard to distinguish from genuine content.

Combating AI-generated disinformation will require the development of new verification technologies and methods, along with efforts to boost critical thinking and media literacy among the public [8].

Conclusions. Modern technologies are a powerful tool in ensuring Ukraine's national security, offering opportunities for the detection, prevention, and response to a wide range of threats. However, the rapid advancement of technology also brings new challenges and risks that require constant attention and appropriate countermeasures. To effectively harness technological potential in the field of national security, Ukraine must: Develop and implement a comprehensive national strategy focused on the integration of advanced technologies in the security and defense sector, taking into account the ethical and legal aspects of their use.

Increase public funding for research and development in artificial intelligence, quantum technologies, biotechnology, unmanned systems, and cybersecurity, while encouraging private investment in these areas.

Improve the legislative framework to regulate the use of emerging technologies in national security, ensuring a balance between protecting national interests and safeguarding citizens' rights and freedoms.

Enhance international cooperation with leading countries and international organizations in areas such as information exchange, joint research, and cyber resilience support programs.

Implement educational programs on cyber and media literacy for the general public and government officials to raise awareness of threats and strategies for countering them.

Promote public-private partnerships to stimulate innovation and develop technological solutions tailored to national security needs.

Give special attention to the ethical dimensions of using artificial intelligence and autonomous systems in military and security contexts, ensuring that human oversight remains integral to critical decision-making.

Given the dynamic nature of technological development and the continuous evolution of national security threats, Ukraine must continuously monitor new trends, adapt its strategies, and strengthen

its own technological capabilities to ensure the reliable protection of its national interests in the future.

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3.2. THE MECHANISM OF CRISIS MANAGEMENT IN THE SPHERE OF NATIONAL SECURITY OF UKRAINE DURING THE RUSSIAN-UKRAINIAN WAR

Introduction. Russia's full-scale invasion of Ukraine in 2022 marked a significant escalation of the conflict that began in 2014, creating a fundamental threat to Ukraine's national security [1]. This has highlighted the urgent need for a reliable and adaptive crisis management mechanism to protect sovereignty, territorial integrity, and national interests [1]. The war exposed vulnerabilities in Ukraine's existing national security system, underscoring the critical need for effective crisis governance. The prolonged and intense nature of the conflict necessitates a shift from reactive crisis response to proactive and adaptive management strategies. The initial stages of the war likely overwhelmed existing protocols, prompting a rapid

evolution in crisis management approaches. Continued aggression demands a system capable not only of responding to present threats but also of anticipating and mitigating future risks.

Effective crisis management is vital for maintaining state functions, protecting citizens, and ensuring the resilience of critical infrastructure during wartime [2]. It involves coordination among various governmental and non-governmental actors to overcome immediate threats and plan for long-term recovery [4]. The ability to manage crises efficiently directly affects Ukraine's capacity to resist aggression and secure its future [1]. The effectiveness of crisis management may prove to be a decisive factor in the outcome of the conflict and the long-term stability of the country. Poor crisis management could lead to systemic failures, erosion of public trust, and an inability to mobilize defense resources effectively. Conversely, a well-functioning system can reinforce national resolve and optimize resource allocation.

Presentation of Key Research Findings. Crisis management involves a system of measures and decisions aimed at diagnosing, preventing, minimizing, and overcoming crisis situations [5]. It is a purposeful activity conducted by national security actors using state capabilities (diplomatic, military, economic, intelligence, and informational) to develop and implement regulatory, coordinating, and monitoring actions. An effective system must be built on principles of anticipation, prevention, and threat mitigation [5]. In the context of national security, crisis management extends beyond economic considerations to encompass all aspects of state security and societal well-being. While some definitions focus on economic stability, the context of war broadens its scope to include military defense, information security, social stability, and the functioning of government institutions under extreme pressure.

The core components of the crisis management mechanism include actors and objects, goals, principles, functions, methods, tools, legal framework, information and communication support, and performance criteria [6]. The key principles are effectiveness, comprehensiveness, coordination, flexibility, and transparency. Crisis management typically proceeds through stages: forecasting, diagnosis, planning,

implementation, control, and evaluation [5]. The multidimensional nature of crisis management requires an integrated approach that encompasses legal, institutional, informational, and strategic elements. Each component is interdependent–for example, successful implementation depends on a solid legal foundation and clearly defined institutional responsibilities, which themselves rely on accurate diagnostics and strategic planning.

Effective crisis management in national security relies on a clear command structure from the President to frontline actors, ministerial accountability for national security agencies, a distinct division between political/strategic leadership and operational command, and the continuous operation and responsiveness of the system regardless of political changes. These principles emphasize the importance of centralized authority, clear accountability, and operational continuity – especially critical in wartime. Any uncertainty in command or responsibility can result in delays and ineffective crisis response. The principle of continuous functioning ensures that the system remains operative even under extreme pressure and political shifts [9].

The Constitution provides a general legal mandate for crisis management in the national security domain, establishing the state's duty to protect its core interests. All subsequent legislation and regulations must align with constitutional principles of national security and the division of powers among branches of government.

The primary legislative acts include the Law of Ukraine "On National Security", which outlines the principles and foundations of security and defense; the Law "On the Legal Regime of Martial Law", which sets the legal basis for martial law including state authority powers and restrictions on rights and freedoms; the Law "On the Defense of Ukraine", which defines the organization and principles of national defense; and the Law "On the National Security and Defense Council (NSDC) of Ukraine", which defines the NSDC's roles and powers. These laws provide concrete legal mechanisms and authorities for implementing crisis response measures within national security and martial law frameworks. The Law on Martial Law is particularly significant as it grants extraordinary

powers to the state during wartime, requiring careful consideration of its implications for civil liberties and democratic governance.

Presidential decrees and Cabinet of Ministers resolutions include orders to impose or extend martial law, enact NSDC decisions, and regulate specific aspects of crisis response and martial law. These acts reflect the practical application of the legal framework, adjusting to evolving security situations and implementing targeted crisis policies. The frequent extensions of martial law underscore the prolonged nature of the crisis and the ongoing need for extraordinary legal measures.

National security strategies and doctrines include the National Security Strategy of Ukraine, which sets priorities, goals, and directions for policy; the Military Security Strategy, which outlines military objectives and approaches; and the Information Security Strategy, which addresses threats and goals in the information domain. These strategic documents define guiding principles for crisis management and outline the state's long-term vision and security priorities. Their development and updates reflect the evolving understanding of national security threats and necessary responses amid the ongoing war [9].

The President of Ukraine serves as the guarantor of state sovereignty, territorial integrity, and national security. The President makes national security and defense decisions through the NSDC and issues decrees on imposing and extending martial law. The President plays a central role in crisis management, holding significant authority in leading national security and defense efforts, especially under martial law. This concentration of power during wartime necessitates robust oversight and accountability mechanisms to prevent potential abuse.

The National Security and Defense Council of Ukraine (NSDC) coordinates and oversees the activities of executive bodies in the areas of national security and defense. It orchestrates efforts to repel armed aggression, protect the population, and maintain public order under martial law. The NSDC plays a key role in strategic planning and decision-making related to national security. As a coordinating authority, it ensures a unified and strategic approach to crisis

management across various government agencies. Its effectiveness depends on facilitating interagency cooperation and ensuring prompt implementation of presidential directives by the relevant executive structures.

The Cabinet of Ministers of Ukraine is responsible for implementing governmental policies on national security and defense. It coordinates and guides the work of ministries and other executive bodies, and develops and approves action plans to implement national security strategies. The Cabinet plays a critical role in translating strategic decisions into specific actions and ensuring seamless government operation during a crisis.

The Ministry of Defense of Ukraine organizes and executes national defense. It commands the Armed Forces of Ukraine, coordinates their responses to military threats, and houses specialized crisis-response units. As the frontline institution in military crisis management, it plays a vital role in defending the country. The ongoing war requires continuous adaptation and enhancement of the Ministry's operational structures, logistics, and coordination with other security branches.

The Security Service of Ukraine (SBU) is tasked with national security, including counterterrorism, counterintelligence, and safeguarding national interests. It monitors and counters non-military threats in information and cyberspace. In the context of hybrid warfare, the SBU is essential in identifying and neutralizing threats beyond the military domain.

The State Border Guard Service of Ukraine secures the country's borders and prevents illicit activities threatening national security. Its role is crucial for maintaining territorial integrity and guarding against infiltration, particularly during wartime, which has escalated its responsibilities and urgency.

Other ministries and agencies – such as the Ministry of Internal Affairs, National Police, State Emergency Service, etc. – also contribute to national security and crisis management. A robust crisis management system depends on the coordinated efforts of these agencies, each with specific duties and expertise. Effective cooperation and information sharing are vital for coherent and timely crisis response.

Rapid mobilization of reserves and territorial defense forces following the full-scale invasion in 2022 exemplified effective crisis management. Military strategy adaptation, logistical adjustments, and supply chain coordination under wartime conditions demonstrated readiness and flexibility, albeit with initial coordination challenges. Analyzing successes and shortcomings from this mobilization offers valuable insights for future crisis management efforts.

Counter-disinformation efforts, morale campaigns, protection of critical information infrastructure from cyberattacks, and strategic communications to inform the public and global partners are prime examples of crisis mechanisms in the information domain. Information security measures have been crucial for maintaining national unity and countering hostile narratives.

Martial law implementation, including its economic impact, regulatory measures, business support mechanisms, and social safeguards, demonstrate economic stabilization efforts. Maintaining economic stability during war requires balancing security needs with economic activity. Evaluating these measures aids in shaping future wartime economic policies.

Humanitarian response, such as evacuating civilians, assisting internally displaced persons (IDPs), and coordinating with international and NGO partners, shows crisis management in humanitarian contexts. The massive population displacement intensified pressure on Ukraine's humanitarian systems and required extensive coordination and resources. Identifying challenges and successes in humanitarian response enhances future crisis readiness.

The NSDC played a pivotal role in coordinating national crisis response across government bodies, issuing critical directives, and shaping wartime strategy. Evaluating the effectiveness of its coordination and decision-making processes is essential for optimizing Ukraine's national security management.

Strategic forecasting and threat assessment to identify potential crises [5], strengthening national resilience across various sectors (economic, social, informational) [4], the development and implementation of national security strategies and doctrines, as well

as international cooperation and partnerships to deter aggression, are essential preventive measures. Proactive actions aimed at preventing crises are crucial for minimizing their impact on national security. Investments in intelligence gathering, early warning systems, and resilience-building initiatives can significantly enhance Ukraine's capacity to withstand future threats [8].

The rapid deployment of forces and resources to eliminate immediate threats, activation of crisis management centers and coordination mechanisms [3], the implementation of martial law measures to ensure public safety and order, and effective communication with the public and stakeholders during crises are key response measures. Swift and coordinated responses are vital for containing crises and mitigating their immediate consequences. Regular crisis response team exercises and trainings, along with clear protocols and communication channels, are essential for effective crisis management.

Military operations to liberate occupied territories and restore territorial integrity, addressing the root causes of the crisis and working toward long-term resolution [7], efforts in post-crisis recovery and reconstruction, as well as reintegration of affected populations and territories, are vital mitigation measures. Overcoming a national security crisis of this magnitude requires continuous and multifaceted efforts encompassing military, political, economic, and social dimensions. The process of overcoming such a crisis is likely to be prolonged and complex, requiring significant resources and international support for recovery and reintegration.

Conclusions. The crisis management mechanism in the field of national security of Ukraine during the Russo-Ukrainian war is a complex and multifaceted system encompassing legislative, institutional, strategic, and practical components. The war has been a severe test for this system, revealing both its strengths – such as the ability for rapid mobilization and adaptation – and its challenges related to coordination, efficiency, and long-term resilience. International cooperation and assistance have played a crucial role in supporting Ukraine in its struggle against the aggressor.

To further strengthen the crisis management mechanism in Ukraine's national security domain, it is recommended to:

– Enhance interagency coordination and information sharing among all actors involved in national security and crisis management.

– Continue developing strategic forecasting and early warning systems for better anticipation of potential crises.

– Pursue adaptation and modernization of the legal and regulatory framework for crisis management based on the lessons of the ongoing war.

– Invest in training and capacity-building for personnel involved in crisis management at all levels.

– Strengthen the national resilience of critical infrastructure and essential services to minimize vulnerability to future threats.

– Develop a comprehensive long-term strategy for post-war recovery and reintegration with clearly defined roles and responsibilities for all stakeholders.

– Continue strengthening international cooperation and partnerships across all areas of national security and crisis response.

– Raise public awareness and media literacy to counter disinformation and enhance societal resilience.

– Implement robust monitoring and evaluation mechanisms to assess the effectiveness of crisis management measures.

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3.3. DIGITALIZATION AS ONE OF THE METHODS OF FORMING THE COMPETITIVENESS, ADAPTABILITY AND FLEXIBILITY OF A CORPORATION DURING THE POST-WAR RECONSTRUCTION OF UKRAINE

Introduction. Despite the hostilities, as well as other difficulties arising from current events, in 2024 Ukraine received the fifth place in the field of development of electronic public services, as well as the first place in the E-Participation index. The expansion of areas and industries of digital services is important for ensuring effective transformational digitalization processes. The volume of planned expenditures for digital reconstruction and development by 2025 occupies the largest share of expenditures for the development of the digital economy (49.6 %), 25.5 % of the total expenditures are planned for the reconstruction of the digital network of ASCs, amounting to 11.87 %. Let's note the fact that in 2022, Ukraine joined the Digital Europe program until 2027. All these developments provide the basis for expanding digitalization processes at domestic enterprises, ensuring high competitiveness, adaptability and flexibility of the corporation for the post-war reconstruction of the domestic infrastructure to ensure future economic prosperity.

Presentation of the main results of the research. In the hour of uncertainty, the financial crisis, which was caused by the outbreak

of military operations, as well as the global economic disruptions in the international arena, has an ongoing nature, which creates a culprit of factors that pose a threat, manifested by increased competitiveness among current foreign technological enterprises. Therefore, given the current situation, there is an increasing need to adapt to internal and external factors that help increase the level of adaptation of Ukrainian IT companies. It should be noted that over the past 12 years, including until 2022, stagnation was observed in the IT industry. Growth on average ranged from 25–30 %. It can be stated that after 2022, the situation in this market deteriorated due to the war, which affected the increase in the volume of non-fulfillment of contract orders. In 2024, the total export revenue of IT services decreased and amounted to $5.8 billion in 11 months. Thus, in order for the situation to change for the better in 2025, it is necessary to solve the main problems in this area: mobilization and difficulties with obtaining a deferment for key specialists; difficult situation in some IT clusters, primarily in Kharkiv; limited opportunities to travel abroad; missile attacks and related blackouts; increased tax burden.

This will help to adapt to the current conditions of uncertainty, overcoming the existing negative aspects inherent in IT spheres. Therefore, digitalization is becoming more relevant, as it is one of the most important directions of growth of human civilization, which allows us to focus on determining the main directions of improving the management mechanisms of technology companies. Expanding access to healthcare, education, and banking will come through the creation of an inclusive society. This will help improve the quality and coverage of public services, expand the way we interact with customers, and expand the range of goods and services at lower prices.

As of the current period, digital technologies are part of business processes in IT companies, which is manifested in the export reduction of the cost of cloud technologies, the cheapening of the cost of software development itself, the increase in free content and services, and the creation of unique products adapted to the client's preferences [7].

Currently, the Ukrainian authorities are engaged in the spread of digitalization processes within the country, including the following

main trends in the transformation of technological enterprises: blockchain, the Internet of Things, cloud computing and digital security, information gathering from various sources, and the impact of 5G. The essence and significance of these technologies are presented in Fig. 1.

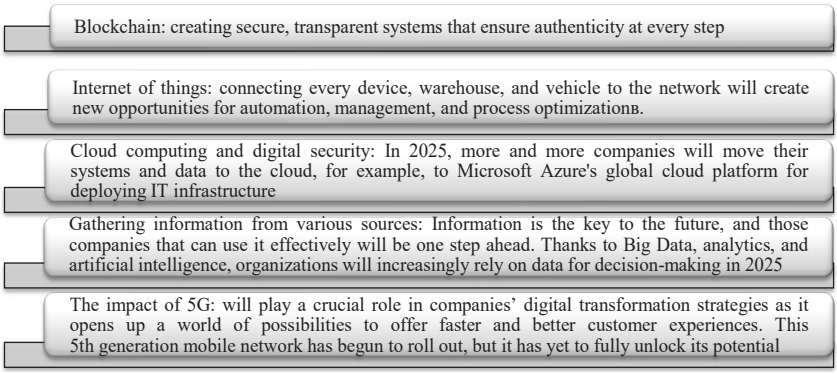

Fig. 1. Key trends in the digitalization of technological enterprises in Ukraine as of 2025

Source: [8; 9]

As a foreign experience of the main digital trends, Finland was taken and the Finnish company Nokia was considered. This Finnish multinational corporation was founded on May 12, 1865 as a single paper factory. Nokia. In 2014, Nokia's mobile phone business was sold to Microsoft [5].

We examined three projects of the Finnish company Nokia: "6G-ANNA", "LEAD leading company" and "SUSTAIN-6G". Nokia is the overall leader of "6G-ANNA", a 6G beacon project funded by Germany. The "6G-ANNA" project is making a significant contribution to the development of technologies that enable the implementation of 6G. The German economy can accumulate the necessary know-how to later independently use 6G networks. Incentives are also being created to increase the production of key components in Germany and Europe. At the same time, it will be ensured that the requirements of leading German industries are included in the 6G standard. In this way, 6G

technologies will become part of the cutting-edge technologies in leading industries at an early stage. Overall, the project results make a significant contribution to the technological sovereignty of Germany and Europe [12]. Fig. 2 shows the storyline of the "6G-ANNA" project, the concept for the German 6G beacon project.

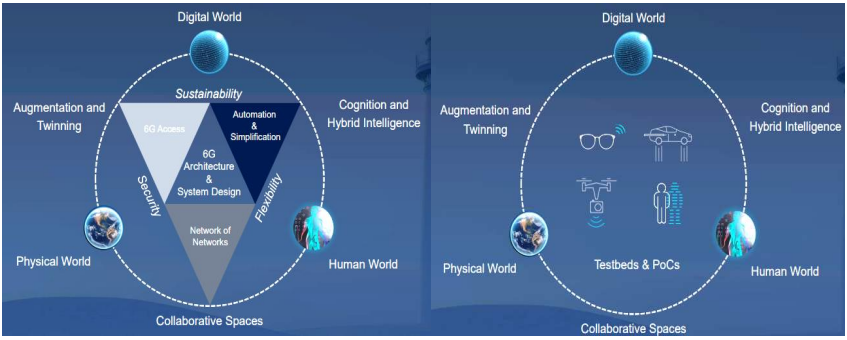

Fig. 2. Concept for the German project "Mayaka 6G": the storyline of the project "6G-ANNA"

Source: [13, p. 5–6]

In 2023, the Finnish company Nokia participated in the competition of leading companies 2023, the other winners of which were Kempower, Patria, Valio and Wärtsilä. The project of the Finnish company Nokia was aimed at developing increased usability, security and energy efficiency of the future internet and metaverse. Therefore, in view of the victory, the Finnish government organization for financing innovation, trade, travel and investment promotion, Business Finland, allocated funding for the Nokia "LEAD leading company" project, the goal of which is to increase the usability, security and energy efficiency of the future Internet and metaverse [10].

It is worth noting that the industrial metaverse is a growing market and offers great business opportunities for Finnish companies. The metaverse refers to a solution that seamlessly connects the physical and digital worlds. For example, the metaverse allows for real-time collaboration, simulation, and remote work.

There are three types of metaverses: consumer metaverse, industrial metaverse, and corporate metaverse. These three types of metaverses, although serving different purposes, will have common features in the future. Different types of metauniverses will be interconnected to varying degrees, and will share common technologies, devices, and interfaces. It is anticipated that each instance of the metauniverse will serve different companies, communities, and users.

Note that the consumer metaverse is primarily focused on entertainment and leisure, while the corporate and industrial metaverses are focused on business applications [6].

Thanks to this flagship corporate project, Nokia has significantly increased its own and partner investments in research, development and innovation (RDI) in Finland.

Already in 2024, the Finnish company Nokia was selected by the Smart Networks and Services Joint Venture (SNS JU) as the leader of the "SUSTAIN-6G" project. This project is designed for 2027 and includes the following industry areas:

– smart power systems: development of microgrids with real-time control based on artificial intelligence for efficient and redundant electricity distribution;

– e-health and telemedicine: Expansion of 6G infrastructure for secure exchange of medical data and remote diagnostics, improving healthcare in underserved areas;

– agriculture: Using 6G technology for agricultural applications with high bandwidth, data analysis and automation, increasing productivity and sustainability [11].

So, let's summarize that the SUSTAIN-6G project is one of the flagship projects of the SNS JU. It significantly strengthens Nokia's leadership in the field of innovative developments. This initiative, together with the Hexa-X and Hexa-X-II projects, helped the Finnish company Nokia lay the foundation for the preliminary standardization of 6G and studied possible options for its use. In addition, the consortium includes various stakeholders, including network equipment suppliers, telecommunications operators, research institutes, industrial manufacturers and SMEs, which provide a comprehensive approach to the development of sustainable innovations.

If we consider the sphere of leadership of the Finnish company Nokia, then Table 1 indicates that it covers organizations for standardization of mobile communication networks, formation of the 5G and 6G ecosystem, organizations for standardization of fixed access, organizations for IP routing, Ethernet switching and optics standardization, and multimedia organizations.

Table 1

Leadership of Finnish company Nokia in the field of intellectual property rights

The name of the field of leadership	The main characteristic
1	2
Mobile network standardization organizations	Including 3GPP and the seven joint standards development organizations ETSI, ATIS, ARIB, TTC, TTA, CCSA and TSDSI. Nokia is also active in industry organizations that promote mobile network technologies and standards, including O-RAN Alliance, GSMA, GSA, 5G Americas and NGMN.
Shaping the 5G and 6G ecosystem	In 2016, Nokia founded the 5G Automotive Association (5GAA). In 2018, Nokia created the 5G Alliance for Connected Industries and Automation (5G-ACIA). And in 2024, Nokia became a founding member of the AI-RAN Alliance. Today, Nokia is shaping the 6G ecosystem and is actively involved in, among others, the NextG Alliance in the US, SNS 6G-IA in Europe and Bharat 6G Alliance in India.
Fixed access standardization organizations	Nokia plays a leading role in standards organizations such as the Broadband Forum and IEEE 802.11. Our active participation in these groups ensures the development of reliable and interoperable fixed access technologies. In addition, we collaborate with key regional standards organizations to support and advance the advancements in local area networking. Nokia was one of the six founding members of the Wi-Fi Alliance in 1999.

Continuation of Table 1

1	2
IP routing, Ethernet switching, and optics standardization organizations	Nokia actively participates in IP routing, Ethernet switching, and optical standardization organizations, including IETF, IEEE 802, ITU, OIF, and ONF. Our participation helps ensure the advancement and interoperability of global networking technologies.
Multimedia organizations	Nokia is an active participant in the Metaverse and MPEG Standards Forum. Our participation helps shape the future of video and audio standards and technologies.

It can be said that digitalization processes help to ensure effective anti-crisis management, which is an interconnected comprehensive company management system characterized by a strategic focus, created to identify and eliminate current and future problems in operations by developing and implementing an effective and modern program of anti-crisis measures [1]. Its main identifiers in terms of forming a company's reputation are competitiveness, adaptability, and flexibility.

Competitiveness in business refers to a company's ability to balance the price and quality of its products and services to provide customers with an optimal experience. Furthermore, competitiveness in business refers to a company's ability to achieve greater sales or customer loyalty than its competitors, due to the quality of its products and services, low prices, or a combination of both factors [2].

Competitiveness in business can be divided into two areas: price competitiveness, when a business can maintain the quality of its goods or services while keeping prices lower than those of its competitors, and structural competitiveness, when a business can maintain better sales or customer loyalty compared to its competitors regardless of the prices it offers.

Note that the concept of "adaptability" is defined as "the ability of a person to adapt to changes in the environment. When you think about your career aspirations, changes directly affect how flexible you can be. The practice of adaptation can include how quickly you are able to respond to change".

Change is a natural part of life; therefore, the ability to adapt is a crucial skill. Active participation helps to embrace change, understand it, be receptive, open, and adaptable.

The third dimension of crisis management in terms of company reputation is flexibility. Workplace flexibility is a strategy for responding to changing circumstances and expectations. Employees who approach their work with a flexible mindset tend to be more valued by employers. Similarly, employers who cultivate a flexible work environment are attractive to employees [4].

A flexible workplace meets the needs of both the employee and the employer. Workplace flexibility is often used as a tool to retain and engage employees. It can also help an organization achieve its goals by increasing productivity. It can be said that the main objects of the mechanism of functioning of work flexibility are employees, employers and the schedule.

As one of the reputational anti-crisis measures to increase competitiveness, adaptability and flexibility, this multinational company applies its code of conduct, which identifies specific risks and problems that employees of international companies may face. Its main points are listed as Nokia's compliance policy in table 2.

In addition, Nokia's corporate governance practices, which comply with Finnish laws and regulations, Nokia's articles of association, the finnish corporate governance code 2020 and the corporate governance standards of the following stock exchanges, were considered as a second anti-crisis management measure: Nasdaq in Helsinki, Euronext in Paris and the New York Stock Exchange ("NYSE").

To briefly describe the essence of the Corporate Governance Code, we note that it is a collection of recommendations on good corporate governance for companies listed on the stock exchange. The recommendations of the corporate governance code supplement the obligations set out in the legislation. the purpose of the corporate governance code is to maintain and promote high quality and international comparability of corporate governance practices applied by Finnish listed companies.

Table 2

Code of conduct: Nokia compliance policy

Name	Essence
1	2
Conflict of interest	The company's activities are carried out in the interests of Nokia and use information, property, resources primarily for the benefit of Nokia and to support Nokia's business needs.
Communication with government officials	Nokia engages with international organizations, governments, officials and policymakers at various levels and in various ways, including as a company providing products and services.
Fair competition	Nokia competes fiercely but fairly. Competition laws (or antitrust laws) regulate the activities of companies, ensuring fair competition in the interests of consumers and other market participants.
Improper payment	Nokia conducts its business and deserves what it deserves. The corporation will not tolerate improper or corrupt payments, including bribes or kickbacks, made directly or indirectly to a customer, government official or third party, including improper gifts; entertainment, gratuities, donations for services such as favorable contract terms, job selection or ignoring normal procedures.
Compliance with trade standards	Nokia is committed to complying with all applicable trade laws and regulations that affect its operations, including export controls, sanctions, anti-boycott and customs compliance. The Corporation is committed to preparing, conducting and reporting international business transactions to trade authorities accurately and transparently.
Working with third parties	Nokia is committed to productive, ethical and transparent relationships with its third parties. The corporation expects all third parties to meet Nokia's standards, comply with and exceed all applicable laws and regulations, and share its values.
Environment	Nokia is constantly striving to prevent environmental pollution and reduce the environmental impact of its products and services during design, procurement, production, use and end-of-life.

Continuation of Table 2

1	2
Fair employment	Management respects all people, regardless of their personal characteristics protected by law. These include age, disability, gender identity, gender characteristics or expression, race, religion or belief, sex, and sexual orientation.
Occupational health and safety, safety techniques and working conditions	The corporation deserves the respect of each other, its contractors, partners, customers and members of the public by providing a safe, healthy and fair work environment.
Human rights	Nokia adheres to the principles of the Universal Declaration of Human Rights and the United Nations General Declaration of the Guiding Principles on Business and Human Rights, and expects its suppliers and business partners to share these values.
Privacy and data protection	Nokia's Privacy Policy embodies the principles of privacy. We design our products and services with privacy and security in mind, and we take all available safeguards to protect your personal data from unauthorized use or disclosure, while maintaining its confidentiality.
Management	Nokia is committed to complying with applicable laws and regulations in all countries where Nokia operates, which govern its financial accounting and reporting to government agencies, investors and the public.
Intellectual property and confidential information	Nokia's intellectual property, which includes patents, software and other copyrighted material, know-how and trade secrets, as well as brands and trademarks, is one of the company's most valuable assets.
Insider trading	In the course of their work, employees may become aware of material, non-public information about Nokia or other companies. Using this material, non-public information for personal or financial purposes, such as buying or selling shares, or disclosing this information to others, undermines market integrity, violates corporate policy, and may be a violation of the law.

Source: [6]

Effective corporate governance contributes to the value creation of Finnish listed companies and their attractiveness as investment objects.

So, let us highlight that in the current situation, one of the natural, most effective and fastest directions for the further development of Nokia Corporation is not only increasing the degree of adaptation and flexibility of enterprises to market needs, but also increasing their competitiveness. To this end, the corporation must use all available opportunities to ensure the widespread use of advanced techniques and progressive technologies already available and used worldwide, the implementation of which will contribute to further effective compliance with the Code of Conduct and the organization of effective corporate governance on the stock exchange in accordance with Finnish laws and regulations.

Conclusions. Based on the analysis, we see that the IT sector provides development prospects and competitive advantages for both SMEs and large companies. However, in Ukraine there are aspects in this area that need to be improved. Thus, only half of medium-sized enterprises (48 %) have a website, and only a third (30 %) of small enterprises. Regarding social media, the use of this communication tool is approaching the frequency of website use. The tool is used by 52 % of large companies and only about 36 % and 27 % of medium and small enterprises, respectively. Some enterprises demonstrate limited use of digital tools.

Therefore, the implementation of developments of foreign corporations and the improvement of financial literacy among employees of technological enterprises in Ukraine, strengthening and improving the level of competitiveness, adaptability and flexibility of domestic enterprises during the post-war reconstruction of Ukraine, are becoming increasingly important today.

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3.4. FEATURES OF THE USE OF DIGITAL TECHNOLOGIES IN THE SERVICE SECTOR: SCIENTIFIC AND PRACTICAL ASPECT

Introduction. Today, modern business is increasingly moving into the digital environment, and service companies are forced to adapt to new conditions to remain competitive. Customers expect fast, convenient and personalised services that are made possible by digital tools. Digital technologies help automate routine operations, reduce costs, improve logistics and human resources management. In addition, the impact of COVID-19 has accelerated the introduction of contactless services, online services and remote communication channels, which has become the new normal. The use of artificial intelligence, Big Data, CRM systems, and the Internet of Things

(IoT) is helping to create new approaches to customer service. Digital technologies allow small companies to compete globally using online platforms, marketplaces and social networks. Therefore, research in this area helps to understand how to effectively integrate new technologies into business service models, provide a better customer experience and stimulate business development.

Presentation of the main results of the study. Today, many scientists are actively studying the peculiarities of using digital technologies in various fields of activity, as this is one of the key topics of modern science and practice. For example, K. Kraus, N. Kraus and O. Marchenko [1] focused on the study of the peculiarities of using the digital technology of the Internet of Things and the latest CRM systems. The authors noted that the digital transformation of modern business changes the forms of activity, restructures organisations, opens up new sources and forms of income, allows attracting more consumers and bringing customer service to a qualitatively new level. The article [2] investigates the peculiarities of using digital technologies in business activities, due to their crucial importance in ensuring the market competitiveness of business entities. Digital tools significantly transform business models, operational processes, channels of communication with consumers, and management approaches. The article also focuses on key areas of their application: e-commerce, digital marketing, financial technologies and customer relationship management (CRM) systems. I. Borysov in his study 'analysed the current legislation in order to identify the impact of the development of information technology on ensuring proper legal regulation of relations in the field of service provision in the context of digitalisation' [3]. T. Zabashtanska, I. Shpirnov and M. Mykhailiuk 'studied the types of digital technologies used in the financial services market of Ukraine, noted the advantages and disadvantages of introducing and using modern digital technologies by financial services market participants' [4]. Among the disadvantages of the practical implementation of the introduction of digital technologies, they noted the low level of financial and digital literacy of consumers of digital financial services, while the advantages are quick access

to banking, insurance, and investment services, cost reduction, personalisation of communications, etc. The authors of article [5] studied the role of digital technologies in transforming business models of modern enterprises, compared traditional and new (digital) business models, and identified the benefits of digital transformation for modern enterprises. As a result, they concluded that digital business models (the latest ones) allow enterprises to be more flexible, efficient and competitive, which is necessary in today's rapidly changing digital environment. U. Balyk, I. Losheniuk, and T. Vader [6] noted that one of the strategic directions of international marketing activities of modern companies is the use of digital technologies as an effective tool for conducting economic activity. In a globalized market environment, digital solutions provide businesses with the opportunity not only to optimize marketing processes, but also to establish direct contact with target audiences in different geographic markets. As part of international marketing, digital tools significantly reduce communication costs, accelerate entry into new markets, increase the accuracy of market risk assessment, and contribute to effective brand positioning. In the study, Y. Stashenko and O. Gavrylovsky [7] considered the concept and essence of digital transformation in trade as one of the key areas of development of the modern economy. Digital transformation in the field of trade not only simplifies and automates business processes but also creates fundamentally new opportunities for companies to grow, scale and enter international markets. Thanks to digital tools, enterprises gain access to new sales channels, expand their target audience, improve the quality of customer service and increase operational efficiency. But the study of the use of digital technologies in the service sector as a key factor in the modernization of service activities, which contributes to increasing the efficiency of business processes, improving customer experience and ensuring the competitive advantages of enterprises, namely: the introduction of digital platforms for online service; the use of mobile applications, digital customer relationship management (CRM) tools; automation of service processes and personalization of services, etc.

The service sector is a set of branches of the national economy that do not create tangible goods but produce a special type of product – a service, which is the result of purposeful, justified activity aimed at satisfying certain needs of the consumer. Services can be both tangible (repairs, transport) and intangible (education, finance, medicine, consulting), and, unlike goods, do not have a physical form and, as a rule, are consumed at the time of provision. In modern conditions of digitalization, this area demonstrates the highest dynamics of development due to the widespread introduction of innovative technologies.

The service sector is one of the three sectors of the economy, which contains all types of commercial services. We are talking about financial, hotel and restaurant, tourist, transport, retail, insurance, medicine, education, entertainment, marketing, etc. Service in the service sector is focused on meeting the needs and desires of customers and solving their problems [8].

In countries with high rates of technological development, the service sector plays a leading role in the economy, providing up to 70 % of the gross domestic product (GDP). At the same time, the level of employment in the service sector is more than 50 % of the total number of the working population [8].

The service sector is gradually gaining a leading position in the economy, ahead of traditional commodity production in terms of development. It demonstrates high dynamism, flexibility and the ability to quickly adapt to changes in market conditions and growing consumer expectations.

The service sector has its own characteristics:

– combination of production and sales in one product;

– absolute dependence on the demand for a particular service and its specifics, including seasonality;

– the presence of large and small organizations in the market;

– priority of psychological, professional, social training of employees;

– the possibility of serious territorial separation of different divisions of organizations [9].

So, the main feature of this area is its focus on the individual needs of the client, which forms new approaches to business organization, marketing and communications. The main digital technologies that are actively used in the service sector (especially in tourism, hotel and restaurant business, retail, finance, etc.) are presented in Table 1.

The importance of key digital technologies in the service sector lies in the fact that they fundamentally change the approach to service delivery, making it faster, more convenient, personalised and scalable.

Table 1

Basic digital technologies in the service sector

Technology	Contents	Effect
1	2	3
Artificial intelligence (AI) and machine learning	Chatbots and virtual assistants (for example, in 24/7 customer support). Personalisation of offers, analysis of customer behaviour. Demand forecasting and marketing automation.	Improving the quality of customer service. Personalisation of services. Automation of routine processes. Forecasting demand and customer behaviour. Reducing costs. Improving marketing. Risk and security management.
Cloud computing	Online services for booking, data storage, and personnel management. Flexible access to systems from any device and reduced IT infrastructure costs.	Accessibility of information at any time and from any place. Reducing the cost of IT infrastructure. Fast scaling. Improved data security. Facilitate collaboration between departments and branches. Integration with other services
Mobile applications	Online booking, food ordering, reviews and payment. A convenient channel of interaction with consumers in real time.	Convenience for customers. Increased loyalty. Quick feedback. Optimisation of service processes. Increase in sales. Contactless service.
Big Data	Analysing large amounts of information about customers, sales, and market trends. Creating targeted offers and business development forecasts.	Deep understanding of customers. Demand forecasting. Optimisation of marketing. Improving the quality of service. Formation of pricing policy. Reducing costs.

Continuation of Table 1

1	2	3
Internet of things (IoT)	"Smart hotel rooms: climate, light, and smartphone access control. Connecting equipment to a single system for easy management.	Improving the customer experience. Automation of processes. Saving resources. Improved security. Quick response to malfunctions. Personalised service.
Augmented and virtual reality (AR/VR)	Virtual tours of hotels or tourist attractions. AR menus in restaurants, interactive experience for customers.	Virtual tours before buying. AR menus in restaurants. Improved customer interaction. Effective staff training. Personalisation of the tourist experience. Attracting a young audience.
E-commerce and online platforms	Integration with booking, delivery, and e-commerce websites. Electronic payment systems (PayPal, Apple Pay, Google Pay).	Availability 24/7. Expansion of the market. Convenience of payment. Increase in income. Automation of processes. Systematisation of reviews and ratings. Effective marketing.
CRM-systems (Customer Relationship Management)	Automated customer relationship management. Keeping a history of orders, contacts, individual offers.	Centralised storage of customer information. Personalised service. Automation of interaction. Analytics and reporting. Improving the level of service. Sales and repeat order management.
Automation systems	POS systems in restaurants and hotels. Software for booking, warehouse, and personnel management.	Speed up customer service. Reducing errors. Full analytics of business processes. Cost optimisation. Improving the quality of service. Improved staff control. Integration with other systems.

Source: compiled by the author

The use of artificial intelligence (AI) in the service sector has a tangible effect on both businesses and consumers. Cloud computing

allows businesses to be flexible, scalable and efficient. The use of mobile applications in the service sector has a significant beneficial effect, as they create convenience for customers and increase business efficiency. Big Data allows businesses to better understand customers, make informed decisions and increase profitability. The use of the Internet of Things (IoT) in the service sector brings tangible benefits, as it makes services smarter, faster and more convenient for both customers and businesses. The use of augmented reality (AR) and virtual reality (VR) creates an immersive, interactive and personalised experience that offers many practical benefits for businesses and customers. The use of e-commerce and online platforms significantly expands access to services, simplifies customer interaction and opens up new revenue channels. CRM (Customer Relationship Management) systems in the service sector help businesses understand their customers better, automate interaction with them and improve the quality of service. The automation system allows you to increase the speed, accuracy and quality of service, reducing costs and the human factor. Thanks to digital tools, businesses can improve customer experience, reduce costs, increase service quality, and compete effectively in the marketplace.

Globally, the tourism and hotel and restaurant business is one of the key components of the service sector, which plays an important role in shaping the national economy, creating jobs and generating budget revenues. For example, in 2024, the tourism sector of Ukraine brought almost UAH 3 billion to the country's budget, which is 89 % more than in 2021 [10]. These industries provide a wide range of services – from organising travel and excursions to accommodation, food and leisure for tourists.

The travel and hospitality industry is one of the most competitive segments of the service sector. This is due to the high market saturation, constant changes in consumer preferences, seasonality of demand, and the availability of a wide range of offers for customers in both physical and digital environments. Digital technologies are becoming an important tool for increasing competitiveness, allowing to optimise business processes, personalise services, interact

effectively with customers and respond quickly to changes in the market situation.

In global practice, digital technologies have become an integral part of the development of the tourism and hotel and restaurant business. Global companies and local businesses are actively implementing innovative solutions to increase efficiency, improve service quality, personalise services and create competitive advantages. For example, Disneyland in the United States is one of the most prominent examples of how artificial intelligence (AI) and augmented reality (AR) are used to improve customer experience and increase park attendance. The company is actively integrating these technologies to make the visit experience even more immersive, personalised and convenient for guests [11]. China is actively using facial recognition at airports, hotels, and tourist attractions. Passengers can go through security without having to show passports or tickets. This significantly reduces the time required for check-in and customs clearance [12]. For China, this is part of the country's strategy to develop safety, convenience and innovative solutions in everyday life. The experience of the African tourism region, a continent with rich natural potential, is among the practices of using digital technologies in the tourism business. Kenya and Tanzania are among the leaders in the implementation of eco-friendly technologies in the tourism sector, particularly in the field of safaris and tourism in national parks. Both countries are actively developing mobile platforms for booking tours and using modern technologies to preserve ecosystems, support sustainable development and provide convenience for tourists [13]. Thus, the use of digital technologies in the tourism and hospitality industries develops differently depending on the region: Europe is focused on sustainability and mass digitalisation, the US relies on tech start-ups and personalisation, Asia is actively implementing AI and smart technologies, and Africa and Latin America are focusing on ecotourism and mobile solutions.

Digital technologies in the travel and hospitality industry are opening up many new opportunities to improve service, increase efficiency and customer convenience.

Fig. 1 shows the main advantages of using digital technologies for the tourism and hotel and restaurant business as a service industry.

Facilitating the booking process	Personalisation of services	Improving customer service	Mobile payments and contactless payments	Collecting and analysing customer feedback
– mobile applications and web platforms; – interactive online platforms (Booking.com, Airbnb, OpenTable)	– data analysis; – use of CRM systems	– chatbots and artificial intelligence (AI); – AI-based digital assistants	– contactless payments via smartphones (Apple Pay or Google Pay); – QR-codes	– big data analysis; – digital platforms (TripAdvisor, Yelp)

Fig. 1. Main advantages of using digital technologies for the tourism and hotel and restaurant business

Source: compiled by the author

Analysing the above advantages, we note that mobile apps and web platforms allow tourists and customers to conveniently book tours, hotels or restaurant tables online, without the need to contact agents or make calls. This greatly simplifies and speeds up the process. Interactive online platforms (Booking.com, Airbnb, OpenTable) allow customers to compare prices, conditions and availability in real time.

Chatbots and artificial intelligence (AI) automate responses to customer questions, providing 24/7 support. This significantly reduces the workload on staff and improves service levels.

Hotels and restaurants are already actively using AI-powered digital assistants to help guests with various issues, such as requesting additional services, menus, or information about local attractions.

The use of digital technologies in the travel and hospitality business has many advantages, but it also carries risks that can affect both businesses and consumers. One of the most significant is the technological risks associated with data security and the reliability of information systems [5]. The risk of leakage of personal information of tourists and customers (names, contacts, credit card details, travel history), hacker attacks on booking systems, CRM or payment services

can paralyse the operation of a hotel or travel company. Insufficient data protection can lead to loss of customer trust and legal liability under laws (e.g. GDPR in Europe).

Organisational challenges are also a significant risk of digital transformation. The introduction of new technologies requires significant changes in the structure and culture of enterprises, which can cause resistance from employees who are unwilling to adapt to new conditions or lack the necessary skills to work with these technologies. In addition, the digital transformation process requires investment in staff training, which increases costs [5].

"Economic risks are also an important aspect of digital transformation. Insufficient financial resources will lead to incomplete or inefficient implementation of digital solutions, which may ultimately fail to deliver the expected results" [14]. The introduction of new technologies (CRM, online booking systems, artificial intelligence, cyber defence) requires significant investment. Small and medium-sized businesses are often unable to finance these upgrades at the appropriate level. Due to incomplete or inefficient implementation of digital solutions, the expected results may not justify the costs. An incorrect assessment of the market or customer needs leads to poor technology choices. Digital technologies in the travel and hospitality industry significantly improve both the customer experience and the efficiency of operational processes. They enable the creation of personalised and convenient services, improve marketing, business management and optimise financial processes. With their help, businesses can not only attract new customers but also maintain the loyalty of existing ones by improving the quality of service.

Conclusions. As a result, it should be noted that in the modern digital economy, the introduction of digital technologies in the service sector is not just a trend, but a necessary prerequisite for the effective functioning of business. Analysis of the scientific and practical aspects of using tools such as artificial intelligence, big data, mobile applications, cloud services, CRM systems, AR/VR, Internet of Things and automation systems indicates their ability to significantly improve the quality of service, the level of personalization, consumer

convenience and business competitiveness. Digital solutions allow you to efficiently design customer experiences, optimize internal processes, reduce costs, and increase profitability at the same time. However, their implementation is associated with a number of difficulties, including economic risks, data protection issues and the need for qualified personnel. Therefore, the digital transformation of the service sector requires an integrated approach that combines innovative technologies, strategic vision, legal regulation and investments in human capital. The use of world experience, adapted to the national context, allows us to develop effective models of digital development of the service sector aimed at sustainable development and meeting the needs of modern consumers.

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3.5. DIGITAL TECHNOLOGIES FOR MONITORING AND MANAGING LOGISTICS CHAINS IN CRISIS CONDITIONS: EU EXPERIENCE DURING THE PANDEMIC AND WAR IN UKRAINE

Introduction. Supply chain logistics in today's globalized world are becoming increasingly complex, integrated, and simultaneously vulnerable to various external influences. Recent years have demonstrated how quickly established logistics routes and processes can change under the influence of unpredictable global-scale crisis phenomena. The COVID-19 pandemic, which began in 2020, dealt an unprecedented blow to international logistics systems, causing border closures, port disruptions, container shortages, and rising transportation costs. In just the first year of the pandemic, container shipping costs increased by an average of 174 % according to the Drewry index [2], and in some directions – up to 400 %. Russia's military aggression against Ukraine in 2022 created a new set of challenges for global supply chains, particularly in the food, energy, and metallurgical sectors.

Under such crisis conditions, traditional approaches to logistics management prove insufficiently effective due to their inflexibility and low adaptability. The ability of logistics systems to rapidly reconfigure,

ensure transparency at all stages of the supply chain, and respond operatively to changes comes to the forefront. It is here that digital technologies demonstrate their transformational potential, providing tools for monitoring, analyzing, and managing logistics processes in real-time [1].

The experience of European Union countries, which faced the need for rapid adaptation of their logistics systems first to pandemic conditions and then to disruptions caused by military actions in Ukraine, is of particular interest for research. European companies actively implemented innovative digital solutions to ensure the resilience of their supply chains, which allowed them to minimize the negative consequences of crisis phenomena. According to research by consulting company McKinsey, European enterprises that invested in digitalization of logistics processes before the pandemic began were able to reduce the negative impact on their operations by an average of 35 % compared to companies that did not prioritize digital transformation [3].

Studying EU experience is particularly relevant in the context of finding ways to diversify logistics routes for Ukrainian exports, which faced unprecedented challenges due to the blockade of Black Sea ports and destruction of transport infrastructure. Before the start of the large-scale military invasion, about 90 % of Ukrainian agricultural and metallurgical exports were carried out through seaports. After their blockade, Ukrainian exporters were forced to reorient to land routes through EU countries, which led to an increase in logistics costs by an average of 40–150 % depending on the type of product and final destination.

Digital technologies offer a set of tools that can significantly optimize logistics planning and transportation execution processes under such complex conditions. Predictive analytics systems based on big data allow for anticipating potential bottlenecks and delays in supply chains. The Internet of Things (IoT) provides real-time cargo tracking, which is especially important when changing routes and modes of transport. Cloud platforms enable instant data updates and access to them by all participants in the logistics chain regardless

of their location. Blockchain technologies increase transparency and trust between partners, ensuring immutability of information about goods movement. Artificial intelligence systems optimize routes and resource planning, considering multiple variable factors.

According to the European Commission [1], about 71 % of EU logistics companies acknowledged that they accelerated their digital transformation plans as a result of the COVID-19 pandemic. As of the end of 2022, over 65 % of European enterprises had implemented at least one digital solution for monitoring and managing their supply chains, and 42 % use comprehensive digital platforms that integrate various functionalities. This trend continued to strengthen under the influence of new logistics challenges related to military actions in Ukraine.

Particularly important is the comparison of different approaches to digitalization of logistics processes that were applied in the EU during different types of crisis phenomena. While during the pandemic, the main focus was on ensuring uninterrupted supplies under quarantine restrictions and unstable demand, in the context of the Russian-Ukrainian war, priority issues became transport corridor security, route diversification, and reducing dependence on Russian energy sources. These differences determined different emphases in the use of digital tools.

The purpose of this study is to analyze the effectiveness of applying digital technologies for monitoring and managing logistics chains in crisis conditions based on the experience of EU countries during the COVID-19 pandemic and under conditions of the Russian-Ukrainian war.

Presentation of Main Research Results. The COVID-19 pandemic created unprecedented challenges for global supply chains, which were particularly acutely felt by European companies due to the high level of international integration of their logistics processes. The main problems faced by logistics systems during the pandemic were: border closures and movement restrictions; imbalance in the distribution of shipping containers; sharp fluctuations in demand for different categories of goods; disruption of supply regularity due to quarantine restrictions on production; labor shortages due to worker illness.

The complexity of these challenges required new approaches to logistics process management based on the use of digital technologies. Table 1 presents the main digital solutions that were implemented by European companies to overcome pandemic logistics challenges and their effectiveness.

Table 1

Effectiveness of Digital Technologies in Overcoming COVID-19 Pandemic Logistics Challenges in EU Countries

Digital Technology	Main Functions	Implementation Examples	Effectiveness (average indicator according to company assessments)
Predictive analytics based on Big Data	Demand forecasting, inventory optimization, identification of potential disruptions in supply chains	Nestlé (Switzerland/ EU), Unilever (Netherlands)	27 % reduction in demand forecast deviations, 18 % reduction in safety stock levels
Digital logistics platforms	Integration of all logistics chain participants, ensuring process transparency, document workflow automation	Maersk TradeLens (Denmark), Kuehne+Nagel (Switzerland/EU)	31 % reduction in administrative costs, 70 % acceleration of document processing
Internet of Things (IoT)	Real-time cargo tracking, goods condition monitoring, automatic status updates	DHL (Germany), CMA CGM (France)	43 % reduction in cargo loss cases, 54 % reduction in incident response time
Cloud logistics solutions	Ensuring remote access to logistics management systems, collaborative work of distributed teams	Geodis (France), DSV Panalpina (Denmark)	25 % increase in productivity under remote work conditions, 35 % reduction in coordination time
Blockchain technologies	Ensuring transparency and immutability of information, simplifying customs procedures	Port of Rotterdam (Netherlands), Carrefour (France)	65 % reduction in document verification time, 51 % reduction in fraud cases

Source: systematized by the author based on data from the European Logistics Association and company reports [6–9]

As shown in Table 1, digital platforms that integrate various functionalities and Internet of Things technologies demonstrated the highest effectiveness in overcoming pandemic logistics challenges. Digital platforms such as Maersk TradeLens [6] and Kuehne+Nagel Connect [4] allowed all participants in the logistics chain to be united in a single information space, ensuring process transparency and operational information exchange. This was especially important under constantly changing restrictions and regulations related to the pandemic.

Internet of Things technologies provided the ability to track cargo movement and condition in real-time, which allowed for quick response to delays and cargo redirection when necessary. For example, German logistics company DHL implemented the Smart Sensor IoT system, which not only tracked cargo location but also controlled temperature, humidity, and other parameters, which was critically important for transporting medical cargo and vaccines [5].

Particularly interesting is the example of implementing predictive analytics based on Big Data by European retailers. For instance, Dutch company Unilever used machine learning algorithms to analyze changes in consumer preferences during the pandemic and adjust their logistics processes according to new demand patterns. This allowed the company to reduce demand forecast deviations by 32 %, significantly exceeding the industry average (27 %) [7].

To visualize the dynamics of implementing various digital technologies in European companies' logistics processes during the COVID-19 pandemic, Figure 1 is presented.

As shown in Figure 1, all categories of digital technologies demonstrate significant growth in implementation levels after the COVID-19 pandemic began. The most substantial growth is observed in cloud logistics solutions (from 43 % to 78 %), which is explained by the need to ensure remote work for logistics departments and coordination of distributed teams under quarantine restrictions [8].

An important aspect of using digital technologies during the pandemic was their role in ensuring the resilience of medical goods and equipment supply chains.

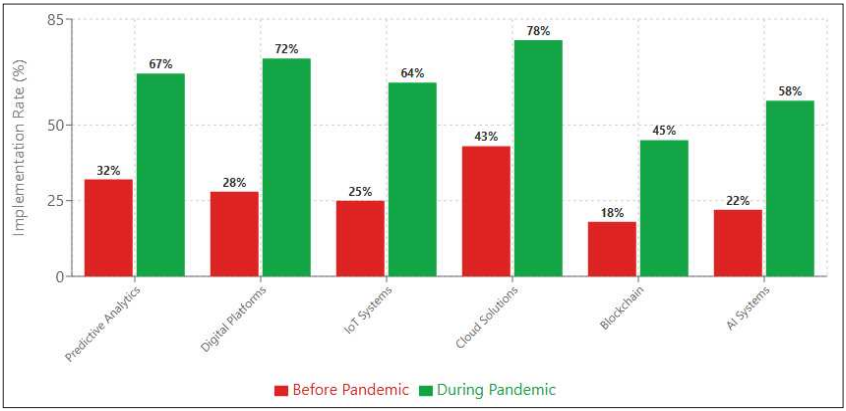

Fig. 1. Dynamics of Digital Technology Implementation in EU Companies' Logistics Processes Before and During COVID-19 Pandemic, %

The European Commission, in cooperation with logistics companies and medical equipment manufacturers, created the digital platform COVID-19 Clearing House for Medical Equipment, which allowed for coordinating the supply of critically important medical goods between EU member states [1]. The platform used artificial intelligence algorithms to optimize resource distribution according to each country's needs and available logistics capabilities.

The economic effect of implementing digital technologies in logistics processes during the pandemic can be assessed by comparing performance indicators of companies with different levels of digitalization. According to research by the European Logistics Association, companies with high levels of logistics process digitalization demonstrated 23 % better financial results during the pandemic compared to companies with low levels of digitalization. In particular, they were able to reduce logistics costs by an average of 15 %, decrease unsatisfied demand levels by 34 %, and accelerate order fulfillment by 29 % [3].

Russia's military aggression against Ukraine, which began on February 24, 2022, created fundamentally new challenges for European logistics systems that differed from problems caused by the

COVID-19 pandemic. Key among them were: blockade of Ukrainian Black Sea ports, through which up to 90 % of exports were carried out; destruction of transport infrastructure; need for urgent diversification of energy supply routes; increased security requirements for transport corridors; need for rapid reorientation of export and import flows.

For Ukrainian enterprises, these challenges proved particularly critical as they threatened the possibility of continuing export operations. At the same time, for European companies, they meant the need to find new sources of agricultural products, metals, and other goods traditionally imported from Ukraine, as well as developing new logistics routes to support the Ukrainian economy.

Table 2 presents a comparative analysis of changes in the structure of Ukrainian product exports by transport mode before and after the start of the large-scale invasion.

Table 2

Structure of Ukrainian Product Exports by Transport Mode, %

Transport Mode	Before War (2021)	After Port Blockade (2022–2023)	Change, p.p.
Maritime	90	5	–85
Railway	7	45	+38
Road	2	30	+28
River	1	20	+19

Source: calculated by the author based on data from the State Statistics Service of Ukraine and the Ukrainian Agribusiness Club

As shown in Table 2, there was a cardinal reorientation of export flows from maritime transport to railway, road, and river transport, which created unprecedented pressure on the corresponding infrastructure and required new approaches to organizing logistics processes. Under these conditions, digital technologies became a key tool for ensuring the efficiency of new logistics routes.

European companies actively implemented digital solutions to support Ukrainian exports and imports under war conditions. Digital platforms for coordinating multimodal transportation played a special

role, allowing the integration of different transport modes into unified logistics chains. For example, Polish logistics company PKP Cargo, in cooperation with Ukrzaliznytsia, developed the digital platform Rail Bridge, which optimized cargo transshipment processes at the border due to the difference in railway gauge [11].

To assess the effectiveness of various digital technologies in overcoming logistics challenges caused by the Russian-Ukrainian war, a survey of 150 European and Ukrainian logistics companies was conducted, the results of which are presented in Table 3.

As shown in Table 3, digital platforms for multimodal transportation (9.2 out of 10 points) and geospatial analytics systems (8.7 points) are rated highest for effectiveness. This is explained by the fact that these technologies directly solve the most critical challenges related to the need for rapid diversification of logistics routes and ensuring their security.

Table 3

Assessment of Digital Technology Effectiveness in Overcoming Russian-Ukrainian War Logistics Challenges

Digital Technology	Effectiveness Assessment (1–10 points)	Main Advantages	Main Limitations
1	2	3	4
Digital platforms for multimodal transportation	9.2	Ensuring seamless integration of different transport modes, optimization of transshipment processes	Require integration with existing management systems, high initial investments
Geospatial analytics systems	8.7	Determining optimal routes considering security risks, monitoring infrastructure condition	Require constant updating of infrastructure and security situation data
Blockchain solutions for customs clearance	8.5	Simplifying and accelerating customs procedures, ensuring transparency	Limited implementation at government level, compatibility issues between different systems

Continuation of Table 3

1	2	3	4
IoT cargo tracking systems	8.3	Real-time monitoring of cargo location and condition	Network coverage problems in certain regions, high equipment costs
Digital twins of logistics objects	7.6	Modeling and optimizing terminal and warehouse operations, capacity planning	Implementation complexity, high development costs
AI systems for risk forecasting	7.4	Identifying potential supply chain problems, recommendations for alternative routes	Limited forecast accuracy in highly uncertain conditions

Source: survey of European and Ukrainian logistics companies conducted by the author, n=150

Particular attention deserves the experience of applying digital technologies to optimize the Polish-Ukrainian border operation, which became a key transit hub for Ukrainian exports after the blockade of seaports. According to the Ministry of Infrastructure of Ukraine, waiting times for freight vehicles at the Polish border in the first months of the war reached 15–20 days, creating significant logistics delays and additional costs.

To solve this problem, the digital system e-Queue was implemented, which allowed optimization of the border crossing process for freight transport. The system is based on electronic queue technology using QR codes and online registration, allowing drivers to plan their arrival at the border and avoid long waits directly in the border zone [12]. The results of implementing the e-Queue system are presented in Figure 2.

Figure 2 shows that implementing the digital queue management system allowed reducing average waiting times at the border from 15–20 days to 3–5 days, significantly improving logistics operation efficiency.

An important aspect of digitalizing logistics processes under war conditions was implementing geospatial analytics systems to determine optimal routes considering security risks.

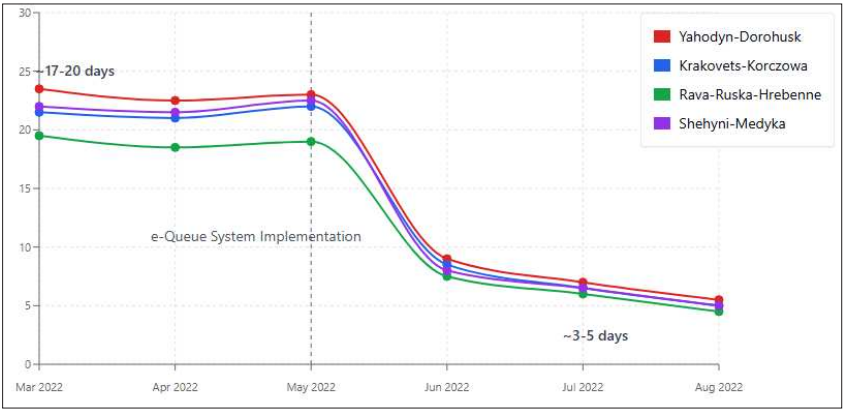

Fig. 2. Dynamics of Waiting Times at Polish-Ukrainian Border
Before and After e-Queue System Implementation, days

For example, Lithuanian company Traxus, together with Ukrainian partners, developed the Safe Route system, which uses data from various sources (including satellite images, social media information, and official reports) to assess the safety of different transport routes and adjust them in real-time [10].

To assess the economic effect of implementing digital technologies in Ukrainian enterprises' logistics processes under war conditions, an analysis was conducted of logistics cost changes for exporting various product types using alternative routes. The analysis results are presented in Table 4.

As shown in Table 4, implementing digital technologies allowed reducing logistics costs for exporting various product types by an average of 15.8–18.5 %. The greatest effect is observed for high-value products (sunflower oil, metal products), as reducing delivery time and increasing logistics process reliability is especially important for them.

It's important to note that the economic effect of implementing digital technologies manifests not only in reducing direct logistics costs but also in shortening delivery times, increasing supply reliability, and reducing risks. These factors are particularly significant under conditions of high uncertainty characteristic of wartime.

Table 4

Impact of Digital Technologies on Logistics Costs for Ukrainian Product Export via Alternative Routes, USD/ton

Product Type	Logistics Costs Before Digitalization	Logistics Costs After Digitalization	Cost Reduction, %	Main Implemented Technologies
Sunflower oil	110	90	18.2	Digital platforms for multimodal transportation, IoT tracking systems
Sunflower meal	95	80	15.8	Geospatial analytics systems, blockchain for customs clearance
Rapeseed oil	115	95	17.4	Digital platforms, risk forecasting systems
Grain crops	105	88	16.2	Digital platforms, IoT systems, blockchain
Metal products	135	110	18.5	Geospatial analytics systems, digital twins of terminals

Source: calculated by the author based on data from Ukrainian exporters, n=45

For a more detailed analysis of the impact of various digital technologies on logistics process efficiency, a regression analysis was conducted, the results of which are presented in Table 5.

The regression analysis results indicate that digital platforms for multimodal transportation (coefficient 0.42) and geospatial analytics systems (coefficient 0.35) have the greatest impact on reducing logistics costs. Meanwhile, blockchain solutions for customs clearance demonstrate the greatest impact on delivery time reduction (coefficient 0.45), which is explained by their ability to significantly accelerate border crossing and customs clearance processes [9].

The identified patterns allow formulating recommendations regarding priority directions for digitalizing logistics processes for different types of enterprises depending on their specific needs.

Table 5

Results of Regression Analysis of Digital Technology Impact on Logistics Process Efficiency

Digital Technology	Impact Coefficient on Logistics Cost Reduction	Impact Coefficient on Delivery Time Reduction	Statistical Significance (p-value)
Digital platforms for multimodal transportation	0.42	0.38	<0.001
Geospatial analytics systems	0.35	0.29	<0.001
Blockchain solutions for customs clearance	0.31	0.45	<0.001
IoT cargo tracking systems	0.28	0.32	<0.001
Digital twins of logistics objects	0.23	0.19	<0.05
AI systems for risk forecasting	0.27	0.34	<0.01

Source: author's calculations based on survey data from Ukrainian and European logistics companies

Integration into European Digital Logistics Ecosystems: Strategic Perspective for Ukrainian Enterprises

The experience of adapting logistics systems to COVID-19 pandemic conditions and the Russian-Ukrainian war demonstrates that the most effective approach to ensuring supply chain resilience is integration into broad digital ecosystems that unite various participants in logistics processes and ensure real-time data exchange [15]. In the context of deepening Ukraine's integration into the European economic space, the issue of Ukrainian enterprises joining European digital logistics ecosystems becomes particularly significant.

The European Union is actively developing several large-scale initiatives in the field of logistics digitalization that form a unified digital logistics space. Key among them are:

– *Digital Transport and Logistics Forum (DTLF)* – a platform for coordinating transport and logistics digitalization in the EU, uniting over 100 public and private organizations [13].

– *Electronic Freight Transport Information (eFTI)* – a system ensuring standardized digital information exchange about freight transportation between enterprises and government agencies [1].

– *European Maritime Single Window (EMSW)* – a single window for maritime transportation that simplifies documentation and procedures in EU ports [14].

– *Digital Services for Freight Transport Networks* – an initiative focusing on creating unified digital infrastructure for managing transport corridors [13].

To assess the readiness level of Ukrainian enterprises for integration into European digital logistics ecosystems, a survey of 120 Ukrainian exporting companies was conducted. The survey results are presented in Figure 3.

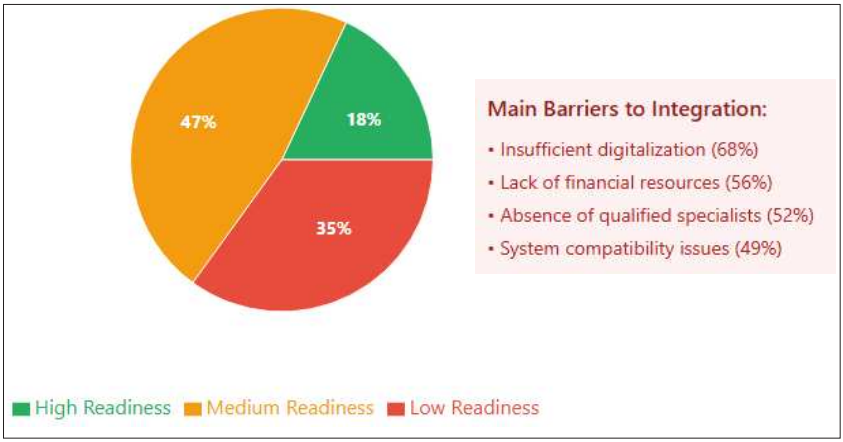

Fig. 3. Readiness Level of Ukrainian Enterprises for Integration into European Digital Logistics Ecosystems, %

Figure 3 shows that only 18 % of Ukrainian enterprises assess their readiness level for integration into European digital logistics ecosystems as high. Most companies (47 %) characterize their

readiness as medium, and 35 % as low. Respondents named the main barriers to successful integration as: insufficient level of internal process digitalization (68 %), lack of financial resources for digital technology investments (56 %), absence of qualified specialists (52 %), insufficient compatibility of existing systems with European standards (49 %).

Based on the analysis of European experience and assessment of Ukrainian enterprises' readiness, a model for gradual integration into European digital logistics ecosystems was developed (Figure 4).

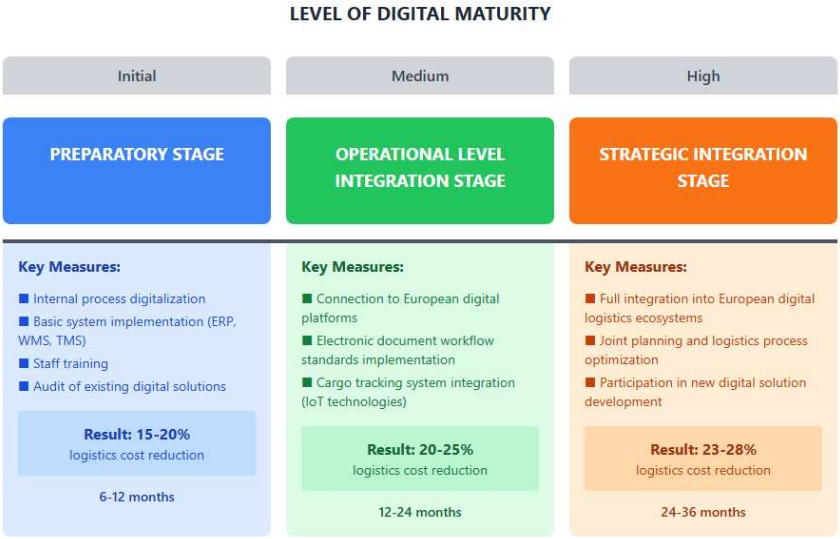

Fig. 4. Model for Gradual Integration of Ukrainian Enterprises into European Digital Logistics Ecosystems

The proposed model includes three main stages:

– preparatory stage – digitalization of enterprise internal processes, implementation of basic digital solutions (ERP, WMS, TMS systems), staff training;

– operational level integration stage – connection to European digital platforms for multimodal transportation, implementation

of electronic document workflow standards, integration of cargo tracking systems;

– strategic integration stage – full integration into European digital logistics ecosystems, joint planning and optimization of logistics processes, participation in developing new digital solutions.

For each stage, key technologies, necessary resources, and expected results are defined, allowing enterprises to plan the digital transformation process according to their capabilities and needs.

According to expert estimates, successful integration of Ukrainian enterprises into European digital logistics ecosystems will allow reducing logistics costs by an average of 23–28 % compared to the current level, shortening delivery time by 30–35 %, and increasing supply reliability by 40–45 %. These improvements will have a significant impact on Ukrainian product competitiveness in European markets [1].

Given the strategic importance of digitalizing logistics processes for ensuring Ukraine's integration into the European economic space, it is advisable to implement government support programs for digital transformation of logistics systems. Such programs may include:

– financial support (grants, preferential loans) for implementing digital technologies in Ukrainian enterprises' logistics processes;

– training programs for preparing specialists in digital logistics;

– promoting Ukrainian companies' participation in European logistics digitalization initiatives;

– harmonization of Ukrainian standards with European ones in the field of digital document workflow and logistics information exchange;

– development of digital infrastructure to ensure reliable functioning of logistics information systems.

An important aspect of ensuring logistics process efficiency is the interaction between digital technologies and physical infrastructure. In the context of post-war recovery of Ukraine, the issue of integrating digital solutions into transport infrastructure reconstruction strategies becomes particularly relevant.

Analysis of European experience demonstrates that the most effective approach is the "digital-first" concept, when planning and

implementing infrastructure projects is carried out considering future digital solutions that will be based on them [15]. In particular, when reconstructing Ukraine's transport infrastructure, it is advisable to immediately provide for:

– deployment of IoT sensor networks for monitoring infrastructure object conditions;

– implementation of artificial intelligence-based transport flow management systems;

– creation of digital twins of transport infrastructure for modeling and optimizing its use;

– development of charging station networks for electric transport with integrated digital management systems;

– implementation of intelligent border infrastructure management systems.

According to expert estimates, integrating digital technologies into transport infrastructure reconstruction processes will allow increasing its efficiency by 25–30 % compared to traditional approaches, as well as ensuring faster adaptation to changes in logistics needs.

To determine priority directions for integrating digital technologies into Ukraine's transport infrastructure reconstruction processes, an expert survey was conducted, the results of which are presented in Table 6.

Table 6

Priority Directions for Integrating Digital Technologies into Ukraine's Transport Infrastructure Reconstruction

Direction	Priority (1–10 points)	Expected Impact on Logistics Process Efficiency
1	2	3
Digitalization of border infrastructure	9.4	60–70 % reduction in border crossing time, 40–50 % increase in throughput capacity
Intelligent railway network management systems	9.1	35–40 % increase in rolling stock utilization efficiency, 25–30 % reduction in delivery time

Continuation of Table 6

1	2	3
Digital solutions for multimodal logistics hubs	8.8	45–50 % acceleration of transshipment processes, 30–35 % increase in infrastructure utilization coefficient
Intelligent transport systems for highways	8.5	20–25 % increase in throughput capacity, 15–20 % reduction in transportation time
Digital infrastructure condition monitoring systems	8.2	25–30 % reduction in infrastructure maintenance costs, 30–35 % increase in transportation safety
Digital solutions for river transport corridors	7.9	30–35 % increase in river transport utilization efficiency, integration into multimodal transportation

Source: expert survey results, n=35 (experts in logistics, transport infrastructure, and digital technologies)

As shown in Table 6, digitalization of border infrastructure has the highest priority, reflecting the critical role of border crossings in ensuring Ukrainian economy export operations under conditions of seaport blockade. Intelligent railway network management systems and digital solutions for multimodal logistics hubs also have high priority, emphasizing the importance of these transport infrastructure elements for ensuring efficient alternative logistics routes.

Based on the conducted analysis, a conceptual model of synergy between digital technologies and Ukraine's transport infrastructure reconstruction strategy can be proposed (Figure 5).

The proposed model provides for interconnected development of physical infrastructure and digital solutions that ensure its efficient use. Key elements of the model are:

a) digital twins of infrastructure objects – virtual models that allow planning and optimizing infrastructure reconstruction and operation processes;

b) integrated logistics platforms – digital solutions that ensure coordination of different transport modes and logistics process participants;

c) IoT-based monitoring and management systems – networks of sensors and actuators that ensure data collection about infrastructure condition and remote management capabilities;

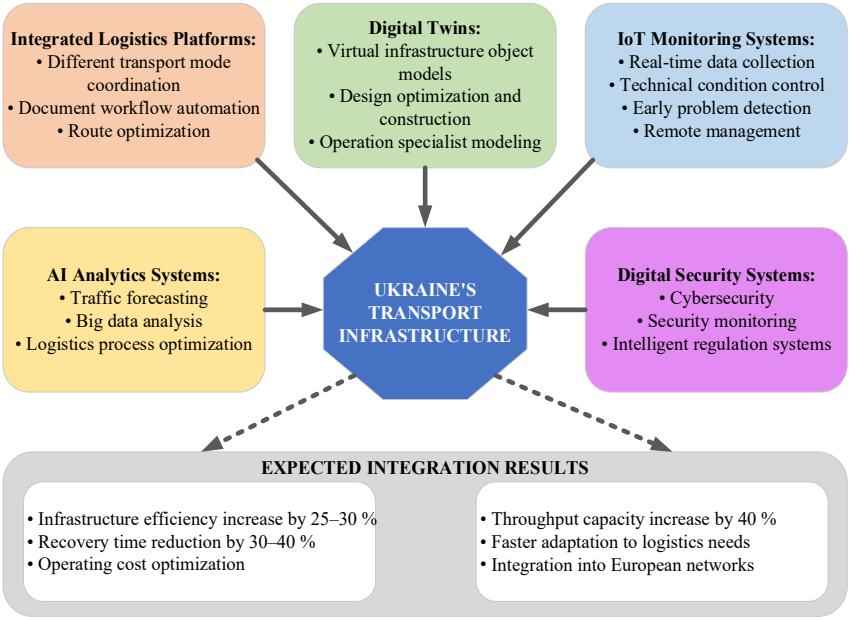

Fig. 5. Conceptual Model of Synergy Between Digital Technologies and Ukraine's Transport Infrastructure Reconstruction Strategy

d) AI-based analytical systems – solutions that analyze large volumes of data to optimize logistics processes and predict potential problems;

e) digital security systems – technologies that enhance transport infrastructure and logistics process security.

Implementing this model requires coordinating efforts of the state, business, and international partners, as well as significant investments.

At the same time, it will allow creating a modern, efficient, and resilient transport-logistics system that will ensure Ukrainian economy competitiveness in the global context.

Conclusions. The conducted study of digital technologies for monitoring and managing logistics chains in crisis conditions allows drawing several important conclusions regarding their role in ensuring logistics system resilience and prospects for their implementation in the Ukrainian economy.

Analysis of EU countries' experience during the COVID-19 pandemic demonstrated that digital technologies became a key factor in adapting logistics systems to unprecedented challenges related to quarantine restrictions, supply chain disruptions, and sharp changes in consumer demand. Digital platforms that integrate various functionalities and unite all logistics chain participants in a unified information space proved most effective. Such platforms allowed reducing administrative costs by an average of 31 % and accelerating document processing by 70 %. Internet of Things technologies also demonstrated high effectiveness, ensuring real-time cargo tracking and reducing cargo loss cases by 43 %.

The Russian-Ukrainian war created fundamentally new challenges for logistics systems that differed from pandemic-caused problems. The blockade of Ukrainian Black Sea ports, through which up to 90 % of exports were carried out, necessitated cardinal reorientation of export flows to railway (share growth from 7 % to 45 %), road (from 2 % to 30 %), and river (from 1 % to 20 %) transport. Under these conditions, digital technologies became a key tool for ensuring new logistics route efficiency. Digital platforms for multimodal transportation (rating 9.2 out of 10 points) and geospatial analytics systems (8.7 points) demonstrated the highest effectiveness in overcoming Russian-Ukrainian war logistics challenges. Regression analysis showed that digital platforms for multimodal transportation (coefficient 0.42) and geospatial analytics systems (coefficient 0.35) have the greatest impact on reducing logistics costs, while blockchain solutions for customs clearance have the greatest impact on delivery time reduction (coefficient 0.45).

Implementing digital technologies in Ukrainian enterprises' logistics processes allowed reducing logistics costs for exporting various product types by an average of 15.8–18.5 %. The greatest effect is observed for high-value products (sunflower oil, metal products), as reducing delivery time and increasing logistics process reliability is especially important for them.

Analysis of Ukrainian enterprises' readiness level for integration into European digital logistics ecosystems showed that only 18 % of companies assess their readiness level as high, while most (47 %) characterize it as medium, and 35 % as low. Main barriers to successful integration are insufficient level of internal process digitalization (68 %), lack of financial resources for digital technology investments (56 %), absence of qualified specialists (52 %), and insufficient compatibility of existing systems with European standards (49 %).

To ensure successful integration of Ukrainian enterprises into European digital logistics ecosystems, a gradual integration model is proposed, including a preparatory stage (internal process digitalization), operational level integration stage (connection to European digital platforms), and strategic integration stage (full integration into European digital logistics ecosystems). Successful implementation of this model will allow reducing logistics costs by an average of 23–28 % compared to the current level, shortening delivery time by 30–35 %, and increasing supply reliability by 40–45 %.

Under conditions of post-war recovery of Ukraine, the issue of integrating digital solutions into transport infrastructure reconstruction strategies becomes particularly relevant. The most effective approach is the "digital-first" concept, when planning and implementing infrastructure projects is carried out considering future digital solutions. The highest priority is digitalization of border infrastructure (9.4 out of 10 points), intelligent railway network management systems (9.1), and digital solutions for multimodal logistics hubs (8.8).

Based on the conducted research, the following recommendations can be formulated for different stakeholders:

For Ukrainian enterprises:

– accelerate digitalization of internal logistics processes, starting with implementing basic systems (ERP, WMS, TMS);

– invest in connecting to European digital logistics platforms, especially those specializing in multimodal transportation;

– develop staff competencies in digital logistics and supply chain management;

– implement IoT-based cargo tracking technologies to ensure logistics process transparency;

– use blockchain solutions to simplify and accelerate customs procedures.

For Ukrainian government agencies:

– develop and implement a state program supporting logistics process digitalization in the Ukrainian economy;

– ensure harmonization of Ukrainian standards with European ones in digital document workflow and logistics information exchange;

– integrate "digital-first" principles into transport infrastructure reconstruction strategies;

– prioritize border infrastructure digitalization to increase throughput capacity and reduce border crossing time;

– promote Ukrainian companies' participation in European logistics digitalization initiatives.

For international partners and organizations:

– provide technical and financial support for logistics process digitalization in Ukraine;

– promote integration of Ukrainian enterprises into European digital logistics ecosystems;

– ensure knowledge and technology transfer in digital logistics;

– invest in digital infrastructure development to ensure reliable functioning of logistics information systems.

Implementing these recommendations will allow increasing efficiency and resilience of logistics systems in Ukraine, promote Ukrainian economy integration into the European economic space, and ensure Ukrainian enterprises' competitiveness in international markets under unprecedented challenges caused by Russian military aggression.

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